Estimating Phenotypic and Genotypic Path Coefficient, an Application on Wheat (*Triticum aestivum* L.) Genotypes

Sahar A. Farag[1], S.K.A. Ismail[2] and Sawsan A. El-Ssadi[3*]

[1]Central Laboratory for Dresden and Statistical Analysis Research, of Agriculture, Research Center -Giza-Egypt
[2]Department of Agronomy, Faculty of Agriculture, Fayoum University, Egypt
[3]Department of Agronomy, Faculty of Agriculture, Cairo University, Egypt

*Corresponding author

A B S T R A C T

Two field experiments were carried out at agriculture research stations of Agriculture Research Center (ARC). In 2014/2015 -2015/2016 seasons, the six parental genotypes were planted and the six parents were planted in a field experiment using the randomized complete block design with three replications. With the trials conducted, the correlation coefficients and path analysis were calculated between grain yield and yield components of wheat genotypes. The results revealed that that Gimaza-7, 10 and Misr1 cultivars were the best yielding among the studied cultivars and the Kafr Elhamam location was the top yielding than the other location (Itay-Elbarood). Positive and significant genotypic and phenotypic correlation was found between yield and No. of tillers per plant (NTP), No. of spikelets/ spike (NSS) and No. of spike /plant. Also, results indicated that, based on path analysis, it could be concluded that the most important sources of variation in grain yield. Genotypic and phenotypic coefficient of variation was high for No. of spike per plant and No. of tillers/plant, suggested that these yield components may be a good selection criteria to improve yield of wheat genotypes.

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important and strategically over the world. In Egypt, wheat is the main cereal crop used as stable food for urban and rural societies and the major source of straw for animal feeding. However, total wheat consumption has drastically increased due to over. Population growth by about 2.5% per year. Egypt imports about 45 % of its wheat requirement. This reflects size of the problem and the efforts needed to increase wheat population. Thus, increasing production per unit area appears to be one of the important factors for narrowing the gab between wheat production and consumption.

Improving yield is one of the most important goals for most 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. Yield, as a function of various components, is a complex character. It was suggested that yield is a function of various components, where it depends on the number of spikes per unit area, the number of wheat 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, studding the direct and indirect effects of yield components on yield provides the basis for its successful breeding programme 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 correlations and path analysis 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.

Mean squares were used to estimate

$\sigma_g^2 = (MSS\text{-}MSE) / r$

$\sigma_{ph}^2 = \sigma_e^2 + \sigma_g^2$, where broad-sense heritability (h^2) was estimated as follows:

$h^2 = (\sigma_g^2 / \sigma_{ph}^2) \times 100$, and the phenotypic, genotypic and environmental coefficients of variation are computed as follows:

$$GCV = 100x \sqrt{\sigma_g^2 / \overline{X}}$$

$$ECV = 100x \sqrt{\sigma_e^2 / \overline{X}}$$

The same mean products were used to estimate

$\sigma_{gij} = (MPS\text{-}MPE) / r$

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

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

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

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

Expected genetic advance: Expected genetic

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

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

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 characters included in the study, which is equal to n (n-1)/2, where n is the number of characters as in Table 2.

The path analysis is carried out according to (Wright, 1921, Dewey and Lu, 1959 and Singh and Narayanan 2000), let n independent variables be significantly correlated with dependent variable Y then the correlation matrices representing correlation coefficients (phenotypic, genotypic and environmental) are given in Table 2.

The correlation coefficient between i[th] independent variables and dependent variable Y is linearly related with the correlation coefficients of ith 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 ith 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:
n x n   nx1   n x1

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

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 obtained. Further, the residual effect is obtained as follows:

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

Two field experiments were conducted at agriculture research stations of Agriculture Research Center (ARC) in Egypt to investigate the effect of leaf rust in yield verities, during the two successive growing seasons of 2014/2015 -2015/2016 in two locations (Itay-Elbarood and Kafr Elhamam). Six Egyptian wheat cultivars namely: Gemmeiza7 and Sids-1 (susceptible), Sakha-93 (partial resistant), Sakha-94 (resistance), Gemeiza10 and Misr-1 (moderately resistant) were used.

