ESTMATING PHENOTYPIC, GENOTYPIC AND ENVIRONMENT PATH COEFFICIENTS IN WHEAT (*TRITICUM AESTIVUM* L.) GENOTYPES

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ABSTRACT

Two field experiments were carried out during two successive seasons on six wheat genotypes at the experimental farm, Faculty of Agriculture, El-Fayoum Univ. In 2005/2006 season, the six parental genotypes were planted and all possible crosses excluding reciprocals were hand made to produce 15 F_1 hybrids. In the second season (2006/2007), the parents and hybrids were planted using the randomized complete block design with five replications. The correlation coefficients and path analysis were calculated between grain yield and yield components of the 21 wheat genotypes. The tested genotypes exhibited significant differences due to the presence of sufficient genetic variability, and standard error values were in the range of 0.5 for spike length to 2.54 for number of grains/spike. Consequently the latter trait showed the highest values of phenotypic, genotypic and environmental variances followed by those of grain yield/ plant. Heritability and genetic advance values were high for days to heading, days to maturity, number of grains /spike and grain yield /plant. Grain yield /plant was positively correlated phenotypically and genotypically with days to heading and days to maturity and negatively with number of grains /spike. Phenotypic path coefficient revealed that the direct effect of days to maturity on grain yield was the highest (0.57) with relative importance of 18.8% followed by those of spike length. Concerning genotypic path coefficient, both traits, respectively, ranked as the first and second traits affecting grain yield /plant. The indirect phenotypic effects on grain yield exhibited by days to heading, days to maturity, plant height and spike length were 0.39, -0.11, 0.22 and 0.028, respectively. The relative importance of indirect genotypic effects on grain yield showed by plant height, days to maturity and spike length were 27.6, 21.1, and 11.8, respectively.

Key words: ANOVA, ANCOVA, Path analysis, Wheat.

INTRODUCION

Improving yield is one of the most important goals for most plant breeders and geneticists working with quantitative traits. Grain yield is a highly polygenic quantitative character that is greatly affected by environmental fluctuations. Grain yield in wheat, as in other crops, is a complex character which resulted as the sum-total of the contributions made by its individual components. **Grafius (1959)** has even doubted the individuality of grain yield. Yield and some of its components, such as the number of spikes per plant, cannot be wholly reliably used as criteria for selection because of their low heritability and wide fluctuations as a result of their interaction with the environment. It was suggested that wheat grain yield is a function of various components, where it depends mainly on the number of spikes per unit area, the number of grains per spike and the average grain weight. The grain yield and yield components of wheat are affected very much by the genotype and the environment. Therefore, as new cultivars are being produced by breeding, the relationships between grain yield and its components should be studied by the breeders. To increase the yield, studying the direct and indirect effects of yield components on yield provides the basis for its successful breeding program and hence the problem of yield increase can be more effectively tackled through exploitation the performance of yield components and selection for closely related characters **(Mehmet and Telat, 2006)**. Based on path analysis, it could be determined the most important sources of variation in grain yield. Significant genotypic and phenotypic variances, differentiated the yield components which may be used as good selection criteria to improve grain yield of wheat genotypes. The aim of this study was to determine the correlation and path coefficients of yield and yield components in bread wheat and evaluate their suitabilities in a breeding program.

MATERIALS AND METHODS

Two variance-covariance matrices necessary for calculating genotypic and phenotypic correlation coefficients as well as for evaluating the path coefficients technique, were obtained from the mean squares and mean cross products of genotypes together with error for different characters measured in a replicated experiment. Analysis of variance for each character and analysis of covariance for all pairs of the studied characters were constructed separately. The expectations of mean squares and mean cross products are given in Table (1).

Table 1: Mean squares (MS), and mean products (MP) from variance-covariance analysis of RCBD.

	Analysis of Variance		Analysis of Covariance	
Source	M.S.	Expectation of M.S.	M.P.	Expectation of M.P.
Replicates	Mr_u	—	Mr_{12}	—
Genotypes	Mt_n	$\sigma^2_e + r\,\sigma^2_g$	Mt_{12}	$\sigma_{eij} + r\,\sigma_{gij}$
Error	Me_n	σ^2_e	Me_{12}	σ_{eij}

*r : number of replications.

