INHERITANCE OF INDUCED GLAUCOUSNESS, GRAIN YIELD, AND YIELD-RELATED TRAITS IN BREAD WHEAT (*Triticum aestivum* L.)

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Glaucousness is the grayish or whitish appearance of leaf blades, sheaths, glumes and stems of plants. This appearance is due to the epicuticular wax exudates produced by plant organ. Inheritance of glaucousness has been previously reported in bread wheat (*Triticum aestivum* L.) (Jensen and Driscoll, 1962; Stuckey, 1972; Liu *et al.* 2007) and in durum wheat (Clarke *et al.*, 1994). Chromosome 2B in wheat cultivar Chinese Spring was first shown to bear a gene for the production of glaucousness by Muramatsu (cited in Driscoll and Jensen, 1964). Chromosome 2D was found to bear a hypomorph of 2B for glaucousness. Two dominant inhibitors of these two genes were also located on 2B and 2D. Chromosome 3A bears the most effective gene for glaucousness of the peduncle (Stuckey, 1972). However, a gene for spike glaucousness, WS, was mapped distally on chromosome 1BS of wild emmer wheat (Peng *et al.*, 2000).

Genetic studies on the inheritance of glaucousness in wheat indicated that glaucousness is dominant to nonglaucousness (Tsunewaki, 1966; Stuckey, 1972; Clarke *et al.*, 1994). However, other studies by Jensen and Driscoll (1962) and Liu *et al.* (2007) demonstrated that nonglaucousness is controlled by a single dominant gene. In addition, the evidence of additive gene action influencing glaucousness was also reported in bread wheat (Stucky, 1972) and durum wheat (Clarke *et al.*, 1994).

Number of spikes/plant, number of kernels/spike and kernel weight are the major components of grain yield in wheat. Due to their importance, the inheritance of grain yield and its components in wheat have been previously studied (Singh *et al.*, 1986; Sidwell *et al.*, 1976; Sun *et al.*, 1972; Hsu and Walton, 1970).

Dominant genetic variance was found to play an important role in the inheritance of number of ears/plant and yield/plant (Hsu and Walton, 1970). However, Singh *et al.* (1986) found that additive genetic variance for grain yield, grains/spike, and seed weight was much more important than dominance variance. While, Sidwell *et al.* (1976) reported that additive and dominance variances were

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much smaller than environmental variance for grain yield and its components except for kernel weight.

Yield component breeding to increase grain yield would be most effective if the components involved were highly heritable, genetically independent or positively correlated, and physiologically unrelated or related in a positive manner (Sidwell *et al.*, 1976; Fonseca and Patterson, 1968).

Heritability for grain yield and its related traits were previously studied in wheat (Kronstad and Foote, 1964; Sidwell *et al.*, 1976). Kronstad and Foote (1964) estimated heritabilities in the narrow sense from parent-progeny regressions on spaced F_1 plants in a 10-diallel cross in winter wheat. All estimates were highly significant except that for grain yield. Sidwell *et al.* (1976) also estimated heritabilities of grain yield and its related traits in a cross between 'Sturdy' and 'Centurk' winter wheats. They found that kernel weight and tiller number displayed rather high broad sense heritabilities while kernel weight was the only trait to display a high narrow sense estimate.

Correlations among grain yield and yield-related traits in wheat have been reported in several studies (Fonseca and Patterson, 1968; Hsu and Walton, 1970; Sidwell *et al.*, 1976). Fonseca and Patterson (1968) found the three components of yield, i.e. number of spikes per plant, number of kernels per spike and kernel weight, were highly correlated with it, and negative correlations among yield components were observed. Hsu and Walton (1970) found yield/plant was positively correlated with ear number/plant, kernel number/ear and 1000-kernel weight. In addition, they obtained a significant positive correlation between ear number/plant and kernel number/ear and a highly significant negative correlation between kernel number/ear and kernel weight.

Sidwell *et al.* (1976) found that tiller number had a positive phenotypic correlation and intermediate genetic correlation with grain yield. Phenotypic correlations of kernel weight and kernels/spike with grain yield were intermediate and low, while their genetic correlations were low and intermediate, respectively. Negative associations were observed between kernel weight and tiller number and between kernel weight and kernels/spike.

