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# THE INTERRELATIONSHIPS BETWEEN GRAIN WEIGHT AND OTHER EAR CHARACTERS IN MAIZE

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By

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## ABSTRACT

Two field experiments were carried out at the Experimental Farm of Agronomy Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt during the two seasons of 2010 and 2011 to evaluate the performance of six maize hybrids (comprising three hybrids from each of single crosses and three-way crosses). The experimental design used was a randomized complete block design with six replications. Four statistical procedures were applied to estimate the relative importance of some grain weight components. The used methods of analysis were simple correlation, multiple linear regression, stepwise multiple linear regression and path analysis. Highly significant and positive association was obtained among all the studied ear traits and grain weight. The results of multiple linear regression model indicated that the ear traits accounted for 79.2% (expressed as $R^2$) of the total variation of grain weight. All ear traits except ear diameter were significantly contributed towards ear grain weight. Considering the model of stepwise multiple linear regression, 75.5% (expressed as $R^2$) of the total variability of ear grain weight were explained by the traits: number of rows/ear, number of kernels / row and 100 kernels weight. The same three traits were also responsible for 80.06% and 78.33% of grain weight using full path analysis model and stepwise path analysis model, respectively. Based on the previous results, it could be concluded that the highest ear grain weight of maize would be obtained by selecting breeding materials that have large numbers of rows/ear and kernels /row and heavy weight of 100 kernels.

***Key words:*** *maize, path coefficients and stepwise path analysis, stepwise regression.*

## 1. INTRODUCTION

The world population is expected to increase from its current 6.7 to 8 billion by about 2020. Since the area of arable land is limited, how to produce more food with limited land resources has been the research focus of domestic and international scholars. Yield of corn (*Zea mays* L.) is considered as a complex inherited character. Therefore, direct selection for yield *per se* may not be the most efficient method for its improvement. But indirect selection for other yield related characters could be more effective (Wannows *et al*., 2010), especially when such traits are closely associated with yield and reflect high heritability estimates.

Information obtained from correlation coefficients among the yield and its related traits could give an initial idea about the more important ones to take in consideration. Breeding decisions built only on the results of correlation coefficient may not always be effective because the simple correlation coefficient measures the mutual association only between a pair of traits neglecting the complex interrelations among all traits (Kang, 1994). Accordingly, the correlations *per se* may not provide deep image about the importance of each component for determining the variability of grain yield. Wannows *et al.* (2010) and Khavari Khorasani *et al.* (2011) reported that highly significant positive correlation values were detected between grain yield/plant and each of ear diameter, ear length, number of grains/row, number of rows/ear and 100 kernels weight.

A path coefficient is a standardized partial regression coefficient, measuring the direct influence of a predictor variable on the response variable. This permits the separation of correlation coefficient into direct effect (path coefficient) and indirect effect (that exerted through other independent variables). Gautam *et al*. (1999)

showed that the maximum direct effects towards grain yield were contributed by ear length followed by shelling percentage. Mohammadi *et al*. (2003) reported that 100 kernel weight and total number of kernels per ear revealed highest direct effects on grain weight/ear( p = 0.74 and p=0.78, respectively), while ear length, ear diameter, number of rows/ear and number of kernels/row were found to fit as second-order variables. Bahoush and Abbasdokht (2008) mentioned that path analysis revealed that 100 kernel weight exerted maximum positive direct effect on grain yield of maize. The present work aimed to study the relationship between grain weight and its related characters in maize using some statistical procedures namely: simple correlation coefficient, full model regression, stepwise multiple linear regression and path coefficient analysis. The results could be useful to plan an appropriate selection protocol for improving grain yield in maize.

## 2. MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm of the Agronomy Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt, during the two consecutive seasons of 2010 and 2011 to evaluate some statistical approaches used for estimating the relationships among ear grain weight and its components in maize. The experimental material included three commercial single crosses (30k08, 30k09 and Bashair), and three of three-way crosses (Giza 311, Giza 323 and Giza 324). The experimental design used was a randomized complete block design with six replicates. The plot area was 17.5 $m^2$ including 5 ridges, each of 5 m long and 0.7 m wide. Cultural practices were maintained at the recommended levels to satisfy maximum grain yield. At harvest, to obtain more reliable results, a large sample size consisting of 30 ears was randomly chosen from each plot to record the data of following seven ear traits:

