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# MULTIVARITE 0F RELATING YIELD COMPONENTS IN A SET OF CORN GENOTYPES

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## ABSTRACT

This work was conducted at the Experimental Farm of Nasser's Faculty of Agricultural Sciences in Lahej Governorate, Yemen, during three seasons 2003, 2004 and 2005. Five statistical procedures of relating yield components to yield; i.e., simple correlation coefficient, the path coefficient analysis, the stepwise regression, the multiple regressions and factor analysis were applied to seven yield contributing characters to determine their functional relationships to yield. Sixteen Maize genotypes were used in this study. Simple correlation coefficient revealed that, number of leaves/plant, ear height, ear length, number of rows/ear, number of kernels/row, 1000-kernel weight and shelling% had the greatest influence on grain yield/h. According to path analysis, weight of 1000-kernel had the greatest direct effect (22.23%) towards grain yield/h. While, number of kernels/row (9.33%) and ear length (9.32%) had the highest indirect effect to grain yield. Multiple linear regressions indicated that the variables which had the highest partial coefficient of determination in seed yield/h, were ear height, ear length, number of rows/ear and 1000-kernel weight ($R^2$ = 43%, 22%, 9% and 12%, respectively). The stepwise regression shows that, 1000-kernel weight, number of kernels/row, number of rows/ear and shelling% were accepted variables which had the highest coefficients of determination with seed yield (88.9%). The factor analysis grouped 7 yield contributing characters in two factors, which altogether were responsible for 70.42% of the total variability in the dependence structure.

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## INTRODUCTION

Yield is a complex character determined by several variables. Hence, it is essential to detect the characters having the greatest influence on yield and their relative contributions to variation in yield. This is useful in designing and evaluating breeding programs particularly, for the newly introduced crops such as corn. So far, various procedures are in use to achieve this aim. These are: simple correlation coefficient, path coefficient analysis, multivariate regression analysis, factor analysis and stepwise regression analysis. Although these procedures are extensively used, yet none of them is free from drawbacks.

**Mohamed** and **Sedhom (1993)** concluded that grain yield/ant of corn was highly positively correlated with ear length, number of grains/row and 100-kernel weight but positively and significantly correlated with both of plant height and ear diameter.

**Shafshak *et al*** (**1989**) and **Ashmawy** and **Mohamed (1998)** in comparison between the full model regression and the stepwise regression procedure concluded that the coefficient of determination for full model regression and partial correlation were higher than stepwise regression. **El**-**Kalla** and **El**-**Rayes (1984), El-Rassas *et al* (1990)** and **Atia *et al* (2001)** used factor analysis in maize and sorghum to determine the dependence relationship between yield and yield components. **Ashmawy (2003)** indicated that, factor analysis approach was more efficient than other procedures. It can help plant breeders to determine the nature and sequence of characters to be selected in breeding programs. **El**-**Badawy (2006)** found that using factor analysis by plant breeders has the potential of increasing the comprehension of causal relationships of variables and can help to determine the nature and sequence of traits to be selected in breeding programs. On the other hand, path coefficient analysis is used to determine the direct and indirect effect, while stepwise is used to determine the best prediction equation for yield.

Hence, the purpose of this study was to compare among five procedures of relating several corn characteristics to yield in sixteen corn genotypes.

## MATERIALS AND METHODS

This work was conducted at the Experimental Farm of Nasser's Faculty of Agricultural Sciences in Lahej Governorate, Yemen during three seasons 2003, 2004 and 2005. Sixteen were used in this study. These single crosses were obtained from half diallel cross owing between six inbreds obtained from Maize Research Institute, Knega in Bulgaria (these inbreds are m.m328, m.m353, mm376, L.T.49.11, CW.1.4 and 74.063.cc13) and commercial variety Knega36. Planting dates were done at 21st, 24th and 21st in October 2003, 2004 and 2005, respectively, in randomized complete block design with three replications. Each plot was 1.2x4.0 m and consisted of two ridges 60 cm apart. Intra-hill spacing was 25 cm. Hills were thinned to one plant/hill after 21 days from planting. Recommended cultural practices for ordinary maize fields in the area were followed during growing seasons. Random sample of 10 guarded plants in each plot were taken to evaluate No. of leaves/plant, ear height (cm), ear length (cm), No. of rows/ear, No. of kernels/row, 1000-kernel weight and shelling %.Grain yield (t/h) was recorded on whole plot basis and adjusted to 15.5% grain moisture content.

