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STUDY OF INTERRELATIONSHIPS AMONG YIELD AND IT'S COMPONENTS BY USING DIFFERENT STATISTICAL METHODS IN SOME EGYPTIAN BREAD WHEAT CULTIVARS

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ABSTRACT

Two field experiments were conducted in 2012/2013 and 2013/2014 growing seasons at the experimental farm of the Faculty of Agriculture, El-Fayoum University. Three Egyptian bread wheat cultivars were evaluated in randomized complete blocks design with three replications for seven traits. The aims were to determine relationship among yield and its components and examine the efficiency of such components in building yield capacity by using three different statistical methods. Significant differences were detected among cultivars for all studied traits. Highly significant and positive correlation estimates were detected among grain yield plant^{-1} and each of number of grains spike^{-1}, spike length, number of spikelets spike^{-1}, 1000-grain weight and harvest index. On the other hand, plant height showed negative association with grain yield plant^{-1}. Path coefficient analysis showed that maximum direct effect and joint effects on grain yield plant^{-1} were contributed mostly by number of grains spike^{-1}, followed by spike length and number of spikelets spike^{-1} were the major contributors towards grain yield. Also, stepwise multiple linear regression analysis revealed that three traits included number of grains spike^{-1}, spike length and number of spikelets spike^{-1} were significantly contributing to variation in grain yield plant^{-1} and responsible for reducing 97.71 %, of total yield variance. In general the results showed that that the number of grains spike^{-1}, spike length and number of spikelets spike^{-1} were the most important traits and they were highly effective on grain yield. Consequently, these traits have to be ranked the first in any breeding program to improve wheat grain yield

Keywords: *Wheat, Grain yield, Statistical procedures, Simple correlation, Path analysis and Stepwise multiple linear regression analysis.*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a major cereal crop in many parts of the world and it is commonly known as king of cereals. It is the staple food for a large part of world population including Egypt. In 2013 wheat cultivated area in Egypt was 1.29 million hectares (3.1 million feddan) which producing 9.5 million tones (FAO, 2014). An important objective of the Egyptian Government is consequently to reduce the dependence on imported wheat by enhancing average grain yield and production. Increasing wheat productivity is a national target in Egypt to fill the gap between wheat consumption and production.

The main objective for a plant breeder is to evolve high yielding cultivars. Grain yield is a complex trait and highly influenced by many genetic factors and environmental fluctuations. In plant breeding programme, direct selection for yield as such could be misleading. A successful selection depends upon the information on the genetic variability and association of morpho-agronomic traits with grain yield.

There are many factors, on which the yield of wheat crop depends, such as plant height, number of spikletes spike^{-1}, number of grains $^{-1}$ spike, spike length, 1000-grain weight and harvest index etc. It is desirable for plant breeder to know the extent of relationship between yield and its various components which will facilitate him in selecting plants of desirable characteristics. The needs of new cultivars having higher grain yield leads to the objective of wheat breeding programs to develop new cultivars having higher quality and greater yielding ability. The knowledge of relationship among various yield components has been successfully exploited towards wheat improvement.

There are various statistical techniques covering correlation, regression, path analysis to evaluate yield and yield components for breeding programs. Abd El-Mohsen and Abd El-Shafi (2014) used four statistical procedures to study the relationship between wheat grain yield and its components. Correlation analysis among yield and yield components is one of the prerequisite techniques to determine the influence of environment on productivity and yield potential Snedecor and Cochran (1981). The information on the nature and magnitude of correlation coefficients help breeders to determine the selection criteria for simultaneous improvement of various characters along with yield. Determination of correlation coefficients between various wheat characters helps to obtain best combinations of attributes for obtaining higher return per unit area. Stepwise multiple linear regression aims to construct a regression equation that includes the variables accounting for the majority of the total yield variation. Ashmawy (2010) used stepwise regression analysis and reported that number of spikes per m^2, number of grains spike^{-1} and 1000 grains of weight were the most important contributing characters in the total variability of grain yield. Soleymanfard (2012) reported that 75 % variation in grain yield was due to spikes per m^2, 1000 grain weight and plant height. Path coefficient analysis separates the direct effects from the indirect effects through other related characters by partitioning the correlation coefficient Dewey and Lu (1959).

