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THE RELATIVE CONTRIBUTION OF YIELD COMPONENTS BY USING SPECIFIC STATISTICAL TECHNIQUES IN CORN

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ABSTRACT

This work was conducted at the Agricultural Research and Experimental Station of the Fac. of Agric., Moshtohor during the two successive summer seasons 2004 and 2005. Four statistical procedures of relating yield components to yield; i.e., 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. A set of thirteen genotypes was used in this study. These genotypes included 8 single crosses (S.C.10, S.C.122, S.C.30K8, S.C. M.9, S.C. M12, S.C. M81, S.C. M52 and S.C. M21), one double cross (D.C. Dahab yellow), three way crosses (T.W.C.310, T.W.C.30B9 and T.W.C.3057) and synthetic variety Giza 2 (open-pollinated variety). Characters measured were: silking date, plant height, ear diameter, ear length, number of kernels/row, number of rows/ear, 100-kernel weight and grain yield/plant. Simple correlation coefficient revealed that, ear diameter, ear length, number of kernels/row and 100-kernel weight had the greatest influence on grain yield/plant. Number of rows/ear was significantly correlated with seed yield/plant. According to path analysis, four of the seven variables, viz, ear length, number of kernels/row, number of rows/ear and weight of 100-kernel accounted for 85% of the total variation in the dependent variable while the remaining variables accounted for 15% of that variation. Weight of 100-kernel proved to have the highest direct contribution to grain yield (25.60%) followed by the number of kernels/row (19.07%), ear length (18.14%) and number of rows/ear (17.20%). Multiple linear regressions indicated that the variables which had the highest partial coefficient of determination in seed yield/plant; were ear diameter, ear length, number of kernels/row and 100-kernel weight (R^2 = 34.4, 11.4%, 10.1 and 17.0%, respectively). The stepwise regression shows that, number of kernels/row and 100-kernel weight was accepted variables which had the highest coefficients of determination with seed yield. The factor analysis grouped 7 yield contributing characters in three factors, which altogether were responsible for 79.87% of the total variability in the dependence structure. 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 program. 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.

Key words: correlation, path coefficient, stepwise linear regressions, factor analysis.

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: 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.

Walton (1972) criticized some statistical techniques (correlation, path coefficient, stepwise regression analysis and multiple linear regressions) and explained that false conclusion could be obtained. He postulated that biologists must seek right assistance from statistical methodology and suggested factor analysis as a new technique to identify growth and plant characters related to yield.

Path coefficient analysis developed by Wright (1921) divides correlation coefficients into direct and indirect effects through alternate path ways, Mohamed and Sedhom (1993) concluded that grain yield/plant of corn was highly positively correlated with ear length, number of grains/row and 100-kernel weight but positively and significantly correlated with either 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-Rasses *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.

Hence, the purpose of this study was to compare among four procedures of relating several corn characteristics to yield in a set of thirteen corn genotypes.

MATERIALS AND METHODS

This work was conducted at the Agricultural Research and Experimental Station of the Fac. of Agric., Moshtohor during the two successive summer seasons 2004 and 2005. Thirteen corn genotypes, widely grown, in Egypt were used in this study. These are: eight single crosses (S.C.10, S.C.122, S.C.30K8, S.C. M9, S.C. M12, S.C. M81, S.C. M52 and S.C. M21), one double cross (D.C. Dahab yellow), three way crosses (T.W.C.310, T.W.C.30B9 and T.W.C.3057) and synthetic variety Giza 2 (open-pollinated variety). The single crosses S.C. M9, S.C. M12, S.C. M81, S.C. M52 and S.C. M21 were developed at Agron. Dept., Fac. of Agric., Moshtohor, Benha University.

Planting has been done at 10th and 13th on June 2004 and 2005, respectively, in randomized complete block design with three replications. Each plot was 3x3.5 m and consisted of five rows 70 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. Silking date was recorded in 50% of the plant silked in whole plot. Random sample of 20 guarded plants in each plot were taken to evaluate plant height (cm), ear length (cm), ear diameter (cm), no. of kernels/row, no. of rows/ear, 100-kernel weight and grain yield/plant which was adjusted for 15.5% moisture.

