# MORPHO-BIOCHEMICAL AND MOLECULAR STUDIES ON WHEAT (*Triticum aestivum* L.) PLANTS FOR DROUGHT TOLERANCE

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**ABSTRACT:** Nine bread wheat (*Triticum aestivum* L.) varieties had been studied under drought stress conditions and compared with their pattern under normal conditions. Analysis of variance of the morphological traits revealed highly significant differences among both treatments and genotypes for most studied traits. The susceptibility test for drought tolerance revealed that the variety "Giza168" showed the highest statistical significant stability to drought stress and could be considered as tolerant variety for drought stress, while the variety "Gemmiza9" was the most susceptible variety to drought stress. According to the two way hierarchical cluster analysis, two main groups were formed. The first included drought tolerant to moderate tolerant varieties "Giza168", "Sakha93", "Gemmiza10", "Sids1" and "Shandawee1" while the second contained drought susceptible to moderate tolerant varieties "Sakha94", "Gemmiza9", "Gemmiza7" and "Gemmiza9". In the second way of the hierarchical clustering (traits clustering), the morphological traits were separated into four clusters. The SDS-PAGE results revealed that the variety "Giza168" is drought stress tolerant variety while the variety "Gemmiza9" is drought susceptible variety. The most two discriminate bands could be noted at molecular weight of 250 and 100 kDa for the tolerant varieties and 60 kDa for the susceptible varieties. According to the cluster analysis, the varieties under study could be differentiated to drought susceptible ("Sids1", "Gemmiza9" and "Sakha94") varieties, intermediate tolerant ("Gemmiza7", "Gemmiza10" and "Shandaweel1") varieties and tolerant ("Giza168", "Sahel1" and "Sakha93") varieties

**Key words:** *Wheat (Triticum aestivum L.)***,** *Drought Stress, Morphological Traits, SDS-PAGE, Grains Storage Protein*

## INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important and the most cultivated cereal crops. Its importance derived from many properties and uses of its grains as well as its straw, which make it a stable food for the world's population. In Egypt, the total production of wheat was about 10.4 million tons in 2013 produced from 3.21 million feddans (Egypt Grain and Feed Annual, 2013).

Drought is aserious environmental problem, which induces significant alterations in plant physiology and biochemistry. Some plants exhibit a number of physiological adaptations that allow them to tolerate water stress conditions. The degree of adaptation to the decrease in water potential caused by drought may vary considerably between species (Savé *et al.,* 1995) and also within species (Parker and Pallardy, 1985). Classification of Egyptian wheat varieties according to their drought tolerance has been carried out by some resspikechers (Shao *et al.,* 2008 and El-Afry *et al.,* 2012). Development of stress tolerant varieties is always a major objective of many breading programs but success has been limited by adequate screening techniques.

It is useful for the plant breader to determine the genetic relationships among the genotypes of the available breading material. The relationship between genotypes, according to Schut *et al.* (1997), is usually based on three sources of information: (1) geographic information about the origin of the genotypes, (2) pedigree information, and (3) information about plant characteristics. Among biochemical techniques SDS-PAGE is widely used due to its simplicity and effectiveness for describing the genetic structure of crop germplasm (Murphy *et al.,* 1990). The analysis of storage protein variation in wheat has proved to be a useful tool not only for diversity studies but also to optimize variation in germplasm collections (Ciaffi *et al.,* 1993).

The objectives of this study was to evaluate nine bread wheat (*Triticum aestivum* L.) varieties under different levels of drought stress and detect their response morphological and biochemical.

## MATERIAL AND METHODS

### 1. Plant material and morphological traits:

The present work was carried out at the Plant Molecular Biology Laboratory (PMBL), Genetic Engineering and Biotechnology Resspikech Institute (GEBRI), University of Sadat City, Minoufiya, Egypt, during the growing seasons 2013/2014 and 2014/2015. Nine bread wheat (*Triticum aestivum* L.) varieties (i.e. “Giza168”, “Sakha94”, “Gemmiza7”, “Gemmiza9”, “Gemmiza10”, “Sids1”, “Shandaweel1”, “Sahel1” and “Sakha93”) have been selected depending on their background concerning the drought tolerance, whereas they included susceptible (“Sakha94”, “Sahel1”, and “Gemmiza9”), medium tolerant (“Gemmiza7”, “Gemmiza10” and “Shandawel1”) and tolerant (“Giza168”, “Sids1” and “Sakha93”) varieties to drought stress. Grains of these cultivars were kindly obtained from Field Crops Resspikech Institute, ARC, Giza, Egypt. The pedigree, types and origins of the wheat cultivars are presented in Table (1).

Twenty eight wheat morphological traits of two replications during two growing season (2013/2014 and 2014/2015) were collected from the nine wheat cultivars under two different drought treatments through all plant growth period. The first treatment was the control whereas the plants were irrigated normally as it is recommended. The second treatment was the drought stressed treatment whereas the plants were irrigated only one time after germination. The collected traits included Angle of flag leaf to culmn, Angle of leaves to culmn, Grain shape, Grain brush length, Apical Rachis Hairiness of Convex Surface, Snap back, Lodging, Peduncle shape, Shape of flag leaf, Rigidity of leaves, Test weight (g/l), Lower glumes shoulder shape, Rigidity of flag leaf, Spike shape in profile, Spike shape at maturity, Lower glumes: External surface hairiness, Width of the second leaf from top (cm), Length of the second leaf from top (cm), Productive tillers, Non-productive tillers, Spike length (cm), Total spike length including awns (cm), Grain number per spike, Spike grain weight(grams), Spike weight (grams), Heading date (days), Plant height (cm) and Lower glumes shoulder width. Five measurements had been taken for each trait and then the average of each trait was calculated to be used for statistical analysis.