In the present study, two contrasting parents i.e. induced glaucous wheat mutant line 6 (GWM6) and nonglaucous wheat cultivar Giza 164, for glaucousness, grain yield, and yield-related traits were crossed to investigate the inheritance of induced glaucousness of leaf blade and spike, yield and yield-related traits; and to elucidate the interrelationships among yield and yield-related traits.

MATERIALS AND METHODS

Plant materials

Two bread wheat genotypes i.e. glaucous wheat mutant line 6 (GWM6) and Giza 164 cultivar were crossed and used as parents in the present study because of their diversity for glaucousness, grain yield and yield-related traits. GWM6 was developed by the wheat breeding program of the Atomic Energy Authority, Anshas, Egypt (Al-Bakry, 2004). It was induced in the first mutated generation (M_1) resulting from irradiation of the wheat cultivar Sids1 with 30 Krad of gamma rays in the winter season, 2001/2002. It has high epicuticular wax content on leaf sheath, leaf blade, peduncle and spike. It has high number of spikelets/spike and high number of kernels/spike but its tiller number is low. However, Giza164 wheat cultivar was obtained from Wheat Department, Crop Research Institute, Agricultural Research Center, Egypt. Leaf blades and spikes of Giza164 cultivar are completely nonglaucous. Giza164 has moderate number of spikelets/spike and moderate number of kernels/spike but its tiller number is high compared to GWM6. In the M_5 generation, the GWM6 was crossed to Giza 164. The F_1, F_2, BC_1, and BC_2 populations were obtained during 2005/2006 and 2006/2007 winter seasons. The parental, F_1, F_2, BC_1, and BC_2 populations were grown during 2007/2008 winter season.

Experimental design

The experiment was conducted in a randomized complete block design at the experimental farm of Plant Research Department, Nuclear Research Center, Atomic Energy Authority, Egypt. The experiment consisted of six replications, each composed of 12 experimental rows as follows:

Population	No. of rows
P_1 (GWM6)	1
P_2 (Giza 164)	1
F_1 (P_1 X P_2)	1
F_2 (F_1 selfed)	5
BC_1 (Backcross of F_1 to P_1)	2
BC_2 (Backcross of F_1 to P_2)	2

Individual grains were planted in 2.5-meter rows. Each row included 25 plants spaced 10 cm apart. Rows were spaced 30 cm apart in plots.

Glaucousness scores and epicuticular wax quantification

Glaucousness was scored visually at anthesis. F_2 plants were classified as glaucous, nonglaucous, and moderately glaucous; BC_1 plants were classified as glaucous and moderately glaucous; and BC_2 plants were classified as moderately glaucous and nonglaucous, based on the appearance of leaf blade and spike.

Epicuticular wax content was quantified gravimetrically as described by Fernandes *et al.* (1964) and Ebercon *et al.* (1977). Thirty flag leaf blades of each of the parents, F_1, F_2-glaucous, F_2-moderately glaucous, F_2-nonglaucous, BC_1-glaucous, BC_1-moderately glaucous, BC_2-moderately glaucous and BC_2-nonglaucous plants were immersed individually, each for 15 sec in 15 ml redistilled chloroform. The extracts were filtered and evaporated at 35°C. After drying for 24 hours at room temperature, the residues were weighed. The amount of wax was calculated against leaf area (both leaf surfaces) as mg/dm^2 of each sample.

Grain yield and yield-related traits data

The following data were collected on 16 healthy, vigorous and bordered plants in each row on an individual plant basis; grain yield/plant (gm), number of spikes/plant, number of spikelets/spike, number of kernels/spike, number of kernels/spikelet, 100-kernel weight (gm), and length of main spike (cm).

