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# Genetic Variability, Correlation and Path Analyses for Yield and Yield Components of Some Bread Wheat Genotypes

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## ABSTRACT

Two field experiments were carried out during 2014/2015 and 2015/2016 seasons under two sowing dates, 24th November (optimum date) 25th December (late date) at the Experimental Farm, Faculty of Agriculture, Zagazig University, Sharkia Governorate, Egypt using eight wheat genotypes to estimate genetic variability, phenotypic and genotypic correlations as well as path coefficient for yield and yield component characters. The results indicated significant differences among wheat genotypes for all the studied characters except chlorophyll content at the two seasons and number of spikes/$m^2$ at the 2nd one only. Wheat genotypes Line 3, Sids 12 Misr 1, and Line 4 performed well under the late sowing date in the two seasons for yield and its component. Maximum phenotypic variance (Vp) and genotypic one (Vg) were recorded for number of spikes /$m^2$ under the two sowing dates and plant height under 2nd one only. The (PCV) and (GCV) ranged from 27.69 and 26.08 % to 90.38 and 85.11% and from 20.26 and 12.66 % to 208.31 and 189.59 % for 1000 grain wheat and number of spikes/$m^2$ under 1st sowing date and 2nd one, respectively. The range observed for heritability (bs) was from (58.42) for number of fertile spikelets/spike to (95.3%) for number of grains /spike and from (39.04) for 1000 grain weight to (89.46%) for plant height under 1st sowing date and 2nd one, respectively. Spike length, number of fertile spikelets/spike, number of spikes /$m^2$, number of grains /spike and 1000-grain weight were the most important traits which greatly correlated with grain yield at both genotypic and phenotypic levels. Maximum positive direct effect on grain yield was contributed mostly by 1000-grain weight (1.104), followed by number of grains/spike (0.626) and number of spikes/$m^2$ (0.352).This means that a slight increase in one of these traits may directly contribute to grain yield. Since these characters could be used as selection criteria for improving wheat grain yield.

**Keywords:** wheat, heat stress, genetic variability, phenotypic and genotypic correlation, path coefficient analysis.

## INTRODUCTION

Bred wheat is the major staple food of Egyptians and it occupies a prominent position in the cropping pattern. Wheat grain yield will be improved through application of the best Technical Recommendations and improvement promising cultivars with tolerance to environmental stresses such as heat stress this is considered a national target in Egypt to fill the gap between wheat consumption and production.

High temperatures cause a morpho-physiological and biochemical modifications in plants, which may lead to a less yield due to their effects on plant development. Grain yield is a quantitative character and greatly affected by many factors. A successful selection for high seed yield depends upon the knowledge about the genetic variations and correlation of different characters with it.

The primary advantage is the partitioning of total variation into phenotypic, genotypic and environmental variations and determine the type of genetic variation and thus helps in determine a breeding programme for the genetic improvement of a trait. Heritability values with genetic advance are more helpful in expecting the genetic gain under selection than heritability values alone.

The information about the link among different yield components has been successfully exploited towards improving wheat grain yield.

Study of correlation over with path analysis provide a better information of the correlation of various traits with seed yield. Path analysis separates the direct effects from the indirect ones across other related traits through partitioning the correlation (Dixit and Dubey, 1984). Several authors determined genetic variance for yield and its component characters in wheat and showed moderate to high heritability and genetic advance (Singh *et al.,* 2014; Yahaya*,* 2014;Ghuttai *et al.,* 2015;Tripathi*et al.,* 2015 and Sharaan *et al.,* 2017). Tahmasebi *et al.* (2013), Zeeshan *et al.*(2014), Khan *et al.* (2015) and Ghallab *et al.* (2016) reported that the high phenotypic and genotypic coefficients of variability observed for most of the yield and yield attributing characters studied in wheat genotypes. Abd El-Mohsen *et al.* (2012) indicated that maximum positive direct effect on grain yield/plant was contributed by number of grains/spike, followed by number of tillers/plant and 1000 grain weights were the major contributors towards grain yield. Azimi *et al.* (2017) showed significant phenotypic and genotypic correlation among all yield components. Moreover, Rahman *et al.* (2016) found that number of spikes/$m^2$, spike length, number of grains/spike and 1000-grains weight were from the characters significantly contributed to the total variation of plant grain yield at both genotypic and phenotypic levels.

This study aimed to estimate genetic variations and association between grain yield and its components of bread wheat, which may be was important to improve this strategical crop through selection of the more contributed characters to grain yield.

## MATERIALS AND METHODS

This study was performed at the Experimental Farm. Fac. of Agric. Zagazig University, Egypt during the two winter growing seasons of 2014/2015 and 2015/2016 under two sowing dates i.e. 24th November (optimum date) and 25th December (late date), respectively, using eight wheat genotypes (Table 1) to estimate genetic variability, phenotypic and genotypic correlations as well as path coefficient analyses for wheat yield and its contributing characters. A complete randomized block design with three replications was used in a factorial arrangement. Plot size was 3.6 $m^2$ (6 rows, 3 meters length with 20 cm apart) and sown at rate of 300 seed/m$^2$. The crop was subjected to the recommended agronomic practices. At anthesis ten guarded plants from each genotype in every replicate were used to estimate plant height and flag leaf area, also leaf chlorophyll content was estimated using SPAD-502 apparatus(Castelli *et al.,* 1996). At harvest, spike length, number of fertile spikelets/spike, number of sterile spikelets/spike, number of spikes/ m$^2$, number of grains/spike, 1000-grain weight and grain yield (ard./fed.) were determined. The obtained data were statistically (ANOVA)analyzed by analysis of variances according to Steel*et al.* (1997). The least significant differences (P<0.05) was calculated for the parameters exhibiting a significant effect and to compare treatments mean. Genotypic and phenotypic variances and co-variances were computed from ANOVA and ANCOVA and used to estimate genotypic and phenotypic correlations among traits. Combined analyses was done to data of the same sowing dates at the two seasons and used to determine phenotypic and genotypic correlations as well as genotypic path coefficient of grain yield and yield contributing characters. Phenotypic and genotypic correlation coefficients were determined according to Kwon and Torrie (1964). Path coefficient analyses was computed according to Dewey and Lu (1959) by solving simultaneous equations using genotypic correlations. Data of wheat grain yield were used to estimate heat stress tolerance measurements as follows:

