



MULTIVARITE OF 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.

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, Knege in Bulgaria (these inbreds are m.m328, m.m353, mm376, L.T.49.11, CW.1.4 and 74.063.cc13) and commercial variety Knege36. 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

Adjusted R-squared = 0.884

Multiple (R) = 0.947

Standard error of estimation = 0.520

R-squared = 0.896

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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تحليل العوامل المتعدده لارتباط مكونات المحصول لمجموعه من التراكيب الوراثية للذرة الشامية

[٨]

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الملخص العربي

تحليل الانحدار المتعدد أن ارتفاع الكوز، طول الكوز، عدد صفوف الكوز و وزن ال ١٠٠٠ حبة لها المساهمة الاكبر فى المحصول بمقدار ٤٣ % ، ٢٢ % ، ٩ % و ١٢ % على التوالى . كما أظهر تحليل الانحدار المتعدد المرحلى ان صفة وزن ال ١٠٠٠ حبة ، عدد الحبوب للصف ، عدد سطور الكوز و النسبة المئوية للتصافى اهم المكونات المؤثرة فى تحديد المحصول بنسبة (٨٨,٩%) . قسم التحليل العاملى للـسبعة صفات تحت الدراسة الى اثنتين من العوامل وقد حققت مقدار ٧٠,٤٢% من التباين الكلى. وعموما يمكن الاستنتاج من هذه الدراسة أن التحليل العاملى افضل الطرق بالمقارنة بالطرق الاخرى والتي يهتم بها ويستخدمها مربي النباتات فى برنامج التربية حيث يعمل على اختصار المتغيرات العديدة والمرتبطة مع بعضها الى عوامل رئيسية محدودة العدد وبكل عامل الصفات التى ترتبط مع بعضها مما يعطى مربي النبات الفرصة فى اختيار أهم الصفات بالتتابع حسب اهميتها ويمكن استخدام معامل المرور فى تحديد مدى مساهمة الصفة بطريقة مباشرة وغير مباشرة فى المحصول بينما يمكن استخدام تحليل الانحدار المتعدد المرحلى فى تحديد أفضل المتغيرات المساهمة فى المحصول .

أجريت هذه الدراسة فى المزرعة البحثية لكلية ناصر للعلوم الزراعية م/لحج لثلاثة مواسم ٢٠٠٣ و ٢٠٠٤ و ٢٠٠٥ استخدمت خمس طرق إحصائية خاصة بدراسة ارتباط مكونات المحصول بعضها ببعض و المعامل الارتباط البسيط و تحليل معامل المرور و تحليل الانحدار المتعدد و تحليل الانحدار المتعدد المرحلى و التحليل العاملى و طبقت الأساليب الإحصائية السالفة على مكونات المحصول الخاصة بستة عشر تركيبة وراثية من الذرة الشامية .

أظهرت مصفوفة معامل الارتباط البسيط وجود ارتباط موجب عالى المعنوية بين محصول الحبوب للهكتار و عدد اوراق النبات ، ارتفاع الكوز ، طول الكوز ، عدد الصفوف للكوز، عدد حبوب الصف ، وزن ال ١٠٠٠ حبة و نسبة التصافى . أوضحت نتائج تحليل معامل المرور أن وزن ال ١٠٠٠ حبة اعطت اعلى تاثير مباشر (٢٢,٢٣%) لمحصول حبوب الهكتار . بينما اعطت صفتى عدد حبوب الصف وطول الكوز اعلى تاثير غير مباشر (٩,٣٣% و ٩,٣٢%) على الترتيب لمحصول الحبوب. أظهر