Analysis of variance for the data of the two parents, GWM 6 and Giza 164, with respect to all the traits studied was performed according to Gomez and Gomez (1984). Estimates of environmental, additive, and dominance variances, and broad sense and narrow sense heritabilities for grain yield and yield-related traits were calculated for each replication and are reported as means of the estimates from the six replications as described by Sidwell *et al.* (1976). Phenotypic and genetic correlations were also calculated as described by Sidwell *et al.* (1976). Path-coefficient analysis was performed for further analyzing the correlations among grain yield and its components as outlined by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Inheritance of induced glaucousness of leaf blade and spike

The difference between glaucous leaf blade of GWM6 and nonglaucous leaf blade of Giza 164 can be observed in Fig. (1). Visual scores of leaf blade and spike glaucousness for F_1 plants of the cross between glaucous wheat mutant line 6 (GWM6) and nonglaucous wheat cultivar Giza 164 were moderately glaucous (Table 1). The F_2 plants from this cross segregated for leaf blade glaucousness as 1 glaucous : 2 moderately glaucous : 1 non-glaucous. The glaucousness of the spike of the same plants segregated as 1 glaucous : 2 moderately glaucous : 1 non-glaucous. The ratio in BC_1 (backcross to the glaucous parent, GWM6) was 1 glaucous : 1 moderately glaucous; and in BC_2 (backcross to the non-glaucous parent, Giza 164) was 1 moderately glaucous : 1 non-glaucous. χ^2 analysis (Table 1) showed a very good fit of the data with the expected ratios.

Epicuticular wax contents of flag leaf blade for GWM6 (P_1), Giza 164 (P_2), F_1, F_2, BC_1, and BC_2 populations are presented in Table (2). Mean epicuticular wax content of F_1 plants was midway between the parents. Means of epicuticular wax content for the segregated F_2-glaucous and BC_1-glaucous plants were close to the glaucous parent (GWM6); F_2-moderately glaucous, BC_1-moderately glaucous plants, and BC_2-moderately glaucous were midway between the parents; however, F_2-nonglaucous and BC_2-nonglaucous plants were close to the nonglaucous parent (Giza 164).

The results of the present study indicated that each of the induced glaucousness of leaf blade and spike is controlled by a single gene. The intermediate phenotype of the heterozygous F_1 plants between the phenotypes of the homozygous parents indicates incomplete dominance between glaucousness and nonglaucousness allels. Midway epicuticular wax content of F_1 plants between the parents was observed. Mean epicuticular wax content for the segregated plants in F_2-glaucous, F_2-moderately glaucous, and F_2-non-glaucous plants; in BC_1-glaucous, BC_1-moderately glaucous plants; and in BC_2-moderately glaucous and BC_2-nonglaucous plants confirmed the single gene hypothesis.

Thus, the induced epicuticular wax content in this study appears to be controlled by either the same gene as glaucousness or by a tightly linked gene as suggested for glaucousness trait studied in durum wheat by Clarke *et al.* (1994). The evidence for additive gene action effect infuencing glaucousness were previously reported in bread wheat (Stucky, 1972) and durum wheat (Clarke *et al.*, 1994).

Association between induced glaucousness of leaf blade and spike

Association between induced glaucousness of leaf blade and spike in the F_2 as number of plants is shown in Table (3). Nine recombinant populations among glaucousness, moderately glaucousness, and nonglaucousness of leaf blade and glaucousness, moderately glaucousness, and nonglaucousness of spike in the F_2 plants were recorded. It appears from the occurrence of plants glaucous for blade leaf but nonglaucous for spike in the segregated F_2 plants, that glaucousness for these two organs could be inherited separately.

This result is in agreement with the observations of Stucky (1972) who suggested that there is not necessarily correlation for glaucousness of peduncle, leaf, and head and they appeared to be under different genetic control.

Inheritance of grain yield and its related traits

Parental means

Sufficient genetic variation between the two parents under study with respect to all the traits studied was observed by the analysis of variance (Table 4). Giza 164 cultivar was higher in grain yield per plant, and had more spikes/plant, while glaucous wheat mutant line 6 (GWM6) had high 100-kernel weight, greater number of kernels/spike, kernels/spikelet, spikelets/spike, and spike length.

Gene action and heritability

Estimates of additive, dominance, and environmental variances and broad-sense and narrow-sense heritabilities are presented in Table (5). Additive and dominance variances were smaller than the environmental variance for grain yield/plant. The additive type of gene action was pronounced in the expression of 100-grain weight, kernels/spike and spikelets/spike. The dominance type of gene action was predominant in the expression of spikes/plant, kernels/spikelet and spike length.

Broad-sense heritability estimates were high for spike length, kernels/spike, 100-kernel weight, kernels/spikelet, and spikelets/spike; and intermediate for spikes/plant and grain yield/plant. Narrow-sense heritability estimates were moderate for 100-kernel weight; low for kernels/spike, spikelets/spike, spike length, kernels/spikelet; and quite low for spikes/plant and grain yield/plant.