Mean squares were used to estimate:

$\sigma^2_g = (\mathbf{Mt_n - Me_n}) / r$

$\sigma^2_{ph} = \sigma_e^2 + \sigma_g^2$, where broad-sense heritability (h^2) was estimated as follows:
$h^2 = (\sigma^2_g / \sigma^2_{ph})$ X 100, and the phenotypic, genotypic and environmental coefficients of variation are computed as follows:

$$PCV = 100x\sqrt{\sigma^2_{ph}}\,/\,\bar{X}$$

$$GCV = 100x\sqrt{\sigma^2_g}\,/\,\bar{X}$$

$$ECV = 100x\sqrt{\sigma^2_e}\,/\,\bar{X}$$

The mean products were used to estimate:

$\sigma_{gij} = (Mt_{12} - Me_{12}) / r$

$\sigma_{phij} = \sigma_{eij} + \sigma_{gij}$, where phenotypic, genotypic and environmental correlation coefficients are computed as follows:

$$r_{ph} = \sigma_{phij} / \sqrt{\sigma^2_{phi} x \sigma^2_{phj}}$$

$$r_g = \sigma_{gij} / \sqrt{\sigma^2_{gi} x \sigma^2_{gj}}$$

$$r_e = \sigma_{eij} / \sqrt{\sigma^2_{ei} x \sigma^2_{ej}} .$$

Expected genetic advance: Expected genetic advance from direct selection for all studied traits was calculated according to **(Singh and Chaudhary 1999)** as follows:

$$\Delta G\% = 100 * k * h^2 * \sigma_{ph} / \bar{X} ,$$

where, $\bar{X}$: general mean and k is selection differential (k= 1.76 for 10% selection).

Calculation of all possible simple correlation coefficients among various studied characters, which is equal to n(n-1)/2, where n is the number of characters as in Table(2).

Table 2: The all possible simple correlation coefficients (correlation matrix) for phenotypic, genotypic and environmental

Phenotypic correlations				
	Y	Ch_1	...	Ch_n
Y	1			
Ch_1	r_{ph1y}	1		
...	...	...	...	...
Ch_n	r_{phny}	r_{ph1n}	...	r_{phnn}
Genotypic correlations				
	Y	Ch_1	...	Ch_n
Y	1			
Ch_1	r_{g1y}	1		
...	...	...	...	...
Ch_n	r_{gny}	r_{g1n}	...	r_{gnn}
Environment correlations				
	Y	Ch_1	...	Ch_n
Y	1			
Ch_1	r_{e1y}	1		
...	...	...	...	...
Ch_n	r_{eny}	r_{e1n}	...	r_{enn}

The matrices in Table(2) are symmetric i.e., $r_{iy} = r_{yi}$, i=1, ..., n.

The path analysis is carried out according to **(Wright, 1921, Dewey and Lu, 1959 and Singh and Narayonan, 2000))**, let n independent variables be significantly correlated with dependent variable Y, then the correlation matrices representing correlation coefficients (phenotypic, genotypic and environment) as given in Table (2). The correlation coefficient between i^{th} independent variables and dependent variable Y is linearly related with the correlation coefficients of i^{th} independent variable with remaining independent variables, the relation is denoted as follows:

$r_{iy} = P_{1y} r_{i1} + P_{2y} r_{i2} + \ldots + P_{ny} r_{ny}$. for i= 1, …, n.

where $P_{1y}, P_{2y}, \ldots, P_{ny}$ are the coefficients in the linear relation and are known as path coefficients. P_{iy} is called the direct effect of i^{th} independent characters (Ch_i) and dependent variable Y. $P_{1y} r_{i1}, P_{2y} r_{i2}, \ldots, P_{ny} r_{in}$ are called the indirect effects of Ch_i on Y. Therefore the simple correlation coefficient (total effect) between Ch_i and Y is the sum of direct and indirect effects of Ch_i on Y. The linear relations are represented by matrix notation as follows:

$$\underset{n \times n}{\begin{pmatrix} 1 & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & 1 \end{pmatrix}} \underset{n \times 1}{\begin{bmatrix} P_{1y} \\ \vdots \\ P_{ny} \end{bmatrix}} = \underset{n \times 1}{\begin{bmatrix} r_{1y} \\ \vdots \\ r_{ny} \end{bmatrix}}$$

