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# GENETICAL STUDIES OF SOME MORPHOLOGICAL TRAITS AND YIELD OF BALADY CABBAGE USING NORTH CAROLINA DESIGN II

**Hany G. Zyada* and H. E.M. A. Ismail**

Hort. Dept., Fac. Agric., Zagazig Univ., Egypt

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**ABSTRACT:** This work was carried out at Ghazala Experimental Farm, Fac. Agric., Zagazig Univ., Egypt, during the two successive winter seasons of 2015/2016 and 2016/2017, to estimates the genetic parameters for Balady cabbage, using North Carolina Mating Design II. Ten selected plants were used for this study (five as males and other five as females) from Balady cabbage population. Results of this study showed insignificant mean squares for male × female interaction for all the studied traits, except that for stem diameter, leaf width, wrapper leaves weight per plant and head height, which were highly significant. Estimations of additive variance ($\sigma^2_A$) were higher than dominance variance ($\sigma^2_D$) for stem diameter, leaf width, head height, head diameter and head weight per plant (yield), indicate the important of additive gene action in the inheritance of these traits. Nevertheless, $\sigma^2_D$ was higher than $\sigma^2_A$ for stem height from wrapper leaves to head, leaf length, and wrapper leaf number and weight per plant, so that the dominance was played very important role in the inheritance of these traits. The heritability in broad-sense ranged from -4.30% for stem height up to wrapper leaves to 83.80% for leaf width. While, narrow-sense of heritability ranged from -2.10% for stem height up to wrapper leaves to 97.35% for head height.

**Key words:** Cabbage, additive variance, dominance variance, degree of dominance, heritability, correlation and North Carolina Design II.

## INTRODUCTION

Cabbage (*Brassica oleracea* var. capitata L.) is widely consumed by different ways all over the world. It considered a rich source of protein comprising all essential amino acids, minerals (calcium, iron, magnesium, sodium, potassium and phosphorus), and antioxidants which is reported to have anti-carcinogenic properties **(Singh *et al*., 2010a,b)**. In addition, cabbage has fiber content and vitamins A, C and K **(Swarup, 2006)**.

Various genetic mating designs have been established to obtain genetic informations that control plant traits, to generate a breeding population for use as a basis in the selection and development of potential varieties **(Acquaah, 2012)**. North Carolina Designs (I, II and III) were developed by **Comstock and Robinson (1948 and 1952)** for studying open pollinated populations. Design II (NCD-II) is commonly used for estimating the additive and dominance variances through using a full-sib and half-sib mating, respectively.

The main advantage of NCD-II design is due to its ability to supply a test of significance for additive genetic variance **(Hill *et al*., 1998)** and successfully used in obtaining estimates of genetic variance in cabbage. Knowledge of genetic informations help breeders to select appropriate breeding method for crop improvement. The genetic components and heritability of yield and its related traits in cabbage have been identified by different genetic designs such as NCD-II **(Alza and Fernandez-Martinez, 1997)** and using line × tester **(Ghaffari *et al*., 2011)**. Description of associations between economic traits of cabbage

* **Corresponding author: Tel. :** +201007016878
**E-mail address:** hgzyada@yahoo.com

is very important in breeding programs. The main purpose for breeders is to achieve an increase in cabbage yield. Yield is a complex character determined by several components having positive or negative effects of this trait.

Therefore, the present study was designed to evaluate mean performance of open pollinated populations using NCD-II (Quassi-diallel) and to estimates genetic control of some traits in Balady cabbage.

## MATERIALS AND METHODS

This work was carried out at Ghazala Experimental Farm, Faculty of Agriculture, Zagazig University, Egypt, during the two successive winter seasons of 2015/2016 and 2016/2017 on cabbage (*Brassica oleracea* var. capitata L.) Balady population. The North Carolina Design II (NCD-II) was used to estimates the genetic parameters for cabbage population.

