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Original Article

Interpretation of Morphological and Quality Characteristics Affecting Yield in Some Bread Wheat (*Triticum aestivum L.*) Genotypes by Path, Correlation Analysis and Genetic Variability

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Abstract *- The genetic variability and genetic relationship between grain yield and some morphological and quality characters in twenty-five spring wheat lines and cultivars were investigated. the study was conducted in Adana in 2018-19 according to the design of the randomized blocks in four replications. the analysis of variance showed highly significant differences among the genotypes for all the characters. the highest estimates of the phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were observed for grain hardness. the low differences between GCV and PCV for all characters indicated that the effects of environmental factors were low. High heritability coupled with high genetic advance (GA) and high genetic advance as a percent of the mean (GAM %) indicated an additive gene effect on grain yield and hardness. Genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients in most characters. As a result, the genotypic path coefficient analysis revealed that text weight, days to heading, and plant height performances should be taken into account in selecting spring wheat breeding programs for rapid improvement of grain yield.*

Keywords *- Wheat, Correlation, Genetic variation, Heritability, Path analysis.*

I. INTRODUCTION

It is necessary to know the genetic and environmental factors to increase the effectiveness of the selection to be made for the purpose among the genotypes that make up the breeding populations [4]. Grain yield is a quantitative character influenced by many genetic factors and environmental fluctuations. the correlation coefficient analysis is a statistical measure used to determine the degree and direction of the relationship between two or more variables. Knowledge of the correlation between yield and yield components helps to use genetic material effectively in inbreeding. Further information on the path coefficient is useful to measure the relationship among yield components and determine their importance for contributing to grain yield correlation studies, along with path analysis providing a better understanding of the association of different characters with grain yield. Path coefficient analysis separates the direct effects from the indirect effects through other related characters by partitioning the correlation coefficient [14].

The genetic diversity and inheritance of the characters are determined the success of the plant breeding program. Genetic variability and heritability analysis help breeders decide on a strategy and use appropriate selection criteria for the desired improvement [16], [22]. This study aimed to obtain information about genetic variability, heritability, reveal the genetic correlation among the characters of spring wheat lines, and partition the genetic correlations into direct and indirect effects to estimate the direct and indirect effects of six characters of grain yield.

II. MATERIALS and METHODS

A. Experimental Site and Design Used

The experiment was founded on a randomized block design with 4 replications at the experimental area of the Eastern Mediterranean Agricultural Research Institute in ADANA during the 2017-2018 growing season.

B. Materials

The experimental material consisted of 5 varieties and 20 lines of spring bread wheat presented in Table 1**.**

Table 1. Genotypes list bread wheat with their pedigree

NO	Pedigrees of Genotypes
1	TUKURU//BAV92/RAYON/6/NG8201/KAUZ/4/SHA7//PRL/VEE#6/3/FASAN/5/MILAN/KAUZ/7/TRCH/SRTU//KACHU
2	MUTUS//ND643/2*WBLL1
3	SUP152/3/INQALAB 91*2/TUKURU//WHEAR
4	ATTILA*2/PBW65*2//KACHU
5	**CEYHAN 99**
6	ROLF07/KINGBIRD #1//MUNAL #1
7	KACHU/CHONTE
8	CNO79//PF70354/MUS/3/PASTOR/4/BAV92/5/WBLL1*2/BRAMBLING
9	KACHU*2/BECARD
10	**YAKAMOZ**
11	MUTUS*2/HARIL #1
12	MUTUS*2/CHONTE
13	MUTUS*2/HARIL #1
14	MUTUS*2/JUCHI
15	**SERİ 2013**
16	IRENA/BABAX//PASTOR/5/ THB//MAYA/NAC/3/RABE/4/MILAN
17	MUTUS*2//ND643/2*WBLL1
18	FALCIN/AESQUARROSA (312)/3/THB/CEP7780//SHA4/LIRA/4/FRET2/5/MUU/6/MILAN/KAUZ//DHARWAR DRY/3/BAV92
19	SOKOLL/3/PASTOR//HXL7573/2*BAU/4/2*PASTOR//HXL7573/2*BAU/3/SOKOLL/WBLL1
20	**OSMANİYEM**
21	TACUPETO F2001/6/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PASTOR/7/ROLF07
22	BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ*2/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI
23	BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ*2/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI
24	WBLL1*2/BRAMBLING//ND643/2*WBLL1
25	**GÖKKAN**

C. Agronomic, Quality and Other Parameters

Different agronomic and quality characters recorded were days to heading, plant height (cm), grain yield (kg/ha), test weight (kg/hl), protein content (%), flour yield (%), grain hardness (psi).