**Table 1: Origin and pedigree of wheat varieties used for molecular marker and morphological analyses.**

| NO | Varity | Origin | Pedigree |
|---|---|---|---|
| 1 | Gemmiza 10 | EGYPT | Maya74“S”/On//1160147/3/Bb/4/Chat”S” /5/ctow |
| 2 | Gemmiza 7 | EGYPT | 7CMH74A630/SX//SERI82/AGENT |
| 3 | Gemmiza 9 | EGYPT | ALD"s"/HUAC//CMH74A-630/SXCGM4583-56M-GM-0GM |
| 4 | Giza 168 | Mexico | MRL/BUC//SERICM93046-8M-0Y-0M-2Y-0B |
| 5 | Sids 1 | EGYPT | HD2172/PAVON"s"//115857/ MAYA 74 "S" SD46-5D-25D-15D-05D |
| 6 | Sakha 93 | EGYPT | SAKHA92/TR810328S88-71-1S-2S-0S |
| 7 | Sakha 94 | EGYPT | Sakha 92 / TR 810328 |
| 8 | Shandaweel-1 | EGYPT | SITELLA/MOCHIS-73/4/NACOZARI-76/AG.IN,var.acutum//3*PAVON-76/3/MIRLO/BUCKBUCK |
| 9 | Sahel-1 | EGYPT | NS-732/PIMA/(SIB)VEERY |

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## 2. Grain Storage Protein

Sodium Dodecyle Sulfate Polyacrylamide Gel Electrophoresis (SDS-PAGE) technique was used to study the protein banding patterns of nine bread wheat (*Triticum aestivum* L.) varieties. Grains of stressed bread wheat varieties (collected from the treatment irrigated only one time after germination in the field experiment) were used for the total grain storage protein extraction as well as the grains of the normal treatment according to the method of Laemmli, (1970). The protein patterns of stressed and non stressed bread wheat grains were compared.

## 3. Data Analysis

For morphological experiment, the bread wheat varieties had been evaluated in completely randomized design (CRD) then the collected data were subjected to analysis of variance (ANOVA) using SPSS 14 (Statistical Package for the Social Sciences), Snedecor and Cochran (1967). The means were compared by the Student's Least Significant Difference (LSD) value of the irrigation treatments and the genotypes at 5% probability level. An equation was used to calculate the susceptibility of the varieties to drought stress according to Fischer and Maurer (1978). as following Susceptibility coefficient =Σ (Treatment mean - Control mean)

The susceptibility result was tested using the Student's LSD values. The averages of the morphological traits were calculated for each variety (the averages of the two seasons and replications). The averages of the morphological data were used for constructing of two-way hierarchical analysis using JMP IN 7 software (Lehman *et al.,* 2005, SAS institute Inc.).

Protein gels were scored as 0/1 for the absence/presence of bands, respectively. Specific bands have been determined for specific varieties and correlation between the morphological traits and the biochemical markers has been made according to the specific protein bands. The similarity coefficient matrix was calculated using the simple matching algorithm, which was used to construct a dendrogram based on the Un-weighted Pair-Group Method with arithmetical algorithms Averages (UPGMA) method (Sneath and Sokal, 1973). The above mentioned analyses were performed using the NTSYS PC 2.0 (Rohlf 2000) software.

## RESULTS AND DISCUSSION

### 1. Morphological Traits

Analysis of variance of the morphological trait was carried out in order to detect the significant differences among the genotypes for all the morphological traits (Table 2). The data revealed highly significant differences among the treatments for all the studied traits except of days to heading trait. Moreover, all traits revealed highly significant differences among genotypes except of spike grain weight (g.), plant height (cm), spike length including awns (cm) and number of non-non-productive tillersin which no significant differences were obtained. Similarly, the interaction between genotypes and treatments was significant for all traits except of the number of non-non-productive tillers(Table 2). The obtained results are in agreement with the results reported by EL-Harty et al. (2008) where they studied the heterosis and genetic analysis of yield and some characteristics in nine bread wheat varieties (*Triticum aestivum* L.) (“Giza168”, “Sakha94”, “Gemmiza7”, “Gemmiza9”, “Gemmiza10”, “Sids1”, “Shandaweel1”, “Sahel1” and “Sakha93”). They studied the combining ability and genetic components for yield and its attributes.. The analysis of variance indicated highly significant differences among the varieties for all evaluated traits. According to the study of Deňcić et al. (2000), wheat present specific behavior due to its morphological traits during drought stress including leaf (shape, expansion, area, size, senescence, pubescence, waxiness, and cuticle tolerance) and root (dry weight, density, and length).

### 2. Least Significant Differences (LSD)

LSD values of genotypes showed that the variety “Sahel1” gave the highest significant mean in the most of the measured traits while the lowest significant mean was obtained from the variety “Shandaweel1” for the most of the measured traits (Table 4). The mean of the variety “Giza168” was placed at intermediate level for the most of the morphological traits. These means represented the ability of yield productivity and growth rate of each variety. However, high values of the traits are not indicator to drought tolerance. The susceptibility test proved that the variety “Giza168” was the most drought tolerant variety while the variety “Gemmiza9” was the most susceptible variety (Table 5).

