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# Development New Genotypes of Cabbage (*Brassica oleracea* Var. *Capitata*) By Using the Bud Pollination Technique and Selection

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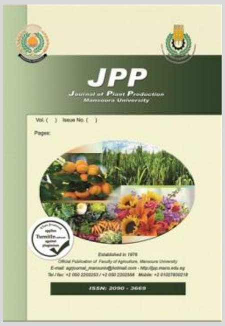


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## ABSTRACT

Field trials were carried out in order to development the cabbage Balady cultivar through selection program using the bud pollination technique. The selected five lines were evaluated at El-Gemmeza Agriculture Research Station farm, Gharbia Governorate, Horticulture Research Institute, Agriculture Research Center during seasons 2021 and 2022. Analysis of variance exhibited significant variance between the genotypes for measured characters. The phenotypic coefficient of variance was noticed to be larger than the corresponding genotypic coefficient of variance for most of traits, indicating that these characters were highly influenced by environment. A high genotypic and phenotypic coefficient was recorded for length of stem (39.45 and 39.23) followed by head weight (35.37 and 35.17), diameter of head (27.45 and 25.63) and number of wrapper leaves (22.36 and 22.11). High heritability in broad sense magnitudes were reported for length of stem (98.90%), head weight (98.84%) and leaf blade length (98.70%). The highest level of genetic advance as percent of mean was reported for stem length (80.37 %) followed by head weight (72.02%) and diameter of head (49.30%). Additionally, the recorded magnitudes for the correlation coefficients, among the various pairs of traits, were positive or negative and highly significant, which may assist in selecting desirable characteristics in cabbage breeding programs. Days to harvest, number of wrapper leaves, head length, head diameter and net head weight exhibited a high heritability coupled with high genetic advance; they are controlled by additive genes and might be employed as efficient selection criterion in the breeding program of high-productivity cabbage cultivars.

***Keywords:*** Cabbage, GCV, PCA, heritability, correlation

## INTRODUCTION

Cabbage (*Brassica oleracea* var. capitata L. *Brassicaceae* family) is one of the most economically viable and famous vegetable cultivated in Egypt. Moreover, cabbage is a leafy biennial plant producing a compact leaves wrapped over each other known as head. It is a temperate vegetable crop, but nowadays there is a great demand of this crop in Egypt. Number of chromosomes (2n=2x=18), Cabbage is a highly cross-pollinated crops. It is mostly utilized for its nutritional properties, especially iron, calcium, potassium and vitamins A, B and K. The edible part of a cabbage has a moisture of (91.9 %), calories in leaves is (27%), carbohydrates (4.6%), proteins (1.3%), fat (0.1%), riboflavin (0.09 mg), thiamine (0.06 mg), β-carotene (1200 µg), iron (0.8 mg), potassium (144 mg), phosphorus (44 mg), sodium (14.1 mg), ascorbic acid (124 mg) and calcium (39 mg) (Haghighi *et al.,* 2020) and contains anti-carcinogenic chemical characteristics, as well as anti-inflammatory properties i.e., isothiocynates, glutathione and glucosinolates (Tajalli *et al.,* 2020; Jabeen and Chadha, 2021; Shahbazi *et al.,* 2021). Furthermore, those chemical compounds have been discovered to contain excellent antioxidants and have demonstrated many health advantages due to their effective free radical characteristics (Rubab *et al.,* 2018). Registered cabbage as a major food resource in the world and is listed as one of the top twenty vegetable crops be cultivated in the world (FAO, 2023). Due to sexual incompatibility issues, traditional plant breeding is a tedious procedure that takes 8–10 years to develop a new variety and is sufficient for crop genetic improvement (Singh *et al.,* 2021). Thus, many investigations directed to the creation of a geen pool with productivity and high quality of cabbage through development a new of cabbage by using the bud pollination technique and selection. In this respect, Koutsika-Sotiriou *et al*., (2010) conducted that bud pollination technique and selection is important for vegetables breeder in selecting and determining genotypes with desirable traits for participation in breeding programs. In Egypt, some local varieties, like "Balady" varieties, showed a relatively low production level and an evident sharp fall in yield and its components traits and exhibited unusual levels of variation in morphological traits between the individual plants of cabbage. Therefore, estimating the variability between cabbage plants for economical traits is very important to develop efficient breeding strategies. However, the broad ranges of variability offered provide significant opportunity for genetic investigations and design of improved genotypes. In this context, many authors such as (Kumar *et al*., 2015) have reported the extent of genetic variation between cabbage genotypes to several economically important characters. They observed that there was abroad ranges of variability estimates between the studied traits of several cabbage genotypes were noticed. The heritability of characteristics determines the amount to which the phenotype of the plant is a guideline to the genotypic structure and thus help the vegetable breeder to build his selection program on the phenotypic performance of the plant. The high heritability coefficient in broad sense illustrated that a considerable amount of phenotypic variation