Hence

$$\begin{bmatrix} P_{1y} \\ \vdots \\ P_{ny} \end{bmatrix} = \begin{pmatrix} 1 & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & 1 \end{pmatrix}^{-1} \begin{bmatrix} r_{1y} \\ \vdots \\ r_{ny} \end{bmatrix}$$

Therefore, the path coefficients are obtained and hence the direct and indirect effects can be determined.. Further, the residual effect is estimated as follows:

$$P_{Ry} = (1 - (P_{1y} r_{i1} + P_{2y} r_{i2} + \ldots + P_{ny} r_{ny}))^{1/2}.$$

This investigation was conducted during 2005/2006 and 2006/2007 seasons at the Experimental Farm (Dar El-Ramed), Faculty of Agriculture, Fayoum University, Egypt. Six bread wheat genotypes (*Triticum aestivum* L.) were used as parental lines. Their commercial names, pedigree and origin are presented in Table (3). In 2005/2006 season, the six parental genotypes were planted and all possible crosses excluding reciprocals were hand made among parental lines to produce 15 F_1 hybrids. In the second season of 2006/2007, the six parents and fifteen hybrids were planted in a field experiment using the randomized complete block design (RCBD) with five replications. Seeds of each entry were spaced 10 cm apart in one row 3 m long and 20 cm between rows. Each entry was represented by one row, all recommended cultural practices were considered. At harvesting time, data were recorded on random samples of 15 guarded plants from each row, for plant height, cm (X_1), days to heading (X_2), days to maturity(X_3), spike length, cm (X_4), number of grains/spike (X_5), 1000-grain weight, g (X_6) and grain yield/plant, g (Y). Direct and indirect effects of traits were evaluated by correlation and path coefficients. Correlation and path coefficients were calculated by using **PATHC** Statistical Computer Program **(Atia, 2007).**

Table (3): The commercial names, pedigree and origin of the wheat parental lines used in this study.

No	Parents	Pedigree	Origin
P_1	Sids 1	HD 2172/Pavon"s"//1158.57/Maya 74 "s"	Egypt
P_2	Giza 168	MRL/BUC//Seri CM93046-8M-OY-OM-2Y-OB	Egypt
P_3	Sakha 94	Opata/Rayon//Kauz	Egypt
P_4	Gemmiza 10	Maya 74 "s"/On//1160-47/3/Bb/4/Chat"s"/5/Ctow	Egypt
P_5	Sakha 93	Sakha 92/TR 81032858871- 15-25-15-05	Egypt
P_6	Sids 4	May S/Mon S/CMH74.A592/3/Giza 157* 2	Egypt

RESULTS AND DISCUSSION

Average values: The tested genotypes were significantly different for all studied traits, indicating the presence of sufficient genetic variability for selection to identify the superior genotypes (Table 4). The standard error was the highest (2.54) for number of grains /spike (X_5), whereas it was the lowest (0.50) for spike length (X_4). Data belong to investigated traits, as average of 21 genotypes, variance components, heritability estimates and expected genetic advance are presented in Table(5). Estimates of phenotypic (σ^2_{ph}) and genotypic (σ^2_g) variances were high, particularly for number of grains /spike (270.9 and 238.7) and grain yield/ plant (131.5 and 109.2 respectively).The two traits also had relatively high environmental (σ^2_e) variance. But the highest σ^2_e value (25.69) was showed by plant height, therefore it had the lowest estimate of heritability (0.56), followed by 1000-grain weight (0.7). However, the results of the traits including, grain yield /plant, exhibited high heritability values more than 0.8. Concerning the expected genetic advance under selection intensity of 10%, the finding showed that it was high for spike length, number of grains /spike and grain yield /plant and low for plant height and days for maturity. These results are in agreement with those reported by **Gibson and Paulsen 1999 and Garcia *et al* 2002.**

Table 4: Mean squares for grain yield/plant (y) and other agronomic characters(X_1 to X_6).