1. Number of rows / ear (NRE). ($X_1$).
2. Number of kernels / row (NKR). ($X_2$).
3. Ear length (EL) in cm. ($X_3$).
4. Ear diameter (ED) in cm. ($X_4$).
5. 100 kernel weight (100KW) gm. ($X_5$).
6. Shelling percentage (SP %). ($X_6$).
7. Ear grain weight (EGW) gm. (Y)

**Statistical procedures**

Four statistical procedures, differing in their mathematical concept; target and final output, were separately evaluated to explore the relationships among ear grain weight and its components in maize. The used models are summarized as follows:

1. Simple correlation: matrix of simple correlation coefficient between ear grain weight and each of other ear traits, computed as outlined by Steel and Torrie (1980).
2. Path analysis: the methodology proposed by Dewey and Lu (1959) was followed to partition the simple correlation coefficient of the previous step into direct and indirect effects using two models of analysis ; full model and stepwise path analyses models. The first model takes in consideration all studied ear traits as components of ear grain weight while the second model concentrated on the most important ear traits as a result of stepwise multiple linear regression model.
3. Multiple linear regressions: full model regression was estimated according to Draper and Smith (1981) using ear grain weight as a resultant variable and its related ear traits as explanatory variables.
4. Stepwise multiple linear regression: this model was applied according to Draper and Smith (1981) to determine the variables that accounted for the majority of the total ear grain weight variability. To avoid the lack of fit of both full model regression and stepwise multiple linear regression as a result of multicollinearity problem (the strong association among ear traits), the level of multicollinearity was estimated using a common measure namely: Variance Inflation Factor (VIF) as suggested by Hair *et al.* (1992). Large VIF values (above 10) reported high collinearity causing a rejected model.

## 3. RESULTS AND DISCUSSION

The basic descriptive statistics for the studied ear traits are shown in Table (1). It is noted that the estimates of coefficient of variation (CV %) were located at the statistically acceptable limits for each character.

### 3.1. Correlation matrix

The simple correlation coefficients among all the studied traits are shown in Table (2). The results revealed that all the studied ear traits had highly significant and positive association with grain weight. The greatest correlation coefficients were recorded between grain weight and each of the number of kernels / row (0.648**) and ear length (0.619**). This result could help the

**Table (1): Basic descriptive statistics for the seven ear traits, over the two seasons.**

| Ear traits | Descriptive statistics | | | | |
|---|---|---|---|---|---|
| | Mean | SD | CV % | Mini. value | Maxi. value |
| No. rows/ear | 12.89 | 0.88 | 6.80 | 10.00 | 16.00 |
| No. kernels/row | 40.40 | 3.25 | 8.04 | 30.00 | 48.00 |
| Ear length, cm | 18.43 | 1.59 | 8.61 | 13.50 | 22.00 |
| Ear diameter, cm | 3.30 | 0.37 | 11.21 | 2.20 | 4.10 |
| 100 kernel weight,gm | 30.9 | 2.90 | 9.39 | 23.27 | 43.24 |
| Shelling % | 0.85 | 0.03 | 3.07 | 0.79 | 0.93 |
| Ear grain weight,gm | 141.73 | 21.89 | 15.44 | 99.00 | 184.44 |

**Table (2): Matrix of simple correlation coefficients among ear grain weight and its components in maize over 2010 and 2011 seasons.**

| Traits | NRE | NKR | EL | ED | 100KW | SP | EGW |
|---|---|---|---|---|---|---|---|
| No. of rows / ear (NRE) | 1 | -0.141 | 0.018 | 0.327** | 0.043 | -0.011 | 0.318** |
| No. of kernels / row (NKR) | | 1 | 0.703** | 0.218 | 0.214 | 0.453** | 0.648** |
| Ear length (EL) | | | 1 | 0.351** | 0.415** | 0.255* | 0.619** |
| Ear diameter (ED) | | | | 1 | 0.095 | 0.041 | 0.398** |
| 100 kernel weight (100KW) | | | | | 1 | 0.417** | 0.563** |
| Shelling percentage (SP) | | | | | | 1 | 0.566** |
| Ear grain weight (EGW) | | | | | | | 1 |

*** and ** significant at 0.05 and 0.01 probability levels, respectively.**

breeder to select high ear grain weight for one or more of these traits.