The commercial names, pedigree and origin are presented in Table 3. The cultivars were planted in a field experiment using the randomized complete block design (RCBD) with three replication. Seed of each entry were spaced 10 cm about in one row 3 m long and 20 cm between rows. The cultivars were planted in15th November in both seasons. All agricultural practices were done as usual in wheat fields. All plots were surrounded by a spreader area equal one meter width planted with the highly susceptible.

Data were recorded on random samples of 10 guarded plants from each row, for PH: Plant height, NTP: No. tillers/plant, FL: Flag Leaf area, NSP: Number of spike/plant, SL: Spike length, NSS: No. spikelets /spike, 1000 GW: weight 1000 grains, Y: Grain yield/ard/fed. Direct and indirect effects of traits were evaluated by correlation and path coefficients. Correlation and path coefficients were calculated by using PATHC Statistical Computer programmed (Atia, 2007).

Results and Discussion

Analysis of variance and mean performance

In this experiment, grain yield, plant height, number of tillers/plant, flag leaf area, number of spike/plant, spike length, number of spikelets/spik, and 1000-- grain weight were studied.

The mean square effect of all studied traits was highly significant for all traits in both locations. It is indicates a substantially additive behavior for these traits of variability (Table 4).

The comparison of varieties under two locations showed that all of traits were high level at Kafr Elhamam than Itay-Elbarood (Table 5).

The effect of cultivar on grain yield was significant at 5% level of significance in both locations (Table 5). This may be due to inherent differences between the cultivars in the yield components like the number of tillers per plant, number of spikelets per spike and 1000 grain weight.

Similar results were reported by Abdel Mohsen *et al.,* 2012. Cultivars Gemmeiza-7 and Gemmeiza-10 produced the highest grain yield (21.29 ard/Fed. and 20.68 ard/Fed, in Kafr Elhamam and Itay-Elbarood,

respectively). The results in table 5 also showed that the cultivars Sids1 and Sakha94 produced the lowest (19.6 ard/fed in Itay-Elbarood and 18.77 in Kafr Elhamam, respectively) comparing with all evaluated genotypes (Abd El-Kreem and Ahamed 2013).

Genetic parameters

Genotypic (GCV) and phenotypic (PCV) coefficient of variability, broad sense heritability (h^2) and genetic advance (EGA) expressed as percent of mean for studied traits, evaluated in six varieties are presented in table 6. High estimates of GCV were obtained by number of spike/plant (20.48 and 17.44%) followed by No. of tillers/ plant (19.65 and 9.49%) in Itay Elbarood and Kafr Elhamam locations, respectively. While moderate values of GCV were observed with plant height and 100-grain weight in both locations.

On the other hand, the values of phenotypic coefficient of variation PCV were slightly higher than their corresponding values of GCV for all traits which reflect somewhat environmental influence on the expression of characters in the two locations. These results indicated that the selection would be effective to improve these traits among the tested genotypes.

The heritability values ranged from 99% for plant height in both locations and 48% for No. of spikelets /spik in Itay Elbarood and 23% flag leaf area length in Kafr Elhamam location, while the values of GA% ranged between 38.81 for No. of spike /plant and 15.91% for grain yield in Itay Elbarood and ranged from 34.401 for No. of spike/plant to 8.597% for flag area in Kafr Elhamam location. Similar results were reported by Kashif and Khaliq (2004), Aycicek and Yildirim (2006), Atia *et al.,* (2007), Ali *et al.,* (2008), Ashmawy *et al.,* (2010), Khan and Dar (2010) and Baloch *et al.,* (2013).

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

Source	Analysis of Variance		Analysis of Covariance	
	M.S.	Expectation of M.S.	M.C.P.	Expectation of M.C.P.
Replicates	Mr_u	—	Mr_{12}	—
Treatments	Mt_n	$\sigma_e^2 + r\,\sigma_g^2$	Mt_{12}	$\sigma_{eij} + r\,\sigma_{gij}$
Error	Me_n	σ_e^2	Me_{12}	σ_{eij}

*r: number of replications.

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.