According to **Comstock and Robinson (1952)**, plant material used for satisfaction this design were chosen randomly from Balady cabbage. In 2015/2016, ten plants were selected for inter-mating, five of them were used as males and the other five were used as females. At flowering stage, each male was crossed with each female. So that, the cross of 5 males × 5 females, resulted 25 cross combinations. At seed maturity (dry seed), each cross was separately threshed, paged and marked by its number.

In 2016/2017, on 10 August, seeds of the 25 crosses were sown separately in speedling trays and after 47 days (on 26/9/2016), were transplanted to open field and arranged in a randomized block design with three replicates. Each plot contains one ridge with eight plants (3.5 m length and 70 cm width). This number of plants was used to evaluate a genotype of cabbage **(Swarup, 1975)**.

Irrigation, fertilization, as well as weed and pest control were practiced followed the recommended methods in district.

### Data Recorded

At harvest stage, morphological traits; *i.e.*, stem height up to wrapper leaves, stem height from wrapper leaves to head, stem diameter, leaf length and leaf width, and yield traits; *i.e.*, wrapper leaves number per plant, wrapper leaves weight per plant, head height, head diameter (at the widthest diameter) and head weight per plant were recorded.

### Statistical Analysis

The statistical model for NCD-II, in this case was as follow:

$$Y_{ijkln} = \mu + S_i + b_{ij} + m_{ik} + f_{il} + m.f_{ikl} + e_{ijkln}$$

Where:

$\mu$: general mean,

$S_i$: effect of ith sets,

$b_{ij}$: effect of jth replications,

$m_{ik}$: effect of kth males,

$f_{il}$: effect of lth females,

$m.f_{ikl}$: effect of male × female, and

$e_{ijkln}$: error association with each observation.

It should be noted that both male and female mean squares would be tested against male × female mean square, if it was significant. The later is, in turn, tested against error mean square.

Estimation of genetic components and genetic parameters

Genetic variance

$$\sigma^2_m = \frac{MS_m - MS_{m.f}}{f.r} \quad \text{(Half-sibs)}$$

$$\sigma^2_f = \frac{MS_f - MS_{m.f}}{m.r} \quad \text{(Full-sibs)}$$

$$\sigma^2_{m.f} = \frac{MS_{m.f} - MS_e}{r} \quad \text{(Interaction of male × female)}$$

Estimation of genetic components and ratios

$\sigma^2_A = 4(\sigma^2_m)$ (**Singh and Choudhary, 1976**)

$\sigma^2_D = 4(\sigma^2_f - \sigma^2_m)$ (**Singh and Choudhary, 1976**)

$h^2_b = \sigma^2_A / \sigma^2_A + \sigma^2_D + \sigma^2_e$ Heritability in broad-sense (**Kearsey and Pooni, 1996**)

$h^2_n = \sigma^2_A - \sigma^2_D / \sigma^2_A + \sigma^2_D + \sigma^2_e$ Heritability in narrow-sense (**Kearsey and Pooni, 1996**)

$\bar{d} = \sqrt{2(\delta^2 D)/\delta^2 A}$ Degree of dominance (**Kearsey and Pooni, 1996**)

# RESULTS

## Analysis of Variance

Results of the analysis of variance for Balady cabbage families resulted from NCD-II for morphological traits (Table 1), indicated that head weight and leaf length were significant for genotypes, and for other traits were highly significant, and insignificant for stem height up to wrapper leaves and stem height from wrapper leaves to head. Results also showed that the variance due to male × female interaction was insignificant for all the studied traits, except that for each of stem diameter, leaf width, wrapper leaves weight per plant and head height, which were highly significant.

Since the interaction of male × female was significant, it should be use to test the mean squares of males and females. On the other side, error variance will be use to test those traits having insignificant male × female. By this manner, the variances due to both males and females were significant and highly significant for all the studied traits, except that for stem height up to wrapper leaves in both males and females, and stem height from wrapper leaves to head, leaf length and wrapper leaves number per plant in males were insignificant mean squares.