On the other hand, the studied ear traits exhibited important trends of association among themselves. Positive and highly significant correlation was found between the number of rows/ ear and ear diameter (0.327**). The correlation between the number of kernels/row and each of the ear length (0.703**) and shelling percentage (0.453**) was found to be positive and highly significant. Also, highly significant and positive correlation coefficient was observed between ear length and each of ear diameter (0.351**) and 100 kernel weight (0.415**), while the shelling percentage had only significant positive association with ear length (0.255*). Furthermore, positive and highly significant correlation was detected between 100 grain weight and shelling percentage (0.417**). The correlation coefficients among the other traits were insignificant.

Accordingly, maize breeders must take interest in the interrelationships among ear traits when planning the breeding program. Mohamed and Sedhom (1993), Mohamed (2004), El- Taweel and Barakat (2006), Saidaiah *et al.* (2008) and Khodarahmpour and Hamidi (2012) stated that the correlation coefficients between grain yield and most ear traits were positive and significant.

It is worthwhile to remember that large sample size of data may be a main reason of the highly significance of some small values of correlation coefficients.

**3.2. Multiple linear regression analysis**

Data presented in Table (3) show the partial regression coefficients and their corresponding probability levels of the ear traits in predicting the ear grain weight using full model regression. The prediction equation was formulated as follows:

$$EKW = -349.8 + 8.21\,(NRE) + 3.18\,(NKR) + 0.65\,(EL) + 7.78\,(ED) + 2.51\,(100\,KW) + 167.97\,(SP).$$

In addition to the high significance of the used

Table (3): Multiple linear regression model to explain grain weight variation using some of its related characters.

| Characters \ Reg. Parameters | Regression coefficient (b) | Standard error (SE) | Probability level (P-value) | Variance inflation factor (VIF) |
|---|---|---|---|---|
| No. of rows / ear (NRE) | 8.213** | 1.546 | 000 | 1.20 |
| No. of kernels / row (NKR) | 3.176** | 0.631 | 000 | 2.38 |
| Ear length (EL) | 0.647 | 1.288 | 0.617 | 2.727 |
| Ear diameter (ED) | 7.778* | 3.82 | 0.046 | 1.303 |
| 100 kernel weight (100KW) | 2.508** | 0.5271 | 000 | 1.527 |
| Shelling percentage (SP) | 167.97** | 60.13 | 0.007 | 1.594 |
| Intercept | -349.8 | | | |
| Model sig.<br>$R^2$<br>Adjusted $R^2$ | 000<br>79.2<br>77.3 | | | |

model (p value < 0.01), it successfully explained 79.2 % of the total variation of grain weight expressed as $R^2$. The residual content ($1 - R^2 = 20.8\%$) may be attributed to unknown variation (random error), human error during measuring the studied traits, and/or some other traits that were not included in the present investigation. The obtained results reported that the traits of number of rows / ear, number of kernels / row, ear diameter, 100 kernel weight and shelling percentage were significantly contributed towards ear grain weight while the ear length was not.

Concerning the goodness of fit of the used model, it is noted that the values of VIF for all the studied traits were less than 10 suggesting that multicollinearity problem is not a serious issue (Judge *et al.*, 1988). Also, the value of the adjusted $R^2$ (82.7) was very close to the $R^2$ (85.3) which considered an indication of the optimum sample size and the goodness of fit for the used model.

**3.3. Stepwise multiple linear regression analysis**

This method was used to determine the more effective ear traits that mostly explained the variation of grain weight. The results of Table (4) show the partial regression coefficient as well as their significance for the accepted limiting three variables that are significantly contributing to the variation of ear grain weight. These variables were number of rows / ear, number of kernels / row and 100 Kernel weight. According to the results, 75.5 % (expressed as $R^2$) of the total variation in ear grain weight could be attributed to these aforementioned three traits. The other three traits were not included in the model due to their very low relative contribution.

The prediction equation for grain weight using the accepted three traits was formulated as follows:

$$EKW = - 246.78 + 9.67\ (NRE) + 4.14\ (NKR) + 3.13\ (100\ KW).$$

On the other hand, the validity of the proposed model was established where the VIF values for the accepted traits were less than 10 indicating no harmful effect of multicollinearity. Also, the adjusted $R^2$ value (74.4) was very near to its corresponding $R^2$ value (75.5) indicating the goodness of fit of the used model. As mentioned before, the number of rows / ear, the number of kernels / row and 100 kernels weight were the most important variables according to stepwise regression model. Therefore, these three traits have to be ranked the first in the breeding programs for improving ear grain weight in maize. The current results of full model regression and stepwise multiple linear regression are in harmony with those obtained by Shafshak *et al.* (1989) and (2009), and Khodarahmpour and Hamidi (2012).