Table.3 The commercial names and pedigree of the varieties

No	Parents	Pedigree	origin
1	GEMMEIZA-7	CMH74.630/5X//SERI82/3/AGENT CGM 4611-2GM-3GM-1GM-0GM	Egypt
2	SIDS 1	HD2173/PAVON"S"//1158.57/MAYA 74 "S" SD46-4SD-2SD-1SD-0SD	Egypt
3	SAKHA 93	SAKHA 92/TR 810328 S8871-1S-2S-1S-0S	Egypt
4	SAKHA 94	OPATA/RAYON/3/JUP/BJY//URES CMBW90Y3180-0EGY	Egypt
5	GEMMIEZA-10	Ald " S" / Huac// CMH47A.30/SX CGM4583-5GM-1GM-0GM	Egypt
6	Misr-1	OASIS/SKAUZ//4*BCN/3/2*PASTOR CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S	Egypt

Table.5 Mean values of grain yield and its related characters for 6 wheat varieties evaluated in adequate and stress locations

No.	Genotype	Plant height (cm)		No. of tillers/plant		Flag Leaf area		No. of spike /plant		Spike length (cm)		No. of kinder		Weight of 1000 grain (g)		Grain Yield /fed (ard)	
		Itay-Elbarood	Kafr Elhamam	Itay-Elbarood	Kafr Elhamam	Itay-Elbarood	Kafr Elhamam	Itay-Elbarood	Kafr Elhamam	Itay-Elbarood	Kafr Elhamam	Itay-Elbarood	Kafr Elhamam	Itay-Elbarood	Kafr Elhamam	Itay-Elbarood	Kafr Elhamam
1	GEMMEIZA-7	115.43	123.03	5.95	5.61	23.61	32.41	11.14	14.28	13.04	19.28	11.73	15.82	39.03	38.16	20.14	21.29
2	SIDS 1	119.18	125.23	5.18	5.67	28.03	30.32	8.05	12.04	10.15	17.22	8.48	14.37	35.15	34.05	19.60	19.89
3	SAKHA 93	122.35	125.69	5.12	5.70	30.11	36.59	11.08	12.85	13.46	15.27	11.85	14.18	38.60	38.92	19.61	20.98
4	SAKHA 94	126.50	126.43	5.30	5.75	30.62	37.90	8.40	11.69	11.82	12.58	11.25	10.90	38.99	35.93	18.77	20.99
5	GEMMIEZA-10	120.46	124.99	3.89	5.31	30.44	36.74	9.17	14.50	16.35	16.47	13.16	15.05	37.59	40.55	20.68	20.86
6	Misr-1	121.85	124.76	3.99	4.89	33.73	37.70	8.10	12.42	13.55	16.42	12.67	13.58	34.89	33.80	20.41	20.27
	LSD	2.782	2.057	1.176	0.843	6.041	9.291	1.36	1.135	1.97	4.076	2.55	1.489	2.87	2.358	1.07	1.026

Table.6 Genetic parameters of grain yield and its related characters computed from 6 wheat varieties evaluated in two locations

Character	Location	Genetic parameters											
		Grand mean		GCV		PhCV		h²		EGA (% mean) at 0.10		EGA (% mean) at 0.5	
		IE.	KE.	IE.	KE.	IE.	KE.	IE.	KE.	IE..	KE.	IE.	KE.
Plant height		120.96	125.02	13.08	13.70	13.16	13.74	0.99	0.99	22.90	24.05	26.80	28.148
Number of tillers/plant		4.90	5.49	19.65	9.49	24.36	13.23	0.65	0.51	27.89	11.97	32.65	14.014
Flag Leaf area		29.42	35.28	11.55	8.68	16.89	18.04	0.47	0.23	13.89	7.35	16.26	8.597
Number of spike/plant		9.32	12.96	20.48	17.44	22.26	18.22	0.85	0.92	33.16	29.39	38.81	34.401
Spike length		13.06	16.21	16.29	13.66	18.64	20.36	0.76	0.45	25.06	16.13	29.33	18.878
Number of spikelets/spike		11.52	13.98	12.9	11.01	18.53	12.73	0.48	0.75	15.81	16.76	18.51	19.618
Weight of 1000 grains		37.37	36.90	9.11	10.01	10.21	10.72	0.80	0.87	14.29	16.46	16.73	19.261
Grain yield/ ard/fed		19.87	20.71	8.29	10.65	8.89	11.06	0.87	0.93	13.59	18.05	15.91	21.129