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was attributable to genotypic variance and was less impacted by the environment. Allard, (1999) they explained that characteristics with low heritability are dependable since their genotypic expression is determined by environmental effects. Therefore, the degree of success in the selection process relies on the value of the heritability coefficient; thus the impact of selection will be achieved faster in traits with a higher heritability coefficient. Many studies were been reported in this regard on cabbage (Dey *et al.,* 2015; Chittora *et al.,* 2016) on cauliflower and (Atter *et al.*, 2009; Meena, *et al.,* 2014) in cabbage. The correlation between different horticultural traits is vital to planning an excellent breeding program. Therefore, using phenotypic correlation coefficient is a significant tool for the vegetable breeder to help pick and determine hard-to-measure traits through the selection of another, easier to measure. So, some authors estimated the correlation between the different pairs of the studied traits; as Nimkar, and Soniya, (2013); Mehtapm, *et al., (*2023) and El- Shoura, and Diab, (2024). They concluded that there were significant correlations among pairs of several economical traits of cabbage which were beneficial in cabbage selection. Additionally, positive and significant correlation of cabbage yield components reported by (Meena *et al.*, 2014). Therefore, the major objective of the current investigation was to development new lines of cabbage by using the bud pollination technique and selection.

## MATERIALS AND METHODS

The experiment was carried out at El-Gemmeza Agriculture Research Station Farm, Gharbia Governorate, Horticulture Research Institute (HRI), Agriculture Research Center (ARC), Egypt during winter season during 2021-2022 growing period. Basic plant materials, which were selected five cabbage lines namely, genotype-1, genotype -2, genotype -3, genotype -4 and genotype -5 respectively, from bud pollination technique with selection from Balady cultivar consist of the basic experimental materials for the study. This variety was chosen because it is commonly cultivated and well-adjusted to the Egyptian environmental circumstances, nonetheless, it exhibits a lot of variation and degradation, which were noticed and reported by many farmers and customers. These genotypes were selected based on their prior information. To prevent bees and other insects from contaminating seed production of lines, the plants are covered with net. Pollen grains are gathered from open flowers on the same day. Before the bud opens, the blooms are wrapped in a paraffin or muslin fabric bag. Bud pollination technique done before 2-4 days from open flowers this technique for two generations gives the highest seed set. Twenty plants were accommodated in each plot of size 2.0-meter X 3.0 meter with spacing of 60 cm X 50 cm. All lines were evaluated in a Randomized Complete Block Design (RCBD) with three replicates. The experiment began in the second week of August, with 20 plants in each replication. Fertilization, irrigation, and weed control, among other things, were carried out on a regular basis to ensure a healthy crop. Harvesting was completed when 90% of the plant population in each plot reached maturity. Data were recorded on ten randomly selected plants of each genotype in all of the three replicates for various traits. Initial visual selection was done accordance to the parameters; leaf blade width (cm), length of stem (cm), leaf blade length (cm), days to harvest (days) , number of non-wrapper leaves (unit), number of wrapper leaves (unit), length of head(cm), diameter of head (cm) and head weight (kg). Collection of samples fresh samples were collected from each line when cabbage heads were at marketable stage.

**Statistical analysis:**

Statistical analyses were performed on the obtained data of the aforementioned characteristics were computed:

$$\text{Genetic variance (Vg)} = \frac{\text{Genotype Mean Square} - \text{Error Mean Square}}{\text{Number of Replicates}}$$

**Environmental Variance = Error Mean Square.**

**Phenotypic Variance (Vp) =Vg + (Ve/r).**

The genotypic, phenotypic, and environmental coefficients of variation were computed as follows:

$$\text{GCV \%} = \sqrt{(Vg/x)}\ X100.$$

$$\text{PCV \%} = \sqrt{(Vp/x)}\ X100.$$

$$\text{ECV \%} = \sqrt{(Ve/x)}\ X100.$$

**GCV%: Genotypic coefficient of variation; Vg: Genotypic variance. PCV% is the phenotypic coefficient of variation; Vp is the phenotypic variance. ECV% stands for environmental coefficient of variation, while Ve represents environmental variance.**

