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Evaluation of some Bread Wheat Mutants for Drought Tolerance Indices under Normal and Drought Conditions

M. A. Afify[1], A. A. El-Hosary[2], S. E. S. Sobieh[1], G. Y. Hmam[2], O. A. Boulot[3], K. F. Alazab[1]
[1]Plant Research Department, Nuclear Research Center, Egyptian Atomic Energy Authority, Egypt.
[2]Agronomy Department, Faculty of Agriculture, Benha University, Egypt.
[3]Wheat Diseases Department, Plant Pathology Research Institute, Agriculture research Center, Giza, Egypt.

Abstract

Bread wheat, is the stable food in more than 40 countries including Egypt of the world. 22 mutants and 5 check bread wheat cultivars were evaluated in (M5) 2017/2018 and (M6) 2018/2019 generations, in two separate irrigation treatments experiments using flood irrigation methods. In the first irrigation treatment, irrigation was done every 10 days, while the second irrigation treatments, irrigation was followed every 20 days. Objectives of the present investigation were: 1- To determine of high yielding and drought tolerant bread wheat genotypes under non stress and stress conditions. 2 – To evaluate of drought tolerance bread wheat genotypes using drought tolerance indices. According to water stress, over two years genotypes traits for bread wheat were decreased 6.19% in number of days to heading, 6.25% in number of days to maturity, 11.60% in plant height, 8.79% in spike length, 23.27% in number of spikes per m2, 9.94% in number of grains per spike, 5.79% in 1000 kernel weight, 34.62% in grain yield (ardb/fed), 12.99% in biological yield (ton/fed), 24.50% in harvest index (%). The highest grain yield (ardb/fed under non-stress was obtained by mut.1, mut.59, mut.31, mut.11, mut.2, and mut.68. Whereas in stress conditions mut.132, mut.31, mut.11, mut.59, mut.68 and mut.65 gave the highest yield. Data indicated that mutants 31, 132, 11, 59, 58, and 1 had the largest values for MP, GMP, HM, YP, and YS indicating, they might be to the best promising tolerance. Whereas genotypes Yakora, Mut.44 and Gemmeiza11 had the smallest value of MP, GMP and HM were the most susceptible genotypes. Grain yield in stress condition (YS) was significantly and positively correlated with STI (r=0.916**), MP (r= 0.860**), GMP (r= 0.913**), HM (r=0.952**), YI (r=0.996**), YSI (r= 0.594**) and RDI (r= 0.596**) and negatively corrected with Tol (r= -0.236), SSI (r= -0.660**) and SDI (r=-0.594**). Grain yield in non-stress condition (YP) was significantly and positively corrected with STI (r=0.858**), MP (r=0.917**), GMP (r=0.864**), HM (r=0.804**), Tol (r=0.651**), YI (r=0.587**), SSI (r=0.296) and SDI (r=0.302) and negatively corrected with YSI (r=- 0.302) and RDI (r=-0.301). Results reveled that STI, MP, GMP, HM and YI indices were significantly and positively correlated with grain yield under two conditions. Results of cluster analysis for all of the drought tolerance indices showed that 27 bread wheat genotypes were classified into 4 classes. Cluster1 contained sensitivity genotypes (mutants 37, 64, 199, 166, 44, cultivars Sakha94, Sakha93 and Yakora) that had high values of stress susceptibility (SSI) and low values of tolerance indices (STI, MP, GMP, HM, and YI). Cluster 2 contained semi sensitive genotypes (Mut.2, Mut.3, Mut.25, Mut.26, Sids12 and Gm11) were recommended for irrigation conditions and separated into two groups. First group comprised genotypes Mut.2 and Mut.3. Second group contained genotypes Mut.26, Sids12, Mut.25 and Gm11. Meantime, Cluster 3 contained semi tolerant genotypes number Mut.65, Mut.99, Mut.38, Mut.49 and Mut.161 and Cluster 4 contained tolerant genotypes that had low values of stress susceptibility and high value of tolerance indices genotypes Mut.1, Mut.59, Mut.28, Mut.142, Mut.11, Mut.31, and Mut.68. Where, Mut.132 separated only in cluster 4.