Table.4 Mean squares for grain yield and other agronomic characters

Loc.	Characters	Comb.	
		MSS	MSE
Itay-Elbarood	Plant height	754.11**	2.79
	Number of tillers/plant	3.28**	0.50
	Flag Leaf area	47.78**	13.16
	Number of spike/plant	11.6**	0.66
	Spike length	14.99**	1.41
	Number of spikelets/spike	8.98**	2.35
	Weight of 1000 grains	37.72**	2.98
	Grain yield/ ard/fed	8.54**	0.41
Kafr Elhamam	Plant height	881.49**	1.53
	Number of tillers/plant	1.06**	0.26
	Flag Leaf area	59.0 N.S	31.11
	Number of spike/plant	15.8**	0.46
	Spike length	20.69**	5.99
	Number of spikelets/spike	7.91**	0.80
	Weight of 1000 grains	42.96**	2.00
	Grain yield/ ard/fed	**14.98**	**0.38**

Table.7 Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among grain yield/plant and its related characters computed from 6 wheat varieties evaluated in two locations

Character	PH	NTP	FL	NSP	SL	NSS	1000 GW	Y
Itay-Elbarood								
PH	1	0.066	0.019	0.033	0.030	0.043	0.019	**0.038**
NTP	0.046	1	0.306	0.544**	-0.080	-0.328	0.305	**0.433**
FL	0.053	0.210	1	0.154	-0.006	0.198	0.087	**0.179**
NSP	0.026	0.527	0.134	1	0.246	0.273	0.154	**0.318**
SL	0.035	-0.102	0.096	0.293	1	0.316	0.138	**0.285**
NSS	0.013	-0.219	0.012	0.292	0.271	1	0.198	**0.407***
1000 GW	0.010	0.305	-0.015	0.184	0.137	0.187	1	**0.179**
Y	0.028	0.365*	0.123	0.251	0.210	0.217	0.183	**1**
Kafr Elhamam								
PH	1	0.112	0.019	0.026	0.026	0.038	0.016	**0.026**
NTP	0.096	1	0.627**	0.708**	0.350*	-0.168	0.324	**0.871**
FL	0.022	0.514**	1	0.145	0.148	0.212	-0.033	**0.148**
NSP	0.025	0.575**	0.175	1	0.200	0.287	0.120	**0.201**
SL	0.033	0.282	0.113	0.189	1	0.293	0.005	**0.205**
NSS	0.026	-0.155	-0.139	0.226	0.203	1	0.176	**-0.079**
1000 GW	0.017	0.351*	-0.019	0.115	0.103	0.138	1	**0.123**
Y	**0.029**	**0.616**	**0.076**	**0.213**	**0.131**	**-0.071**	**0.109**	**1**

Abbreviations: PH: Plant height, NTP: No. tillers/plant, FL: Flag Leaf area, NSP: Number of spike/plant, SL: Spike length, NSS: No. spikelets/spike, 1000 GW: weight 1000 grains, Y:Grain yield/ard/fed

Table.8 The direct and indirect effects of six predictor characters on grain yield/plant at genotypic and phenotypic levels computed from 6 wheat varieties evaluated in two locations