The LSD values of the four treatments (e.g. Five irrigations, Four irrigations, Three irrigations, Two irrigations and One irrigation) showed that the treatments Four irrigations and Three irrigations were not significantly different from the control treatment (Five irrigations) for the following traits: Angle of flag leaf to culmn, productive tillers, number of non active tillers, and days to heading. Both treatments significantly surpassed the control in the traits leaves number and plant height (Table 3). The treatment Four irrigations significantly surpassed all the other treatments including the control in the length of the second leaf from top and rigidity of leaves traits. The control treatment (Five irrigations) gave the best significant response for the traits number of branches, while plant weight (g) and number of seeds per plant. On the other hand, treatment (One irrigation) produced the lowest response to drought stress for all the studied traits and significantly different from all other treatments. Moreover, no significant differences were obtained among the treatments for the heading date trait which

Table 2

Table 3

Table 4

Table 5

means that this trait did not affect by drought stress (Table 3). Leaves number, plant height (cm), number of productive tillers, plant weight (gm) and spike grain number significantly differed among the treatments and differentiated between the drought tolerant and susceptible varieties. These traits could be considered as morphological markers for drought stress response in bread wheat and proposed to be controlled by high gene number and have low heritability than the trait of heading date and consequently affected by the environmental stresses.

Shi *et al.* (2010) reported that drought stress affect on both vegetative and reproductive stages and therefore responses of plants to drought stress at both stages is crucial to progress in genetic engineering and plant breading. Rizza *et al.* (2004) observed that spikely maturity, small plant size, and reduced leaf area can be related to drought tolerance. On the other hand, Lonbani and Arzani (2011) claimed that the length and flag leaf area in wheat increased while the width of the flag leaf did not significantly change under drought stress. Mumtaz *et al.* (2014) reported that drought stress of wheat at vegetative stage was more drastically affected as compared to stress at reproductive stage.

## 3. Two-way hierarchical Cluster Analysis:

A two-way hierarchical cluster analysis was carried out using JMP IN 7 software for the nine wheat varieties and the 28 morphological traits. According to this analysis, the wheat varieties were separated into two main groups. The first cluster included the varieties “Giza168”, “Sakha93”, “Gemmiza10”, “Sids1” and “Shandawee1”. The second cluster containing the varieties “Sakha94”, “Gemmiza9”, “Gemmiza7” and “Gemmiza9” (Figure 1). Varieties in the first cluster are suggested to be drought tolerant to moderate tolerant varieties; while varieties in the second cluster are proposed to be drought susceptible to moderate tolerant varieties.

In the second way of the hierarchical clustering (traits clustering), the morphological traits were separated into four clusters. The first cluster included nine morphological traits while the second cluster contained eight morphological traits. The third cluster included five traits and the fourth cluster included six traits (Figure 1).

According to the morphological results, the variety “Giza168” was the most variety tolerant to the drought while the variety “Gemmiza9” was the most one susceptible to the drought.

## 4. Grain Storage Protein Pattern

In order to find out biochemical markers associated with the above findings, SDS-PAGE for the total grain storage protein of all varieties (control and drought stress treated) had been performed. through one-dimensional SDS-PAGE analysis. Optical differences were obtained between drought tolerant and susceptible wheat varieties. Positive protein markers were assigned to the tolerant varieties such as “Giza168” and “Sahel1”. At least two different protein bands (at molecular weight of 250 kDa and 100 kDa) have been assigned to the pattern of those varieties for example and not appspikeed in the pattern of susceptible varieties such as “Gemmiza9” (Figure 2). On the other hand, negative protein markers have been assigned to susceptible varieties such as “Gemmiza9” and “Sakha93”. In the pattern of those varieties for example, a protein band has been obtained at molecular weight of about 60 kDa and does not appspikeed in the pattern of the drought tolerant varieties (Figure 2).

The above findings prove that the variety “Giza168” is drought stress tolerant mean while the variety "Gemmiza9" is drought stress susceptible. The most two discriminate bands could be noted at molecular weight of 250 and 100 kDa for the tolerant varieties and 60 kDa for the susceptible varieties (Figure 2). Accordingly, the varieties under study could be differentiated to drought as: ("Sids1", "Gemmiza9" and "Sakha94"), susceptible and varieties as: ("Gemmiza7", "Gemmiza10" and "Shandaweel1") . intermediate tolerant and varieties as: ("Giza168", "Sahel1" and "Sakha93") tolerant. Robinson *et al.*, (1990) suggested that the disappspikeance of polypeptides during stress were compensated by the increased synthesis of others. Moreover, Parker *et al.*, (2000) reported that despite the reduction in protein levels under salt stress, the cells preferentially synthesized a few specific proteins that are termed stress proteins.