1. Tolerance index (ToL) (Rosielle and Hambling, 1981). Tol= YP- Ys
2. Heat sensitivity index (HSI) (Fischer and Maurer, 1978). H.S.I= (1-YS/ YP)/SI and HI= (1- ỲS/ỲP); Where, HI: Heat stress intensity.
3. Relative performance (P) (Abo-Elwafa and Bakheit, 1999).

P= (YS/YP)/R Where, R= (ỲS/ỲP); YP= Yield potential under normal conditions.

YS= Yield potential under late sowing date conditions.

ỲS and YP= yield of all genotypes in the late sowing date and optimum one, respectively.

**Table 1. Pedigree and origin of the eight studied wheat genotypes.**

| Genotypes | Pedigree | Origin |
|---|---|---|
| Sids 12 | BUC//7C/ALD/5/MAYA74/ON//1160-147/3/BB/GLL/4/HAT″S″/S/MAYA-VUL//CMH74A. 630/4*SX.SD7096-4SD-1SD-1SD-OSD. | Egypt |
| Gemmeiza 12 | BUC//7C/ALD/5/MAYA74/ON//1160.147/3/BB/GLL/4/CHAT"S"/6/MAYA/VUL//CMH 74A.630/4*SXSD70964SD-1SD-1SD-0SD | Egypt |
| Misr 1 | OASIS/KAUZ//4*PASTOR.CMss00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S | Egypt |
| Line 1 | CROC_1/AE,SQUARROSA(224)//OPATA/3/PASTRO.CMSA00Y00086S-0P0Y-040M-040SY-030M-12ZTY-0M-0SY | Surya |
| Line 2 | T,DICOCCON P194614/AE,SQUARROSA (409)//BCN.CMSS00M001113S-050Y-020M-030Y-030M-3Y-0M-0Y | Surya |
| Line 3 | ICB97-1207-0AP | Surya |
| Line 4 | Sakha 93/Sids6.CGZ(16)GM-2GM-OGM | Egypt |
| Line 5 | YANAC/3/PRL/SARA//TSI/VEE#5/4/CROC_1/, CMSA00Y00810T-040M-0P0Y-040M-040SY-030M-7ZTM-0ZTY | Surya |

## RESULTS AND DISCUSSION

### Mean performance

Mean performance for yield and its components under two sowing dates during both seasons and combined analyses (the same sowing dates over the two seasons) are given in Tables (2, 3 and 4). Significant differences among wheat genotypes were observed for all characters under the study in all cases. All characters of the studied genotypes were affected by sowing dates except chlorophyll content in the two seasons and number of sterile spikelets/spike in 1$^{st}$ season only. It is evident from Tables (2,3 and 4) that wheat genotypes Line 3 , Sids 12, Misr 1, and Line 4 performed well under the late sowing date in the two seasons for yield and its component. On the other hand, the other genotypes were greatly affected by late sowing date.

### Phenotypic and genotypic coefficients of variation

The estimates of variance, coefficient of variation, heritability and genetic advance for all the ten characters studied are given in Table (5). Phenotypic coefficients of variation (PCV) were equivalent to their relating genotypic coefficients of variation (GCV), showing few impact of environment on the advertising of these traits. Nevertheless, great correspondence was recorded between genotypic coefficients of variation and phenotypic ones in every one of the traits under the two sowing dates. Maximum phenotypic variance (Vp) was recorded for number of spikes /m$^2$ were (265.24) and (997.8) under 1$^{st}$ sowing date and 2$^{nd}$ one, respectively, and plant height (29.57) under 2$^{nd}$ sowing date only.

Similarly, the genotypic variance (Vg) was also high for number of spikes /m$^2$ (234.25) and (826.46) under 1$^{st}$ sowing date and 2$^{nd}$ one, respectively, and plant height (26.45) under 2$^{nd}$ sowing date only. Less difference in the assessments of genotypic and phenotypic variances and higher genotypic values compared to environmental one for all the characters, suggesting that the variations attendant among the genotypes were mainly through genetic reason with minimum effect of environment and hence more heritable.

High phenotypic (PCV) and genotypic (GCV) were detected for all the studied traits under the two sowing dates.

Estimates of phenotypic coefficient of variation (PCV) were higher than their corresponding genotypic (GCV) one under the two sowing dates, indicating the little effect of environment on the expression of these characters. However, good correspondence was recorded between genotypic coefficient of variation and phenotypic one in all the characters.