Heritability in broad sense percentage for all traits were estimated accordance to Allard, (1999) as follow

$$(h^2_{b.s}\ \%) = \frac{Vg}{Vph}\ X\ 100.$$

$$\text{Genetic Advance (GA)} = K\ \sqrt{Vp\ X\ h2b.s}$$

**Where,** **K = 2.06 at 5 % intensity of selection and Vp = Phenotypic variance.**

Genetic advance is calculated as a percentage of the mean

$$(\text{GAM \%}) = \frac{GA}{X}\ x\ 100.$$

Estimation of phenotypic ($r_{ph}$) and genotypic ($r_g$) correlations coefficient among pairs of the plant traits as illustrated by Singh and Chaudhary, (1985). The significance of the $r_{ph}$ and $r_g$ as described by (Cochran and Cox 1957). Statistical analysis was performed on each characteristic under consideration using CO - STAT software (2004).

## RESULTS AND DISCUSSION

**Analysis of Variance:**

Analysis of variance exhibited significant differences ($p < 0.01$) among cabbage genotypes for all measured traits, examples include; leaf blade length, leaf blade width, stem length, days to harvest, number of non-wrapper leaves, number of wrapper leaves, length of head, diameter of head, and head weight. Table, 1 displays the estimated mean squares for nine measured traits of five cabbage genotypes. This indicates that there is enough diversity in cabbage to allow for successful selection and crop development. Researchers studying several morphological traits in other *Brassica* species found similar results (Thakur and Vidyasagar, 2016; Chatterjee *et al.,* 2018; Aktar *et al.*, 2019; El- Shoura, and Diab, 2024). These findings align with recent publications by Singh *et al.,* (2015), who underlined the relevance of large genotypic variety in cabbage breeding efforts. Variability, the most significant property of any population, is extremely crucial in breeding programs. Genetic variability estimation is a crucial prerequisite for achieving a response to selection since breeding progress is determined by the amount, type, and degree of genetic variability (Nandhini *et al.,* 2020). This significant variation suggests that these traits are influenced by genetic factors;

aligning with findings from other studied, For instance, (Ullah *et al.,* 2015; Bhat *et al.,* 2020; Mehtap *et al.,* 2023), who reported similar genetic variability in cabbage and its implication for breeding programs. These findings are significant for further research into the selection of potential genotypes in cabbage breeding.

**Table 1. Analysis of variance and mean squares of all cabbage genotypes for the variables examined.**

| S.V Traits | df | Leaf blade length (cm) | Leaf blade width (cm) | Stem length (cm) | Days to harvest (days) | Number of non- wrapper leaves (unit) | Number of wrapper leaves wrapper | Head length (cm) | Head diameter (cm) | Head weight (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 2 | 0.154 | 0.531 | 0.079 | 8.867 | 0.004 | 0.029 | 0.379 | 8.117 | 0.090 |
| Genotypes | 4 | 251.38** | 136.67** | 60.96** | 300.37** | 10.70** | 100.90** | 10.84** | 174.74** | 12.57** |
| Error | 8 | 1.097 | 10.03 | 0.225 | 4.658 | 0.061 | 0.758 | 0.093 | 8.169 | 0.049 |

****: significant at 0.01 levels of probability.**

**Mean Performance of Genotypes:**

Table 2 displays the mean performance of the genotypes for several attributes. The mean magnitudes of genotypes were recorded for leaf blade length (42.62 - 63.42 cm), leaf blade width (33.33 - 51.83 cm), stem length (6.58 - 18.08 cm), days to harvest (64.25 - 90.58 days), number of non-wrapper leaves (7.50 -11.67), number of wrapper leaves (18.75 - 32.67); head length (20.67 - 25.58 cm), head diameter (23.42 - 41.83 cm), and head weight (4.13 - 8.96kg). The genotype with the greatest leaf blade width (51.83cm) and net head weight (8.96 kg) demonstrated higher performance, showing the possibility of selection in breeding programs. Conversely, genotype 4 had lower values for most parameters, suggesting that it may not be suitable for cultivation. In terms of maturation time, genotype 4 was the earliest (64.25 days), which is advantageous for early market supply. However, its lower yield potential may restrict its commercial appeal; it also strikes a balance between early maturity and yield potential. This is congruent with the findings of Kumar *et al.,* (2020); they stated that the necessity of choosing genotypes with desired features for efficient cabbage production. The variety in leaf traits, such as wrapper and non-wrapper leaf numbers, relates to variances in head compactness and protection, both of which are important for marketability and transportation (Pivovarov *et al.,* 2017). Genotype 1 had the highest net head weight (8.96 kg), followed by genotype 2 (6.79 kg), and genotype 4 had the lowest (4.13 kg). Genotype 1 also had higher values for head diameter (41.83 cm) and length (25.58 cm), making it the most promising line for commercial production. Various studies on cabbage qualities found varying findings depending on environmental conditions (Cervenski *et al.,* 2011; Manmeet *et al.,* 2018: Sharma *et al.,* 2019a; Singh *et al.,* 2021). The outcomes indicate that genotype 1 possesses excellent agronomic traits that are suited for yield increase. The least significant difference (LSD) values at the 5% and 1% levels support the reliability of these differences, particularly for variables like as stem length and head weight, where genotypes performed differently.