### Statistical procedures

The combined data for the two experiments of yield and its components were subjected to following statistical procedures:

1- Basic statistics and simple correlation matrix: Arithmetic mean, standard deviation, standard error and simple correlation coefficient were calculated among the studied characters as described by **Steel** and **Torrie (1987).**
2- Path coefficient analysis was used as applied by **Dewey** and **Lu (1959)** and **Duarte** and **Adams (1972).**
3- Stepwise linear regression, **(Draper** and **Smith**, **1966),** to determine the appropriate variables responsible for most variation in yield. The relative contribution was calculated as ($R^2$).
4- The factor analysis by **Cattell (1965).**

Multiple linear regressions between seed yield and yield components so as to construct a prediction model for yield; coefficient of determination $R^2$ was estimated to evaluate the relative contribution **(Snedecor** and **Cochran**, **1967).**

## RESULTS AND DISCUSSION

The mean values, minimal and maximal values together with statistics associated with means are given in **Table (1)** for the seven characters evaluated in this study. The range in general shows that there was wide variability in each character evaluated.

### Simple correlation coefficient

Data of simple correlation coefficient matrix are shown in **Table (2).** Data indicate that 1000-kernel weight , number of kernels/row, ear length, ear height, number of rows/ear, shelling% and number of leaves/plant had the greatest influence on grain yield/h with r values being 0.907**, 0.754**, 0.754**,0.652**, 0.592**, 0.526** and 0.405**, respectively. Another correlation worthy of some attention that between 1000-kernel weight and ear height, ear length, number of rows/ear and number of kernels/row with r values being 0.664**, 0.751**, 0.525** and 0.698**, respectively. High association of ear height, ear length, number of rows/ear, number of kernels/row, 1000-kernel weight, shelling% and number of leaves/plant with grain yield/plant is of interest the plant breeder because it is relatively easily identifiable character in the field. These results are in agreement with those obtained by **Mohamed** and **Sedhom (1993), Nasr (1998), Atia *et al* (2001), Ashmawy (2003)** and **El-Badawy (2006).**

### Path coefficient analysis

Direct, indirect effects, coefficient of determination and relative importance of each variable to grain yield/h are presented in **Table (3)**. From this table, it could be concluded that the most important sources of variation in grain yield/h were the direct effect of 1000-kernel weight followed by indirect effect of number of kernels/row through 1000-kernel weight followed by indirect effect ear length through 1000-kernel weight at the combined analysis. These effects account for approximately 40.88% of grain yield/h variation. 1000-kernel of

**Table 1. Mean value, minimum, maximum, standard deviation and standard error for maize yield characteristics**

| Characters | Min. | Max. | Mean | S.D. | S.E. |
|---|---|---|---|---|---|
| **No. of leaves/plant** | 10.03 | 14.03 | 11.80 | 1.16 | 0.14 |
| **Ear height (cm)** | 57.50 | 91.47 | 75.77 | 13.43 | 1.65 |
| **Ear length (cm)** | 9.80 | 21.13 | 15.11 | 2.56 | 0.32 |
| **No. of rows/ear** | 10.60 | 16.27 | 13.10 | 0.99 | 0.12 |
| **No. of kernels/row** | 18.67 | 44.73 | 30.78 | 5.79 | 0.71 |
| **1000-kernel weight (g)** | 198.20 | 352.90 | 271.37 | 38.70 | 4.76 |
| **Shelling%** | 77.27 | 88.87 | 83.07 | 38.70 | 4.76 |