**Table 2. Mean Performance of eight wheat genotypes for Plant height, Flag leaf area and Chlorophyll content under two sowing dates during both seasons and combined analysis (the same sowing dates over the two seasons).**

| Characters | Plant height (cm) | | | | Flag leaf area ($cm^2$) | | | | Chlorophyll content (SPAD reading) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seasons | | Combined over two seasons | | Seasons | | Combined over two seasons | | Seasons | | Combined over two seasons | |
| Genotypes | 1st season | 2nd season | 1st sowing date | 2nd sowing date | 1st season | 2nd season | 1st sowing date | 2nd sowing date | 1st season | 2nd season | 1st sowing date | 2nd sowing date |
| Sids 12 | 99.50 | 96.67 | 103.00 | 93.00 | 31.26 | 37.31 | 41.167 | 27.40 | 46.6 | 42.9 | 44.3 | 45.20 |
| Gemmeiza 12 | 102.67 | 103 | 105.67 | 100.00 | 35.65 | 28.44 | 37.880 | 26.21 | 45.6 | 48 | 47.9 | 45.67 |
| Misr 1 | 102.83 | 99.83 | 104.00 | 98.67 | 34.3 | 34.68 | 42.722 | 26.26 | 46.0 | 47.6 | 48.1 | 45.53 |
| Line 1 | 98.50 | 99.17 | 100.00 | 97.67 | 36.84 | 28.56 | 37.068 | 28.33 | 50.4 | 52 | 51.2 | 51.13 |
| Line 2 | 96.00 | 91.67 | 102.00 | 85.67 | 29.38 | 34.5 | 39.415 | 24.47 | 47.4 | 44.8 | 45.1 | 47.03 |
| Line 3 | 103.83 | 99.83 | 108.33 | 95.33 | 35.85 | 40.44 | 44.257 | 32.03 | 47.3 | 51.9 | 49.7 | 49.47 |
| Line 4 | 99.00 | 96.67 | 104.00 | 91.67 | 37.5 | 37.43 | 45.058 | 29.87 | 48.5 | 50.2 | 49.4 | 49.33 |
| Line 5 | 93.50 | 89.83 | 96.00 | 87.33 | 29.0 | 31.76 | 33.242 | 27.52 | 51.2 | 50.5 | 50.8 | 50.83 |
| Mean | 99.48 | 97.08 | 102.875 | 93.67 | 33.72 | 34.14 | 40.1 | 27.76 | 47.9 | 48.5 | 48.3 | 48.03 |
| GxS | * | * | * | * | * | * | * | * | NS | NS | NS | NS |
| $LSD_{0.05}$ | 3.25 | 4.13 | 1.56 | 1.88 | 4.21 | 2.38 | 1.56 | 1.66 | 1.64 | 2.68 | 0.79 | 1.53 |

**Table 3.Mean Performance of eight wheat genotypes for number of fertile spikelets / spike, number of sterile spikelets / spike, spike length and number of spikes /$m^2$under two sowing dates during both seasons and combined analysis (the same sowing dates over the two seasons).**

| Characters | Number of fertile spikelets / spike | | | | Number of sterile spikelets / spike | | | | Spike length (cm) | | | | Number of spikes /$m^2$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seasons | | Combined data over two seasons | | Seasons | | Combined data over two seasons | | Seasons | | Combined data over two seasons | | Seasons | | Combined data over two seasons | |
| Genotypes | 1st season | 2nd season | 1st sowing date | 2nd sowing date | 1st season | 2nd season | 1st sowing date | 2nd sowing date | 1st season | 2nd season | 1st sowing date | 2nd sowing date | 1st season | 2nd season | 1st sowing date | 2nd sowing date |
| Sids 12 | 17.3 | 18.6 | 19.03 | 16.90 | 1.37 | 1.2 | 1.48 | 1.08 | 10.2 | 10.4 | 10.82 | 9.74 | 257.7 | 287.1 | 332.67 | 212.17 |
| Gemmeiza 12 | 17.9 | 19.2 | 19.98 | 17.13 | 3.3 | 1.7 | 2.88 | 2.10 | 10.3 | 10.8 | 11.23 | 9.87 | 275 | 292 | 334.17 | 232.83 |
| Misr 1 | 18.5 | 17.3 | 20.43 | 15.37 | 1.9 | 1.1 | 1.20 | 1.77 | 10.8 | 10.8 | 11.27 | 10.31 | 300 | 282.5 | 338.83 | 243.67 |
| Line 1 | 19.8 | 16.2 | 19.10 | 16.90 | 1.5 | 1.3 | 1.37 | 1.45 | 11.0 | 11.1 | 10.65 | 11.43 | 252.8 | 262.8 | 305.00 | 210.67 |
| Line 2 | 18.0 | 16.9 | 19.17 | 15.74 | 2.1 | 1.3 | 2.16 | 1.23 | 9.3 | 9.1 | 9.70 | 8.68 | 258.8 | 255.3 | 315.00 | 199.17 |
| Line 3 | 19.8 | 20.8 | 22.47 | 18.13 | 2.1 | 1.4 | 1.90 | 1.60 | 11.0 | 12.4 | 12.63 | 10.75 | 353 | 285.5 | 343.83 | 294.67 |
| Line 4 | 16.7 | 18.5 | 19.00 | 16.13 | 2.1 | 1 | 1.81 | 1.33 | 9.4 | 9.6 | 9.84 | 9.14 | 266.7 | 267.3 | 305.00 | 229.00 |
| Line 5 | 18.2 | 17.9 | 19.20 | 17.00 | 2.08 | 1.2 | 1.95 | 1.33 | 10.3 | 10.3 | 10.85 | 9.72 | 252.8 | 277.5 | 313.17 | 217.17 |
| Mean | 18.28 | 18.17 | 19.80 | 16.66 | 2.06 | 1.28 | 1.84 | 1.49 | 10.3 | 10.6 | 10.87 | 9.95 | 277.1 | 276.3 | 323.46 | 229.916 |
| GxS | * | * | * | * | NS | * | * | * | * | * | * | * | * | NS | * | * |
| $LSD_{0.05}$ | 1.45 | 1.94 | 1.27 | 0.99 | 0.67 | 0.55 | 0.20 | 0.29 | 0.81 | 0.91 | 0.64 | 0.41 | 20.4 | 20.1 | 7.68 | 6.21 |