**Table 2. Mean performance of all cabbage genotypes on measured traits.**

| Genotypes Traits | Leaf blade length (cm) | Leaf blade width (cm) | Stem length (cm) | Days to harvest (days) | Number of non- wrapper leaves (unit) | Number of wrapper leaves (unit) | Head length (cm) | Head diameter (cm) | Head weight (kg) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 61.58 | 51.83 | 13.67 | 76.50 | 10.75 | 32.67 | 25.58 | 41.83 | 8.96 |
| 2 | 63.42 | 42.17 | 16.08 | 90.58 | 11.67 | 18.75 | 23.25 | 27.33 | 6.79 |
| 3 | 49.58 | 40.92 | 10.92 | 69.17 | 7.5 | 26.00 | 23.00 | 29.58 | 4.85 |
| 4 | 42.62 | 33.33 | 6.58 | 64.25 | 7.58 | 30.92 | 20.67 | 23.42 | 4.13 |
| 5 | 47.58 | 38.67 | 18.08 | 77.83 | 10.08 | 22.33 | 21.42 | 23.17 | 4.34 |
| Minimum value | 42.62 | 33.33 | 6.58 | 64.25 | 7.50 | 18.75 | 20.67 | 23.42 | 4.13 |
| Maximum value | 63.42 | 51.83 | 18.08 | 90.58 | 11.67 | 32.67 | 25.58 | 41.83 | 8.96 |
| LSD at 5 % | 1.97 | 2.10 | 0.93 | 4.06 | 0.46 | 1.63 | 0.57 | 5.38 | 0.41 |
| LSD at 1 % | 2.86 | 3.06 | 1.35 | 5.91 | 0.67 | 2.38 | 0.83 | 7.83 | 0.60 |

**Estimates of genetic variability:**

The establishment of genetic parameters for the examined cabbage attributes indicated high genetic diversity between genotypes, which is critical for successful selection and crop development. Most characters (such as, leaf blade length, maturity time) have a limited gap between *GCV* and *PCV*, indicating that environmental influences on these traits are minimal. This is consistent with (Dey *et al.,* 2015; Chittora *et al.,* 2016; Kumar *et al.,* 2018) on cauliflower; (Mehtap *et al.,* 2023; El- Shoura and Diab, 2024), cabbage (Sharma *et al.,* 2019b), broccoli (Nandhini *et al.,* 2020), kale (Wudneh, 2020; Gorka *et al.,* 2021), and authors reported that the phenotypic coefficient of variability was larger than the genotypic coefficient of variability. Traits with moderate genotypic coefficient of variation (GCV) and low genetic advance as percentage of mean (GAM) (for example, head length) may be impacted by non-additive gene effects or epistatic interactions, rendering direct selection ineffective unless supplemented with alternative breeding strategies. Table 3 shows the estimations of phenotypic coefficients of variation and genotypic coefficient of variation, heritability, genetic advance as percentage of mean values, and ranges of mean values for all of the traits analyzed. The genotypes tested have a wide genetic background, as seen by the range of mean values. Leaf blade length (33.33 - 51.8.3 cm), leaf blade width (42.62-63.42 cm), stem length (6.58-10.08 cm), days to harvest (64.25-90.58 days), number of non-wrapper leaves (7.50-11.67), number of wrapper leaves (18.75-32.67), length of head (20.67- 25.58 cm), diameter of head (23.42-41.83 cm) and head weight (4.13-8.96 kg) all had a wide range of mean values. The genotypic coefficient of variation ranged from 8.31 to 39.23% for the different studied traits. A high genotypic coefficient of variation was found for stem length (39.23%) and head weight (35.17%), whereas a moderate genotypic coefficient of variation was discovered for head diameter (25.63%) and number of wrapper leaves (22.11%). The genotypic coefficient of variance for head length was low (8.31%). Previous studies found that the biggest genotypic coefficient of variation was for length of stem, occurred followed head weight, head diameter, and number of wrapper leaves (Chittora and Singh, 2015). Similarly, the greatest (PCV) was observed for stem length (39.45%) and head weight (35.37%), while for characters such as head diameter (27.45%), number of wrapper leaves (22.36%), number of non-wrapper leaves (19.95%), leaf blade width (17.47%), and leaf blade length (17.36%), the (PCV) was moderate. The phenotypic coefficient of variation for head length was low (8.42%). Previous studies (Kaur *et al.,* 2018) revealed a high phenotypic coefficient of variation for stem length (39.45 %) and head weight (35.37%), but a low estimate for head length (8.31%).