The parameters phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) [10], heritability (broad sense) h2 [23], genetic advance (GA), genetic advance as percent of the mean (GAM%) [18] were estimated using the formulas admitted. GCV and PCV category according to the scale suggested by [37] (low <10%; Moderate 10-20%; High >20%), h2 category according to the scale suggested by referance [32] (low <30%; moderate 30-60%; high >60%), and GA and GAM % category according to the scale suggested by referance[18] (low <10%, moderate 10-20%, and high >20%) were evaluated.

D. Data Analysis

The variance analysis of parameters of PV, GV, PCV, GCV, h2, GA, GAM % for genetic variability and the correlation and path coefficients analysis was carried out using TNAUSTAT statistical software [25]. the direct and indirect effects of path analysis were also calculated for different grain yield components using the procedure given by referance [12].

III. RESULTS AND DISCUSSION

In the present study, the analysis of variance revealed highly significant differences in all characters. It indicates the existence of sufficient variability among the genotypes tested and provides a good opportunity for bread wheat improvement programs. Table 2 presents the existence of considerable genetic variability for selection and breeding. Similar results were reported by reference [3], [6] [19], [20] and[16].

Table 2. Analysis of Variance for some characters studied of bread wheat genotypes

		Mean Squares						
Source of var.	**df**	**GY**	**DH**	**PH**	**FY**	**TW**	**GH**	**PC**
Genotype	24	48012.14**	409.15**	1.21**	32.66**	63.08**	41.79**	39.94**
Replications	3	12580.11*	9.37	17.09**	1543.77**	44.27	3775.20**	1060.42**
Error	72	4068.76	28.63	0.62	4.85	21.95	7.19	15.93

*: P<0.05; **:P<0.001; df: Degrees of freedom; Grain Yield (GY) (kg/ha), Days to Heading (DH) (day), Plant Height (PH) (cm), Flour Yield (FY) (%),Test Weight (TW) (kg/hl) Grain Hardness (GH) (pci), Protein Content (PC) (%).

Range of variation, general mean (GMean), standard errors (SE), coefficient of variation CV (%) as descriptive statistics estimates for some agronomic and quality characters studied of wheat genotypes examined are shown in Table 3.

Table 3. The estimates of descriptive statistics

	Characters						
Genotypes	**GY**	**DH**	**PH**	**FY**	**TW**	**GH**	**PC**
1	8620.13	83.50	106.25	57.12	82.59	40.23	11.78
2	9130.20	85.25	110.25	55.11	86.69	40.48	11.22
3	9570.10	84.00	107.50	56.55	82.30	38.15	11.09
4	7920.88	88.25	115.75	53.99	81.36	40.48	11.32
5	6740.98	88.25	110.50	53.61	74.88	32.68	12.26
6	8920.13	83.75	110.00	60.45	77.95	34.30	11.29
7	9040.30	86.25	113.50	60.74	79.66	37.55	11.40
8	8760.20	84.00	110.25	61.26	81.43	41.23	10.79
9	9180.13	83.50	107.25	57.06	83.30	42.15	12.52
10	7100.73	85.00	100.75	54.16	84.13	63.33	11.49
11	8270.93	83.25	118.75	58.43	83.36	64.51	11.81
12	8210.43	83.75	109.75	54.29	87.31	46.71	10.75
13	11630.13	84.75	107.75	58.30	86.01	57.03	10.97
14	8990.90	88.25	112.25	59.94	81.63	57.25	11.57
15	6260.78	93.00	111.50	61.30	84.03	56.36	11.88
16	8230.43	86.75	113.00	64.24	86.96	57.09	11.01
17	7860.28	81.25	113.50	58.90	87.96	60.42	12.83
18	862.70	83.50	112.25	63.18	84.68	60.45	11.44
19	7990.13	85.00	107.00	60.50	82.40	61.19	11.13
20	7260.78	89.25	109.25	63.27	86.63	55.01	12.67
21	9040.78	83.50	119.75	57.35	79.52	55.37	11.89
22	8820.13	88.50	107.75	59.90	83.21	55.97	11.55
23	9600.70	80.00	108.75	61.10	86.71	57.75	11.54
24	9640.30	88.75	111.25	59.86	82.39	58.50	11.44
25	7750.00	85.00	110.75	52.96	81.26	57.75	11.26
Range of variation	5640.3 - 13980.9	72-103	95-130	44.07- 84.14	68.10-98.90	20.7-70.41	8.4-14.07
GMean	8530.04	85.45	110.61	58.54	83.13	50.88	11.56
SE.	31.89	1.10	2.34	1.34	2.00	2.68	0.39
CV (%)	7.48	2.58	4.24	4.58	4.80	10.52	6.83