## Average Mean Performance

Average mean performance (males and females) of the 25 families resulted from crossing of 5 males × 5 females to establish NCD-II (Table 2), revealed that, mean values of the progenies derived from the males and females had high and low values, for No.9 and No.4, and No.6 and No.5 in stem height up to wrapper leaves; No.10 and No.5, and No.6 and No.4 in stem height from wrapper leaves to head; No.8 and No.1, and No.6 and No.3 in stem diameter; No.8 and No.4, and No.6 and No.1 in leaf length; No.9 and No.2, and No.7 and No.3 in leaf width; No.7 and No.5, and No.10 and No.4 in wrapper leaf number per plant; No.8 and No.2, and No.6 and No.4 in wrapper leaf weight per plant; No.9 and No.2, and No.10 and No.3 in both head height and head diameter; and No.7 and No.2, and No.6 and No.3 in head weight (yield), respectively.

## Genetic Components

The genetic components of the studied cabbage traits resulted from the NCD-II analysis are presented in Table 3. The results showed that estimates of additive ($\sigma^2_A$) were higher than dominance ($\sigma^2_D$) for stem diameter, leaf width, head height, head diameter and head weight per plant (yield). On the contrary, estimates of dominance variance were higher than additive variance for stem height from wrapper leaves to head, leaf length, and wrapper leaf number and weight per plant. However, those two components ($\sigma^2_A$ and $\sigma^2_D$) were negative and having equal values for stem height up to wrapper leaves.

Concerning estimates the degree of dominance (the root square of additive over dominance), results in Table 3 show that these values were higher than unit having positive and negative signs for all the studied traits, except that for head diameter which is less than unit.

For estimates of heritability in both broad and narrow-sense (Table 3), the results revealed that the values of heritability in broad-sense ranged from -4.30% for stem height up to wrapper leaves to 83.80% for leaf width. On the other hand, the estimates of heritability in narrow-sense ranged from -2.10% for stem height up to wrapper leaves to 97.35% for head height. Moreover, the estimates of narrow-sense were less than in broad-sense heritability for all the studied traits. Nevertheless, narrow-sense heritability in stem diameter, head height, head diameter and head weight per plant (yield) was higher than broad-sense heritability, that due to negative value of $\sigma^2_D$.

# DISCUSSION

Results of NCD-II reflected insignificant mean squares due to male × female for all the studied traits, except that for stem diameter, leaf width, wrapper leaf weight per plant and head height, which were highly significant. Moreover, males and females mean squares were significant and highly significant for all the studied traits, it means that the selected plants from open pollinated population are different and had sufficient variability. So selection of a good plants in wrapper leaf number per plant, head diameter, head height and head weight may

**Table 1. Mean squares for ten traits of cabbage resulted from NCD-II during 2016/2017 season**

| SOV | df | Stem height up to wrapper leaves (cm) | Stem height from wrapper leaves to head (cm) | Stem diameter (cm) | Leaf length (cm) | Leaf width (cm) | Wrapper leaf No./ plant | Wrapper leaf wt./ plant (kg) | Head height (cm) | Head diameter (cm) | Head wt./ plant (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reps** | 2 | 2.56 | 0.05 | 0.05 | 16.70* | 12.60** | 11.75** | 0.64** | 1.70 | 0.75 | 0.82* |
| **Genotypes** | 24 | 1.54 | 0.32 | 0.24** | 7.50* | 12.44** | 3.11** | 0.15** | 5.96** | 4.65** | 0.37* |
| **Males** | 4 | 1.45 | 0.10 | 0.50** | 2.30 | 20.60** | 1.28 | 0.17** | 12.13** | 10.35** | 0.91** |
| **Females** | 4 | 1.38 | 0.63* | 0.30** | 20.70** | 30.83** | 13.58** | 0.33** | 7.65* | 9.58** | 0.47** |
| **Male×female** | 16 | 1.61 | 0.30 | 0.16** | 5.50 | 5.80** | 0.96 | 0.10** | 3.99** | 1.99 | 0.20 |
| **Error** | 48 | 1.95 | 0.21 | 0.05 | 4.10 | 1.29 | 1.02 | 0.04 | 1.26 | 1.90 | 0.17 |

NCD-II: North Carolina Design II.
NS, * and **: insignificant, significant and highly significant at 5% and 1% levels of probability, respectively.