Characters		MSS	MSE
Plant height , cm	(X_1)	190.3**	25.68
Days to heading	(X_2)	352.3**	4.260
Days to maturity	(X_3)	191.6**	4.300
spike length, cm	(X_4)	37.10**	1.200
Number of grains /spike	(X_5)	1225.7**	32.30
100-grain weight, g	(X_6)	71.60**	5.600
grain yield/plant, g	Y	568.4**	22.20

Table 5: Means, standard errors(SE), components of variance (σ^2_{ph}, σ^2_g and σ^2_e), heritability estimates (h^2), coefficient of variability for phenotypic and genotypic and expected genetic advance.

Char.	Mean	SE	σ^2_{ph}	CV% σ^2_{ph}	σ^2_g	CV% σ^2_g	h^2	σ^2_e	G%
X_1	105.23	2.27	58.61	7.28	32.92	5.45	0.56	25.69	7.19
X_2	103.52	0.92	73.86	8.30	69.60	8.05	0.94	4.27	13.77
X_3	155.66	0.93	41.75	4.15	37.46	3.93	0.89	4.28	6.56
X_4	14.228	0.50	8.415	20.39	7.17	18.82	0.85	1.24	30.58
X_5	73.276	2.54	270.9	22.46	238.7	21.08	0.88	32.28	34.83
X_6	51.200	1.06	18.79	8.47	13.21	7.10	0.70	5.59	10.47
Y	55.874	2.11	131.5	20.52	109.24	18.71	0.83	22.23	30.01

Correlation coefficients: Phenotypic, genotypic and environmental correlation coefficients are given in Table (6). Simple correlation coefficients showed that there were relatively high positive genotypic (r=0.569) and phenotypic (r=0.500) correlations between days to heading (X_2) and grain yield. Grain yield was also positively and significantly correlated with days to maturity (X_3) genotypically (0.644) and phenotypically. (0.551). Whereas, correlation coefficient was negative and significant between grain yield and grains/spike(X_5) genotypically (-0.292) and phenotypically (-0.223). Similar results have been reported between grain yield and above mentioned characters (Ismail, 2001). Plant height and 1000- grain weight showed insignificant positive association with grain yield. This result are in agreement with the results of **El-Marakby *et al.*, (1994)**. However, **Esmail (2000)** estimated negative correlations between grain yield with plant height and grain weight and positive correlations between grain yield and days to heading.

Path coefficient analysis: The response variable grain yield (Y) and six predictor variables ,i.e., plant height, cm (X_1) , days to heading (X_2) , days to maturity (X_3) , spike length, cm (X_4), number of grains/spike (X_5) and 1000-grain weight, g (X_6) were studied for phenotypic, genotypic and environment path coefficient and presented in Tables (7 , 8 and 9).

In regard to phenotypic path coefficient, the direct effect of days to maturity (X_3) on grain yield was the highest (0.57) and the relative importance was of 18.8%. The second value of direct effect showed by spike length(X_4) on grain yield (0.35) with a relative importance about of 7.3%, While days of heading (X_2) and plant height showed low relative importance, 1.96 and1.61 % respectively. The indirect effects of days to heading (X_2), days to maturity(X_3) plant height (X_1) and spike length (X_4) were 0.39, -0..11, 0.215 and -.028 with relative importance of 14.4, 11.8, 9.8 and 2.1%, respectively. The results are in line with those reported by **Gebeyehou *et al.*, 1982, Garcia *et al.*, 1991 and Dofing and Knight, 1992.**

Table 6: The correlation matrices for phenotypic, genotypic and environment

	X_1	X_2	X_3	X_4	X_5	X_6	Y
Phenotypic correlations							
X_1	1	0.462**	0.444**	-.397**	-.483**	-.279**	0.048
X_2		1	0.875**	-.386**	-.698**	-.167*	0.500**
X_3			1	-.391**	-.721**	-.159*	0.551**
X_4				1	0.781**	0.463**	0.099
X_5					1	0.408*	-.223**
X_6						1	0.093
Y							1
Genotypic correlations							
X_1	1	0.642**	0.642**	-.602**	-.722**	-.552**	0.042
X_2		1	0.931**	-.426**	-.741**	-.184*	0.569**
X_3			1	-.462**	-.785**	-.178*	0.644**
X_4				1	0.857**	0.549**	0.088
X_5					1	0.457**	-.292**
X_6						1	0.074
Y							1
Environment correlations							
X_1	1	-.0316	-.0579	0.0788	0.1069	0.1890	0.0709
X_2		1	0.245*	-.0456	-.278**	-.1331	-.0346
X_3			1	0.1072	-.2131*	-.1020	-.0337
X_4				1	0.283**	0.183*	0.1574
X_5					1	0.259*	0.192*
X_6						1	0.165*
Y							1

Table 7: Direct and indirect effects of yield components and their relative importance in grain yield of wheat for seasons of 2005 and 2006. (Phenotypic path coefficient).