The grain yield ranged from 5640.3 to 13980.9 kg/ha. the days to heading, plant height, flour yield, grain hardness, protein content and test weight ranged from 72 to 103 days, 95 - 130 cm, 44.07% - 84.14%, 20.7 - 70.41 (pci), 8.4%-14.07%, 68 - 98 kg hl respectively. Naser et al. (2020) reported that test weight ranged from 79.37 – 84.20 gram/hl.

the assessment of genetic variability, estimates of various parameters as phenotypic variance (PV), genotypic variance (GV), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (broad sense) h^2, genetic advance GA and genetic advance as percent of the mean (GAM%) were analyzed for investigation characters in Table 4.

Table 4. The estimates of genetic components for some characters of wheat

	Components						
Characters	**PV**	**GV**	**PCV**	**GCV**	**h2**	**GA**	**GAM%**
GY	15054.61	10985.85	14.38	12.29	72.97	184.44	21.62
DH	11.81	6.95	4.02	3.09	58.89	4.17	4.88
PH	32.24	10.28	5.13	2.90	31.89	3.73	3.37
FY	15.84	8.65	6.80	5.02	54.59	4.48	7.65
TW	21.93	6.00	5.63	2.95	27.36	2.64	3.18
GH	123.77	95.13	21.87	19.17	76.86	17.62	34.62
PC	0.77	0.15	7.60	3.32	19.12	0.35	2.99

Phenotypic variance (PV), Genotypic variance (GV), Phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV), Heritability (broad sense) h2, Genetic advance GA, Genetic advance as percent of the mean Firstly, the relative magnitude of the phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for different characters was comparatively examined. PCV was higher than the GCV in all examined characters. the difference between PCV and GCV in characters was quite low, so we thought that the role of the environment was also minimal. the estimates of PVC and GCV were moderate for grain yield (12.29), and similar results were reported by reference [8], [5]. the estimates of PVC and GCV were low for days to heading (3.09), plant height (2.90), flour yield (5.02), test weight (2.95), protein content (3.32). the finding of days to heading was supported by [7], [30], [8]. the finding of plant height was supported by [30], [5]. But [7], [30] were reported to be moderate. Test weight was supported by references [8], [30], [5]. the highest estimates of PCV and GCV were observed for grain hardness. Protein content finding was supported by reference [5].

Moderate heritability (%) was observed for days to heading, plant height, and flour yield except for test weight and protein content which had low heritability. High heritability estimates were recorded for grain yield and grain hardness. Similar results for grain yield were reported by referance [8], [30], [33]. Reference [3], [28], [29] also shows moderate heritability estimates for plant height and days of heading support the present findings. Reference [9] reported low heritability estimates for the test weight. Reference [24] reported that flour yields were more heritable than test weight and protein content.

The genotypes' high heritability in grain yield and grain hardness (72.97 and 76.86%, respectively) showed that selection based on phenotypic performance could be more effective. When the genotypes were evaluated for grain yield and hardness, GAM was determined to be 21.62% and 34.62%. High heritability coupled with a high GAM value indicates a strong additive gene effect on yield and hardness. Therefore, simple selection based on the phenotypic variation in yield and hardness can be quite effective.

Low heritability with low genetic advance values was found for plant height and number of grains, indicating slow progress through selection for these characters. the low heritability for these two components is a result of some variances constituting the environment variance. Reference [35] shows the highest heritability with more genetic advances for plant heigh. in the present investigation, high heritability values coupled with high genetic advance (Table 4) were recorded for grain yield and hardness. It indicates that, most likely, the heritability is due to an additive gene effect, and selection may be effective in early segregating generation for these characters. These results support the earlier studies reported [31], [34].