To view the above facts and keeping the importance of production of wheat crop in view, the present study was undertaken to in order to determine the dependence relationship between grain yield and yield component traits of three Egyptian cultivars of bread wheat by using certain statistical procedures under El-Fayoum region conditions. The aim of this study to help wheat breeders, how to determine the effect of yield components and what yield components could be efficiently used in breeding programs.

MATERIALS AND METHODS

Experimental site and plant materials:

This investigation was carried out at the experimental farm of the Faculty of Agriculture, El-Fayoum University, during the two winter seasons of 2012/2013 and 2013/2014. The experimental material comprised of three Egyptian bread wheat cultivars (*Triticum aestivum* L.), namely: Miser 1, Sakha 93 and Sids 12. These cultivars were used as treatments and evaluated in the study. Wheat cultivars were obtained from the Agric. Res. Center, Ministry of Agriculture, Egypt.

Layout and experimental design:

The experiment was laid out in randomized complete blocks design with three replications. The unit area of experimental plot was 10.5 m^2 (3 x 3.5 m).

Cultural practices:

Cultivars were sown at the seed rate of 60 kg/fed and sowing dates were 11th and 17th of November in the two successive seasons, respectively. The plants were subjected to recommended package of agronomic and plant protection practices to obtain a healthy crop. All the recommended cultural practices were followed up to harvest.

Recording of observations:

Data were recorded on ten randomly selected plants for the following traits viz., plant height (cm), number of spikelets spike^{-1}, number of grains spike^{-1}, spike length (cm), 1000-grain weight (g), harvest index (%) and grain yield plant^{-1} (g).

Statistical analysis and interpretation of data:

Keeping in view the objectives set out for the study, following statistical tools and methods have been deployed.
Normality distributions in each trait were checked out by the Wilk Shapiro test (Neter , 1996). The data were analyzed according to the randomized complete blocks design over years. A combined analysis of variance was conducted for the two seasons according to Gomez and Gomez (1984). Homogeneity test of variances were performed according to procedures reported by Gomez and Gomez (1984). Thus, if hypothesis that the two error variances are homogeneous cannot be rejected, the combined analysis of variance was computed. The differences among cultivars, was considered significant if the P-values were ≤ 0.05.

The combined data of yield and yield components over both seasons were used the following statistical procedures. In order to determine the relationships between examined traits and seed yield per plant, correlation coefficients were calculated with the MSTAT-C software package (Freed , 1989). The path coefficient analysis was performed by examining seed yield per plant as a dependent variable for major contributor's traits to seed yield per plant via OpenStat version 1.9, a computer program, as suggested by William Miller (2007). Modeling was performed according to the stepwise multiple linear regression method, backward variable selections were applied using Statgraphics Plus for windows (Manugistics, 1998) and SPSS computer software (1999).

Descriptive analysis:

The raw data was compiled by taking the means of all plants taken for each treatment and replication for different traits in both seasons. The pooled means of both seasons were subjected to further statistical and biometrical analysis. Simple statistical estimates, viz. average, range, standard error and coefficient of variation were analyzed according to Steel (1997).

Simple correlation:

A matrix of simple correlation coefficients between grain yield/plant and its components was computed according to Snedecor and Cochran (1981).

Path coefficient analysis:

Path coefficient analysis was made on the basis of phenotypic correlation coefficients taking grain yield as effect and the remaining estimated characters as cause. Direct and indirect effects of component characters on grain yield were worked out using path coefficient analysis Dewey and Lu (1959).

Stepwise multiple linear regression:

Stepwise multiple linear regression was used in order to determine the most important variables (independent variables) significantly contributed to total yield (dependent variable) variability (Draper and Smith, 1981).

RESULTS AND DISCUSSION

Combined Analysis of Variance:

A test of homogeneity for error variance for each variable was done according to Gomez and Gomez (1984). Results of mean square from combined analysis of variance (ANOVA) of seed yields and related characters are presented in Table 1.