**Table 4. Mean performance of eight wheat genotypes for number of grains /spike, 1000-grain weight and Grain yield/fad. under two sowing dates during both seasons and combined analysis (the same sowing dates over the two seasons).**

| Characters | Number of grains /spike | | | | 1000-grain weight (gm) | | | | Grain yield (ard./fad.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seasons | | Combined data over two seasons | | Seasons | | Combined data over two seasons | | Season | | Combined data over two seasons | |
| Genotypes | 1st season | 2nd season | 1st sowing date | 2nd sowing date | 1st season | 2nd season | 1st sowing date | 2nd sowing date | 1st season | 2nd season | 1st sowing date | 2nd sowing date |
| Sids 12 | 47.9 | 46.167 | 48.80 | 45.30 | 41.433 | 48.533 | 45.900 | 44.07 | 19.942 | 18.371 | 20.094 | 18.371 |
| Gemmeiza 12 | 48.58 | 43.767 | 50.66 | 41.68 | 44.8 | 46.15 | 47.167 | 43.78 | 18.371 | 12.847 | 21.168 | 12.847 |
| Misr 1 | 53.5 | 50.5 | 56.33 | 47.67 | 45.567 | 47.55 | 49.100 | 44.02 | 17.524 | 11.267 | 23.701 | 11.267 |
| Line 1 | 49.17 | 42.667 | 49.50 | 42.33 | 43.617 | 46.667 | 46.683 | 43.60 | 14.309 | 9.467 | 17.808 | 9.467 |
| Line 2 | 50.55 | 45.85 | 50.50 | 45.90 | 42.933 | 44.167 | 45.650 | 41.45 | 14.727 | 10.920 | 17.361 | 10.920 |
| Line 3 | 55.2 | 53.783 | 59.15 | 49.83 | 48.867 | 45.333 | 50.367 | 43.83 | 23.287 | 18.538 | 25.667 | 18.538 |
| Line 4 | 49.43 | 43.733 | 50.35 | 42.82 | 47.6 | 44 | 45.167 | 44.27 | 16.706 | 12.789 | 18.375 | 12.789 |
| Line 5 | 51.13 | 45.453 | 51.49 | 45.12 | 44.083 | 41.833 | 45.967 | 42.12 | 16.865 | 11.456 | 19.188 | 11.456 |
| Mean | 50.68 | 46.49 | 52.10 | 45.08 | 44.86 | 45.53 | 47.000 | 43.39 | 17.72 | 13.21 | 20.420 | 13.207 |
| GxS | * | * | * | * | * | * | * | * | * | * | * | * |
| $LSD_{0.05}$ | 2.52 | 2.48 | 1.2 | 1.92 | 2.58 | 1.43 | 0.89 | 1.46 | 2.36 | 1.34 | 1.44 | 1.39 |

High estimates of the (PCV) and (GCV) were detected for number of spikes/$m^2$ (208.31 and 189.59) and (90.38 and 85.11); grain yield (101.73 and 89.67) and (67.85 and 63.68); flag leaf area (48.25 and 42.69) and (64.64 and 62.2) in 2nd sowing date and 1st one, respectively. Whereas, moderate values of the (PCV) and (GCV) were observed for number of grains/spike (51.4 and 50.18) and (44.68 and 39.73); chlorophyll content (36.65 and 35.75) and (38.72 and 33.72) ) in 1st sowing date and 2nd one, respectively and plant height (37.67 and 36.04) in 1st sowing date only. Moreover, low estimates of the (PCV) and (GCV) were showed for number of fertile spikelets/spike (31.63 and 24.18) and (25.78 and 19.09); spike length (30.02 and 26.65) and (30.47 and 26.12) and 1000-grain weight (27.69 and 26.08) and (20.66 and 12.33) in 1st sowing date and 2nd one, respectively. Similar results were reported by Ghallab *et al.* (2016) where the estimates of PCV and GCV were high for number of spikes/$m^2$.

The highest heritability estimates were detected for number of grains/spike (95.3%), flag leaf area (92.59%), plant height (91.52 %), 1000-grain wheat (88.72%),grain yield (ard./fad.) (88.68%), number of spikes/$m^2$ (88.66 %) and spike length (78.81 %) under the 1st sowing dates. While under the 2nd one the highest heritability were observed for plant height (89.46%), number of spikes/ $m^2$ (82.83%), number of grains/spike (79.73%), flag leaf area (78.29%), grain yield (ard./fad.) (77.70%), chlorophyll content (76.76%) and spike length (73.45%).Moderate heritability estimates were detected for number of fertile spikelets/spike under the two sowing dates. Low estimates of heritability were detected for 1000 grain weight under the 2nd sowing date only. High heritability values for these traits indicated that the variation observed was mainly under genetic control and was less affected by the environment and the possibility of progress from selection. Also high heritability values for yield and its component were found (Singh *et al.,* 2014; Yahaya *et al.,* 2014;Ghuttai*et al.,* 2015;Tripathi*et al.,* 2015 and Sharaan *et al.,* 2017).

Genetic advance ranged were 7.21 and 10.03 for plant height, 7.81and 4.11 for flag leaf area, 4.99 and 4.22 for chlorophyll content, 1.69 and 1.19 for number of fertile spikelets/spike, 1.6 and 1.45 for spike length, 29.72 and 53.97 for number of spikes/ m2, 7.29 and 4.89 for number of grains / spike, 3.47 and 1.07 for 1000 grain weight and 5.6 and 5.92 for grain yield under 1st sowing date and 2nd one, respectively. Similarly, Ghallab *et al.*(2016) observed high value of genetic advance for number of spikes/plant, plant height and 1000-grain weight.