Accurate genotype selection is the main goal for yield breeding of any crop. Direct selection between genotypes can often be misleading, as the quantitative characters that make up the yield are affected by environmental conditions. the knowledge of the degree and direction of the relationship between yield characters and yield is important for selection efficiency. Correlation analysis estimates the degree and direction of the relationship between variables [1] and are widely used in breeding selection programs, especially in polygenic characters such as yield. the phenotypic and genotypic correlations for some characters are presented in Table 5.

Table 5. Genotypic, phenotypic, environmental and simple correlation coefficients for some characters

		DH	PH	FY	TW	GH	PC
GY	GENO (r)	-0.478**	-0.0532	0.1364*	0.1923**	-0.0627	-0.5886**
	PHEN (r)	-0.2789**	0.0305	0.0804	0.0533	-0.0657	-0.1720**
	ENV.(r)	0.1036*	0.1309*	-0.0160	-0.0737	-0.0751	0.1023*
	SIMPLE (r)	-0.4104**	-0.0186	0.1168*	0.1291*	-0.0636	-0.3712**
DH	GENO (r)		-0.0232	0.1182*	-0.3291**	-0.0280	0.0402
	PHEN (r)		0.1050*	0.1029*	-0.0629	0.0036	0.1058*
	ENV.(r)		0.2175**	0.0830	0.1267*	0.0728	0.1601**
	SIMPLE (r)		0.0322	0.1125*	-0.2047**	-0.0175	0.0701
PH	GENO (r)			0.1741**	-0.3357**	0.0663	0.0422
	PHEN (r)			0.0814	-0.0154	0.0785	0.1895**
	ENV.(r)			0.0157	0.1192*	0.1151*	0.2413**
	SIMPLE (r)			0.1318**	-0.1658**	0.0696	0.1258**
FY	GENO (r)				0.3303**	0.3651**	0.1085**
	PHEN (r)				0.1794**	0.1823**	-0.0073
	ENV.(r)				0.0901	-0.1670**	-0.0698
	SIMPLE (r)				0.2566**	0.3020**	0.0480
TW	GENO (r)					0.7069**	0.0675
	PHEN (r)					0.2686**	-0.0572
	ENV.(r)					-0.1357**	-0.0947
	SIMPLE (r)					0.5060**	-0.0064
GH	GENO (r)						0.1427**
	PHEN (r)						0.0512
	ENV.(r)						-0.0081
	SIMPLE (r)						0.0944

Grain yield (GY), Days to Heading (DH), Plant Height (PH), Flour Yield (FY), test weight (TW), Grain Hardness (GH), Protein Content(PC)

Genotypically, grain yield exhibited a positive and highly significant relationship with FY and TW, while a negative and highly significant relationship was recorded between DH and PC. Similar findings were reported for DH by [19], [22] reported that grain yield showed an insignificant and positive association with DH and PC. A positive and insignificant relationship was recorded between GY and PH. Reference [2] findings support the results of PH and DH. [11] also reported a significant and positive correlation between GY and PH. Grain yield showed a highly significant and positive genotypic and phenotypic correlation with FY and TW, whereas PH, TW, and GY had significance only at the phenotypic level. Protein percentage was significantly correlated with the hardness index. These were in agreement with [27], [13].

The path analysis model explains how multiple independent variables are arranged into a single dependent variable by dividing the correlation coefficient and the determination coefficient [15]. Estimates of direct effect and indirect effect are presented in Table 6.

Table 6. Genotypic path analysis with the dependent variable, direct (bold phase) and indirect components to grain yield bread wheat

	DH	PH	FY	TW	GH	PC	GENO (r)
DH	**-0.815**	0.1854	0.0033	0.0387	-0.0018	0.0008	-0.5886**
PH	0.3896	**-0.3878**	0.0014	0.0335	0.0031	0.0003	0.0402
FY	0.0434	0.009	**-0.0619**	0.0494	0.0031	-0.0008	0.0422
TW	-0.111	-0.0458	-0.0108	**0.2837**	-0.0031	-0.0045	0.1085**
GH	-0.157	0.1276	0.0208	0.0937	**-0.0093**	-0.0086	0.0675
PC	0.0511	0.0109	-0.0041	0.1036	-0.0066	**-0.0122**	0.1427**

RESIDUE=0.7142; Grain yield (GY), Days to Heading (DH), Plant Height (PH), Flour Yield (FY), Test Weight (TW), Grain Hardness (GH), Protein Content (PC).