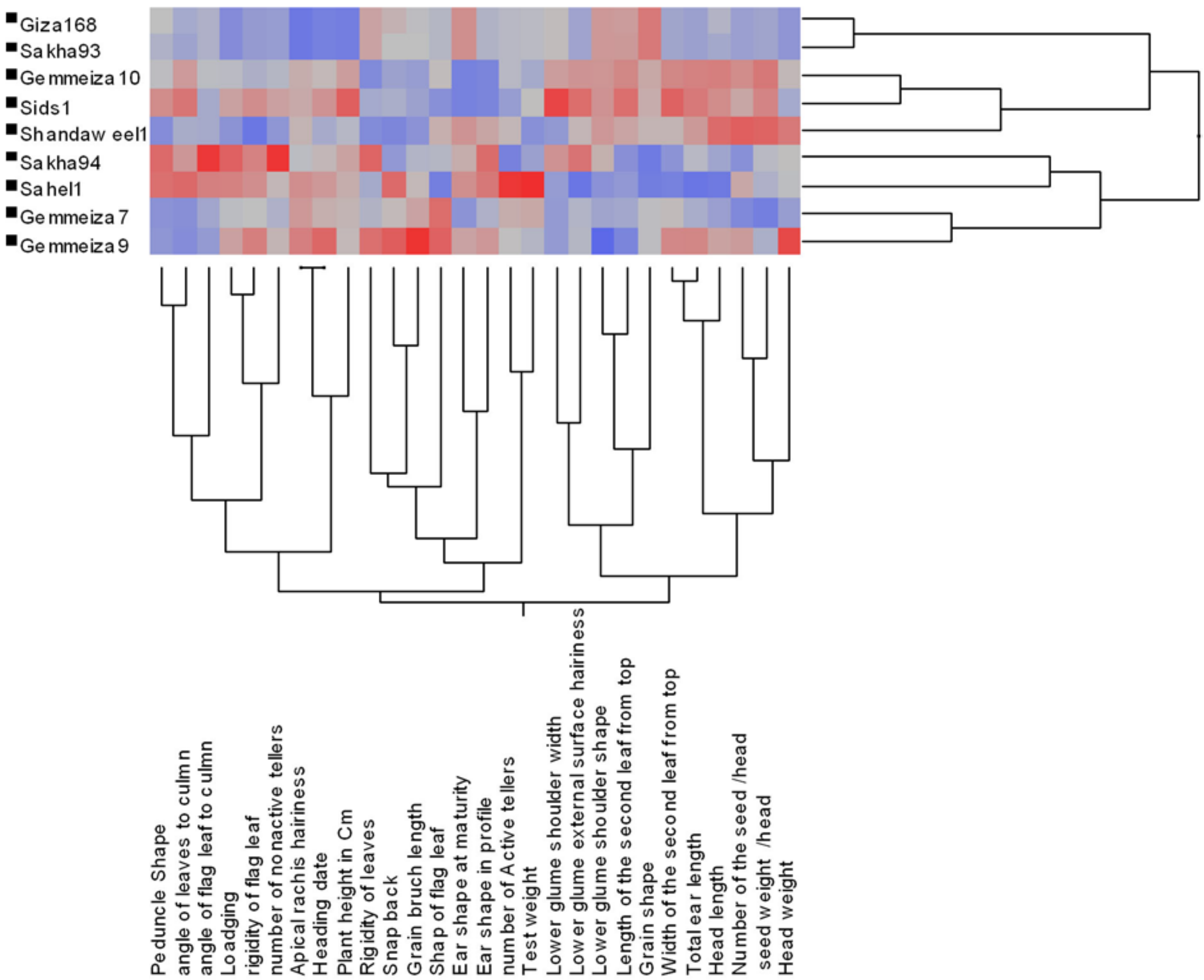


**Figure 1: Two-way hierarchical clustering of wheat varieties using Ward's method in JMP IN 7 software.**

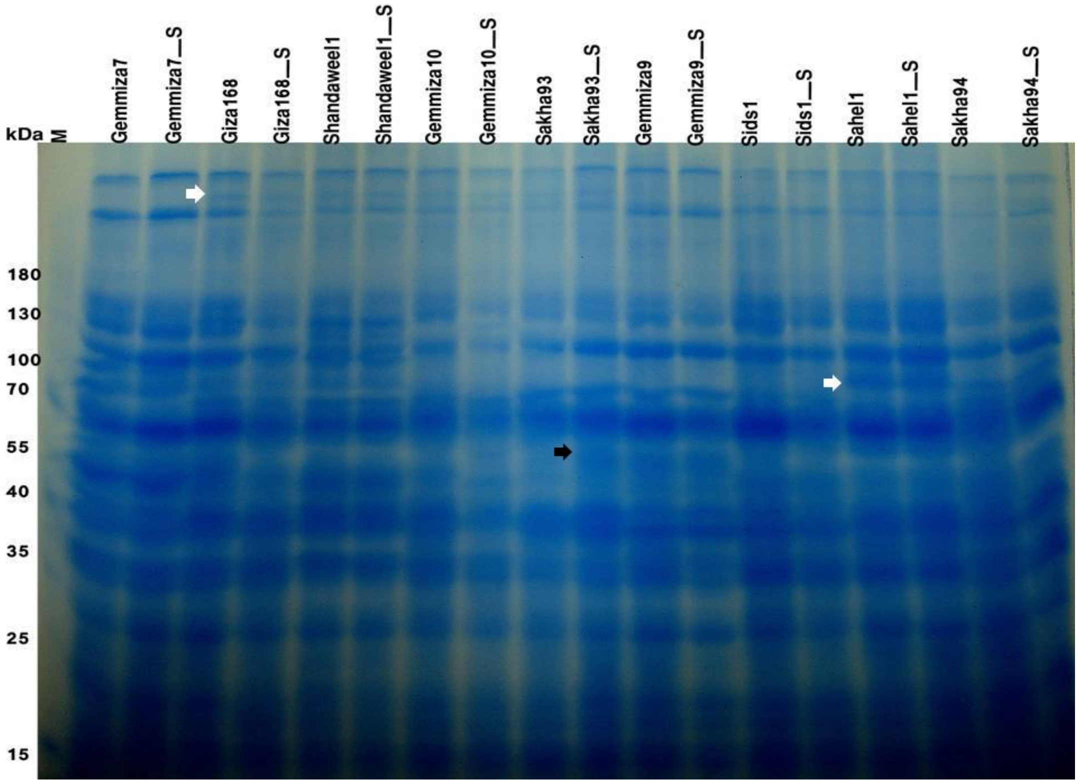


**Figure 2: SDS-PAGE protein pattern of nine drought stressed bread wheat varieties separated on 15% SDS-PAGE. The white arrows show positive protein markers and black arrow shows negative marker associated with drought tolerance.**