**Table 2. Simple correlation coefficients for 8 characters of 16 maize genotypes grown over three seasons**

| Characters | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | Y |
|---|---|---|---|---|---|---|---|---|
| **No. of leaves/plant ($X_1$)** | 1.00 | | | | | | | |
| **Ear height ($X_2$)** | 0.597** | 1.000 | | | | | | |
| **Ear length ($X_3$)** | 0.552** | 0.554** | 1.000 | | | | | |
| **No. of rows/ear ($X_4$)** | 0.227* | 0.497** | 0.297** | 1.000 | | | | |
| **No. of kernels/row ($X_5$)** | 0.367** | 0.519** | 0.887** | 0.314** | 1.000 | | | |
| **1000-kernel weight ($X_6$)** | 0.485** | 0.664** | 0.751** | 0.525** | 0.698** | 1.000 | | |
| **Shelling% ($X_7$)** | 0.224* | 0.255** | 0.225* | 0.360** | 0.259** | 0.452** | 1.000 | |
| **Grain yield/h (Y)** | 0.405** | 0.652** | 0.754** | 0.592** | 0.754** | 0.907** | 0.526** | 1.000 |

*** and ** significant at 5% and 1% level of probability, respectively.**

weight proved to have the highest direct effect to grain yield (22.23%) followed by indirect effect number of kernels/row through 1000-kernel weight (9.33%) and indirect effect ear length through 1000-kernel weight (9.32%). Although, 1000-kernel weight had the highest simple correlation (0.907) with grain yield/h. These results are in partial agreement with those obtained by **Mohamed** and **Sedhom (1993)**, **Ashmawy** and **Mohamed (1998)** and **El-Badawy (2006).**

## Multiple linear regression

Data in **Table (4)** show the prediction model by using multiple linear regressions for grain yield/h of maize and its components. The prediction equation was formulated as follows:

$$Y = -14.805 - 0.1530X_1 + 0.0105X_2^{**} + 0.0885X_3^{**} + 0.219X_4^{**} + 0.0422X_5 + 0.0296X_6^{**} + 0.1120X_7$$

The relative contribution for all yield factors explained 89.6% of the total variation in grain yield and 10.4% could be due to residual. Ear height, ear length, number of rows/ear and 1000-kernel weight had the highest relative contribution of determination ($R^2$ = 43%, 22%, 9% and 12%, respectively). The other characters had small contribution to the total yield variance. **Ashmawy (2003)** and **El-Badawy** (**2006**) came to similar conclusion.

## Stepwise multiple linear regression

The accepted and removed variables and their relative contributions in predicting grain yield/h are presented in **Table (5).** The accepted variables had the highest coefficient of multiple determination with the yield adjusted for variables already added. The prediction equation is formulated as follows: $Y = -15.016 + 0.0226X_6^{**} + 0.0706X_5 + 0.2420X_4 + 0.0970X_7$. According to this equation