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).
5- 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

Analyses of variances for all traits in each season as well as the combined analysis are presented in Table (1). Test of homogeneity revealed that the error variance for the two seasons were homogenous, therefore combined analysis was processed. Year's mean squares were significant for all the studied traits except for silking date, plant height, no. of rows/ear and 100-kernel weight. Results in Table (1) showed that genotypes mean squares were significant for all traits in the two growing seasons as well as the combined data except silking date, ear diameter, no. of rows/ear and 100-kernel weight in the first season and silking date, no. of rows/ear and grain yield/plant in the second season. The interactions between crosses and year mean squares were no significant for all of the studied characters. Such results indicated that these crosses behaved in similarly from one seasons to another.

The mean values, minimal and maximal values together with statistics associated with means are given in Table (2) for the seven characters evaluated in this study. The range in general shows that there was wide variability in each character evaluated.

Table (1): Mean squares from ordinary analysis for the studied traits in maize over two years.

Trait S.O.V	d.f.		Silking date			Plant height			Ear diameter (cm)			Ear length (cm)			No.of rows/ear		
			S1	S2	Comb.	S1	S2	Comb.	S1	S2	Comb.	S1	S2	Comb.	S1	S2	Comb.
Years		1			6.78			684.11			3.08**			48.65**			0.24
Blocks/Y	2	4	5.15	4.18	4.67	99.7	437.87	286.8	0.01	0.08	0.05	1.3	0.49	0.90	2.50	3.8	3.15
Genotypes	12	12	4.34	6.37	9.79**	520.1**	447.59**	930.7**	0.08	0.14*	0.18**	6.63**	2.65**	7.82**	1.99	1.94	3.35**
Genotypes x Y		12			0.92			37.00			0.04			1.46			0.59
Error	24	48	2.09	2.96	2.53	121.3	70.32	95.81	0.05	0.06	0.05	0.68	0.84	1.76	1.06	1.32	1.19

Cont. : Mean squares from ordinary analysis for the studied traits in maize over two years.

Trait S.O.V	d.f.		No.of kernels /row			100-Kernel weight			Grain yield/plant(g)			Grain yield/fedan(kg)		
			S1	S2	Comb.	S1	S2	Comb.	S1	S2	Comb.	S1	S2	Comb.
Years		1			35.61**			0.23			2533*			576544*
Blocks/Y	2	4	2.95	5.82	4.02	11.55	0.001	5.77	98	273	186	81926	12997	47461
Genotypes	12	12	29.64**	15.66	42.72**	25.14	14.8*	38.07**	4686*	2700	6374**	595672**	403651**	938172**
Genotypes x Y		12			2.59			1.90			1013			61152
Error	24	48	7.79	10.37	9.10	7.99	6.04	7.02	1660	1410	1535	72992	52774	62883

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

Data of simple correlation coefficient matrix are shown in Table (3). Data indicate that ear diameter, ear length, number of kernels/row and 100-kernel weight had the greatest influence on grain yield/plant with r values being 0.576**, 0.648**, 0.695** and 0.649**, respectively. Number of rows/ear was significantly correlated with seed yield/plant with r value 0.248. On the other hand, Silking date and plant height were not significantly correlated with grain yield/plant. Another correlation worthy of some attention is that between 100-kernel weight and ear diameter, ear length and number of kernels/row with r values being 0.318, 0.512 and 0.493, respectively. High association of ear diameter, ear length, number of kernels/row and 100-kernel weight 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) and Ashmawy (2003).

Path coefficient analysis:

Direct, indirect effects, total contribution and percent contribution of each variable to grain yield/plant are presented in Table (4). Evidently, four of the seven variables, viz, ear length, number of kernels/row, number of rows/ear and weight of 100-kernel accounted for 85% of the total variation in the dependent variable while the remaining variables accounted for 15% of that variation.

100-kernel of weight proved to have the highest direct contribution to grain yield (25.60%) followed by the number of kernels/row (19.07%) and ear length (18.14%). Although, number of kernels/row had the highest simple correlation (0.695) with grain yield/plant. Moderate direct effect on grain yield could be noted for this character (19.07%). These results are in partial agreement with those obtained by Mohamed and Sedhom (1993) and Ashmawy and Mohamed (1998).