Character	Level	Indirect effects						
		PH	NTP	FL	NSP	SL	NSS	1000 GW
Itay-Elbarood								
PH	G	-0.0771	0.0966	-0.0065	-0.0248	0.0082	0.0492	-0.0073
	Ph	-0.0065	0.0286	-0.0002	-0.0065	0.0088	0.0047	-0.0007
NTP	G	-0.0051	1.4729	-0.1062	-0.4081	-0.0222	-0.3794	-0.1192
	Ph	-0.0003	0.6233	-0.0008	-0.1303	-0.0260	-0.0807	-0.0198
FL	G	-0.0014	0.4500	-0.3477	-0.1157	-0.0017	0.2291	-0.0338
	Ph	-0.0004	0.1306	-0.0038	-0.0331	0.0244	0.0046	0.0010
NSP	G	-0.0026	0.8007	-0.0536	-0.7507	0.0681	0.3163	-0.0601
	Ph	-0.0002	0.3282	-0.0005	-0.2475	0.0746	0.1078	-0.0119
SL	G	-0.0023	-0.1181	0.0021	-0.1848	0.2767	0.3657	-0.0540
	Ph	-0.0002	-0.0635	-0.0004	-0.0724	0.2549	0.1001	-0.0089
NSS	G	-0.0033	-0.4829	-0.0688	-0.2052	0.0874	1.1573	-0.0772
	Ph	-0.0001	-0.1364	-0.0001	-0.0723	0.0691	0.3690	-0.0121
1000 GW	G	-0.0014	0.4493	-0.0301	-0.1156	0.0382	0.2288	-0.3907
	Ph	-0.0001	0.1898	0.0001	-0.0455	0.0349	0.0690	-0.0649
Kafr Elhamam								
PH	G	0.2033	-0.2203	0.0265	0.0403	0.0217	-0.0590	0.0140
	Ph	-0.0716	0.1256	-0.0107	-0.0111	-0.0037	0.0062	-0.0057
NTP	G	0.0228	-1.9644	0.8718	1.1056	0.2876	0.2613	0.2860
	Ph	-0.0069	1.3125	-0.2461	-0.2597	-0.0314	-0.0370	-0.1157
FL	G	0.0039	-1.2326	1.3893	0.2257	0.1213	-0.3302	-0.0292
	Ph	-0.0016	0.6747	-0.4787	-0.0790	-0.0126	-0.0331	0.0063
NSP	G	0.0053	-1.3905	0.2008	1.5620	0.1642	-0.4469	0.1058
	Ph	-0.0018	0.7549	-0.0837	-0.4516	-0.0211	0.0540	-0.0378
SL	G	0.0054	-0.6874	0.2051	0.3121	0.8218	-0.4565	0.0045
	Ph	-0.0024	0.3699	-0.0542	-0.0855	-0.1115	0.0485	-0.0339
NSS	G	0.0077	0.3298	0.2948	0.4486	0.2411	-1.5561	0.1553
	Ph	-0.0019	-0.2037	0.0664	-0.1022	-0.0227	0.2384	-0.0454
1000 GW	G	0.0032	-0.6258	-0.0459	0.1870	0.0042	-0.2735	0.8836
	Ph	-0.0012	0.4608	0.0092	-0.0519	-0.0115	0.0329	-0.3295

Abbreviations: PH: Plant height, NTP: No. tillers/plant, FL: Flag Leaf area, NSP: Number of spike/plant**,** SL: Spike length, NSS: No. spikelets/spike, 1000 GW: weight 1000 grains, Y: Grain yield /ard/fed

Table.9 The relative importance (RI %) for six predictor characters on grain yield/ plant at genotypic and phenotypic levels computed from 6 wheat varieties evaluated in two locations

Characters	Locations	AE.		KE.	
		Genotypic	Phenotypic	Genotypic	Phenotypic
Direct effect					
Plant height x1		0.0657	0.0023	0.1351	**0.1061**
Number of tillers/plant x2		**24.0072**	**20.9871**	**12.6185**	**35.6356**
Flag Leaf area x3		1.3380	0.0008	**6.3113**	**4.7396**
Number of spike/plant x4		**6.2366**	**3.3080**	**7.9779**	**4.2178**
Spike length x5		0.8472	3.5088	2.2082	**0.2574**
Number of spikelets/spike x6		**14.8217**	**7.3535**	**7.9176**	**1.1761**
Weight of 1000 grains x7		1.6891	0.2278	2.5532	**2.2455**
Indirect effects					
Plant height (X_1) *Via*	X_2	0.1648	0.0201	0.2928	**0.3723**
	X_3	0.0110	0.0001	0.0352	**0.0316**
	X_4	0.0424	0.0046	0.0536	**0.0329**
	X_5	0.0140	0.0062	0.0288	**0.0109**
	X_6	0.0839	0.0033	0.0784	**0.0183**
	X7	0.0124	0.0005	0.0186	**0.0168**
Number of tillers/ plant (X_2) *Via*	X_3	3.4634	0.0538	11.1994	**13.3608**
	X_4	13.3040	8.7746	14.2039	**14.1021**
	X_5	0.7235	1.7473	3.6945	**1.7072**
	X_6	12.3692	5.4352	3.3565	**2.0097**
	X7	3.8850	1.3318	3.6746	**6.2814**
Spike length (X_3) *Via*	X_4	0.8907	0.0136	2.0508	**1.5638**
	X_5	0.0129	0.0101	1.1020	**0.2501**
	X_6	1.7634	0.0019	3.0001	**0.6549**
	X7	0.2601	0.0004	0.2652	**0.1253**
Number of spikelets/spike (X_4) *via*	X_5	1.1314	1.9944	1.6770	**0.3947**
	X_6	5.2558	2.8828	4.5656	**1.0079**
	X7	0.9992	0.3192	1.0805	**0.7069**
Number of grains/spike (X_5) *via*	X_6	2.2397	2.7551	2.4533	**0.2239**
	X7	0.3304	0.2449	0.0240	**0.1566**
Number of spikelets/spike (x6)	X7	1.9780	0.4838	1.5806	**0.3723**
Total (direct + indirect)		97.9405	61.4718	94.1574	**91.8541**
Residuals		2.0595	38.5282	5.8426	**8.1459**
TOTAL		**100.0000**	**100.0000**	**100.0000**	100.0000