## 5. Cluster analysis:

According to cluster analysis, the studied wheat varieties were distributed into three groups. The middle group containing the varieties "Gemmiza7", "Gemmiza10" and "Shandaweel1" which were characterized by intermediate tolerance to drought stress (Figure 3). At the upper most of the dendrogram, the varieties "Giza168" and "Sahel1" came in the same cluster while "Sakha93" variety was separated apart from the other varieties. At the most lower part of the cluster, the varieties "Sids1" and "Sakha94" were aggregated while the variety "Gemmiza9" was separated apart from the other two varieties. The most related patterns (of the different treatments for the same variety) were assigned for "Giza168" and "Giza168_S", "Sakha94" and "Sakha94_S", "Gemmiza9" and "Gemmiza9_S" while most different ones were "Sids1" and "Sahel1" varieties (Figure 3). Thus the results of the cluster analysis support the results of the other experiments whereas the wheat varieties were separated in relation to their drought tolerance abilities. Similar results were found by. Parchin *et al.,* (2014) Compared protein pattern and drought tolerance in common wheat genotypes. They used SDS-PAGE as indicator for the stress response. And they reported that cluster analysis assigned the genotypes into three groups with High-yielding, moderate-yielding and low-yielding. The SDS-PAGE analysis showed that resistant genotype (Pishgam) has lower variation in the protein bands pattern but three sensitive genotypes have most variation in the protein bands pattern. In the contrary, Mumtaz and Ahmad., (2012) divided the wheat genotypes into drought susceptible ("Sids1", "Shandaweel1", and "Gemmiza10"), medium tolerant ("Gemmiza7", "Gemmiza9" and "Sakha94") and tolerant ("Giza168", "Sahel1" and "Sakha93") varieties.

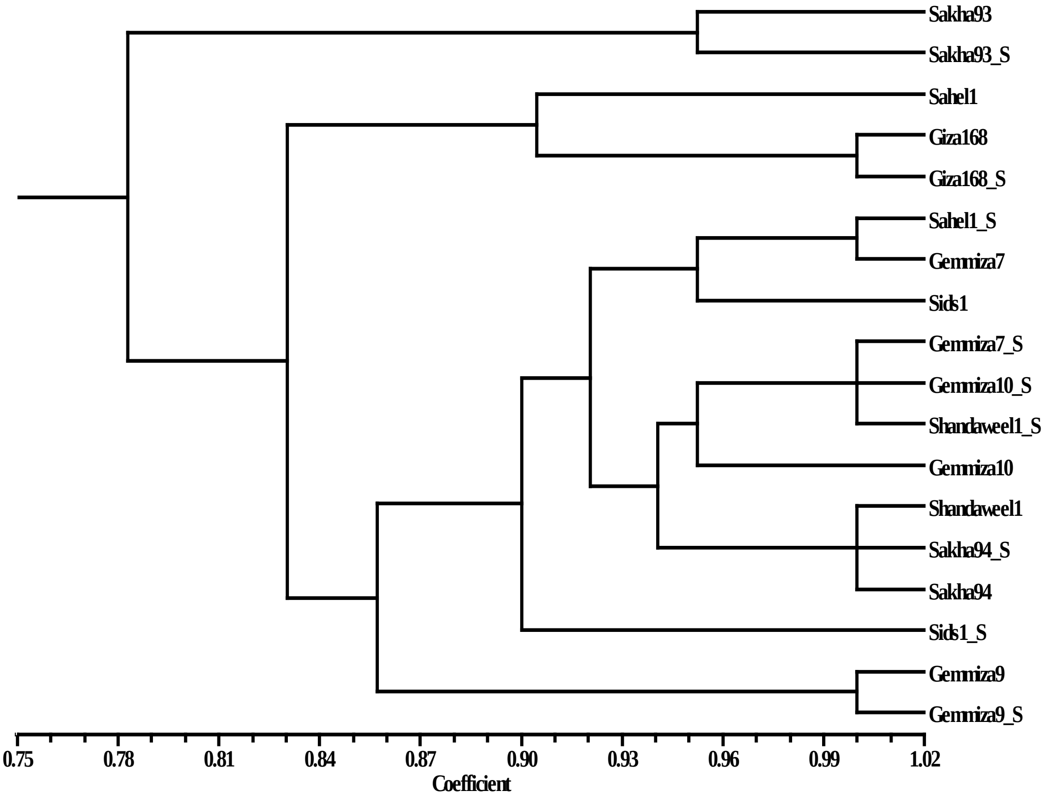


**Figure 3: Cluster analysis for nine bread wheat varieties. using the morphological traits and the UPGMA clustering method .**

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# دراسات مورفولوجية وبيوكيميائية وجزيئية على قمح الخبز لتحمل الجفاف