The results showed year effect to be highly significant ($p<0.01$) for all studied traits and cultivars effect was highly significant ($p<0.01$) for all for all studied traits indicating considerable amount of genetic variation present in the material. High magnitude of variation in the experimental material was reflected by high values of mean and range for almost all studied traits . This result implied that this population of wheat cultivars would respond positively to selection. A close view of results (Table 1) showed that the effect of interaction between wheat cultivars and years was statistically significant for all traits under study. This result indicates that the performance of cultivars was not the same from one year to another. Also, significant effect of this interaction was detected, revealing that the tested cultivars ranked differently from year to year. Therefore, it could be concluded that environmental significantly affected the performance of the present wheat cultivars. The varietal differences in growth, yield and yield components obtained in this study are in agreement with those obtained by El-Sarag and Ismaeil (2013), Baloch, (2013) and Abd El-Mohsen and Abd El-Shafi (2014).

Table 1. Mean squares corresponding to various sources of variation for grain yield and other traits in some wheat cultivars over the two studied seasons

SOV	df	Plant height (cm)	No. of spikelet's spike^{-1}	No. of grains spike^{-1}	Spike length (cm)	1000-grain weight (g)	Harvest index (%)	Grain yield plant^{-1} (g)
		Mean squares						
Years	1	41.59**	79.95**	177.09**	119.75**	55.57**	43.13**	110.32**
Replications/years	4	1.57	3.94	6.64	5.035	4.15	1.59	6.02
Cultivars	2	72.24**	120.27**	277.25**	172.11**	79.16**	61.325**	225.26**
Cultivars x Years	2	18.73*	49.37**	133.21**	67.05**	35.75**	24.97**	119.31**
Error	8	3.12	5.23	13.27	7.45	3.25	2.27	9.17

* and ** = Significant at $P \leq 0.05$ and 0.01, respectively.

Performance of yield and its components:

Basic statistical parameters: minimum and maximum values, mean values, standard deviation and coefficient of variation for three cultivars under investigation of all studied traits are presented in (Table 2). The results show that the coefficient of variation was the highest for number of grains spike^{-1}, followed by grain yield plant^{-1}. Plant height had the lowest value, followed by, harvest index. Spike length, number of spikletes spike^{-1} and 1000-grain weight showed moderate values for the coefficient of variation. Similar results have been reported by Abd El-Mohsen (2012) and Ashmawy (2010).

Table 2. Basic statistical parameters for yield and its components in wheat cultivars: minimum (Min) and maximum values (Max), mean values, standard deviation (S.D) and coefficient of variation (C.V) across two seasons

Traits	Min.	Max.	Mean	S.D	C.V%
Plant height (cm) (x_1)	104.88	107.81	106.12	1.10	1.04
Number of spikelets spike^{-1} (x_2)	15.23	18.53	17.01	0.93	5.47
Number of grains spike^{-1} (x_3)	46.25	58.25	52.13	4.95	9.50
Spike length (cm) (x_4)	11.59	13.57	12.61	0.73	5.79
1000-grain weight (g) (x_5)	43.14	47.47	45.49	1.60	3.52
Harvest index % (x_6)	40.13	42.46	41.28	0.66	1.60
Grain yield plant^{-1} (g) (y)	9.75	11.93	10.67	0.76	7.12

Means of grain yield varied between 9.75 and 11.93 g per plant. Number of spikletes spike^{-1} ranged from 12.23 to 13.53. Plant height was between 104.88 and 107.81cm, whereas the number of grains spike^{-1} was between 46.25 and 58.25, thousand spike length, 1000-grain weight and harvest index were between 11.59 and 13.57 cm, 43.13 and 47.47 g., 40.13 and 42.46 %, respectively (Table 2). Such considerable range of variations provided a good opportunity for yield improvement. The coefficient of variation (CV %) is a good base for comparing the extent of variation. In addition, the CV% is a parameter which is not related to unit of measured traits and will be effective in comparing of the studied traits. CV% between different characters with different scales is shown in Table 2. The CV% of the traits varied from 1.04 % (for plant height) to 9.50 % (for number of grains spike^{-1}) and were therefore in the acceptable range as commonly observed in field experiments (Abd El-Mohsen and Abd El-Shafi, 2014).