The phenotypic coefficients of variation estimations were consistently higher than the equivalent genotypic coefficient of variation magnitudes, indicating an environmental effect. High estimates of genotypic and phenotypic coefficient of variations were found for stem length and head weight, indicating that selection based on these characteristics might aid in the successful isolation of desired varieties. It suggested that there was a wide range for improvement in this characteristic, either by direct selection among genotypes or by incorporating selected parents in hybridization. Moderate PCV and GCV magnitudes were reported for the diameter of the head, number of wrapper leaves, number of non-wrapper leaves, leaf blade width, and leaf blade length, indicating that these might be improved. Similarly, Mehtap *et al.,* (2023) they reported high phenotypic and genotypic coefficients of variation for stem length and net head weight, while Chatterjee *et al.,* (2018) recorded moderate coefficients of variation for head diameter, number of wrapper and non-wrapper leaves, leaf blade width, and leaf blade length. Heritability and the genotypic coefficient of variation combined would provide the most accurate information on the extent of genetic advancement that can be anticipated from selection, as the genotypic coefficient of variation only is insufficient to identify the degree of variation that is heritable. To help the breeder select the traits for selection, it is crucial to determine the heritability. Traits including stem length (cm), head weight (kg), number of wrapper leaves and time to harvest maturity (days) showed high heritability values (> 95%). This suggested that selection according to phenotypic performance would be successful since these attributes are primarily controlled by genetic factors with low environmental influence. These results are congruent with those of Johanson *et al.,* (1995); they proposed that a credible sign of additive gene activity is significant heritability paired with high genetic progress.

Traits stem length (98.90%) and head weight (98.84%) showed both high heritability and substantial genetic advance as percentages of the mean (75.02%, 80.37%), indicating the presence of additive gene effects. Such qualities can be significantly enhanced by simple selection. Abhishek *et al.*, (2021) reached similar findings, emphasizing that high heritability combined with high GAM indicates traits regulated by additive genes. The greatest broad sense heritability was recorded for stem length (98.90%), followed by head weight (98.84%), leaf blade length (98.70%), number of non wrapper leaves (98.31%), number of wrapper leaves (97.78%), and length of head (97.47%), suggesting that these measured traits would respond positively to selection due to their high heritability in broad sense. In a comparable manner, high heritability in the broad sense was noticed for the number of non wrapper leaves and the number of wrapper leaves, indicating that these characteristics might react positively for selection (Sharma *et al.*, 2019a). A High heritability in broad sense estimates were also found for head weight and head length and head diameter. Leaf blade width shown modest heritability. Similarly, the length of the stem showed the highest projected genetic advance (GA %), whereas net head weight, head diameter, and number of wrapper leaves showed moderate genetic advance. Low genetic progress magnitudes were detected for the number of non wrapper leaves, leaf blade length (cm), leaf blade diameter (cm), days to harvest (maturity), and head length (cm). Previous research have also found higher genetic progress for stem length (Singh *et al.,* 2013), net head weight (Hasan *et al.,* 2014), and number of wrapper leaves (Chittora and Singh, 2015). High broad sense heritability ($h^2_{b.s}$) and high genetic advance as percentage of mean (GA %) were observed for stem length and head weight, indicating that additive influences predominate in the inheritance of these characters. High heritability, together with high genetic progress and GCV, was reported for stem length, followed by net head weight (Kaur *et al.,* 2018; Gorka *et al.,* 2021). Traits with high $h^2_{b.s}$ and GA are thought to be under the influence of additive genes, therefore they can be enhanced in Ethiopian Kale by phenotypic selection (Wudneh, 2020).