Keywords: Wheat mutations, gamma radiation, drought tolerance indices, cluster analysis.

Introduction

Bread wheat (*Triticum aestivum* L.) is highly adaptable to different ecological areas and has an important role in human nutrition (**Dhanda et al., 2004; Nazar et al., 2012**). It is reported that the global wheat cultivation is approximately 222.9 million hectares and world wheat production is around 720 million tons by Food Agriculture Organization (**FAO, 2015**). In Egypt, total wheat production of grain reached about 9 million tons resulted from 3.4 million feddens with 2.65 ton/feddens, while the consumption of wheat grains is about 15 million tons (**Anonymous, 2016**). Decreasing the gap between wheat production and consumption is a national aim of Egypt. This gap could be limited through increasing production per unit area by breeding new varieties with high yielding ability and increasing the cultivated area. According to many previous studies, reduction in the cycle length of the plant life **(Bayomi, et al., 2008; and Hamam, 2008)** and grain filling periods and rates **(Madani et al., 2010)** were some of the primary effects of water deficit. Imposition of water stress caused a greater reduction in plant height **(Mahamed, et al., 2011),** biological, straw and grain yield and its components and harvest index **(Waraich and Ahmed, 2010; Mohammadi, et al., 2011; and Saeidi and Abdoli, 2015)**. On the other hand, in some studies, some agronomic characters did not affect under reduced irrigation such as number kernels per spike **(Tahmasebi, et al., 2007)** and kernel weight **(Okuyama, et al., 2004**). Several drought indices have been used for screening drought tolerant genotypes based on yield under drought and normal environments **(Talebi et al., 2009 and Mursalova et al., 2015)** such as: Stress susceptibility index (SSI) (**Fischer** and **Maurer, 1978**), stress tolerance index (STI), geometric mean productivity (GMP) **(Fernandez, 1992),** mean productivity (MP), tolerance index (TI) (**Rosielle** and **Hamblin, 1981**), yield stability index (YSI) (**Bouslama & Schapaugh, 1984),** harmonic mean (HM) **(Chakherchaman et al., 2009),** sensitivity drought index (SDI) (**Farshadfar** and **Javadinia, 2011**), drought resistanc index (DRI) (**Lan, 1998**) and relative drought index (RDI) (Fischer et al., 1998). Consequently, **Mohammadi et al. (2012), Mursalova et al. (2015)** and **Ali** and **El-Sadek (2016)** indicated that GMP, MP and STI were more efficient indices for recognizing high performance genotypes under diverse moisture stress. Over 232 different crops and plant species have been subjected to mutation breeding, including various essential crops, such as wheat, rice, grapefruit, rapeseed, sunflower, cotton and banana (**International Atomic Energy Authority, IAEA, 2015**). More than 3222 mutant varieties have been directly or in directly derived through mutation induction including 256 bread wheat varieties, (**IAEA, 2018**). More than 67% of the mutant varieties were obtained through direct mutation (**Ahloowalia et al., 2004**; **Malusznski, et al., 2001).** Induced mutation have been applied to produce mutant varieties by changing the plant characteristic for a significant increase in production and improve quality (**Ahloowalia et al., 2004**; **Shu, et al., 2012).** The mutant variety database contains released and registered mutant plant with improved traits in five main categories: agronomic and botanic traits (48%), quality and nutrition traits (20%), yield and contributions (18%), resistance to biotic stress (9%) and tolerance to abiotic stresses (4%). For the 3222 officially registered mutants, 5569 improved characters are listed, implying that many mutants show several improved traits, (**IAEA, 2016**). **The main objectives of the present investigation were:** 1 – to determine of high yielding and drought tolerant bread wheat genotypes under well-watering and stress-watering conditions. 2 – to evaluate of drought tolerance bread wheat genotypes using drought tolerance indices.