**Table 2. Average mean performance of the families results males and females for ten traits of cabbage resulted from NCD-II during 2016/2017 season**

| Genotype | | Stem height up to wrapper leaves (cm) | Stem height from wrapper leaves to head (cm) | Stem diameter (cm) | Leaf length (cm) | Leaf width (cm) | Wrapper leaf No./ plant | Wrapper leaf wt./ plant (kg) | Head height (cm) | Head diameter (cm) | Head wt./ plant (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Males** | **6** | 8.06 | 3.68 | 4.16 | 32.88 | 35.42 | 12.62 | 1.452 | 18.76 | 24.26 | 3.254 |
| | **7** | 8.54 | 3.74 | 4.18 | 33.58 | 34.72 | 12.96 | 1.676 | 20.86 | 25.64 | 3.830 |
| | **8** | 8.56 | 3.78 | 4.60 | 33.96 | 36.00 | 12.32 | 1.677 | 20.34 | 25.76 | 3.661 |
| | **9** | 8.94 | 3.72 | 4.24 | 33.44 | 37.76 | 12.38 | 1.643 | 21.04 | 26.50 | 3.805 |
| | **10** | 8.60 | 3.90 | 4.26 | 33.56 | 35.28 | 12.24 | 1.505 | 20.28 | 25.12 | 3.442 |
| **Females** | **1** | 8.46 | 3.68 | 4.44 | 31.94 | 35.84 | 12.82 | 1.475 | 20.14 | 25.30 | 3.440 |
| | **2** | 8.32 | 3.92 | 4.30 | 34.46 | 37.34 | 12.48 | 1.724 | 21.14 | 26.12 | 3.803 |
| | **3** | 8.68 | 3.72 | 4.14 | 32.88 | 33.88 | 12.64 | 1.673 | 19.14 | 24.14 | 3.393 |
| | **4** | 9.00 | 3.50 | 4.14 | 34.82 | 37.08 | 10.96 | 1.390 | 20.48 | 25.94 | 3.712 |
| | **5** | 8.24 | 4.00 | 4.36 | 33.32 | 35.04 | 13.62 | 1.690 | 20.38 | 25.78 | 3.644 |
| **LSD at 5%** | | Ns | ns | 0.37 | Ns | 1.86 | 1.66 | 0.332 | 1.84 | 2.26 | NS |

NCD-II: North Carolina Design II.

**Table 3. Estimates of genetic parameters and genetic ratios of cabbage resulted from NCD-II**

| Genetic estimates | Stem height up to wrapper leaves (cm) | Stem height from wrapper leaves to head (cm) | Stem diameter (cm) | Leaf length (cm) | Leaf width (cm) | Wrapper leaf No./ plant | Wrapper leaf wt./ plant (kg) | Head height (cm) | Head diameter (cm) | Head wt./plant (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| $\sigma^2_m$ | - 0.01 | - 0.01 | 0.02 | - 0.21 | 0.99 | 0.02 | 0.01 | 0.54 | 0.56 | 0.05 |
| $\sigma^2_f$ | - 0.02 | 0.02 | 0.01 | - 0.01 | 1.67 | 0.84 | 0.02 | 0.24 | 0.51 | 0.02 |
| $\sigma^2_{m.f}$ | - 0.11 | 0.03 | 0.03 | 0.47 | 1.50 | - 0.06 | 0.02 | 0.91 | 0.03 | 0.01 |
| $\sigma^2_A$ | - 0.04 | - 0.04 | 0.09 | 0.85 | 3.95 | 0.08 | 0.02 | 2.17 | 2.24 | 0.19 |
| $\sigma^2_D$ | - 0.04 | 0.12 | - 0.06 | 4.90 | 2.73 | 3.28 | 0.04 | - 1.20 | - 0.21 | - 0.12 |
| $\bar{d}$ | 1.41 | - 2.45 | - 1.00 | 3.39 | 1.18 | 9.06 | 2.10 | - 1.04 | - 0.42 | - 1.13 |
| $h^2_b$ | - 4.30 | 27.60 | 61.50 | 58.40 | 83.80 | 76.70 | 61.00 | 44.25 | 51.78 | 28.45 |
| $h^2_n$ | - 2.10 | 13.80 | 88.90 | 8.60 | 49.60 | 1.80 | 19.00 | 97.35 | 56.85 | 78.70 |