Multiple linear regression:

Data in Table (5) show the prediction model by using multiple linear regressions for grain yield/plant of maize and its components. The prediction equation was formulated as follows:

$$Y = -425.65 - 5.05X_1 + 0.66X_2 - 21.26^{**}X_3 + 7.63^{**}X_4 + 2.8^{**}X_5 + 23.62^{**}X_6 + 8.10^{**}X_7$$

Table (2): Mean value, minimum, maximum, standard deviation and standard error for maize yield characteristics.

Characters	Min.	Max.	Mean	S.D.	S.E.
Silking date	61.67	67.67	64.22	1.34	0.26
Plant height (cm)	241.67	290.33	264.83	12.81	2.51
Ear diameter (cm)	4.33	5.40	4.98	0.28	0.05
Ear length (cm)	17.97	23.47	20.61	1.46	0.29
No. of kernels/row	37.27	48.47	42.14	2.78	0.55
No. of rows/ear	12.23	15.53	14.14	0.80	0.16
100-kernel weight (g)	32.07	42.30	38.76	2.53	0.50
Grain yield/plant (g)	188.67	296.17	242.16	34.87	6.84

Table (3): A matrix of simple correlation coefficients for 8 characters of 13 maize genotypes grown in 2004 and 2005 seasons.

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	Y
Silking date (X_1)	1.000							
Plant height (X_2)	-0.370^{*}	1.000						
Ear diameter (X_3)	-0.186	0.132	1.009					
Ear length (X_4)	-0.199	0.139	0.748^{**}	1.000				
No. of kernels/row (X_5)	0.041	-0.012	0.685^{**}	0.620^{**}	1.000			
No. of rows/ear (X_6)	0.486^{*}	-0.261^{*}	0.184	-0.107	0.206	1.000		
100-kernel weight (X_7)	0.157	-0.096	0.318^{*}	0.512^{**}	0.493^{**}	-0.194	1.000	
Grain yield/plant (Y)	0.046	0.0138	0.576^{**}	0.648^{**}	0.695^{**}	0.248^{*}	0.649^{**}	1.000

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

Table (4): Direct and indirect effects of seven characters in maize for 13 genotypes grown in 2004 and 2005 seasons.

Characters	Direct effect	Indirect effect	Total correlation	Direct effect (%)
Silking date	-0.044	0.090	0.046	2.70
Plant height (cm)	0.206	-0.068	0.138	12.80
Ear diameter (cm)	-0.068	0.508	0.576^{**}	4.24
Ear length (cm)	0.291	0.357	0.648^{**}	18.14
No. of kernels/row	0.306	0.389	0.695^{**}	19.07
No. of rows/ear	0.277	-0.029	0.248	17.20
100-kernel weight (g)	0.412	0.237	0.649^{**}	25.60

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

The relative contribution for all yield factors explained 80.4% of the total variation in grain yield and 19.6% could be due to residual. Ear diameter, ear length, number of kernels/row and 100-kernel weight had the highest relative contribution of determination (R^2 = 34.4, 11.4%, 10.1 and 17.0%, respectively) followed by number of rows/ear (R^2 = 4.5%). The other characters had small contribution to the total yield variance.

Stepwise multiple linear regression analysis:

The accepted and removed variables and their relative contributions in predicting grain yield/plant are presented in Table (6). 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: $Y = -236.20 + 6.22X_5 + 5.58X_6$

According to this equation 80.40% of the total variation in grain yield could be linearly related to variations in all variables. Whereas, 60.73 of the total grain yield variation could be attributed to variable accepted and 19.70% could be due to variables removed. The accepted variables were number of kernels/row (X_5) and 100-kernel weight (X_7). Those variables were responsible for 48.32% and 12.41%, respectively of yield variance. Variables removed were silking date (X_1), plant height (X_2), ear diameter (X_3), ear length (X_4) and number of rows/ear (X_6).