Materials and Methods

1 – Materials

Five check bread wheat cultivars and 22 bread wheat mutant lines were evaluated in M_5 and M_6 generation, (Mut1, Mut2, Mut3, Mut11, Mut99, Mut199, Mut26, Mut28, Mut37, Mut38, Mut59, Mut64, Mut65, Mut44, Mut68, Mut25, Mut31, Mut49, Mut161, Mut166, Mut132 and Mut142) (Table 2), which released as a result of exposed dry grains of the three local bread wheat cultivars (Gemmeiza11, Sids12 and Sakha 93) to different doses of gamma rays (0, 250, 300 and 350Gy) in season 2013/2014. The origin and pedigree of five check bread wheat varieties are presented in Table 1.

Table 1. The origin and pedigree of the used bread wheat cultivars**.**

Cultivar	**Pedigree**	**Main traits**
Gemmeiza11 (Gm11)	BOW"S" /KVZ"S"// 7C/SERI82/3/GIZA168 /SKHA61.	High yield and Moderately susceptible to stem rust
Sids-12 (Sd12)	BUC//7C/ALD/5/MAYA74/ON//1160147/3/BB/GLL/4/CHAT"S"/6/MAYA/VUL//CMH74A.630//4*SX.	High yield and Susceptible to stem rust
Sakha93 (Sk93)	Sakha 92/TR810328 S 8871-1S-2S-1S-0S.	High yield and Susceptible to stem rust
Sakha94 (Sk94)	OPATA/RAYON//KAUZCMBW90Y3180-0TOPM-3Y-010M-010M-010Y-10M-015Y-0Y-0AP-0S	Drought tolerance and Resistance to stem rust
Yakora Rojo (YK)	Ciano 67/Sonora 6411 Klien Rendidor/3/1L815626Y-2M-1Y-0M-302M	Drought tolerance

Table 2. The origin of the 22 bread wheat mutants (in M5 generation) induced via gamma irradiation.

Mutants	**Pedigree**	**Main traits**
Mut.1	GM11 – 250Gy	R + H.y
Mut.2	GM11 – 250Gy	R + H.y
Mut.3	GM11 – 250Gy	R + H.y
Mut.11	GM11 – 350Gy	R – MR + H.y
Mut.99	GM11 – 350Gy	MR + H.y
Mut.199	GM11 – 350Gy	MR + H.y
Mut.25	Sk93 – 250Gy	MR + H.y
Mut.26	Sk93 – 250Gy	R + H.y
Mut.28	Sk93 – 250Gy	R + H.y
Mut.31	Sk93 – 250Gy	MR + H.y
Mut.37	Sk93 – 250Gy	R + H.y
Mut.38	Sk93 – 300Gy	R + H.y
Mut.44	Sk93 – 300Gy	R
Mut.49	Sk93 – 300Gy	MR + H.y
Mut.59	Sk93 – 350Gy	R + H.y
Mut.64	Sk93 – 350Gy	R + H.y
Mut.65	Sk93 – 350Gy	R + H.y
Mut.68	Sk93 – 350Gy	R
Mut.161	Sk93 – 250Gy	MR + H.y
Mut.166	Sk93 – 250Gy	MR + H.y
Mut.132	Sd12 – 250Gy	MR + H.y
Mut.142	Sd12 – 250Gy	MR + H.y

R= Resistance to stem rust, MR= Moderate Resistance to stem rust, H.y= High yield

Soil analysis:

Soil field analysis were presented in Table 3. Soil samples were taken before sowing, at 30-cm depth from the surface layer.

Table 3. Properties of the soil used in the study.

pH (1:2.5)	**EC*** (dS m^{-1})	**CaCO$_3$** (g kg^{-1})	**OM** (g kg^{-1})	**SP**** (%)		
6.85	0.70	0.0	0.25	19.4		
Soluble Ions (mmol$_c$ L^{-1})						
Cations			**Anions**			
Na^{+}	1.7		**CO$_3^{-2}$**	0.0		
K^{+}	1.3		**HCO^{-3}**	2.4		
Ca^{+2}	2.5		**CL^{-}**	1.3		
Mg^{+2}	0.9		**SO$_4^{-2}$**	3.3		
Available nutrients * (mg kg^{-1})						
N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
0.01	0.00	0.23	0.29	0.00	0.03	0.01
Total nutrients (mg kg^{-1})						
N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
1.13	0.02	0.69	0.74	0.01	0.10	0.20
Particle size distribution (%)						
Sand		**Silt**		**Clay**		**Texture**
95.0		5.0		0.0		Sand

***EC in paste extract ; **SP**: Saturation percent ; Extracts for available nutrients: KCl (N), Na$_2$CO$_3$ (P), NH$_4$-OAc (K) and DTPA (Fe, Mn, Zn and Cu).