**Table 3. Estimation of genotypic variance, phenotypic variance, the proportion of phenotypic and genotypic coefficient of variation, heritability in broad sense ($h^2_{b.s}$), genetic advance and genetic advance as percentage of mean for various quantitative traits of cabbage genotypes.**

| S.O.V.<br>Traits | Genotypic variance | Phenotypic variance | GCV | PCV | Heritability in broad sense | Genetic advance | GA as % of mean |
|---|---|---|---|---|---|---|---|
| Leaf blade length (cm) | 83.426 | 84.523 | 17.25 | 17.36 | 98.70 | 18.69 | 35.30 |
| Leaf blade width (cm) | 42.213 | 52.243 | 15.70 | 17.47 | 80.80 | 12.03 | 29.07 |
| Stem length (cm) | 20.246 | 20.471 | 39.23 | 39.45 | 98.90 | 9.22 | 80.37 |
| Days to harvest | 98.569 | 103.227 | 13.12 | 13.43 | 95.49 | 19.99 | 26.41 |
| Number of non-wrapper leaves | 3.547 | 3.608 | 19.78 | 19.95 | 98.31 | 3.85 | 40.41 |
| Number of wrapper leaves | 33.381 | 34.139 | 22.11 | 22.36 | 97.78 | 11.77 | 45.04 |
| head length (cm) | 3.582 | 3.675 | 8.31 | 8.42 | 97.47 | 3.85 | 16.90 |
| Head diameter (cm) | 55.525 | 63.694 | 25.63 | 27.45 | 87.17 | 14.33 | 49.30 |
| Head weight(kg) | 4.175 | 4.224 | 35.17 | 35.37 | 98.84 | 4.18 | 72.02 |

**GCV= percentage of genotypic coefficient of variation, and PCV= percentage of phenotypic coefficient of variation**

**Variability estimates in cabbage genotypes:**

Table 4 shows that the estimated magnitudes of the parameters, standard deviation coefficient of variation, and standard error for the examined significant cabbage characteristics. The results clearly showed that the genotypes were characterized by considerable variability for the majority of the measured traits, as evidenced by the calculated coefficients of variation (CV %). The predicted magnitudes for standard deviation and standard error for leaf blade width were 7.23 and 1.83, respectively. The SD, C.V., and S.E. estimates for stem length were 4.52 and 0.27, respectively. These somewhat high estimations indicated a considerable variance in stem length between cabbage genotypes. Also, the predicted leaf blade lengths were 9.19 and 0.61, consequently. The estimated magnitudes for standard deviation and standard error for days to harvest were 7.23 and 1.83, respectively, showing a significant range in the number of days to harvest (days). Otherwise, these characteristics showed little variance for the number of non wrapper leaves per plant. The calculated magnitudes of SD (5.84) and SE (0.50) for the number of wrapper leaves / plant indicate significant variance across cabbage genotypes. Furthermore, a significant range was found in the diameter of the head; the estimated values were 7.98 and 1.65.

**Table 4. Estimates of variability parameters; standard deviation (S.D.), coefficient of variation (C.V. %) and standard error (S.E.) for the studied characters of cabbage genotypes.**

| Traits/ SOV | SD | CV % | SE |
|---|---|---|---|
| Leaf blade length (cm) | 9.19 | 17.36 | 0.61 |
| Leaf blade width (cm) | 7.23 | 17.47 | 1.83 |
| Stem length (cm) | 4.52 | 39.45 | 0.27 |
| Days to harvest (days) | 10.16 | 13.43 | 1.25 |
| Number of non-wrapper leaves | 1.90 | 19.95 | 0.14 |
| Number of wrapper leaves | 5.84 | 22.36 | 0.50 |
| Head length (cm) | 1.92 | 8.42 | 0.18 |
| Head diameter (cm) | 7.98 | 27.45 | 1.65 |
| Head weight (kg) | 2.06 | 35.37 | 0.13 |

**SD = standard deviation, CV %= coefficient of variation and SE = standard error**

The acquired results indicate relatively low estimates of S.D. and S.E. for the head weight trait. Characters with high coefficients of variability of more than 35% were stem length (39.45%) and head weight (35.37%), which, given their high heritability, indicate significant genetic potential. The characteristics' head diameter and number of wrapper leaves, on the other hand, revealed rather low levels of variability, with estimated coefficients of variation C.V. % of 27.45% and 22.36%, respectively. The four remaining parameters, *i.e.,* head length, days to harvest (days), leaf blade length, leaf blade width, and number of non-wrapper leaves, had the lowest coefficients of variation values, and recorded at 8.42, 13.43, 17.36, 17.47, and 19.95%, respectively. In general, it can be argued that all investigated traits might benefit from appropriate selection procedures, but to variable degrees depending on the amount of variety available in the population. Since a result, the majority of the analyzed cabbage traits looked to have a high probability of improvement, since they retained relatively significant variability in the original population. The results were broadly consistent with those of Kumar *et al.,* (2010), and Ragheb, (2015) on cabbage; they discovered wide ranges of variance in the majority of the analyzed traits. In the same manner, Damarany, (1989a) reported broad ranges of variation in the majority of the analyzed cabbage traits and suggested that the researched traits may be enhanced by mass selection. Similarly, Solieman, (1992) noted that the Balady native cabbage cultivar is a significant source of diversity and may be utilized as the primary genetic material in breeding projects to increase crop quality.