**Table 5. Variance, phenotypic (PCV) and genotypic (GCV) coefficients of variability, broad sense heritability( $h^2_b$) and genetic advance (GA) for the yield and yield components of bread wheat genotypes over two sowing dates.**

| Characters | Plant height (cm) | | Flag leaf area (cm2) | | Chlorophyll content(SPAD reading) | | Number of fertile spikelets/spike | | Number of sterile spikelets/spike | |
|---|---|---|---|---|---|---|---|---|---|---|
| Genetic parameters | 1st sowing date | 2nd sowing date | 1st sowing date | 2nd sowing date | 1st sowing date | 2nd sowing date | 1st sowing date | 2nd sowing date | 1st sowing date | 2nd sowing date |
| Phenotypic Variance ($\sigma^2$p) | 14.6 | 29.57 | 16.76 | 6.46 | 6.49 | 7.11 | 1.98 | 1.11 | 0.3 | 0.14 |
| Genotypic Variance ($\sigma^2$g) | 13.36 | 26.45 | 15.51 | 5.06 | 6.17 | 4.46 | 1.16 | 0.61 | 0.27 | 0.09 |
| Environmental Variance ( $\sigma^2$e) | 1.24 | 3.11 | 1.24 | 1.4 | 0.32 | 1.65 | 0.82 | 0.5 | 0.02 | 0.05 |
| PCV (%) | 37.67 | 56.19 | 64.64 | 48.25 | 36.65 | 38.72 | 31.63 | 25.78 | 40.01 | 30.14 |
| GCV (%) | 36.04 | 53.14 | 62.2 | 42.69 | 35.75 | 33.72 | 24.18 | 19.09 | 38.01 | 24.9 |
| $h^2_b$ (%) | 91.52 | 89.46 | 92.59 | 78.29 | 95.1 | 76.76 | 58.42 | 54.84 | 92.86 | 68.28 |
| GA | 7.21 | 10.03 | 7.81 | 4.11 | 4.99 | 4.22 | 1.69 | 1.19 | 0.52 | 0.52 |

**Table 5.cont.**

| Characters | Spike length (cm) | | Number of spikes /$m^2$ | | Number of grains /spike | | 1000 grain weight(gm) | | Grain yield (ard./fad.) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Genetic parameters | 1st sowing date | 2nd sowing date | 1st sowing date | 2nd sowing date | 1st sowing date | 2nd sowing date | 1st sowing date | 2nd sowing date | 1st sowing date | 2nd sowing date |
| Phenotypic Variance ($\sigma^2$p) | 0.98 | 0.92 | 265.24 | 997.8 | 13.77 | 9 | 3.6 | 1.78 | 9.4 | 10.62 |
| Genotypic Variance ($\sigma^2$g) | 0.77 | 0.68 | 234.25 | 826.46 | 13.12 | 7.12 | 3.2 | 0.7 | 8.34 | 13.67 |
| Environmental Variance ( $\sigma^2$e) | 0.21 | 0.25 | 29.96 | 171.22 | 0.65 | 1.88 | 0.41 | 10.9 | 1.06 | 3.05 |
| PCV (%) | 30.02 | 30.47 | 90.38 | 208.31 | 51.4 | 44.68 | 27.69 | 20.26 | 67.85 | 101.73 |
| GCV (%) | 26.65 | 26.12 | 85.11 | 189.59 | 50.18 | 39.73 | 26.08 | 12.66 | 63.68 | 89.67 |
| $h^2_b$ (%) | 78.81 | 73.45 | 88.66 | 82.83 | 95.3 | 79.73 | 88.72 | 39.04 | 88.68 | 77.70 |
| GA | 1.6 | 1.45 | 29.72 | 53.97 | 7.29 | 4.89 | 3.47 | 1.07 | 5.6 | 5.92 |

**Table 6. Phenotypic correlation ($r_p$) (upper diagonal) and genotypic correlation ($r_g$) (lower diagonal) coefficients among yield and its component in breed wheat for combined of 1st sowing date over the two seasons.**

| Genotypic correlation / Phenotypic correlation | Plant height (cm) | Flag leaf area ($cm^2$) | Chlorophyll content(SPAD reading) | Spike length (cm) | Number of fertile spikelets/spike | Number of sterile spikelets/spike | Number of spikes /$m^2$ | Number of grains /spike | 1000 grain weight(gm) | Grain yield (ard./fad.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | 1 | 0.79* | -0.24 | 0.53 | 0.76* | 0.21 | 0.68* | 0.53 | 0.6* | 0.67* |
| Flag leaf area ($cm^2$) | 0.74* | 1 | -0.25 | 0.16 | 0.45 | -0.25 | 0.34 | 0.44 | 0.35 | 0.46 |
| Chlorophyll content(SPAD reading) | -0.2 | -0.21 | 1 | 0.27 | 0.22 | -0.1 | -0.34 | 0.26 | 0.22 | 0.08 |
| Spike length (cm) | 0.43 | 0.15 | 0.25 | 1 | 0.99** | 0.03 | 0.85** | 0.81** | 0.98** | 0.94** |
| Number of fertile spikelets/spike | 0.6* | 0.39 | 0.16 | 0.75* | 1 | 0.03 | 0.83** | 0.99** | 0.99** | 0.99** |
| Number of sterile spikelets/spike | 0.19 | -0.26 | -0.09 | -0.04 | 0.1 | 1 | 0.08 | -0.14 | -0.37 | -0.05 |
| Number of spikes /m2 | 0.63* | 0.36 | -0.3 | 0.67 | 0.64* | 0.08 | 1 | 0.68* | 0.8** | 0.93** |
| Number of grains /spike | 0.51 | 0.43 | 0.26 | 0.71* | 0.79** | -0.15 | 0.61* | 1 | 0.94** | 0.91** |
| 1000- grain weight(gm) | 0.58 | 0.34 | 0.23 | 0.75* | 0.74* | -0.2 | 0.72* | 0.88** | 1 | 0.96** |
| Grain yield (ard./fad.) | 0.65* | 0.43 | 0.08 | 0.84** | 0.78** | -0.05 | 0.81** | 0.86** | 0.88** | 1 |