2 – Methods

M5 and M6 generation (2017/2018 and 2018/2019)

In each season, the studied bread wheat genotypes were evaluated in two separate irrigation regime experiments using flood irrigation methods (various irrigation intervals). The first irrigation treatments, irrigation every 10 days (well-watering, WW), while the second irrigation treatments, irrigation every 20 days (water-stress; WS). Twenty- seven bread wheat genotypes were used and sown on ^{21}th, November during 2017/2018 and 2018/2019 growing seasons. The soil was in texture, sandy (Table 3).

A randomized complete block design with three replications was used for each water irrigation treatment. Each plot consisted of 8 rows, 3m long and 30cm wide, individual grains were spaced 10cm within row. Recommended cultural practices for wheat cultivation in new land in Egypt were applied at the proper time.

Estimation of yield-related traits

At harvest stage, 10 individual plants / plot in every replication were harvested to measure the following traits. Days to 50% heading (DTH), Days to 50% Physiological maturity (DTM), Plant height(cm) (PH), Spike length (cm) (SL), Grains / spike (GPS), 1000-grain weight (gm) (1000GW), Number of spikes per one square meter (m^2), Grain yield (ardb/fed) , Biological yield (ton/fed) and Harvest index.

Drought tolerance indices

Drought tolerance indices were calculated by the following formula Table (4).

Table 4. Drought tolerance indices

Stress susceptibility index	SSI = [1- (Ys / Yp)] / [1-($\overline{Ys}$ / $\overline{Yp}$)].	(Fischer and Maurer, 1978)
Tolerance	TOL = Yp – Ys	(Rosielle and Hamblin, 1981)
Mean productivity	MP= (Yp + Ys) / 2	(Rosielle and Hamblin, 1981)
Geometric mean productivity	GMP = $\sqrt{(Ys \times Yp)}$	(Fernandez, 1992)
Stress tolerance index	STI= (Ys×Yp) / $\overline{Yp}^{\,2}$	(Fernandez, 1992)
Yield index	YI= Ys/ $\overline{Ys}$	(Gavuzzi et al., 1997)
Yield stability index	YSI= Ys / Yp	(Bouslama and Schapaugh, 1984)
Harmonic mean	HAM= 2(Ys)(Yp) / (Ys+Yp)	(Kristin et al., 1997)
Sensitivity drought index	SDI= (Yp-Ys) /Yp	(Farshadfar and Javadinia, 2011)
Relative drought index	RDI= (Ys/Yp) / ($\overline{Ys}$ / $\overline{Yp}$)	(Fischer and Maurer, 1978)

Where, Ys and Yp represent yield in stress and non-stress conditions respectively. Also, Ys$^-$ and Yp$^-$ are mean yield of all genotypes in stress and non-stress conditions respectively. Si is the stress intensity and calculated as: Si= 1-(YS$^-$ / Yp$^-$).

Results and Discussion

Analysis of variance and mean performance:

Analysis of variance for yield and its components, i.e., number of days to heading, number of days to maturity, plant height, spike length, number of spikes/ m^2, number of grains / spike, 1000 kernel weight, biological yield (ton/fed), grain yield (ardb/fed) and harvest index under drought stress and non-stress conditions as well as combined analysis are presented in Table 5. Results indicated that mean square due to irrigation treatments were highly significant for all studied traits indicating overall differences between the two years of study.

Genotypes mean square were significant for all studied traits indicating wide diversity between all studied genotypes. Moreover, significant mean squares between genotypes and irrigation treatments interaction were detected for all studied traits expect spike length and biological yield in M$_5$ generation, and expect spike length, 1000 kernel weight and biological yield in M$_6$ generation.