**3.4. Path analysis**

Information obtained from simple correlation coefficient can be enlarged by partitioning it into direct and indirect effects for a given set of causal interrelationships.

**Table (4): Regression parameters of the accepted variables according to stepwise multiple linear regression.**

| Characters \ Reg. Parameters | Regression coefficient (b) | Standard error (SE) | Probability level (P-value) | Variance inflation factor (VIF) |
|---|---|---|---|---|
| **No. of rows / ear (NRE)** | **9.67**** | **1.517** | **000** | **1.026** |
| **No. of kernel / row (NKR)** | **4.138**** | **0.419** | **000** | **1.073** |
| **100 kernel weight (100KW)** | **3.128**** | **0.464** | **000** | **1.054** |
| **Intercept** | **-246.78** | | | |
| **Model sig.** | **000** | | | |
| **$R^2$** | **75.5** | | | |
| **Adjusted $R^2$** | **74.4** | | | |

**Table (5): Full model path analysis (direct and joint effects) of ear grain yield and its related characters in maize.**

| Characters | NRE | NKR | EL | ED | 100KW | SP | $r_{xy}$ |
|---|---|---|---|---|---|---|---|
| **No. of rows / ear (NRE)** | **<u>0.328</u>** | **-0.067** | **0.0008** | **0.0423** | **0.015** | **-0.0016** | **0.318**** |
| **No. of kernels / row (NKR)** | **-0.046** | **<u>0. 478</u>** | **0.033** | **0.028** | **0.0757** | **0.079** | **0.648**** |
| **Ear length (EL)** | **0.006** | **0.336** | **<u>0.047</u>** | **0.046** | **0.147** | **0.037** | **0.619**** |
| **Ear diameter (ED)** | **0.107** | **0.104** | **0.017** | **<u>0.1302</u>** | **0.0336** | **0.0059** | **0.398**** |
| **100 kernel weight (100KW)** | **0.014** | **0.102** | **0.0196** | **0.0124** | **<u>0.354</u>** | **0.0604** | **0.563**** |
| **Shelling percentage (SP)** | **-0.0036** | **0.2597** | **0.0121** | **0.0053** | **0.1477** | **<u>0.1449</u>** | **0.566**** |

**- Residual effect = 0.4725**

**Table (6): Stepwise path analysis (direct and joint effects) of ear weight yield and its related characters in maize.**

| Characters | NRE | NKR | 100KW | $r_{xy}$ |
|---|---|---|---|---|
| **No. of rows / ear (NRE)** | **<u>0.387</u>** | **-0.087** | **0.017** | **0.318**** |
| **No. of kernels / row (NKR)** | **-0.055** | **<u>0.614</u>** | **0.089** | **0.648**** |
| **100 kernels weight (100KW)** | **0.131** | **0.017** | **<u>0.415</u>** | **0.563**** |

**- Residual effect = 0.496 - The direct effects occupied the diagonal cells (bold and underlined).**

Considering the path analysis based on all the studied ear traits (full model), the matrix of direct and joint effects is shown in Table (5). The maximum direct effect was obtained for the number of kernels / row (0.478), followed by 100 kernels weight (0.354) and the number of rows / ear (0.328). On the other hand, the previous three traits recorded small indirect effect values through the other traits. In another words, the indirect effects of the three traits were less important compared to their corresponding direct effects. In accordance, the high positive direct effects for number of kernels / row, 100 kernels weight and number of rows / ear in addition to their highly significant coefficients of correlation are evidence that the indirect selection through these traits would be effective for improving ear grain weight in maize.

In contrast, although highly significant positive coefficients of correlation were recorded between ear grain weight and each of ear length, ear diameter and shelling percentage, the direct effects for these traits were very small. This result may be returned to that path analysis separate the indirect effects from the simple correlation coefficient where the indirect effect values for the preceding three traits were more considerable compared to their direct effects. The highest indirect effects values for ear length and shelling percentage on ear grain weight were observed through each of