The bold and underline cells indicate to the highest values.
Abbreviations: PH: Plant height, NTP: No. tillers/plant, FL: Flag Leaf area, NSP: Number of spike/plant, SL: Spike length, NSS: No. spikelets/spike, 1000 GW: weight 1000 grains, Y: Grain yield /ard/fed

Genotypic and phenotypic correlations

Phenotypic and genotypic correlation coefficients are presented in Table 7. Grain yield showed positive and significant genotypic correlation with number of tiller per plant and number of spikelets/spike (r=0.433 and 0.407) while phenotypic correlation showed positive and significant for number of tiller /plant (r= 0.365) in Itay-Elbarood and with number of tiller/ plant (r= 0.871 and r= 0.616) in Kafr Elhamam location over two years in genotypic and phenotypic, respectively. This may may be attributed to extended period of tillering as the result of conducive field conditions (e.g. lower temperature) during the vegetative phase and delaying tillering end. This idea is supported by Fischer, 1985 who stated that tillering extended until intraplant competition is strong enough to limit the availability of resources for the growth of new tillers.

The direct and indirect effects of six predictor characters on grain yield/plant at genotypic and phenotypic levels computed from 6 wheat varieties evaluated in two locations are presented in Tables 8 and 9.

The results of path coefficient analysis (Table 9) exhibited high positive direct effect of number of tiller/plant on grain yield 24.0072 and 20.9971 in Itay-Elbarood and 12.6185 and 35.6356 in Kafr Elhamam) in both genotypic and phenotypic levels, respectively, followed by number of speckles/ spike on grain yield (14.8217 and 7.3535) for genotypic and phenotypic levels, respectively in Itay-Elbarood and for number of spike /plant (7.9779 and 4.2178) for genotypic and phenotypic levels, respectively in Kafr Elhamam over two seasons. Therefore direct selection through number of tillers/ plant trait will be effective for yield improvement. Similar results direct effect on grain yield was reported by Carcia *et al.,* (1991), Dofing and

Knight (1992), Tammam and El-Syed (2000), Okuyama *et al.,* (2004) and Abd El-Mohsen and Abd El-Shafi (2014).

On the other hand, the indirect effect for number of tillers /plant via number of spike per plant exhibited high positive effect (13.304 and 8.77 for genotypic and phenotypic levels, respectively) in Itay-Elbarood and also, high positive effect (14.21 and 14.102 for genotypic and phenotypic level, respectively) in Kafr Elhamam (Table 9). Also, indirect effect of number of tillers/plant trait via number of spikelets /spike was positive and high (12.37 and 5.44 for genotypic and phenotypic level, respectively) in Itay-Elbarood while it was positive and high through Flage leaf area (11.20 and 13.36 for genotypic and phenotypic level, respectively) in Kafr Elhamam. These results are similar to those obtained by Abd El-Mohsen *et al.,* (2012) and Abd El-Mohsen and Abd El-Shafi (2014).

It is concluded that Gimaza-7, 10 and Misr1 cultivars were the best yielding among the studied cultivars and the Kafr Elhamam location was the top yielding than the other location (Itay-Elbarood). Genotypic and phenotypic correlation analyses in the two locations reflected a strong positive correlation between grain yield and number of tillers per plant, number of spikelets per spike and No. of spike per plant. The path analyses fortified the outcomes of the correlation and indicated that these three traits had high direct effect on grain yield in both locations. It is worth mentioning that some compensatory tendencies among these contributes were noted. Also the inconsistency in the levels of their estimates in terms of correlations and direct effects coupled with the high residual effects suggests an important role of environmental modification and genetic variability effect on performance of the investigated cultivars from year to year.

However, it could be concluded that number of tillers per plant, number of spikelets per spike and No. of spike per plant warrant attention of wheat breeder for improving grain yield.

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