**Table 3. Direct and indirect effects of yield attributes in maize for 16 genotypes grown over three seasons**

| Source of variation | Effects | C.D. | R.I.% |
|---|---|---|---|
| **-Direct effect of No. of leaves/plant** | -0.1216 | 0.0148 | 1.1768 |
| **Indirect effect via Ear height** | -0.0726 | -0.0152 | 1.2134 |
| **Indirect effect via Ear length** | -0.0671 | -0.0198 | 1.5765 |
| **Indirect effect via No. of rows/ear** | -0.0276 | -0.0076 | 0.6034 |
| **Indirect effect via No. of kernels/row** | -0.0446 | -0.0142 | 1.1288 |
| **Indirect effect via 1000-kernel weight** | -0.0590 | -0.0623 | **4.9610** |
| **Indirect effect via Shelling%** | -0.0272 | -0.0089 | 0.7105 |
| **-Direct effect of Ear height** | 0.1050 | 0.0110 | 0.8777 |
| **Indirect effect via Ear length** | 0.0817 | 0.0172 | 1.3664 |
| **Indirect effect via No. of rows/ear** | 0.0628 | 0.0132 | 1.0491 |
| **Indirect effect via No. of kernels/row** | 0.0825 | 0.0173 | 1.3786 |
| **Indirect effect via 1000-kernel weight** | 0.3509 | 0.0737 | **5.8656** |
| **Indirect effect via Shelling%** | 0.0418 | 0.0088 | 0.6985 |
| **-Direct effect of Ear length** | 0.1475 | 0.0218 | 1.7329 |
| **Indirect effect via No. of rows/ear** | 0.0408 | 0.0120 | 0.9580 |
| **Indirect effect via No. of kernels/row** | 0.1409 | 0.0416 | 3.3108 |
| **Indirect effect via 1000-kernel weight** | 0.3968 | 0.1171 | **9.3220** |
| **Indirect effect via Shelling%** | 0.0369 | 0.0109 | 0.8660 |
| **-Direct effect of No. of rows/ear** | 0.1373 | 0.0189 | 1.5011 |
| **Indirect effect via No. of kernels/row** | 0.0499 | 0.0137 | 1.0908 |
| **Indirect effect via 1000-kernel weight** | 0.2774 | 0.0762 | **6.0652** |
| **Indirect effect via Shelling%** | 0.0590 | 0.0162 | 1.2896 |
| **-Direct effect of No. of kernels/row** | 0.1589 | 0.0252 | 2.0010 |
| **Indirect effect via 1000-kernel weight** | 0.3688 | 0.1172 | **9.3309** |
| **Indirect effect via Shelling%** | 0.0424 | 0.0135 | 1.0736 |
| **-Direct effect of 1000-kernel weight** | 0.5284 | 0.2792 | **22.2282** |
| **Indirect effect via Shelling%** | 0.0741 | 0.0783 | **6.2307** |
| **-Direct effect of Shelling%** | 0.1638 | 0.0268 | 2.1372 |
| **Residual** | 0.3209 | 0.1036 | **8.2467** |

**C.D. =Coefficient of determination R.I. = Relative importance.**

**Table 4. The relative contribution of seven characters for predicting yield of maize using multiple linear regression analysis**

| Characters | Regression coefficients | Standard error (S.E.) | Relative contribution ($R^2$%) |
|---|---|---|---|
| No. of leaves/plant | -0.153 | 0.081 | 1 |
| Ear height (cm) | 0.0105 | 0.008 | 43** |
| Ear length (cm) | 0.0885 | 0.070 | 22** |
| No. of rows/ear | 0.2190 | 0.082 | 9** |
| No. of kernels/row | 0.0422 | 0.027 | 1 |
| 1000-kernel weight (g) | 0.0296 | 0.003 | 12** |
| Shelling% | 0.112 | 0.034 | 1 |

Y- Intercept = -14.802 Standard error of estimation = 0.520
Adjusted R-squared = 0.884 R-squared = 0.896
Multiple (R) = 0.947

Table 5. Accepted and removed variables according to stepwise analysis and their relative contribution ($R^2$) in grain yield of maize

| Characters | Regression coefficients | Standard error (S.E.) | Relative contribution ($R^2$%) |
|---|---|---|---|
| **Accepted variables:** | | | 84.8 |
| 1000-kernel weight | 0.0226 | 0.003 | 82.2 |
| No. of kernels/row | 0.0706 | 0.016 | 2.9 |
| No. of rows/ear | 0.2420 | 0.079 | 2.3 |
| Shelling% | 0.0970 | 0.034 | 1.5 |
| **Removed variables:** | | | 0.7 |
| Ear height | | | |
| Ear length | | | |
| No. of leaves/plant | | | |

Y- Intercept = -15.061 Standard error of estimation = 0.525
Adjusted R-squared = 88.2% R-squared for accepted = 88.9%
R-squared for removed = 0.70% Multiple (R) = 0.943

89.60% of the total variation in grain yield could be linearly related to variations in all variables. Whereas, 88.90% of the total grain yield variation could be attributed to variable accepted and 0.70% could be due to variables removed. The accepted variables were, 1000-kernel weight ($X_6$), number of kernels/row ($X_5$), number of rows/ear ($X_4$) and shelling% ($X_7$). Those variables were responsible for 82.2%, 2.9%, 2.3% and 1.5%, respectively of yield variance. Variables removed were ear height ($X_2$), ear length ($X_3$) and number of leaves/plant ($X_1$).