Table (5): The relative contribution of 7 characters for predicting yield of maize using multiple linear regression analysis.

Characters	Regression coefficients	Standard error (S.E.)	Relative contribution (R^2%)
Silking date	-5.059	3.746	0.2142
Plant height	0.663	0.313	2.7869
Ear diameter	-21.259	24.483	34.417**
Ear length	7.628	4.417	11.4347**
No. of kernels/row	2.797	2.046	10.0590**
No. of rows/ear	23.621	6.701	4.451*
100-kernel weight	8.101	2.051	17.0400**

Y- Intercept =-425.647 **Standard error of estimation** =18.1978
Adjusted R-squared = 0.728 **R-squared** = 0.804
Multiple (R) = 0.897

Table (6): 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:			60.73
No. of kernels/row (X_5)	6.22	1.88	48.32**
100-kernel weight (X_7)	5.58	2.07	12.41**
Removed variables:			19.70
Silking date			
Plant height			
Ear diameter			
Ear length			
No. of rows/ear			

Y- Intercept = -236.20 **Standard error of estimation** = 22.78
Adjusted R-squared = 0.6000 **R-squared for accepted variables** = 0.6073
R-squared for removed variables = 0.1970 **Multiple (R)** = 0.7790

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 partial correlation coefficient 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) and Ashmawy (2003).

Factor analysis:

The factor analysis divided the 7 variables into three factors, which explained 79.87% of the total variability in the dependence structure in Table (7). A summary of the composition of variables of the three factors with loadings is given in Table (8). The first factor included the variables ear diameter, ear length and number of kernels/row, which accounted for 38.43% 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 Silking date and plant height, which accounted for 23.81% of the total variability in the dependence structure: This may be regarded as growth factor. Factor three contributed 17.63% of the total variances this factor included number of rows/ear and 100-kernel weight. The factors 1 and 3 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 three factors altogether accounted for 79.87% of the total variation in the dependence structure (Table, 7 and 8).

Table (7): Principle factor matrix after orthogonal rotation for 7 characters in maize.

Characters	Common factor coefficients			Communality (h^2)
	Factor 1	Factor 2	Factor 3	
Silking date	-0.0496	0.831	0.216	0.740
Plant height (cm)	0.0753	-0.761	0.014	0.584
Ear diameter (cm)	0.896	-0.197	0.175	0.873
Ear length (cm)	0.863	-0.167	-0.222	0.821
No. of kernels/row	0.877	0.122	0.045	0.785
No. of rows/ear	0.175	0.429	0.840	0.920
100-kernel weight (g)	0.579	0.363	-0.633	0.867
Latent roots	2.690	1.667	1.234	
Variance ratio for factor %	38.426	23.812	17.630	79.868

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 and Ashmawy 2003). The greatest benefit of factor analysis can be delineating areas of further researches designed to test the validity of the suggested factors. 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.

Table (8): Summary of factor loadings for 7 characters in maize.

Variables	Loading	% Total communality
Factor 1:		38.426
Ear diameter	0.896	
Ear length	0.863	
No. of kernels/row	0.877	
Factor 2:		23.812
Silking date	0.831	
Plant height	-0.761	
Factor 3:		17.630
No. of rows/ear	0.840	
100-kernel weight	-0.633	
Commulative variance		79.868

CONCLUSIONS

Four procedures of statistical analysis were used to study relationship of yield components and yield in a set of corn genotypes to compare between the four procedures used in this concern. Results showed clearly that the path coefficient analysis revealed that the number of kernels/row and 100-kernel weight had the highest relative contribution to yield/plant. Stepwise regression showed according to the equation that 80.4% of the total yield variation could be linearly related to variables included in the model and 60.73% of the total seed yield variation could be attributed to variable acceptance (number of kernels/row and 100-kernel weight) and 19.70% could be due to variable removal. The most important variables were the number of kernels/row and 100-kernel weight. In the multiple linear regression 80.4% of plant yield variation could be linearly related to variables inserted in the model. The factor analysis divided the 7 variables into three factors, which explained 79.87% of the total variability in the dependence structure. The first factor included the variables ear diameter, ear length and number of kernels/row, which accounted for 38.43% of the total variance. Generally, 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 program. 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. The results of the analysis techniques indicated that ear length, number of rows/ear, number of kernels/row and 100-kernel weight were the most important contributing variables in the total variability of grain yield/plant. These variables have to be ranked the first in breeding program for improving grain yield of maize.