**Genotypic and phenotypic correlation coefficients:**

Correlation coefficients were recorded for each cut and aggregated data to compare the many attributes under consideration. The pooled data results indicated that leaf blade width (cm), leaf blade length (cm), number of wrapper leaves, and head diameter all exhibited a positive and substantial connection with net head weight at the phenotypic and genotypic levels (Table 5). Head weight was also shown to be extremely significant and strongly linked with all characteristics at the genotypic and phenotypic levels, except for stem length, days to harvest, and number of non wrapper leaves (Meena *et al.,* 2010; Rauf, and Abdur Rahim, 2018; Sharma *et al.,* 2019b; El- Shoura, and Diab, 2024).

**Table 5. Phenotypic and genotypic correlation coefficients of different traits studied in cabbage genotypes.**

| Characters | | Leaf blade width (cm) | Stem length (cm) | Leaf blade length (cm) | Days to harvest (days) | Number of non- wrapper leaves/plant | Number of wrapper leaves/ plant | Head length (cm) | Head diameter (cm) |
|---|---|---|---|---|---|---|---|---|---|
| Stem length (cm) | $r_g$ | 0.40* | | | | | | | |
| | $r_{ph}$ | 0.36* | | | | | | | |
| Leaf blade length (cm) | $r_g$ | 0.81** | 0.51** | | | | | | |
| | $r_{ph}$ | 0.72** | 0.51** | | | | | | |
| Days to harvest (days) | $r_g$ | 0.41* | 0.80** | 0.80** | | | | | |
| | $r_{ph}$ | 0.36* | 0.78** | 0.78** | | | | | |
| Number of non-wrapper leaves | $r_g$ | 0.58** | 0.79** | 0.93** | 0.92** | | | | |
| | $r_{ph}$ | 0.62** | 0.78** | 0.82** | 0.89** | | | | |
| Number of wrapper leaves | $r_g$ | 0.22 | -0.65** | -0.23 | -0.72** | -0.43* | | | |
| | $r_{ph}$ | 0.20 | -0.64** | -0.23 | -0.69** | -0.42* | | | |
| Head length (cm) | $r_g$ | 0.67** | 0.28 | 0.83** | 0.38* | 0.51** | 0.22 | | |
| | $r_{ph}$ | 0.66** | 0.27 | 0.82** | 0.37* | 0.50** | 0.22 | | |
| Head diameter (cm) | $r_g$ | 0.94** | 0.06 | 0.65** | 0.11 | 0.32* | 0.52** | 0.95** | |
| | $r_{ph}$ | 0.79** | 0.06 | 0.61** | 0.10 | 0.30* | 0.48** | 0.88** | |
| Head weight (kg) | $r_g$ | 0.93** | 0.28 | 0.88** | - 0.48** | 0.23 | 0.98** | 0.94** | 0.90** |
| | $r_{ph}$ | 0.83** | 0.28 | 0.87** | - 0.47** | 0.23 | 0.87** | 0.92** | 0.83** |

***, ** = Significant at 0.05 and 0.01 levels of probability, consequently.**

The most significant and favorable connection was found between head weight and the number of wrapper leaves (0.98 and 0.87), followed by head weight and head length (0.94 and 0.92). The characteristic, time to harvest (maturity), revealed a substantial and negative association with head weight. Previous research has also found a negative and substantial correlation between the number of wrapper leaves and the length of the stem and the duration to harvest maturity. This finding in agreement with the results obtained by Cervenski *et al., (*1998) and Hany and Ismail, (2018). They found a substantial and positive association between head weight and length and diameter of head in cabbage. In addition, the significant positive correlation between net head weight, head diameter, and head length, selecting genotypes with the appropriate length and diameter of head, and net head weight will successfully produce highly productive genotypes (Mehtap *et al.,* 2023). Meena *et al.,* (2014) found a substantial and positive association between total net head weight, number of wrapper leaves, and head diameter in cabbage. While there is a positive and significant correlation between net head weight with head length, number of wrapper leaves, and days to maturity (harvest) in cauliflower by ( Nimkar and Soniya, 2013; Chatterjee *et al.,* 2018). As can be seen from the table 5, some negative associations were reported between the cabbage characteristics. Head weight was highly negatively correlated with days to harvest. Number of wrapper leaves was highly negative associated observed stem length, days to harvest and number of non – wrapper leaves. Dey *et al.,* (2015); they explained that knowing the correlation between head weight and its contributing traits can help a plant breeders determining the degree of correlation between them and improving selection effectiveness by using desirable combinations of traits while minimizing the retarding effect of negatively correlated traits. These findings give important insights on cabbage breeding strategies for increasing productivity, and adaptability to changing environmental conditions.