**Table 7. Phenotypic correlation ($r_p$) (upper diagonal) and genotypic correlation ($r_g$) (lower diagonal) coefficients among yield and its component in breed wheat for combined of 2nd sowing date over the two seasons.**

| Genotypic correlation / Phenotypic correlation | Plant height (cm) | Flag leaf area ($cm^2$) | Chlorophyll content(SPAD reading) | Spike length (cm) | Number of fertile spikelets/ spike | Number of sterile spikelets/spike | Number of spikes /$m^2$ | Number of grains /spike | 1000 grain weight(gm) | Grain yield (ard./fad.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | 1 | 0.2 | -0.27 | 0.77* | 0.21 | 0.82** | 0.43 | -0.15 | 0.98** | 0.2 |
| Flag leaf area ($cm^2$) | 0.17 | 1 | 0.56 | 0.48 | 0.67* | -0.02 | 0.79** | 0.28 | 0.56 | 0.6* |
| Chlorophyll content(SPAD reading) | -0.24 | 0.5 | 1 | 0.41 | 0.4 | -0.17 | 0.04 | -0.12 | -0.35 | -0.09 |
| Spike length (cm) | 0.55 | 0.4 | 0.24 | 1 | 0.59* | -0.33 | 0.5 | 0.14 | 0.6 | 0.03 |
| Number of fertile spikelets / spike | 0.16 | 0.62* | 0.32 | 0.3 | 1 | 0.28 | 0.59* | 0.01 | 0.19 | 0.67* |
| Number of sterile spikelets/ spike | 0.64* | -0.12 | -0.34 | -0.34 | -0.06 | 1 | 0.56 | -0.07 | 0.56 | -0.15 |
| Number of spikes /m2 | 0.41 | 0.6 | 0.13 | 0.27 | 0.42 | 0.29 | 1 | 0.66* | 0.54 | 0.58* |
| Number of grains /spike | -0.12 | 0.27 | -0.05 | 0.03 | 0.25 | -0.16 | 0.5 | 1 | -0.08 | 0.51 |
| 1000- grain weight(gm) | 0.53 | 0.49 | -0.05 | 0.28 | 0.16 | 0.06 | 0.38 | -0.09 | 1 | 0.55 |
| Grain yield (ard./fad.) | 0.17 | 0.39 | -0.23 | -0.06 | 0.48 | -0.16 | 0.5 | 0.44 | 0.27 | 1 |

**Heat stress tolerance measurements:**

Heat stress tolerance measurements were calculated for determining the stress tolerant wheat genotypes based on minimization of yield, losses at late sowing date compared to favorable sowing one (optimum). Data of heat stress tolerance measurements Table (8) indicate that, wheat genotypes with high estimates of relative performance (P) such as Sids 12, Line 3 and Line 4 yielded less different estimates tolerance index (ToL) between yield under late sowing date (YS) and yield under optimum sowing one (YP) and coupled with heat sensitivity index (HSI), where higher estimates of HSI (>1) reavaled a higher degree of sensitivity to heat stress for genotypes and vice versa.

The results of (P) and (ToL) are joined with (HSI) and showed that Sids 12 was in the first order (1.414) in sensitivity to heat stress followed by Line 3 (1.117) while Line 4 was moderate (1.0761). The results of heat tolerance measurements coupled with yield attributes characters, so Sids 12, Line 3 and Line 4 had low to moderate values of yield contributing characters under stress conditions. The remaining wheat genotypes Gemmeiza 12, Misr 1 , Line 1, Line 2 and Line 5 appeared to be more tolerant to heat stress as they recorded H.S.I less than unity, these genotypes had in general high values of yield attributes.

**Genotypic and phenotypic correlations**

Phenotypic and genotypic correlation coefficients among studied with other characters under 1st sowing date are showed in Table (6). The genotypic correlation coefficient values for most of the characters were higher in magnitude than the corresponding phenotypic one under the two sowing dates, indicating that association among these characters was largely under genetic control and indicated the superiority of genetic variance in expression of characters. Similar conclusion was obtained by Tripathi *et al.* (2015).

**Table 8. Heat stress tolerance measurements of grain yield for eight bread wheat genotypes**

| Genotypes | Tolerance index (Tol) | Heat sensitivity index (HSI) | Relative performance (P) |
|---|---|---|---|
| Sids 12 | 1.723 | 1.45 | 1.414 |
| Gemmeiza 12 | 8.321 | 0.936 | 0.938 |
| Misr 1 | 12.434 | 0.725 | 0.735 |
| Line 1 | 8.341 | 0.795 | 0.822 |
| Line 2 | 6.441 | 0.956 | 0.973 |
| Line 3 | 7.129 | 1.143 | 1.117 |
| Line 4 | 5.586 | 1.073 | 1.0761 |
| Line 5 | 7.732 | 0.912 | 0.923 |

In respect with the normal sowing date, grain yield showed positive correlation with plant height (0.65* and 0.67*), spike length (0.84** and 0.94**), number of fertile spikelets/spike (0.78** and 0.99**), number of spikes / $m^2$ (0.81** and 0.93**), number of grains /spike (0.86** and 0.91**) and 1000 grain weight (0.88** and 0.96**) at both phenotypic and genotypic levels, respectively.

Plant height exhibited positive significant phenotypic and genotypic association with flag leaf area (0.74* and 0.79*), number of fertile spikelets/spike (0.6* and 0.76*), number of spikes /$m^2$ (0.63* and 0.68*), respectively, while 1000 grain weight was associated in a positive and significant manner in genotypic association and was positive non- significant in phenotypic association.

Spike length showed positive and significant phenotypic and genotypic correlation with number of fertile spikelets/spike (0.75* and 0.99**), number of grains /spike (0.71*and 0.81**) and 1000 grain weight (0.75* and 0.98**) for 1st and 2nd sowing dates, respectively, while number of spikes/$m^2$ was associated in a positive and significant manner in genotypic correlation and was positive non- significant in phenotypic association.