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المساهمة النسبية لعوامل المحصول باستخدام بعض الطرق الإحصائية المتخصصة فى الذرة الشامية

محمود الزعبلاوى محمود البدوى
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أجريت هذه الدراسة بمركز التجارب والبحوث الزراعية بكلية الزراعة بمشتهر موسمي ٢٠٠٤ و٢٠٠٥ إستخدمت أربع طرق إحصائية خاصة بدراسة ارتباط مكونات المحصول بعضها ببعض والمحصول وهى تحليل معامل المرور وتحليل الانحدار المتعدد وتحليل الانحدار المتعدد المرحلي والتحليل العاملى وطبقت الأساليب الإحصائية السالفة على مكونات المحصول الخاصة بثلاثة عشر صنف من الذرة الشامية وهى ثمانى هجن فردية هى فردى ١٠، ١٢٢، ٣٠ك٨، ٩، ١٢، ٨١، ٥٢، ٢١ وهجين زوجى دهب وثلاثة هجن ثلاثية ٣١٠، ٣٠ب٩، ٣٠٥٧ والصنف التركيبى جيزه ٢. وكانت الصفات المدروسة هى ارتفاع النبات، ميعاد التزهير، سمك الكوز، طول الكوز، عدد الحبوب فى الصف، عدد الصفوف للكوز، ووزن ١٠٠ حبه ومحصول الحبوب للنبات. أظهرت مصفوفة معامل الارتباط البسيط وجود ارتباط موجب عالى المعنوية بين محصول الحبوب للنبات، بين سمك الكوز، طول الكوز، عدد الصفوف للكوز ووزن ال١٠٠ حبة . أوضحت نتائج تحليل معامل المرور أن أربع متغيرات من السبعة هى طول الكوز، عدد الحبوب فى الصف، عدد الصفوف للكوز ووزن الــ١٠٠ حبه بمقدا ٨٥% من المساهمة فى مقدار التباين الكلى التى لها تأثير على المحصول و١٥% فقط لباقى العوامل. حيث حققت وزن الــ١٠٠ حبة أعلى قيمه بمقدار ٢٥,٦٠% وعدد الحبوب للصف بمقدار ١٩,٠٧% وطول الكوز بمقدار ١٨,١٤% وعدد الصفوف للكوز بمقدار ١٧,٢٠ % . أظهر تحليل الانحدار المتعدد ان صفة سمك الكوز، طول الكوز، عدد الحبوب فى الصف ووزن ال١٠٠ حبة لها المساهمة الاكبر فى المحصول بمقدار ٣٤,٤ % و١١,٤% و١٠,١% و١٧% عى التوالى .كما أظهر تحليل الانحدار المتعدد المرحلى ان صفة عدد الحبوب للصف ووزن ال١٠٠ حبة اهم المكونات المؤثرة فى تحديد المحصول وقسم التحليل العاملى للسبعة صفات تحت الدراسة الى ثلاثة عوامل وقد حققت الثلاثة عوامل مجتمعة مقدار ٧٩,٨٧% من التباين الكلى .وجد أن التحليل العاملي افضل الطرق بالمقارنة بالطرق الاخري والتي يهتم بها ويستخدمها مربي النباتات في برنامج التربيه حيث يعمل علي اختصار المتغيرات العديدة والمرتبطة مع بعضها الى عوامل رئيسية محدودة العدد وبكل عامل الصفات التى ترتبط مع بعضها مما يعطى مربى النبات الفرصة فى اختيار أهم الصفات بالتتابع حسب اهميتها ويمكن استخدام معامل المرورفى تحديد مدى مساهمة الصفة بطريقة مباشره وغير مباشره فى المحصول بينما يمكن استخدام تحليل الانحدار المتعدد المرحلي في تحديد أفضل المتغيرات المساهمة فى المحصول.