## CONCLUSION

The genotypic coefficient variance was lower than the phenotypic coefficient variance for all studied investigated, suggesting that the environment has a significant impact on the traits' inheritance. Stem length, net head weight, leaf blade length and the number of non wrapper leaves all recorded a high heritability percentage in broad sense. On the other side, the genetic progress was mainly determined by stem length, net head weight, leaf blade length, and the number of non wrapper leaves. A strong positive correlation was found between head weight, head length, number of wrapper leaves, and head diameter. These traits must be considered in the creation of high - producing cabbage genotypes. The findings highlight how choosing genetically varied parents based on key yield-contributing characteristics might improve breeding efficiency and expedite genetic improvements in cabbage. The discovered diversity also indicates the possibility of generating superior cultivars with higher yields and quality. This variability may be used to create superior cultivars that address both commercial needs and environmental concerns. Future study should concentrate on discovering the underlying genetic pathways and investigating additional factors that contribute to overall success in cabbage growing.

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## إستنباط تراكيب وراثية جديدة من الكرنب من خلال التلقيح البرعمى والإنتخاب

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### الملخص

تهدف هذة الدراسة الحصول على تراكيب وراثية جديدة من الكرنب (الصنف البلدى) بما يتوافق مع الظروف المحلية عن طريق التلقيح البرعمى والإنتخاب لذلك أجريت هذة الدراسة بمزرعة محطة البحوث الزراعية بالجميزة - معهد بحوث البساتين – مركز البحوث الزراعية خلال موسمى الزراعة ٢٠٢١ و ٢٠٢٢ وأجريت الدراسة فى تجربة مصممة بطريقة قطاعات كاملة العشوائية فى ثلاث مكررات وقد تم أخذ القياسات التالية طول نصل الورقة (سم) ، عرض نصل الورقة (سم) وطول الساق (سم) و الأيام حتى الحصاد( الأيام) وعدد الأوراق الداخلية الملتفة ، عدد الأوراق الخارجية الغير ملتفة و طول الرأس (سم) ، قطر الرأس(سم) ووزن الرأس (كجم)، وقد أظهرت النتائج عند تحليل التباين الى وجود إختلافات عالية المعنوية بين التراكيب الوراثية الجديدة فى الصفات محل الدراسة مما يمكن معه أهمية البدء بإتباع أحد برامج التربية لتحسين الكرنب لإنتاج تراكيب وراثية أفضل فى صفاتها من الكرنب البلدى. وكانت التباينات المظهرية أكبر من نظيرتها الوراثية وتشكل الجزء الأكبرمن التباين الكلى مما يدل على أهمية التباين البيئى وتأثيره على التعبير على إظهار هذه الصفات. وتباينت قيم معاملات التباين الوراثي من صفة إلى أخرى. وكانت أعلى قيم لمعامل التوريث لوحظت لصفات طول الساق (٩٨,٩٠٪) ووزن الرأس (٩٨,٨٤ %) وطول نصل الورقة (٩٨,٧٠) على التوالى كما لوحظت نسبة توريث عالية بالمعنى الواسع مع تقدم وراثي عالي كنسبة مئوية من المتوسط وخاصة الصفات طول الساق (٨٠,٣٧ %) ووزن الرأس (٧٢,٠٢ %) وقطر الرأس (٤٩,٣٠ %) على التوالى. أشارت النتائج إلى الدور الكبير للتباين الإضافي في وراثة تلك الصفات والتى يمكن تحسينها بشكل فعال من خلال الإنتخاب. أظهر معامل الإرتباط بين كل زوج من الصفات قيماً موجبة أو سالبة (فى الإتجاة المرغوب) وعالية المعنوية لبعض الصفات خاصة وزن الرأس (كجم) مع كلاً من عدد الأوراق الداخلية الملتفة للنبات وطول وقطر الرأس وعرض نصل الورقة والأيام حتى الحصاد على التوالى.، مما يشير الى أن الإنتخاب لصفة واحدة من تلك الصفات سيكون مرتبطاً بتحسين الصفات الأخرى وكذلك يدل على أهمية هذه الصفات أثناء عملية الإنتخاب حيث يمكن الإنتخاب الموجهه لهذه الصفات وإنتاج تراكيب وراثية عالية الإنتاجية.