The major difference between multiple linear regression and stepwise multiple linear regression was that, in the latter, the variable added in each step was the one which made the greatest reduction in the error sum of squares. It was also the one having the highest relative contribution of determination with the dependent variable for fixed values of those variables added previously. Therefore, one concluded that the order which the variables added was significant. The previous results, revealed that:

1) The accepted variables have to be ranked the first in any breeding program for improving yield.
2) The stepwise multiple linear regressions used to determine the best prediction equation for yield, but it could not explain the interrelationship of the characters measured.

These results are in agreement with those obtained by **Shafshak *et al* (1989)**, **Mohamed** and **Sedhom (1993), Atia *et al* (2001), Ashmawy (2003)** and **El-Badawy (2006).**

**Factor analysis**

The factor analysis divided the 7 variables into two factors, which explained 70.42% of the total variability in the dependence structure in **Table (6).** A summary of the composition of variables of the two factors with loadings is given in **Table (7).** The first factor included the variables ear height, ear length, number of kernels/row, 1000-kernel weight and number of leaves/plant which accounted for 55.58% of the total variance. It had high loadings for three variables. These variables were of almost equal importance and communal with factor 1. Factor 2 consisted of number of rows/ear and shelling% which accounted for 14.84% of the total variability in the dependence structure. The factors 1 and 2 included the variables associated with ear parameters. The results indicated that the estimated whole communality was rather adequate to interpret the major portion of variations in the dependence structure in that the two factors altogether accounted for 70.42% of the total variation in the dependence structure **(Table, 6 and 7)**.

From the previous results, it could be concluded that, factor analysis is the one that can be used successfully for analysis for large amounts of multivariate data, and should be applied more frequently in field experiments (**Atia *et al* 2001**; **Ashmawy**, **2003** and **El-Badawy**, **2006**). The greatest benefit of factor analysis can be delineating areas of further researches designed to test the validity of the suggested factors.

**Table 6. Principle factor matrix after orthogonal rotation for seven characters in maize**

| Characters | Common factor coefficients | | Communality ($h^2$) |
|---|---|---|---|
| | Factor 1 | Factor 2 | |
| No. of leaves/plant | 0.683 | 0.149 | 0.489 |
| Ear height (cm) | 0.693 | 0.402 | 0.642 |
| Ear length (cm) | 0.939 | 0.0923 | 0.890 |
| No. of rows/ear | 0.238 | 0.782 | 0.668 |
| No. of kernels/row | 0.864 | 0.132 | 0.764 |
| 1000-kernel weight (g) | 0.752 | 0.498 | 0.814 |
| Shelling% | 0.934 | 0.808 | 0.662 |
| Latent roots | 3.891 | 1.04 | |
| Factor variance ratio % | 55.58 | 14.84 | 70.42 |

**Table 7. Summary of factor loadings for seven characters in maize**

| Variables | Loading | % Total communality |
|---|---|---|
| **Factor 1:** | | 55.58 |
| No. of leaves/plant | 0.682 | |
| Ear height | 0.693 | |
| Ear length | 0.939 | |
| No. of kernels/row | 0.864 | |
| 1000-kernel weight (g) | 0.752 | |
| **Factor 2:** | | 14.84 |
| No. of rows/ear | 0.782 | |
| Shelling% | 0.808 | |
| Cummulative variance | | 70.42 |

## CONCLUSION

Using factor analysis by plant breeders has the potential of increasing the comprehension of causal relationships of variables and can help to determine the nature and sequence of traits to be selected in a breeding program. While, path coefficient analysis is used to determine the direct and indirect effect, while stepwise is used to determine the best prediction equation for yield.

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