NCD-II: North Carolina Design II.
$\sigma^2_m$: males variance, $\sigma^2_f$: females variance, $\sigma^2_{m.f}$: male×female interaction variance, $\sigma^2_A$: additive variance, $\sigma^2_D$: dominance variance, $\bar{d}$: degree of dominance, $h^2_b$: heritability in broad-sense and $h^2_n$: heritability in narrow-sense.

improving cabbage population. Similar result on cauliflower were reported by **Gad *et al.* (1985)**.

There was also a high correspondence between average mean performance of the males and females in all the studied traits. Nevertheless, insignificant differences in stem height up to wrapper leaves and stem height from wrapper leaves to head were also reported by **Balkaya *et al.* (2005) and Kibar *et al.* (2015 and 2016)**, in a study that assessed of 36 morphological traits of leaf and head cabbage genotypes.

Estimations of $\sigma^2_A$ and $\sigma^2_D$ for stem diameter, leaf width, head height, head diameter and head weight, showed that $\sigma^2_A$ was higher than $\sigma^2_D$, indicated the importance of the additive gene action for these traits. On the other side, $\sigma^2_D$ was higher than $\sigma^2_A$ for stem height from wrapper leaves to head, leaf length, and wrapper leaf number and weight per plant, indicating the importance of dominance gene effects in the inheritance of these traits. Obtained results are in accordance with **Sparrow *et al.* (2004)** on *Brassica oleracea*.

Estimates of degree of dominance, were higher than unit for all the studied traits, indicating over-dominanc. However, the degree of dominance of head diameter was less than unity, indicating the existence of complete and partial dominance effect. For the last traits, environments play a respectable portion in the expression of these traits. Similar results were obtained by **Sparrow *et al.* (2004)** on *Brassica oleracea*.

Estimates of heritability revealed that, the values of heritability in broad-sense varied between -4.30% in stem height up to wrapper leaves to 83.80% for leaf width. While, the estimates of narrow-sense heritability varied between -2.10% for stem height up to wrapper leaves to 88.90% for stem diameter. The higher values of broad-sense heritability indicated higher importance of genetic effects in control of the traits, while low values depended to high extent to environmental factors, so that it requires to improve some agricultural factors such as sowing date, fertilization and irrigation. Furthermore, the high narrow-sense heritability indicate the importance of the additive gene action for the genetic control of the traits, medium narrow-sense implied the importance of both additive and dominance gene action. While, low value indicate the importance of the dominance gene action for the genetic control of the trait **(Golabadi *et al.*, 2015)**.