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## الملخص العربى

تم تقييم تسعة اصناف مصرية من قمح الخبز تحت مستويات مختلفة من الجفاف كما تمت دراسة أنماط البروتين المخزن في الحبوب في ظل ظروف إجهاد الجفاف ومقارنته مع نمطها في ظل الظروف الطبيعية.وذلك بإستخدام طريقة ال SDS–PAGE. وقد كشف اختبار تحليل التباين في الصفات المورفولوجية عن وجود اختلافات معنوية بين كل من المعاملات والتراكيب الوراثية المختلفة لمعظم الصفات المدروسة وقد أظهر الصنف جيزة ١٦٨ أعلى قدرة لتحمل الجفاف ، في حين أن الصنف" جميزة ٩" كان اقل الاصناف في تحمل الجفاف . ووفقا للتحليل العنقودي الهرمي ثنائي الإتجاهات، فقد تشكلت مجموعتين رئيسيتين شملت الأولي اصناف متحملة إلي متوسطة التحمل للجفاف "Giza168"، "Sakha93"، "Gemmiza10"، "Sids1"و "Shandawee1" بينما شملت الثانية الاصناف الحساسة الجفاف الى معتدلة "Sakha94"، "Gemmiza9"، "Gemmiza7"و "Gemmiza9". وفي الإتجاه الثاني (التحليل العنقودي للصفات)، تم فصل الصفات المورفولوجية إلى أربع مجموعات. وقد كشفت نتائج ال SDS–PAGE أن الصنف "Giza168" هو متحمل للجفاف في حين أن الصنف "Gemmiza9"هو حساس للجفاف وكذلك لوحظ وجود حزم من البروتين تميز الاصناف المتحملة للجفاف عند وزن جزيئي ٢٥٠ و ١٠٠ كيلو دالتون للأصناف المتحملة و ٦٠ كيلو دالتون للأصناف الحساسة .ووفقا للتحليل العنقودى لبيانات البروتين فقد تم تصنيف أصناف القمح قيد الدراسة إلي أصناف حساسة للجفاف وهي "Sids1" ، "Gemmiza9"و "Sakha94" وأصناف متوسطة التحمل للجفاف وهي "Gemmiza7" ، "Gemmiza10"و "Shandaweel1" وأصناف متحملة للجفاف وهي "Giza168" ، "Sahel1"و "Sakha93" . وبالتالي فإن نتائج التحليل العنقودي تدعم نتائج التجارب الأخرى في حين تم فصل أصناف القمح كل فيما يتعلق بقدرته علي تحمل الجفاف.

**Table 2: Combined analysis of variance for 28 wheat morphological traits from nine wheat genotypes under different drought stress treatments.**

| Source | DF | Peduncle Shape | Loadging | Apical rachis hairiness | angle of flag leaf to culmn | rigidity of flag leaf | angle of leaves to culmn | Rigidity of leaves | Spike shape at maturity | Snap back | Spike shape in profile | Shap of flag leaf | Lower glume | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | shoulder width | shoulder shape | surface hairiness |
| Genotype(G) | 8 | 239.5** | 441.6** | 298.1** | 320.0** | 472.9** | 555.1** | 511.0** | 62.8** | 596.7** | 450.7** | 8.2** | 479.1** | 103.1** | 391.5** |
| Treatment(T) | 4 | 153.6** | 889.8** | 341.5** | 501.3** | 126.0** | 756.3** | 367.5** | 88.0** | 205.1** | 201.8** | 57.5** | 410.9** | 100.1** | 345.8** |
| G*T | 32 | 27.3** | 378.6** | 65.2** | 183.7** | 67.2* | 101.4** | 155.2** | 62.5** | 90.8** | 123.9** | 10.5** | 120.0** | 9.3* | 80.4** |
| Error | 855 | 141.3 | 310.9 | 573.2 | 142.7 | 921.8 | 365.1 | 927.4 | 163.3 | 939.4 | 448.1 | 146.8 | 748.8 | 142.50 | 624.8 |
| Source | DF | productive tillers | non-productive tillers | Grain shape | Grain bruch length | Plant height in Cm | Heading date | Length of 2nd leaf from top | Width of 2nd leaf from top | Total spike length | Spike length | Grain number per spike | Spike weight | spike grain weight | Test weight |
| Genotype | 8 | 37.1** | 223.5* | 212.42** | 637.1** | 25530.8** | 7330.0** | 4311.3** | 19.6** | 947.2** | 374.9** | 12539.6** | 61.9** | 67.4** | 536954.1** |
| Treatment | 4 | 674.3** | 82.4 N.S | 453.1** | 285.4** | 101984.3 N.S | 22088.3** | 10747.3** | 40.9** | 5656.5 N.S | 1962.3** | 162989.0** | 746.9** | 471.7 N.S | 1216244.3** |
| G*T | 32 | 37.5** | 475.4 N.S | 90.6** | 83.2** | 3615.7** | 1309.6** | 5173.6** | 5.3** | 220.9** | 152.2** | 8498.7** | 38.0** | 21.0** | 140446.6** |
| Error | 855 | 245.5 | 11917.6 | 504.9 | 611.1 | 14218.0 | 5547.3 | 6630.0 | 11.6 | 790.4 | 433.9 | 47261.9 | 180.1 | 85.4 | 464802.6 |

***indicate significance at the 0.01 level of probability,   N.S: not significant*

**Table 3: Effect of irrigation treatment on traits under study of 28 wheat morphological traits from nine wheat genotypes.**