Correlation analysis:

Simple correlation coefficients among grain yield plant^{-1} of wheat and its related traits computed and presented in Table (3). These estimates are clearly show that grain yield/plant exhibited highly significant and positive correlation with number of grains spike^{-1} (r = 0.991**), spike length (r = 0.989**) and number of spikelets/spike (r = 0.978**), seed index (r = 0.921*) and harvest index (r = 0.919*). In contrast, plant height showed highly significant and negative correlation with grains yield per plant (r = -0.823**). Similar results were reported by Leilah and Al-Khateeb (2005) and Fellahi (2013).

Table 3. Matrix of simple correlation coefficients among yield and its components in wheat cultivars over the two studied seasons

Variables	X_1	X_2	X_3	X_4	X_5	X_6	Y
Plant height (cm) (X_1)	1.00						
No. of spikelets spike^{-1} (X_2)	- 0.325 ns	1.00					
No. of grains spike-^{1} (X_3)	- 0.893 **	0.975**	1.00				
Spike length (cm) (X_4)	- 0.417 ns	0.945**	0.955**	1.00			
Seed index (g) (X_5)	- 0.102ns	0.833*	0.921**	0.913**	1.00		
Harvest index % (X_6)	- 0.527 ns	0.856*	0.883**	0.879**	0.815*	1.00	
Grains yield plant^{-1} (g) Y	- 0.823 **	0.978**	0.991**	0.989**	0.921**	0.919**	1.00

ns,*and** = Non-significant, Significant at P ≤ 0.05 and 0.01, respectively.

Path coefficient analysis:

The coefficients of determination and relative importance, according to path analysis, for grain yield/plant and its related traits are shown in Table (4). The results revealed that the greatest parts of grain yield/plant, variation were accounted for the direct effects of number of grains spike^{-1} (22.02%), spike length (17.31%) and number of spikelets spike^{-1} (14.21%). The large contribution of these traits grain yield/plant, plus the ease of visually measuring them supported their importance as selection criteria in wheat improvement programs. Similar results were reported by Khan and Dar (2010), Fellahi (2013), Iftikhar (2012) and Pirdashti (2012). Regarding the relative importance of components of joint effects, it appeared that the highest value was observed for the indirect effect of number of grains/spike via spike length (13.21%), number of spikelets spike^{-1} via number of grains spike^{-1} (9.05%) and number of spikelets spike^{-1} via spike length (7.02%) on grain yield plant^{-1}. Generally, the studied traits explained 95.81% of variation in grains yield plant^{-1}. Residual effects (4.19%) indicated that six traits included in this study explained high percentage of variation in grain yield.

Table 4. Direct and indirect effects of some important traits and their relative contribution in grain yield/plant over 2012-2013 and 2013-2014 seasons

Traits			Grain yield/plant	
			CD*	RI %**
Direct effects				
Plant height (cm)		X_1	- 0.223	1.17
No.of spikelets^{-1} spike		X_2	0.221	14.21
No. of grains spike^{-1}		X_3	0.402	22.02
Spike length (cm)		X_4	0.341	17.31
Seed index (g)		X_5	0.033	2.43
Harvest index %		X_6	0.013	1.04
Total (direct)			0.787	58.18
Indirect effects				
X_1 via	No.of spikelets spike^{-1}	X_2	- 0.119	0.17
	No. of grains spike^{-1}	X_3	- 0.102	0.30
	Spike length (cm)	X_4	- 0.015	0.19
	Seed index (g)	X_5	- 0.005	0.27
	Harvest index %	X_6	- 0.001	0.33
X_2 via	No. of grains spike^{-1}	X_3	0.087	9.05
	Spike length (cm)	X_4	0.049	7.02
	Seed index (g)	X_5	0.041	1.03
	Harvest index %	X_6	0.023	1.04
X_3 via	Spike length (cm)	X_4	0.093	13.21
	Seed index (g)	X_5	0.037	0.72
	Harvest index %	X_6	0.021	0.52
X_4 via	Seed index (g)	X_5	0.013	1.47
	Harvest index %	X_6	0.011	1.27
X_5 via	Harvest index %	X_6	0.005	1.04
Total (indirect)			0.138	37.63
Total (direct + indirect)			0.925	95.81
Residual			0.075	4.19
Total			1.000	100.00

*CD = Coefficient determination. ** RI = Relative importance.