Characters	Direct effect X_i			Indirect effect X_i / X's			Total effect		
	Effects	CD*	RI %	Effects	CD*	RI %	Effects	CD*	RI %
X_1	-.167	.278	1.61	0.215	-.07	9.84	.048	-.04	11.4
X_2	0.184	.034	1.96	0.393	.145	14.4	.577	.179	16.3
X_3	0.571	.325	18.8	-.106	-.12	11.8	.464	.204	30.6
X_4	0.354	.126	7.27	-.028	-.02	2.07	.327	.106	9.3
X_5	-.050	.002	0.14	0.010	-.00	.06	-.039	.001	.202
X_6	0.025	.001	0.03	0.00	0.00	0.00	.025	.001	0.03
Total D+I							1.401	.447	67.9
Residual								.553	32.1
Total								1.00	100

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

Concerning genotypic path coefficient, the highest direct effect of days to maturity (X_3) on grain yield was 1.02 with a relative importance of 12.8%. The direct effect of spike length(X_4) on grain yield (0.76) with a relative importance of 7.06% ranked as the second. The direct effect of plant height(X_1) on grain yield was negative (-0.646) and the relative importance of 5.1%. The relative importance for the indirect effects of plant height(X_1), days to maturity(X_3) and spike length(X_4) on grain yield were 27.6, 21.1 and 11.8, respectively. All of these characters had a positive direct effect on the grain yield as detected by **Gebeyehou *et al.*, 1982, Garcia *et al.*, 1991 and Dofing and Knight, 1992.**

Table 8: Direct and indirect effects of yield components and their relative importance in grain yield of wheat for seasons of 2006 and 2007. (Genotypic path coefficient)

Characters	Direct effect X_i			Indirect effect X_i / X's			Total effect		
	Effects	CD*	RI %	Effects	CD*	RI %	Effects	CD*	RI %
X_1	-.646	0.417	5.1	.688	-.89	27.6	0.04	-.47	32.7
X_2	-.155	0.013	0.16	1.09	-.25	4.92	0.98	-.24	5.09
X_3	1.025	1.052	12.8	.140	.288	21.1	1.16	1.34	33.9
X_4	0.760	0.578	7.06	-.637	-.97	11.8	0.12	-.39	18.9
X_5	-.562	0.316	3.86	-.129	.145	1.77	-.69	.46	5.6
X_6	-.282	0.080	0.97	0.00	0.0	0.0	-.28	.08	0.97
Total D+I							1.34	.777	97.3
Residual								.223	2.7
Total								1.00	100

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

Environment path coefficient, the values of direct effect (0.138, 0.108 and 0.098), respectively were recorded for number of grains/spike (X_5), direct effect 1000-kernel weight, g (X_6) and spike length (X_4) on grain yield. The relative importance of (1.906%, 1.164% and 0.959) were showed by number of grains/spike (X_5), direct effect 1000- garin weight, g (X_6) and spike length (X_4) on grain yield, respectively. All of these characters had positive direct effect on the grain yield except days to maturity (X_3). This result is in agreement with that of **(Gebeyehou *et a*l, (1982), García *et al.*, (1991and 2002) and Gibson and Paulsen. (1999).**

Table 9: Direct and indirect effects of yield components and their relative importance in grain yield of wheat for seasons of 2005 and 2006. (Environment path coefficient).