**Table (7): The coefficient of determination (CD) and relative importance (RI %) of ear grain weight components in maize, according to full and stepwise path analysis.**

| Characters | | Full model path analysis | | Stepwise path analysis | |
|---|---|---|---|---|---|
| | | CD | RI % | CD | RI % |
| **Direct effects** | | | | | |
| No of rows / ear (NRE) | | 0.108 | 9.91 | 0.1495 | 13.1875 |
| No of kernels / row (NKR) | | 0.229 | 21.01 | 0.3766 | 33.2174 |
| 100 kernels weight (100KW) | | 0.125 | 11.47 | 0.1722 | 15.1924 |
| Ear length (EL) | | 0.0022 | 0.20 | | |
| Ear diameter (ED) | | 0.0169 | 1.55 | | |
| Shelling percentage (SP) | | 0.0209 | 1.92 | | |
| **Indirect effects** | | | | | |
| NRE *via* | NKR | -0.044 | 4.04 | -0.0669 | 5.902 |
| | 100 KW | 0.010 | 0.92 | 0.0138 | 1.217 |
| | EL | 0.0006 | 0.06 | | |
| | ED | 0.028 | 2.57 | | |
| | SP | -0.001 | 0.09 | | |
| NKR *via* | 100 KW | 0.072 | 6.61 | 0.109 | 9.6147 |
| | EL | 0.038 | 3.49 | | |
| | ED | 0.027 | 2.48 | | |
| | SP | 0.075 | 6.88 | | |
| 100KW *via* | EL | 0.014 | 1.28 | | |
| | ED | 0.009 | 0.83 | | |
| | SP | 0.043 | 3.94 | | |
| EL *via* | ED | 0.004 | 0.37 | | |
| | SP | 0.003 | 0.28 | | |
| ED *via* | SP | 0.002 | 0.18 | | |
| Total (direct + indirect) | | 0.78 | 80.06 | 0.7544 | 78.332 |
| Residuals | | 0.22 | 19.94 | 0.2456 | 21.668 |
| Total | | 1.000 | 100 | 1.00 | 100 |

**Note: Bold and underlined cells indicate the highest values of direct and indirect effects.**

number of kernel / rows and 100 kernels weight recording (0.336 and 0.146) for ear length and (0.26 and 0.148) for shelling percentage, respectively.

Considering ear diameter, the important part of its indirect effects were observed through each of number of rows / ear (0.107) and number of kernels / row (0.104).

Because stepwise multiple linear regression models determine the ear traits that mostly reflected the total variation of ear grain weight, some researchers prefer to use only the traits selected by stepwise regression model in path analysis. The matrix of direct and indirect effects using stepwise path analysis is presented in Table (6). These results are exactly in parallel line with those obtained by full model of path analysis where the highest direct effect was recorded *via* number of kernels / row (0.614) followed by 100 kernels weight (0.415) and number of rows / ear (0.389). Moreover, the values of their indirect effects were trivial through each other. The current findings are consistent with Gautam *et al.*, (1999), Kumar and Kumar (2000), Mohen *et al.*, (2002), Bello *et al.*, (2009) and Wannows *et al.*, (2010).

The coefficient of determination (CD) and relative importance (RI %), using both of path analysis as a full model and stepwise model, are shown in Table (7). The results revealed that the greatest part of grain weight was explained by the direct effect of the number of kernels / row (21.01 and 33.22), followed by 100 kernels weight (11.47 and 15.19) and the number of rows / ear (9.91 and 13.19) for the two types of path analysis, respectively. The great contribution of these traits on ear grain weight supported their importance as selection criteria in maize breeding programs.

According to the relative importance of the joint effects, it appeared that the highest values were recorded for the indirect effect of the the number of rows / ear on grain weight through its associations with the number of grains / row (4.04 and 5.90) followed by the joint effect of number of grains / row *via* 100 kernel weight (6.61 and 9.61) for the two types of path analysis (full model and stepwise model), respectively. In addition, the full model of path analysis recorded other important indirect effects, such as, that recorded for number of kernels / row through both of ear length (3.49) and shelling percentage (6.88), and the indirect effects of 100 kernels weight *via* shelling percentage (3.94). Ineffective values of relative importance were obtained by the other direct and indirect effects. Totally, the studied traits accounted for 80.06 % of the ear grain weight variation using full model path analysis while only 78.33 % was the explained part by stepwise path analysis.

Although, the two models of path analysis partially showed similar trends the authors appreciated to use full model path analysis because it included all the studied traits and consequently gave more information compared to the other model. The current results are in accordance with those observed by Mohamadi *et al.* (2003) and Rafiq *et al.* (2010).