Number of fertile spikelets/spike showed positive significant phenotypic and genotypic association with number of spikes /$m^2$ (0.64* and 0.83**), number of grains /spike (0.79** and 0.99**) and 1000 grain weight (0.74* and 0.99**), respectively.

Number of spikes /$m^2$ exhibited positive significant phenotypic and genotypic association with number of grains /spike (0.61*and 0.68*) and 1000 grain weight (0.72* and 0.8**), respectively.

Number of grains /spike exhibited positive significant phenotypic and genotypic association with 1000 grain weight (0.88**and 0.94**), respectively. Similar results of positive association of seed yield t with number of spikes/$m^2$, 1000 grains weight, spike length and number of grains / spike were observed by (Azimi *et al.,* 2017). The study of correlation among yield and yield contributing traits suggests that spike length, number of fertile spikelets/spike, number of spikes /$m^2$, number of grains /spike and 1000-grain weight were the most important characters which showed positive correlation with grain yield. Therefore, these traits could be used in breeding program as a selection criteria to improve cultivars with high grain yield.

It is evident that, in the late sowing date, there were positive significant phenotypic and genotypic correlation between flag leaf area and number of fertile spikelets/spike. Positive significant genotypic correlation was detected between grain yield and each of flag leaf area, number of fertile spikelets/spike and number of spikes/ $m^2$; plant height and each of spike length, number of sterile spikelets/spike and 1000 grain weight; flag leaf area and number of spikes; spike length and number of fertile spikelets/spike; number of fertile spikelets/spike and number of spikes and number of spikes /$m^2$ and number of grains /spike.

**Path coefficient analysis**

Genotypic path coefficient values of all the traits with grain yield in the 1st sowing date are show in Table (9). Maximum positive direct effect on grain yield was contributed greatly by 1000 grain weight (1.104), followed by number of grains / spike (0.626) and number of spikes / $m^2$ (0.352). This means that a slight increase in one of these traits may directly contribute to grain yield. On the other hand, the maximum negative direct effect was exhibited by chlorophyll content (-0.284), followed by flag leaf area (-0.187) and number of sterile spikelets / spike (-0.104).

The highest positive indirect effects on wheat grain yield were detected by number of fertile spikelets/spike (1.093) followed by spike length (1.082), number of grains/spike (0.883) and plant height (0.662) via 100 grain weight, respectively. Also, number of sterile spikelets/spike (0.620), 100 grain weight (0.588) and spike length (0.507) via number of grains/ spike, respectively. Flag leaf area also had a cognizable indirect effect (0.386) via 1000-grain weight, number of grains /spike (0.275) and plant height (0.282). Chlorophyll content showed indirect effect via 1000-grain weight with moderate contribution (0.243).

Spike length showed indirect effect via number of fertile spikelets/spike (0.279) and number of spikes/$m^2$ (0.299).moreover, number of spikes/$m^2$ had great indirect effect via number of grains/spike (0.426). whereas, spike length, number of spikes /$m^2$ and number of fertile spikelets /spike had considerable indirect effects (0.190), (0.239) and (0.279) via number of grains /spike, respectively.

Genotypic path coefficient values of all the traits with grain yield in the 2nd sowing date are showed at (Table 10). Maximum positive direct effect on grain yield was contributed greatly by 1000 grain weight (1.087), followed by number of spikes / $m^2$ (0.638),number of grains / spike (0.634),number of fertile spikelets/spike (0474) and spike length (0.464). This means that a slight increase in one of these traits may directly contribute to grain yield. There was appreciable positive direct effect on grain from chlorophyll content (0.241) and flag leaf area (0.169).On the other hand, negative direct effect was exhibited by number of sterile spikelets / spike (-0.086)

**Table 9. Genotypic path coefficient analysis of nine characters on grain yield (ard./ fad.) in wheat (combined of 1st sowing date over the two years)**

| Characters | Plant height (cm) | Flag leaf area (cm2) | Chlorophyll content (SPAD reading) | Spike length (cm) | Number of fertile spikelets/spike | Number of sterile spikelets/spike | Number of spikes /$m^2$ | Number of grains /spike | 1000- grain weight(gm) |
|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | 0.357 | -0.148 | 0.068 | 0.124 | 0.214 | -0.022 | 0.239 | 0.332 | 0.662 |
| Flag leaf area($cm^2$) | 0.282 | -0.187 | 0.071 | 0.037 | 0.127 | 0.026 | 0.120 | 0.275 | 0.386 |
| Chlorophyll content (SPAD reading) | -0.086 | 0.047 | -0.284 | 0.063 | 0.062 | 0.010 | -0.120 | 0.163 | 0.243 |
| Spike length (cm) | 0.189 | -0.030 | -0.077 | 0.234 | 0.279 | -0.003 | 0.299 | 0.507 | 1.082 |
| Number of fertile spikelets/spike | 0.271 | -0.084 | -0.062 | 0.232 | 0.282 | -0.003 | 0.292 | 0.620 | 1.093 |
| Number of sterile spikelets/spike | 0.075 | 0.047 | 0.028 | 0.007 | 0.008 | -0.104 | 0.028 | -0.088 | -0.408 |
| Number of spikes / m2 | 0.243 | -0.064 | 0.097 | 0.199 | 0.234 | -0.008 | 0.352 | 0.426 | 0.883 |
| Number of grains / spike | 0.189 | -0.082 | -0.074 | 0.190 | 0.279 | 0.015 | 0.239 | 0.626 | 1.038 |
| 1000-grain weight (gm) | 0.214 | -0.065 | -0.062 | 0.229 | 0.279 | 0.038 | 0.282 | 0.588 | 1.104 |