Moreover, results of association (correlation) between some important traits (Table 4); *i.e.*,

**Table 4. Correlation coefficient between morphological traits with both head diameter and weight of cabbage**

| Trait | Stem height up to wrapper leaves (cm) | Stem height from wrapper leaves to head (cm) | Stem diameter (cm) | Leaf length (cm) | Leaf width (cm) | Wrapper leaf No./ plant | Wrapper leaf wt./ plant (kg) | Head height (cm) | Head diameter (cm) | Head wt./plant (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Head diameter (cm)** | 0.197 | 0.041 | 0.140 | 0.507** | 0.667** | -0.117 | 0.149 | 0.740** | - | 0.813** |
| **Head weight (kg)** | 0.298 | -0.056 | 0.094 | 0.494* | 0.626** | -0.042 | 0.398* | 0.709** | 0.813** | - |

NS, * and **: insignificant, significant and highly significant at 5% and 1% levels of probability, respectively.

cabbage yield (head diameter and weight), reflected positive and significant correlation between leaf length, leaf width, wrapper leaf weight per plant and head height with cabbage yield. So, to improve the yield selection for the previous traits and selection against the traits that had negative correlation (stem height from wrapper leaves to head and wrapper leaf number per plant) with head diameter and weight. These results suggest that for improving cabbage yield, recurrent selection program, to maintain additive portion in the population of cabbage. In this case, recurrent selection is a helpful to improve cabbage yield and it's related traits, and to select against the traits that has negative correlation with yield.

## Conclusion

It seems from previous study that Balady cabbage population had a significant variation in most of the morphological and yield traits. These findings are important for breeding studies in the future. This work had contributed to better understanding of variability of the studied traits. Moreover, the importance of both additive and dominance gene actions for the genetic control of the traits under study to establish recurrent selection. Recurrent selection would seem to be useful to improve the traits that has high $\sigma^2_A$, and get information about undesirable traits such as stem height from wrapper leaves to head, leaf length and wrapper leaf number per plant to get new improve population.

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# دراسات وراثية لبعض الصفات المورفولوجية والمحصول للكرنب البلدي باستخدام تصميم نورث كارولينا II (NCD-II)

**هاني جمال زيادة – هاني السيد محمد علي إسماعيل**

قسم البساتين- كلية الزراعة- جامعة الزقازيق- مصر

أجرى هذا العمل في مزرعة غزالة بكلية الزراعة جامعة الزقازيق – مصر، خلال الموسمين الشتويين ٢٠١٥/٢٠١٦ و٢٠١٦/٢٠١٧، لتقدير المدلولات الوراثية في الكرنب البلدي باستخدام تصميم نورث كارولينا II، تم استخدام عشرة نباتات منتخبة لهذه الدراسة (٥ كآباء ومثلهم كأمهات) من عشيرة الكرنب البلدي، أظهرت نتائج هذه الدراسة عدم وجود معنوية للتفاعل بين الآباء والأمهات لكل الصفات ماعدا قطر الساق وعرض الورقة ووزن الأوراق المفتوحة لكل نبات وارتفاع الرأس حيث كانت عالية المعنوية، تقديرات تباين الإضافة كانت أعلي من تباين السيادة لصفات قطر الساق وعرض الورقة وارتفاع الرأس وقطر الرأس ووزن الرأس (المحصول)، إشارةً إلي أهمية الفعل الجيني الإضافي في وراثة هذه الصفات، بينما كان التباين الوراثي السيادي أعلي من التباين الإضافي لصفات ارتفاع الساق من الأوراق المفتوحة حتى الرأس وطول الورقة وعدد ووزن الأوراق المفتوحة لكل نبات، لذلك فإن السيادة لها دوراً هاماً في وراثة هذه الصفات، درجة التوريث بالمعني الواسع تراوحت من ٤,٣٠% لصفة ارتفاع الساق حتى الأوراق المفتوحة إلى ٨٣,٨٠% لصفة عرض الورقة، بينما تراوحت درجة التوريث بالمعني الضيق من ٢,١٠% لصفة ارتفاع الساق حتى الأوراق المفتوحة إلى ٩٧,٣٥% لصفة ارتفاع الرأس.

**المحكمون :**

**١- أ.د. لطفـــي عبدالفتاح بدر** أستاذ الخضر – كلية الزراعة بمشتهر – جامعة بنها.

**٢- د. محمد محمد عبدالحميد** أستاذ المحاصيل المساعد – كلية الزراعة – جامعة الزقازيق.