The use of various statistical models by plant breeders or agronomists presents the potential of increasing the comprehension of the causal relationships among traits and can help to determine the nature and sequence of traits to be selected in a breeding program.

Finally, from the current investigation, it could be recommended that the important ear traits, overall the used statistical procedures, were the number of rows / ear, number of kernels / row and 100 kernels weight. These traits would enable the breeders to realize higher yielding hybrids of maize.

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## العلاقات المتداخلة بين وزن حبوب الكوز وبعض صفات الكوز الأخرى فى الذرة الشامية

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* المعمل المركزى لبحوث التصميم والتحليل الاحصائى - مركز البحوث الزراعية – الجيزة - مصر

**ملخص**

أجرى هذا البحث بهدف تقدير المساهمة النسبية لصفات الكوز الاكثر تاثيرا فى وزن الحبوب فى الذرة الشامية حيث تم استخدام اربعة طرق احصائية لتحليل المتغيرات المتعددة تشمل الارتباط البسيط – الانحدار الخطى المتعدد – الانحدار المتعدد المرحلى - معامل المرور. أقيمت تجربتان حقليتان بالمزرعة البحثية لكلية الزراعة – جامعة الازهر (القاهرة) خلال موسمى الزراعة 2010 و 2011. أشتملت التجربة الواحدة على ثلاثة هجن فردية (بشاير ، 30 k 8 ، 30 k 9) و ثلاثة من الهجن الثلاثية (جيزة 311 ، جيزة 323 ، جيزة 324) تمت زراعتها فى تصميم القطاعات الكاملة العشوائية باستخدام ستة مكررات. و قد تم اختيار 30 كوز عشوائيا من كل قطعة تجريبية و أخذت الصفات التالية عليها :

| | |
|---|---|
| 1 - وزن حبوب/كوز (جم) | 2- عدد صفوف/كوز |
| 3- عدد حبوب/صف | 4- طول الكوز (سم) |
| 5- قطر الكوز (سم) | 6- وزن الـ 100 حبة (جم) |
| 7- نسبة التصافى | |

اوضحت النتائج وجود ارتباطات موجبة وعالية المعنوية بين وزن الحبوب وجميع صفات الكوز الاخرى حيث سجلت صفات عدد حبوب الصف ، طول الكوز ، نسبة التصافى ووزن 100 حبة اعلى قيم لمعامل الارتباط . اشارت نتائج نموذج الانحدار الخطى المتعدد ان صفات الكوز المدروسة قد اسهمت بحوالى 79.2 % من التباين الكلى لصفة وزن حبوب الكوز. تشابهت النتائج المتحصل عليها باستخدام تحليل الانحدار المتعدد المرحلى و تحليل معامل المرور حيث كانت صفات عدد صفوف الكوز ، عدد حبوب الصف ووزن 100 حبة هى الصفات الاكثر اسهاما فى وزن حبوب الكوز. وقد تحققت شروط جودة التوفيق لكل من نموذج الانحدار الخطى المتعدد و كذا نموذج الانحدار المتعدد المرحلى و التى تمثلت فى معنوية كلا النموذجين وكذا كانت قيمتى معامل التحديد مرتفعة مما يعكس قدرة النموذجين المقترحين على تفسير التباين الخاص بصفة وزن حبوب الكوز. ومن الجدير بالذكر ان البحث اشار الى اهمية تقارب قيمة كل من معامل التحديد و معامل التحديد المعدل كمؤشر على جودة التوفيق للنموذج و كذا اهمية قياس معامل تضخم التباين كدليل على وجـــود

وخطورة ظاهرة الازدواج الخطى . من ناحية اخرى فان النتائج لم تختلف عند تطبيق نموذج معامل المرور باستخدام كل صفات الكوز او الصفات الاكثر اسهاما فقط ولكن يفضل استخدام النموذج الكامل حيث يعطى قدرا اكبر من المعلومات فيما يتعلق بالعلاقات بين جميع الصفات تحت الدراسة. وبناء على ما سبق فان صفات عدد صفوف الكوز ، عدد حبوب الصف ، وزن 100 حبة هي الأكثر إسهاما في وزن حبوب الكوز سواء عن طريق التأثير المباشر أو غير المباشر مما يشير إلى أهمية أخذ هذه الصفات في الاعتبار من قبل المربى عند وضع برامج التربية لتحسين محصول الذرة الشامية.

**المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد (63) العدد الثالث (يوليو2012): 243-251.**