**Table 10 Genotypic path coefficient analysis of nine characters on grain yield (ard./ fad.) in wheat (combined of 2nd sowing date over the two years)**

| Characters | Plant height (cm) | Flag leaf area (cm2) | Chlorophyll content | Spike length (cm) | Number of fertile spikelets/ spike | Number of sterile spikelets/ spike | Number of spikes /$m^2$ | Number of grains /spike | 1000 grain weight(gm) |
|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | 0.014 | 0.034 | -0.065 | 0.358 | 0.100 | 0.071 | 0.275 | -0.095 | 1.065 |
| Flag leaf area ($cm^2$) | 0.003 | 0.169 | 0.135 | 0.223 | 0.318 | 0.002 | 0.504 | 0.178 | 0.609 |
| Chlorophyll content | -0.004 | 0.095 | 0.241 | 0.190 | 0.190 | 0.015 | 0.026 | -0.076 | -0.380 |
| Spike length (cm) | 0.011 | 0.081 | 0.099 | 0.464 | 0.280 | 0.029 | 0.319 | 0.089 | 0.652 |
| Number of fertile spikelets/spike | 0.003 | 0.113 | 0.096 | 0.274 | 0.474 | -0.024 | 0.377 | 0.006 | 0.206 |
| Number of sterile spikelets/spike | -0.012 | -0.003 | -0.041 | -0.153 | 0.133 | -0.086 | 0.358 | -0.044 | 0.609 |
| Number of spikes /m2 | 0.006 | 0.134 | 0.010 | 0.232 | 0.280 | -0.048 | 0.638 | 0.419 | 0.587 |
| Number of grains /spike | -0.002 | 0.047 | -0.029 | 0.065 | 0.005 | 0.006 | 0.421 | 0.634 | -0.087 |
| 1000 grain weight(gm) | 0.014 | 0.095 | -0.084 | 0.279 | 0.090 | -0.048 | 0.345 | -0.051 | 1.087 |

The highest positive indirect effects were detected by plant height (1.065), Spike length (0.652), number of sterile spikelts/spike (0.609), flag leaf area (0.609) and number of spikes / $m^2$ (0.587) via 100 grain weight, respectively. Also, number of spikes / $m^2$ (0.419) via number of grains/ spike. Flag leaf area also had a cognizable indirect effect (0.504) via number of grains / spike and number of fertile spikelets/spike(0.318). Chlorophyll content showed indirect effect via spike length and number of fertile spikelets / spike (0.190). Spike length showed indirect effect via number of fertile spikelets /spike (0.280) and number of spikes /$m^2$ (0.319).Also, number of fertile spikelets/spike had a cognizable indirect effect via number of spikes / $m^2$ (0.377) and spike length (0.274). Also, Spike length (cm), number of fertile spikelets/spike and flag leaf area had considerable indirect effects (0.232), (0.280) and (0.134) via number of spikes / $m^2$, respectively.

It could be concluded that 1000-grain weight, number of grains /spike, number of spikes /$m^2$, number of fertile spikelets /spike, and spike length appeared to contribute to the grain yield (ard./fad.). Therefore, indirect selection for these traits may be effective for improving grain yield of wheat.

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## الاختلافات الوراثية، الارتباط وتحليل معامل المرور للمحصول ومكوناته فى بعض التراكيب الوراثية لقمح الخبز

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أقيمت تجربتان حقليتان خلال الموسمين الزراعيين 2014 /2015 و 2016/2015 لدراسة الاختلافات الوراثية ومعاملى الارتباط المظهرى والوراثى وتحليل معامل المرور لمحصول الحبوب ومكوناته لثمانية تراكيب وراثية من قمح الخبز (سدس 12، جميزة 12، مصر 1، سلالة 1، سلالة 2، سلالة 3، سلالة 4 وسلالة 5) تحت ظروف ميعادين للزراعة (24 نوفمبر و25 ديسمبر). أشارت النتائج الى وجود اختلافات وراثية بين التراكيب الوراثية فى جميع الصفات تحت الدراسة، فيما عدا صفة محتوى الكلوروفيل تحت ظروف ميعادى الزراعة وصفة عدد السنابل/م$^2$ تحت الميعاد الثانى. تفوقت التراكيب الوراثية سلالة 3، سدس 12، مصر 1 وسلالة 4 تحت ميعادى الزراعة. سجلت صفة عدد السنابل/م$^2$ أعلى القيم لكل من التباين المظهرى والوراثى تحت ميعادى الزراعة. كانت أعلى القيم لنسبة الاختلافات المظهرية والوراثية (90.38 و 85.11%) و(208.31 و 189.89) لصفة عدد السنابل/م$^2$ , بينما كانت أقلها (24.69 و26.08%) و(20.26 و12.6%) لصفة وزن 1000 حبة تحت ميعادى الزراعة الأول والثانى، على التوالى.تراوحت قيم كفاءة التوريث من 58.42% لصفة عدد السنيبلات الخصبة/السنبلة إلى 95.3% لصفة عدد الحبوب/السنبلة فى الميعاد الأول، بينما تراوحت فى الميعاد الثانى من 39.04% لصفة وزن 1000 حبة إلى 89.46% لصفة إرتفاع النبات. سجل ارتباط موجب ومعنوى بين كمية محصول الحبوب وكل من صفات طول السنبلة، عدد السنيبلات الخصبة / السنبلة، عدد السنابل / م$^2$، عدد الحبوب / السنبلة ووزن 1000 حبة على المستويين المظهرى والوراثى.أوضحت نتائج تحليل معامل المرور أن أهم الصفات ذات التأثير المباشر على كمية المحصول كانت وزن 1000 حبة (1.104)، عدد الحبوب / السنبلة (0.626) وعدد السنابل / م$^2$ (0.352). ويتضح من هذه النتائج أن الانتخاب لأحد هذه الصفات يؤدى الى تحسين صفة كمية المحصول.