Table 5: Mean squares for the studied characters in combined analysis of 27 bread wheat genotypes under normal and drought stress conditions in M5 and M6 generation.

Source of Variation	Degree of freedom	No. of days to heading	No. of days to maturity	Plant height	Spike length	Number of spikes/ M2	Number of grains/spike	1000kernel weight	Biological yield	Grain yield	Harvest index
M5 generation											
(I)	1	450.0**	2871**	5415**	106**	84872**	1875**	376.3**	32.4**	1384**	3721**
Rep/I	4	0.790	2.82	1.215	0.109	12.383	6.502	3.349	0.020	0.077	1.339
(G)	26	161.9**	39.5**	283.9**	9.82**	3386.9**	305.7**	246.7**	1.76	7.58**	34.2**
I x G	26	5.346**	2.9**	14.7**	0.470	466.4**	18.6**	3.103**	0.231	2.55*	5.7**
Error	104	2.809	0.289	0.238	0.058	31.33	2.475	1.672	0.010	0.110	0.401
M6 generation											
(I)	1	2365.2**	3068**	5281**	98.6**	75920**	2400**	361.8**	26.44**	1329.6**	3741**
Rep/I	4	7.025	1.57	1.803	0.532	32.519	0.245	1.935	0.081	1.252	2.234
(G)	26	522.6**	76.85**	288.2**	10.1**	3878.1**	392.1**	283.1**	1.834*	9.085**	37.87**
I x G	26	2.409**	4.697**	16.98**	0.308	413.63**	18.82**	1.441	0.187	2.142**	5.209**
Error	104	2.05	0.452	0.240	0.035	15.627	1.590	1.852	0.006	0.122	0.686

**** Denote significant differences at 0.01 level, respectively.** Where: (I) Irrigation and (G) Genotypes.

Normal and drought conditions:

Under water stress conditions, the number of days to heading was observed from 74.00 to 93.67. While, in non-stress condition, the number of days to heading was ranged from 78.00 to 101.17 (Table 6). Over two years water stress caused decreased (6.19%) in the number of days to heading. In stress condition, the number of days to maturity was observed from 122.50 to 134.33. While, under normal irrigation conditions, the number of days to maturity was varied from 133.00 to 142.33 (Table 6). Over two years water stress caused decreased (6.25%) in number of days to maturity. In non-stress condition, the plant height was observed from 80.63 to 110.33cm. Whereas in stress condition, the plant height was measured from 67.30 to 97.93cm (Table 6). According to average of two years plant height was reduced (11.60%) compare to irrigated condition. In stress condition, the spike length was observed from 13.90 to 19.07cm, whereas in non-stress condition, the spike length was measured from 15.63 to 20.33cm (Table 6). Over two years spike length water stress caused decreased (8.79%). In non-stress condition, the number of spikes per m^2 ranged between 138.17 to 227.33 (Table 6). While in stress condition, varied from 86.33 to 182.50 spikes per m^2. Over two years water stress caused decreased (23.27%) in the number of spikes per m^2. Under normal conditions, the highest number of spikes per m^2 was obtained from mut.44 and mut.64 (227.33), followed by yakora (226.33), mut.68 (225.83), mut.31 (224.50) and mut.25 (220.50). Whereas, under stress conditions the genotypes- mut.59 (182.50), mut.31 (179.33), mut.68 (179.17), mut.49 (169.33) and mut.65 (168.00) (Table 6). In stress conditions, the number of grains per spike ranged from 49.73 to 84.22. Whereas under normal conditions number of grain per spike ranged from 61.35 to 87.83. Over two year's water stress caused (9.94%) decreased in number of grain per spike. The highest number of grains per spike was obtained from mut.11 (87.83) followed mut.132 (85.53), sids12 (83.25), mut.142 (82.80) and mut.99 (82.73) under normal conditions. While in stress condition the genotypes mut.132 (84.22) followed by mut.11 (80.22), sids12 (77.83), mut.142 (76.02) and mut.99 (73.65) (Table 6). Under normal irrigation conditions, 1000 kernel weight varied from 42.75 to 66.05gm (Table 6). While in stress conditions, values ranged from 40.47 to 60.32gm. Over two years, water stress caused 5.79% decreased in 1000-kernel weight. The highest 1000-kernel weight was obtained from mut.199 (66.05gm) followed by mut.132 (62.57gm), mut.11 (61.77gm), mut.1 (60.48gm) and mut.2 (57.85gm) under non-stress condition. Whereas in stress conditions, the genotypes mut.199 (60.32gm) followed by mut.1 (59.13gm), mut.132 (58.35gm), mut.11 (58.27gm) and mut.142 (57.75gm). Grain yield (ardb/fed) over two years yield under stress condition ranged from 9.21 to 13.24 ardb/fed and from 14.52 to 19.28 ardb/fed in irrigated conditions. The mean grain yield was decreased by 34.62% in stress conditions compare to non-stress conditions over two years. These results provide also possibility of select genotypes under both stress and non-stress conditions for high yield potential and drought tolerance. According to mean grain yield over two years for normal irrigation conditions, mut.1 followed by mut.59 , mut.31, mut.11, mut.2, mut.3 and mut.68 showed best performance with 19.28 , 19.04, 18.48, 18.40, 18.36 and 18.25 (ardb/fed) respectively. For mean grain yield (ardb/fed) under stress conditions, the highest values were derived from bread wheat genotypes were mut.132, mut.31, mut.11, mut.59, mut.68 and mut.28 with give values of 13.24, 12.65, 12.43, 12.12, 12.10 and 11.95 respectively. These genotypes derived from bread wheat genotypes which high yield potential and tolerant against to water limited conditions **(Aktas, 2016 and El-Safy, et al. 2020).** Under stress conditions, the biological yield (ton/fed) ranged from 3.82 to 6.37 ton /fed. While, under non-stress conditions, the biological yield ranged from 4.13 to 7.47 ton/fed. Over two years water stress decreased the biological yield by (12.99%). Harvest index (%) under normal irrigation conditions ranged from 32.70 to 45.48%. Whereas, under stress conditions the same trait ranged from 24.09 to 36.26%. Over two years the harvest index % was decreased by water stress (24.50%). **(Al Saadoon et al. 2017, EL Hosary et al. 2016 and EL Hosary et al. 2019).**

Table 6: Mean performance for yield and yield attributes under normal and water stress conditions and reduction% for 27 tested genotypes over two years.