In the present study as well as in previous studies (Kronstad and Foote 1964; Sidwell et al. 1976), grain yield had low heritability estimate. This means that grain yield is highly influenced by environmental effects and genetic improvement through selection for yield per se would not be effective due to the masking effects of the environment on the genotypic effects. Selection for yield-related traits offers opportunities in improving grain yield.

Among yield-related traits, 100-kernel weight had the highest narrow-sense heritability estimate as well as high broad-sense heritability estimate. High estimates of heritability for kernel weight were previously reported by Bhatt (1972), and Sidwell *et al.* (1976). This indicates that kernel weight would be the most responsive trait to direct selection; however, to improve grain yield through selection for kernel weight, heritability estimates along with the correlation between kernel weight and grain yield, and yield-related traits must be considered as suggested by Sidwell *et al.* (1976).

Correlations among grain yield and yield-related traits

Phenotypic and genotypic correlation coefficients between all pairs of grain yield and yield-related traits in this study are presented in Table (6). Number of spikes/plant had the highest positive phenotypic correlation with grain yield/plant (0.77), but they had intermediate genotypic correlation (0.41). A higher positive genotypic correlations than phenotypic correlations between kernels/spikelet and grain yield/plant (0.74) and between kernels/spikelet and kernels/spike (0.95) were recorded. The phenotypic and genotypic correlation of 100-kernel weight with grain yield/plant, spikes/plant, kernels/spike, kernels/spikelet, and spikelets/spike were negative. The largest positive phenotypic and genotypic correlations occurred between length of spike and number of spikelets/spike (0.67 and 1.00, respectively).

The high positive phenotypic correlation but intermediate genetic correlation between number of spikes/plant and grain yield/plant means that the phenotypic association between these two traits is not only due to genes but also due to environmental effects. High positive genotypic correlations than phenotypic correlations between kernels/spikelet and grain yield/plant and between kernels/spikelet and kernels/

spike refer to strong genetic association between kernels/spikelet and both of grain yield/plant and kernels/ spike. The negative phenotypic and genotypic correlations of 100-kernel weight with grain yield/plant, spikes/ plant, kernels/ spike, kernels/spikelet, and spikelets/spike indicate that the simultaneous improvement of kernel weight and these traits may be difficult. The largest positive phenotypic and genotypic correlations occurred between length of spike and number of spikelets/spike indicate that these two characters are not genetically independent.

Path coefficient analysis

Further information on the nature of the interrelationships among grain yield/plant, number of spikes/plant, number of kernels/spike, and 100-grain weight was obtained by path coefficient analyses of the phenotypic and genotypic correlation coefficients. This was accomplished by assigning direct and indirect effects among yield and yield-related traits by the methods described by Dewey and Lu (1959). Grain yield was considered the resultant variable and number of spikes/plant, number of kernels/spike, and 100-kernel weight the causal variables. A path diagram based on phenotypic correlation coefficients is presented in Fig. (2), where P represents the direct effect (path coefficient) and r denotes the phenotypic correlation between the traits involved in the system (Table 6). The residual, X, was assumed to be independent of the other variables and in effect measures the failure of the three components to account for grain yield. Each component had a direct influence acting alone and an indirect influence acting in combination with the other variables with which it was correlated.

The direct and indirect phenotypic and genotypic effects of number of spikes/plant, number of kernels/spike, and 100-grain weight on grain yield/plant are presented in Table (7). Number of spikes/plant had the largest direct effect phenotypically (0.96) and intermediate genotypic effect (0.57). The direct genetic effect of kernels/spike was intermediate (0.48), while its direct phenotypic effect was low (0.37). The direct phenotypic and genetic effect of 100-kernel weight were low (0.27 and 0.11). The total phenotypic and genetic correlations of kernel weight with grain yield/plant were negative (-0.14 and -0.25, respectively).

The direct effect of number of spikes/plant in the phenotypic path analysis was much larger than its direct effect in the genetic analysis. There was little increase in the direct effect of kernek/spike at the genetic level compared to the phenotypic level.