| Treatment | Peduncle Shape | Loadging | Apical rachis hairiness | angle of flag leaf to culmn | rigidity of flag leaf | angle of leaves to culmn | Rigidity of leaves | Spike shape at maturity | Snap back | Spike shape in profile | Shap of flag leaf | Lower glume | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | shoulder width | shoulde r width | shoulder width |
| 5 Irrigations | 1.28e | 3.62a | 7.05a | 5.46a | 5.19d | 6.18a | 4.11d | 2.05d | 3.89d | 1.68e | 1.83a | 5.78a | 2.78a | 4.23a |
| 4 Irrigations | 1.59d | 2.54b | 7.51b | 5.44a | 5.23cd | 5.47b | 4.68c | 2.29c | 4.62c | 1.92d | 1.58b | 5.29b | 2.57b | 4.81b |
| 3 Irrigations | 1.88c | 1.88c | 7.61c | 5.44a | 5.49bc | 4.71c | 4.8c | 2.48b | 4.72bc | 2.49c | 1.5bc | 4.81c | 2.37c | 4.93c |
| 2 Irrigations | 2.25b | 1d | 8.33c | 4.79b | 5.56b | 3.89d | 5.34b | 2.55b | 4.98b | 2.76b | 1.38c | 4.66c | 2.39c | 5.34c |
| 1 Irrigation | 2.41a | 1d | 8.78d | 3.53c | 6.22a | 3.78d | 6a | 3a | 5.33a | 2.99a | 1.06d | 3.77d | 1.78d | 6.1d |
| Treatment | producti ve tillers | non-producti ve tillers | Grain shape | Grain bruch length | Plant height in Cm | Heading date | Length of 2nd leaf from top | Width of 2nd leaf from top | Total spike length | Spike length | Grain number per spike | Spike weight | spike grain weight | Test weight |
| 5 Irrigations | 2.36a | 1.58a | 4.98a | 5.18a | 123.65a | 94.42a | 29.59a | 2.09a | 19.74a | 13.25a | 72.35a | 4.82a | 3.91a | 841.66a |
| 4 Irrigations | 2.32a | 1.64a | 4.76b | 4.6b | 118.5b | 93.72a | 27.14c | 1.87b | 18.47b | 12.19b | 63.28b | 4.29b | 3.23b | 812.39b |
| 3 Irrigations | 1.49b | 1.64a | 4.37c | 4.3c | 110.56c | 92.06b | 27.99b | 1.72c | 16.69c | 11.42c | 55.6c | 3.91c | 2.69c | 807.11b |
| 2 Irrigations | 0.61c | 1.64a | 3.83d | 3.89d | 102.39d | 86.44c | 27.09c | 1.62d | 15.02d | 10.51d | 44.59d | 2.85d | 2.17d | 761.38c |
| 1 Irrigation | 0.29d | 1.64a | 3e | 3.56e | 94.18e | 81.44d | 19.62d | 1.47e | 12.64e | 8.92e | 34.19e | 2.36e | 1.9e | 739.88d |

*Values connected with the same are not significantly different from at 0.05 probability level*

**Table 4: LSD means comparisons of nine wheat genotypes evaluated under different irrigation treatments**

| Genotype | Peduncle Shape | Loadging | Apical rachis hairiness | angle of flag leaf to culmn | rigidity of flag leaf | angle of leaves to culmn | Rigidity of leaves | Spike shape at maturity | Snap back | Spike shape in profile | Shap of flag leaf | Lower glume | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | shoulder width | shoulder width | shoulder width |
| Giza168 | 1.9 c | 1.16e | 6.86e | 4.74cd | 4.91c | 4.38c | 5.4b | 2.7a | 4.88b | 2.14c | 1.4abc | 4.94c | 2.6a | 4.64d |
| Sakha94 | 2.7a | 3.18a | 7.8d | 6.36a | 6.32a | 5.37b | 6.18a | 2.56a | 3.92de | 3.39a | 1.4bc | 5.44b | 2.46a | 5.98a |
| Sakha93 | 1.7d | 1.1e | 6.84e | 4.7d | 4.88c | 4.24c | 5.36b | 2.7a | 4.7bc | 2.11c | 1.4abc | 4.92c | 2.6a | 4.62d |
| Sahel1 | 2.6a | 2.78b | 8.36ab | 5.6b | 6.16a | 6a | 4.58c | 2.7a | 5.94a | 3.24a | 1.6c | 4.22d | 1.98b | 3.88e |
| Gemmeiza7 | 1.3e | 1.94d | 8.26abc | 4.56d | 5.54b | 3.86d | 4.76c | 2.19b | 4.8bc | 2.08c | 1.3ab | 4.18d | 2.14b | 4.88cd |
| Gemmeiza9 | 1.4e | 2.4c | 8.5a | 4.38e | 6.36a | 3.82d | 6.04a | 2.61a | 6.12a | 2.85b | 1.6a | 4.18d | 1.65c | 4.92cd |
| Gemmeiza10 | 1.9cd | 1.92d | 8.04bcd | 4.88c | 5.24bc | 5.32b | 4d | 2.07b | 4.1d | 1.32b | 1.5abc | 5.3bc | 2.62a | 5.6b |
| Sids1 | 2.4b | 2.38c | 8.08bcd | 4.6d | 6.18a | 5.82a | 4.56c | 2.07b | 4.36cd | 1.32d | 1.4c | 6.42a | 2.64a | 6.04a |
| Shandaweel1 | 1.2e | 1.22e | 7.98cd | 4.6d | 4.22d | 4.42c | 4.02d | 2.68a | 3.56e | 2.68b | 1.5abc | 4.16d | 2.61a | 5.2c |
| Genotype | productive tillers | non-productive tillers | Grain shape | Grain bruch length | Plant height in Cm | Heading date | Length of 2nd leaf from top | Width of 2nd leaf from top | Total spike length | Spike length | Grain number per spike | Spike weight | spike grain weight | Test weight |
| Giza168 | 1.36bc | 1.12ab | 4.76a | 4.26cd | 101.37f | 85.16f | 27.66b | 1.65d | 15.72d | 11.08d | 51.12c | 3.39d | 2.6c | 789.8c |
| Sakha94 | 1.09d | 2.76a | 3.36c | 4.04de | 112.6bc | 90.1d | 23.69d | 1.59e | 16.32c | 10.83de | 49.6c | 3.66c | 2.7c | 773.3ef |
| Sakha93 | 1.37bc | 1.11ab | 4.8a | 4.3cd | 101.1f | 85.1f | 27.76b | 1.66d | 15.71d | 10.88de | 50.99c | 3.38d | 2.6c | 789.4cd |
| Sahel1 | 1.89a | 1.62ab | 3.38c | 4.42bc | 111.54bcd | 91.6bc | 24.13cd | 1.53f | 14.64e | 10.15f | 55.57b | 3.63c | 2.7c | 854.5a |
| Gemmeiza7 | 1.47b | 1.35ab | 4.16b | 4.72b | 110.9cd | 90.5cd | 24.94c | 1.77c | 16.04cd | 10.74e | 48.92c | 3.43d | 2.3d | 802.8b |
| Gemmeiza9 | 1.41bc | 1.64ab | 4.16b | 6.38a | 110.49de | 94.1a | 23.11d | 1.89b | 17.54ab | 11.59c | 56.37b | 4.19a | 2.7c | 786.1cd |
| Gemmeiza10 | 1.37bc | 1.42ab | 4.4b | 3.58f | 113.1b | 90d | 28.46ab | 1.89b | 17.64a | 11.98ab | 57.37ab | 3.68c | 3.1ab | 779.4de |
| Sids1 | 1.23cd | 1.82ab | 4.36b | 3.68ef | 118.9a | 91.9b | 29.45a | 1.99a | 17.79a | 11.85bc | 55.69b | 3.49cd | 3.1b | 793.4bc |
| Shandaweel1 | 1.44bc | 1.02b | 4.3b | 3.36f | 108.7e | 88.1e | 27.35b | 1.78c | 17.21b | 12.22a | 60.39a | 3.97b | 3.2a | 763.6f |