In the present investigation, grain yield was considered a dependent variable, and days to heading, plant height, flour yield, test weight, grain hardness, and protein content were independent variables.

Genotypic path analysis showed TW had the highest positive direct effect (0.2837) on GY. Its indirect effects for the TW on GY were negative via other characters. on the other hand, the genotypic correlation coefficient (0.1085) positively affected the direct positive relationship of TW.
DH had the highest negative direct effect (-0.815) on GY. Similar results for DH were reported [38].

This character's small and negligible negative indirect effect on grain yield was registered through GH. Relatively high and negative genotypic correlation between GY (-0.5886) was largely due to the highest negative direct effect (Table 6).

Plant Height, Flour Yield, Grain Hardness, and Protein Content had a negative and direct effect on grain yield (-0.3878), (-0.0619), (-0.0093), and (-0.0122), respectively. the plant height result was supported by [17] and [28].

Phenotypic path analysis showed that GH was the highest positive direct effect (0.3489) on grain yield in Table 7. the indirect effects of GH via PH and FY were positive, and the phenotypic correlation was positive for GH (0.2608). PH showed the highest negative direct effect (-0.5218) on grain yield. Indirect effects of FY TWand GH were negative for PH but low in magnitude. the phenotypic correlation was negative for PH (-0.5218), which may be mainly due to the indirect negative contribution of PH (-0.4775) (Table 7). FY and TW had positive and direct effects on grain yield (0.2671) and (0.0245). DH and PC had negative and direct effects on grain yield (-0.479) and (-0.1332), respectively.

Table 7. Phenotypic path analysis with the dependent variable, direct (bold phase) and indirect components to grain yield bread wheat

	DH	PH	FY	TW	GH	PC	PHEN (r)
DH	**-0.479**	0.0541	-0.0413	0.0098	0.0536	-0.0233	-0.4258**
PH	0.0497	**-0.5218**	-0.0024	-0.0082	-0.0228	0.0281	-0.4775**
FY	0.0741	0.0047	**0.2671**	0.0011	0.0065	-0.0061	0.3473**
TW	-0.191	0.1752	0.0119	**0.0245**	-0.1179	0.0053	-0.0919*
GH	-0.074	0.034	0.005	-0.0083	**0.3489**	-0.0452	0.2608**
PC	-0.084	0.1099	0.0123	-0.001	0.1183	**-0.1332**	0.0225

RESIDUE=0.607; Grain yield (GY), Days to Heading (DH), Plant Height (PH), Flour Yield (FY), Test Weight (TW), Grain Hardness (GS), Protein Content (PC)

IV. CONCLUSION

The analysis of variance showed highly significant differences between the genotypes of all characters studied, meaning that data from the above diverse material showed wide variability. PCV values were higher than GCV, but the difference variability between these two estimates for all characters was very close. Regarding the genetic parameters, grain yield (kg/ha) and grain hardness were recorded with high heritability, GA, and GAM %values. High heritability in broad sense values indicates that the environment fewer influences the characters understudy in their expression. Therefore, the wheat breeders may make superior genotypes selection based on phenotypic performance for these characters. the genotypic correlation coefficients were larger than the phenotypic correlation coefficients in all characters, indicating a strong natural relationship between character pairs. the genotypic, phenotypic, and environmental correlation coefficients with the grain yield are positive FY and HL. An increase in these characters will ultimately increase the grain yield. So, a correlation study revealed that selection based on FY and HL would effectively increase grain yield. Therefore, the results suggest that these characters can be used for grain yield selection. Phenotypic path coefficient analysis revealed that grain hardness was the highest positive direct effect. Genotypic Path coefficient analysis revealed that test weight had the highest positive direct effect while Days to heading and plant height had the highest negative direct effect on grain yield. As a result, text weight, Days to heading, and plant height performances should be taken into account in selecting spring wheat breeding programs for rapid improvement of grain yield.

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