Path coefficient analysis of grain yield and its related traits reveald that the direct effect of number of spikes/plant in the phenotypic analysis was much larger than its direct effect in the genetic analysis. This result indicates that a large portion of the direct effect of number of spikes/plant on grain yield/plant was due to nonadditive genetic or environmental effects or both. The direct phenotypic and genetic effects of number of spikes/plant were reduced due to the negative indirect effects via number of kernels/spike and 100-kernel weight. There was little increase in the direct effect of kernels/spike at the genetic level compared to the phenotypic level, which suggests that it is little affected by nonadditive genetic or environmental effects or both. The direct phenotypic and genetic effects of number of kernels/spike were reduced due to the negative indirect effects via number of spikes/plant and 100-kernel weight. The direct effect of kernel weight on grain yield was low because of negative indirect effects via number of spikes/plant and kernels/spike. The results of this study indicated that the improvement of grain yield by selection for number of spikes/plant, number of kernels/spike, and 100-kernel weight may be limited as a result of the negative associations among these traits.

SUMMARY

The present study was conducted to investigate the inheritance of induced glaucousness of leaf blade and spike, yield and yield-related traits in a cross between induced glaucous wheat mutant line 6 and nonglaucous wheat cultivar Giza 164 and to elucidate the interrelationships among yield and yield-related traits. Leaf blade and spike glaucousness for F_1 plants were moderately glaucous. The F_2 plants segregated for leaf blade and spike glaucousness as 1 glaucous : 2 moderately glaucous : 1 non-glaucous. This indicates that each of the induced glaucousness of leaf blade and spike is controlled by a single gene with incomplete dominance. Environmental variance was overriding dominance and additive variances for grain yield/plant. The additive type of gene action was pronounced in the expression of 100-grain weight, number of kernels/spike and number of spikelets/spike. The dominance type of gene action was predominant in the expression of number of spikes/plant, number of kernels/spikelet and spike length. Narrow-sense heritability estimates were high for 100-kernel weight; intermediate for number of kernels/spike, number of spikelets/spike, spike length, number of kernels/spikelet; and moderately low for number of spikes/plant and grain yield/plant. The results of path coefficient analysis indicate that the improvement of grain yield by selection for spikes/plant, kernels/spike, and kernel weight may be limited as a result of the negative associations among these traits.

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Table (1): Leaf blade and spike glaucousness scores and tests of expected phenotypic segregation ratios of bread wheat cross between glaucous wheat mutant line 6 (GWM6) and nonglaucous wheat cultivar Giza 164.

Generation	Leaf blade					Spike				
	ng	mg	gl	Expected ratio	χ^2	ng	mg	gl	Expected ratio	χ^2
GWM6 (P_1)	-	-	120			-	-	120		
BC_1 (P_1/F_1)	-	98	104	1:1	0.178**	-	110	92	1:1	1.604**
F_1	-	120	-			-	120	-		
F_2	127	241	112	1:2:1	0.372*	121	225	134	1:2:1	0.989*
BC_2 (P_2/F_1)	108	116	-	1:1	0.286**	114	110	-	1:1	0.072**
Giza 164 (P_2)	120	-	-			120	-	-		

ng, nonglaucous; mg, moderately glaucous; gl, glaucous, * Significant limit of χ^2 ($P = 0.05$, df = 2) = 5.99
** Significant limit of χ^2 ($P = 0.05$, df = 1) = 3.84

Table (2): Flag leaf blade epicutucular wax contents in 30 leaf blades (mg/dm^2) of the F_1, F_2, BC_1, BC_2, and parental generations in bread wheat cross between glaucous wheat mutant line 6 (GWM6) and nonglaucous wheat cultivar Giza 164.

Generation	Phenotype of leaf blade	Mean	Variance
GWM6 (P_1)	gl	2.48	0.008
F_1	mg	1.97	0.017
F_2	gl	2.39	0.194
	mg	2.00	
	ng	1.53	
BC_1 (F_1xP_1)	gl	2.41	0.087
	mg	2.16	
BC_2 (F_1xP_2)	mg	1.92	0.041
	ng	1.55	
Giza 164 (P_2)	ng	1.47	0.005

gl, glaucous; mg, moderately glaucous; ng, nonglaucous.

Table (3): Number of plants as a level of association between glaucousness for leaf blade and spike in the F_2 plants of bread wheat cross between glaucous wheat mutant line 6 (GWM6) and nonglaucous wheat cultivar Giza 164.