Stepwise multiple linear regression:

In order to remove effect of non-effective traits in regression model on grain yield, stepwise regression was used. In stepwise regression analysis, grain yield plant^{-1} (Y) as dependent variable and other traits as independent variables were considered. Accepted variables and their relative contributions are shown in Table (5).

The results showed that number of grains spike^{-1}, spike length and number of spikelets spike^{-1} with R^2 = 97.71%, had justified the maximum of yield changes. It is observed from the results that number of grains spike^{-1} was the most important character followed by spike length and number of spikelets spike^{-1}. The relative contributions in the total variation of grain yield were 63.07%, 21.03% and 13.61 % for the above mentioned traits, respectively. Due to their low relative contributions, the other variables were not included in the model. Consequently, based on the final step of stepwise regression analyses, the best prediction equation was formulated as follows:

$Y = 2.73 + 0.21\ X_3 + 0.39\ X_4 + 0.\ 23\ X_2$

Where, Y, X_3, X_4 and X_2 are grain yield plant^{-1}, number of grains spike^{-1}, spike length and number of spikelets spike^{-1}, respectively. Existence of significant R square in a successful regression equation indicates the effectiveness of these traits to increase grain yield. Therefore, these traits were considered as the main grain yield components. The unexplained variation (2.29% of the total) may be due to variation in other yield components. A positive regression coefficient of the three variables implies that defining a logical index selection with these variables, considering their correlation coefficients with grain yield, might be a good strategy for increasing grain yield in wheat. The results of this analysis are in agreement with Soleymanfard (2012) reported that 75 % variation in grain yield was due to number of spikes per m^2, 1000 grain weight and plant height. Shamsi (2011) who found that spike number, grains number per spike and thousand kernel weight were introduced into stepwise regression model, accounting for 98 % of grain yield variance.

Table 5. Accepted variables and their relative contribution (model R^2) and regression coefficient (b) in predicting wheat grain yield by the stepwise procedure analysis over 2012-2013 and 2013-2014 seasons

Step	Acceptance variables	Model R^2	b	R^2 %	Constant
1	No.of grains spike^{-1} (X_3)	0.6307	0.21	97.71	2.73
2	Spike length (X_4)	0.8410	0.39		
3	No.of spikelets spike^{-1} (X_2)	0.9771	0.23		

The multiple statistical procedures which have been used in this study showed that number of grains spike^{-1} (X_3), spike length (X_4) and numbers of spikelets spike^{-1} (X_2) were the most important yield variables to be considered for these cultivars. These procedures were shown in Table (6) for all studies variables. Thus, high yield of wheat plants based on these cultivars can possibly be obtained by selecting breeding materials with high values of these traits.

Table 6. Wheat traits identified as crucial in grain yield with each one of the used statistical techniques

Traits	Statistical methods			Total score
	Simple correlation	Path analysis	Stepwise regression	
Plant height (cm) (X_1)				0
Number of spikelets spike^{-1} (X_2)	√	√	√	3
Number of grains⁄spike (X_3)	√	√	√	3
Spike length (cm) (X_4)	√	√	√	3
1000-grain weight (g) (X_5)	√			1
Harvest index % (X_6)	√			1

CONCLUSIONS

The data obtained from this study could be useful for wheat breeders, statisticians, agronomists and grain producers in order to increase grain yield and understand the nature of the relationship between the most important variables affecting the yield of wheat.

According to the results obtained, it may be concluded that the multiple statistical procedures which have been used in this study showed that number of grains spike^{-1}, spike length and numbers of spikelets spike^{-1} were the major and the most constant source accounting for variation as total contribution in grain yield. Hence they warrant attention of wheat breeder for improving grain yield.

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