**Table 5: Estimation of Susceptibility for 28 wheat morphological traits from nine wheat cultivars under different drought stress treatments.**

| Genotype | Peduncle Shape | Loadging | Apical rachis hairiness | angle of flag leaf to culmn | rigidity of flag leaf | angle of leaves to culmn | Rigidity of leaves | Spike shape at maturity | Snap back | Spike shape in profile | Shap of flag leaf | Lower glume shoulder width | Lower glume shoulder shape | Lower glume surface hairiness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Giza168 | 11a | -5a | 10.5d | -3.75b | 4.75d | -20.5f | 13.25c | 1.88f | 11.25e | 7.625d | -7h | -13.5f | -5e | 7.8f |
| Sakha94 | 8.25d | -22.75e | 10e | -8f | 6.5c | -14b | 3.5g | 2.63d | 11.5d | 4.875f | -2b | -19.5g | -6.8g | 12d |
| Sakha93 | 8.75c | -5a | 10.5d | -3.75b | 4.75d | -22h | 13.25c | 1.88f | 21.25a | 7.625d | -7hh | -13.5f | -5e | 7.8f |
| Sahel1 | 7.5e | -27.75f | 4.5h | -17.5g | 4.5e | -12.5a | 19.75a | 4.38c | 11.75c | 9.25c | -2.4c | -9.75c | -6.5f | 11e |
| Gemmeiza7 | 3.75g | -20.75c | 9.5f | -5.5d | 6.75b | -14.3c | 3.25h | 6.75b | 5h | 7.25d | -5e | -10.25d | -4.5b | 11e |
| Gemmeiza9 | 4.375f | -32.5g | 7.5g | -7.75e | 7a | -14.8d | 4.25f | 2e | 5.25g | 10.63b | -4.8d | -10.25d | -4.4a | -1g |
| Gemmeiza10 | 10.625b | -21d | 13b | -1.5a | 3g | -21g | 11.25d | 13.4a | 13.75b | 4g | -6.6g | -8.75b | -4.8c | 20a |
| Sids1 | 10.625b | -32.75h | 13.5a | -5c | 3.5f | -14.8d | 19.5b | 13.4a | 4.5i | 4g | -1.9a | -7.25a | -4.5b | 13c |
| Shandaweel1 | 3h | -11b | 12.25c | -5c | 1.5h | -19.8e | 11.5e | 0.38g | 7f | 21a | -6.4f | -10.5e | -4.9d | 15b |

| Genotype | productive tillers | non-productive tillers | Grain shape | Grain bruch length | Plant height in Cm | Heading date | Length of 2nd leaf from top | Width of 2nd leaf from top | Total spike length | Spike length | Grain number per spike | Spike weight | spike grain weight | Test weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Giza168 | -12.875g | 0.75d | -15f | -6.75a | -136.25a | -92.5f | -33.87d | -3.06a | -40.45e | -17.9a | -200c | -13.688d | -15d | -514c |
| Sakha94 | -7.5a | 16.375a | -8c | -12g | -180e | -73.8e | -60.11g | -3.83d | -36.65c | -28.4h | -305h | -15.525f | -15d | -984h |
| Sakha93 | -12.875 | 0.75d | -15f | -8.75d | -136.25a | -92.5f | -36.77e | -3.06a | -40.45e | -26.5g | -200c | -13.688d | -15d | -514c |
| Sahel1 | -17h | 0.875c | -7.75b | -7.25b | -237g | -48.8c | -27.13b | -3.44b | -25.76a | -20.6c | -255f | -11.275b | -9.7a | -494b |
| Gemmeiza7 | -12.25f | -1.875e | -10.5e | -9.75e | -163.75b | -43.8b | -73.84h | -5.43g | -36.33b | -22e | -164a | -10.563a | -11b | -702e |
| Gemmeiza9 | -11.125c | -5.75g | -10.5e | -7.75c | -181.38f | -42.5a | -76.08i | -3.81c | -37d | -18.9b | -195b | -13.813e | -11b | -724f |
| Gemmeiza10 | -11b | -4.125f | -7.5a | -17.75i | -173.75d | -43.8b | -21.65a | -6.28h | -51.44h | -25.2f | -252e | -18.075g | -17e | -520d |
| Sids1 | -11.5d | -7.875h | -8c | -16.5h | -163.75b | -51.3d | -31.13c | -5.08f | -46.38f | -21.9d | -216d | -13.138c | -14c | -758g |
| Shandaweel1 | -12e | 3.375b | -8.75d | -11.75f | -166.25c | -48.8c | -41.85f | -4e | -47.44g | -42.3i | -270g | -21.713h | -19f | -305a |

*Values connected with the same letter are not significantly different at 0.05 probability level*