Phenotype of leaf blade	Phenotype of spike			Total number of plants
	gl	mg	ng	
gl	38	53	21	112
mg	67	120	54	241
ng	29	52	46	127
Total number of plants	134	225	121	480

gl, glaucous; mg, moderately glaucous; ng, nonglaucous.

Table (4): Parental means and mean squares of the analysis of variance for yield related traits.

Parents	Grain yield/plant (gm)	Spikes/ plant	100-kernel weight (gm)	Kernels/ spike	Kernels/ spikelet	Spikelets/ spike	Spike length (cm)
GWM6 (P_1)	26.67	4.46	5.33	111.88	4.24	26.85	23.60
Giza164 (P_2)	40.98	10.29	4.82	84.79	3.42	24.79	17.14
Mean squares	622.51**	101.97**	1.93**	2204.04**	2.00**	14.26**	127.60**

** Significant at 0.01 level of probability.

Table (5): Estimates of additive, dominance, and environmental variances and broad (h^2_b) and narrow-sense (h^2_n) heritabilities (± SE) for grain yield and yield-related traits.

Trait	Additive variance	Dominance variance	Environmetal variance	h^2_n	h^2_b
Grain yield/ plant (gm)	39.96 ± 9.61	71.59 ± 17.09	90.94 ± 18.26	0.20 ± 0.05	0.55 ± 0.01
Spikes/plant	4.10 ± 2.98	6.76 ± 3.29	5.37 ± 2.57	0.24 ± 0.01	0.63 ± 0.06
100-kernel weight (gm)	0.24 ± 0.13	0.13 ± 0.05	0.13 ± 0.07	0.48 ± 0.14	0.74 ± 0.03
Kernels/spike	120.05 ± 13.7	111.29 ± 6.89	75.46 ± 7.64	0.39 ± 0.01	0.75 ± 0.02
Kernels/spikelet	0.15 ± 0.01	0.18 ± 0.02	0.13 ± 0.01	0.32 ± 0.02	0.72 ± 0.02
Spikelets/spike	2.37 ± 1.05	1.96 ± 0.41	1.85 ± 0.30	0.38 ± 0.06	0.70 ± 0.02
Spike length (cm)	1.88 ± 0.22	2.43 ± 0.36	0.93 ± 0.17	0.36 ± 0.08	0.82 ± 0.06

Table (6): Phenotypic and genotypic correlation between pairs of the characters studied.

Character	Grain yield/ plant (gm)	Spikes /plant	100-kernel weight (gm)	Kernels /spike	Kernels /spikelet	Spikelets /spike
Spikes/plant	0.77** 0.42 ± 0.23					
100-kernel weight (gm)	-0.14** -0.23 ± 0.17	-0.39** -0.48 ± 0.31				
Kernels/spike	0.10 0.34 ± 0.13	-0.25** -0.22 ± 0.14	-0.10 -0.18 ± 0.21			
Kernels/spikelet	0.04 0.74 ± 0.19	-0.31** -0.55 ± 0.25	-0.06 -0.61 ± 0.19	0.18** 0.95 ± 0.22		
Spikelets/spike	0.23** 0.17 ± 0.12	0.13** -0.03 ± 0.11	-0.13** -0.76 ± 0.21	0.34** 0.12 ± 0.07	0.06 0.22 ± 0.15	
Spike length	0.06 0.05 ± 0.12	-0.12* -0.10 ± 0.22	0.11* 0.36 ± 0.26	0.36** 0.17 ± 0.15	0.19** -0.59 ± 0.20	0.67** 1.00 ± 0.26

Upper value in each cell is the phenotypic correlation coefficient with n-2 = 478 df and must exceed 0.10 and 0.12 to be significant at the 0.05 (*) and 0.01 (**) probability levels, repectively; lower value is the genotypic correlation coefficient with its standard error.

Table (7): Phenotypic and genotypic path analysis of direct and indirect effects on grain yield in wheat cross GWM6 x Giza164.