Characters	Direct effect X_i			Indirect effect X_i / X's			Total effect		
	Effects	CD*	RI %	Effects	CD*	RI %	Effects	CD*	RI %
X_1	0.028	.0008	0.079	0.043	.0024	.249	.0709	.0032	.328
X_2	0.026	.0006	0.066	-.059	-.0031	.305	-.0337	-.002	.371
X_3	-.008	.0001	0.000	-.030	.0005	.085	-.0384	.0006	.0916
X_4	0.098	.0096	0.959	0.059	.0116	1.15	.1573	.0213	2.112
X_5	0.138	.0192	1.906	0.028	.0078	.774	.1666	.0269	2.681
X_6	0.108	.0117	1.164	0.000	0.000	.000	.1082	.0117	1.681
Total D+I							.4311	.0613	6.75
Residual								.9387	93.25
Total								1.00	100

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

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تقدير معاملات المرور المظهرية والوراثية في القمح

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الهدف من هذه الدراسة هو تحليل مسار العلاقات المتبادلة بين المحصول و مكوناته للوصول الي اهم هذة المكونات لاستخدامها في برامج التربية. ولتحقيق ذلك تم تطبيق تجربة حقلية أجريت في مزرعة كلية الزراعة، جامعة الفيوم. في موسم ٢٠٠٥/٢٠٠٦ زرعت ستة أباء وتم إجراء التهجينات المتبادلة بين الأباء. وفي الموسم الثاني ٢٠٠٦/٢٠٠٧، تم زراعة الآباء الستة والهجن الخمسة عشر فى تصميم قطاعات كاملة العشوائية بخمسة مكرارات وتم حساب معاملات الارتباط وتحليل المسار المظهرى والوراثي البيئي لكمية محصول حبوب النبات والصفات تحت الدراسة التالية: طول النبات (X1)،موعد طرد السنابل (X2)، موعد النضج (X3)، طول السنبلة (X4)، عدد الحبوب فى السنبلة (X5)، وزن الالف حبة (X6). وأشارت النتائج إلى أنه استنادا إلى تحليل المسار المظهرى كان الأثر المباشر لصفة النضج (X3) على محصول النبات بلغ ٠,٥٧ بأهمية نسبية ١٨,٨ ٪. وكان هذا التأثير بالنسبة لطول السنبلة (X4) علي المحصول ٠,٣٥ بأهمية نسبية حوالي٧,٣ ٪. وكانت الأهمية النسبية لصفة طرد السنابل (X2) 1.96% وطول النبات (X1) ١,٦١ ٪.اما التأثير غير المباشرة لصفة طرد السنابل (X2)،موعد النضج (X3) وارتفاع النبات (X1) ، طول السنبلة (X4) كانت، ٠,٣٩، ٠,٢١٥، -٠,١١ و-٠,٢٧ على التوالي وبأهمية نسبية ١٤,٤٪ ، ١١,٨٪ ، ٩,٨٪ و ٢,١٪ على التوالي. أما بالنسبة لتحليل المسار الوراثي ظهر أن الأثر المباشر لصفة النضج (X3) علي المحصول قد بلغ نحو ١,٠٢ وبأهمية نسبية ١٢,٨٪، والأثر المباشر لصفة طول السنبلة (X4) على محصول الحبوب ٠,٧٦ وبأهمية نسبية ٧,٠٦٪. الأثر المباشر لارتفاع النباتات (X1) على محصول الحبوب -٠,٦٤٦ وبأهمية نسبية ٥,١٪. الأهمية النسبية للتأثير غير المباشر لارتفاع النباتات (X1)، موعد النضج (X3) وطول السنبلة (X4) على محصول الحبوب فكانت ٢٧,٦٪ و٢١,١٪ و ١١,٨٪ على التوالي.

وبالنسبة لتحليل المسار البيئي ظهر أن الأثر المباشر كان موجبا لجميع الصفات(٠,٠٢٨٣، ٠,٠٢٥٨، ٠,٠٩٨٢، ٠,١٣٨ و ٠,١٠٨) علي التوالي لارتفاع النباتات (X1)، طرد السنابل (X2)، طول السنبلة (X4)، عدد الحبوب فى السنبلة (X5)، وزن الالف حبة (X6) ماعدا موعد النضج (X3) (-٠,٠٠٨) و بالتالي كانت أعلي قيمة للأهمية النسبية لصفات عدد الحبوب فى السنبلة (X5)، وزن الالف حبة (X6) حيث بلغت (١,٩٠٦% و ١,١٦٤%) علي التوالى.