Pathway	Phenotypic value	Genotypic value
Yield vs. spike number		
Direct effect	0.96	0.57
Indirect effect via kernel weight	- 0.10	- 0.05
Indirect effect via kernels/spike	- 0.09	- 0.10
Total correlation	0.77	0.42
Yield vs. kernels/spike		
Direct effect	0.37	0.48
Indirect effect via spike no.	- 0.24	- 0.12
Indirect effect via kernel weight	- 0.03	- 0.02
Total correlation	0.10	0.34
Yield vs. kernel weight		
Direct effect	0.27	0.11
Indirect effect via spike no.	- 0.37	- 0.27
Indirect effect via kernels/spike	- 0.04	- 0.09
Total correlation	-0.14	- 0.25
Residual	0.53	0.63

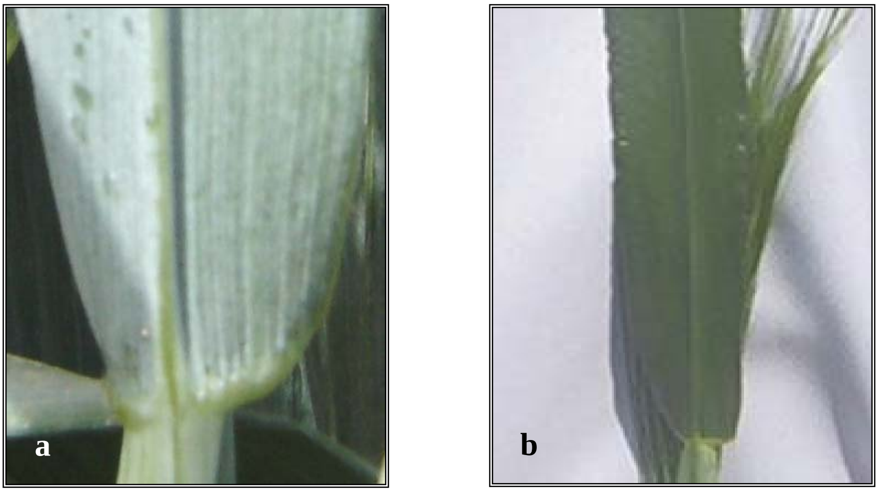

Fig. (1): a: Glaucous leaf blade of glaucous wheat mutant line6 (GWM6). b: Nonglaucous leaf blade of Giza164 cultivar.

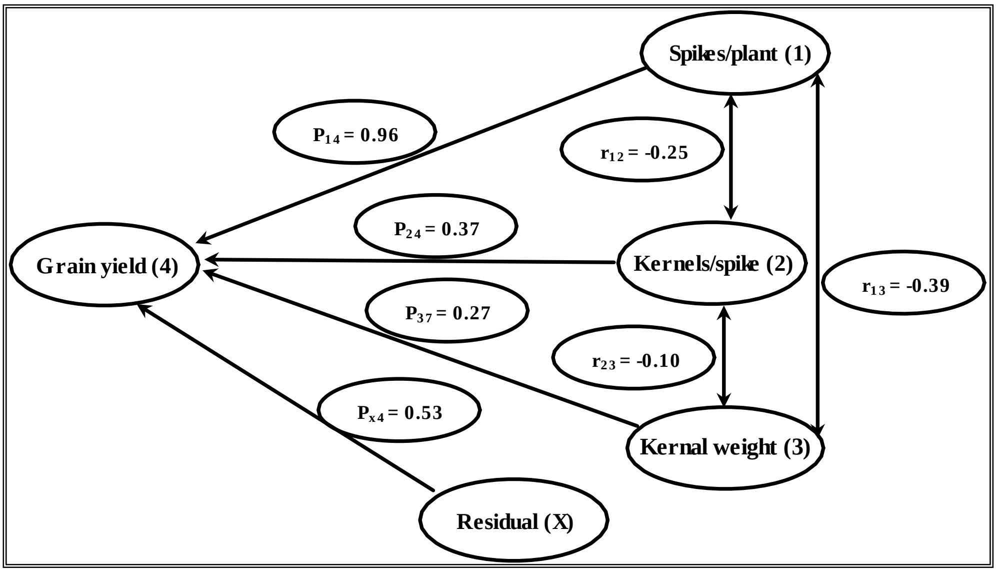

Fig. (2): Phenotypic path analysis diagram of yield and yield-related traits in a cross between glaucous wheat mutant line 6 and Giza164 cultivars.