Genotypes	No. of days to heading			No. of days to maturity			plant height (cm)			Spike length (cm)			Number of spikes/m2		
	N	S	R%	N	S	R%	N	S	R%	N	S	R%	N	S	R%
Mut.1	86.33	80.33	6.9	139.8	128.67	7.99	107.97	96.07	11.02	19.70	17.67	10.32	176.50	131.5	25.5
Mut.2	84.33	78.33	7.1	138.0	127.50	7.61	107.93	94.40	12.54	19.27	17.60	8.65	205.50	148.3	27.8
Mut.3	85.17	77.50	9.0	137.0	127.00	7.30	105.30	94.93	9.85	18.20	17.40	4.40	176.17	135.5	23.1
Mut.11	82.33	76.33	7.3	134.5	125.33	6.82	99.97	86.03	13.94	19.77	18.10	8.43	161.50	137.7	14.8
Mut.25	95.00	89.17	6.1	139.3	131.50	5.62	100.90	90.60	10.21	17.17	15.97	6.99	220.50	152.8	30.7
Mut.26	98.33	93.17	5.3	139.8	132.83	5.01	105.00	92.27	12.13	17.13	15.70	8.36	191.67	166.3	13.2
Mut.28	96.67	90.17	6.7	139.0	131.50	5.40	97.80	90.77	7.19	17.23	15.73	8.70	192.83	153.7	20.3
Mut.31	101.2	92.67	8.4	142.3	134.33	5.62	100.57	92.30	8.22	16.97	15.03	11.40	224.50	179.3	20.1
Mut.37	94.33	87.83	6.9	139.2	130.50	6.23	104.83	92.77	11.51	18.40	16.90	8.15	181.17	154.3	14.8
Mut.38	94.00	88.83	5.5	141.7	132.33	6.59	93.23	79.93	14.27	18.13	17.20	5.15	171.67	152.0	11.5
Mut.44	79.00	74.17	6.1	131.0	122.50	6.49	84.03	74.47	11.38	17.70	14.80	16.38	227.33	142.0	37.5
Mut.49	92.67	87.17	5.9	139.0	129.33	6.95	99.43	89.97	9.52	16.10	14.57	9.52	209.50	169.3	19.2
Mut.59	95.67	88.83	7.1	141.8	132.00	6.93	93.70	79.37	15.30	18.90	17.33	8.29	213.83	182.5	14.7
Mut.64	98.50	93.67	4.9	139.3	131.17	5.86	99.23	83.13	16.22	16.53	15.27	7.66	227.33	162.3	28.6
Mut.65	92.50	87.67	5.2	135.3	129.50	4.31	98.23	83.90	14.59	16.53	15.30	7.46	204.33	168.0	17.8
Mut.68	80.83	75.83	6.2	132.7	125.50	5.40	97.97	80.10	18.24	18.33	16.50	10.00	225.83	179.2	20.7
Mut.99	84.67	80.33	5.1	135.2	126.17	6.66	97.93	91.70	6.36	19.47	18.77	3.60	147.83	128.7	12.9
Mut.132	78.17	74.67	4.5	132.8	124.17	6.52	103.70	90.83	12.41	19.43	17.47	10.12	151.33	121.8	19.5
Mut.142	83.67	78.83	5.8	138.2	130.33	5.67	110.33	94.07	14.74	19.27	17.97	6.75	161.00	124.8	22.5
Mut.161	94.33	88.17	6.5	139.5	131.83	5.50	90.27	81.67	9.53	19.17	17.73	7.48	200.33	150.3	24.9
Mut.166	95.33	89.17	6.5	138.8	131.83	5.04	96.03	88.43	7.91	17.33	15.67	9.61	192.50	158.0	17.9
Mut.199	84.00	79.50	5.4	135.3	126.50	6.53	102.33	92.83	9.28	20.33	19.07	6.23	138.17	109.0	21.1
Gm11	83.17	77.00	7.4	136.2	126.50	7.10	104.10	91.03	12.55	18.67	17.00	8.93	166.17	112.7	32.2
Sd12	78.00	74.17	4.9	135.7	124.67	8.11	97.10	83.23	14.28	18.57	16.63	10.42	142.67	86.33	39.5
Sk93	82.67	79.50	3.8	137.0	128.50	6.20	92.50	85.83	7.21	17.60	15.30	13.07	199.33	126.7	36.5
Sk94	95.33	89.33	6.3	138.0	130.67	5.31	105.30	97.93	7.00	17.13	15.13	11.67	179.50	134.0	25.4
Yakora	78.33	74.00	5.5	133.0	125.17	5.89	80.63	67.30	16.54	15.63	13.90	11.09	226.33	157.8	30.3
Mean	**88.69**	**83.20**	**6.2**	**137.4**	**128.81**	**6.25**	**99.12**	**87.62**	**11.60**	**18.10**	**16.51**	**8.79**	**189.46**	**145.4**	**23.3**
L.S.D0.05	**2.07**	**1.44**		**0.82**	**0.54**		**0.54**	**0.59**		**0.25**	**0.25**		**5.64**	**7.48**	

Table 6: continued

Genotypes	Number of grains / spike			1000 kernel weight (gm)			Biological yield (ton/fed)			Grain yield (ardb/fed)			Harvest index (%)		
	N	S	R%	N	S	R%	N	S	R%	N	S	R%	N	S	R%
Mut.1	79.15	69.23	12.53	60.48	59.13	2.23	7.33	6.18	15.68	19.28	11.67	39.44	39.44	28.31	28.22
Mut.2	75.83	69.69	8.10	57.85	55.92	3.34	6.86	5.60	18.34	18.36	10.31	43.86	40.16	27.59	31.32
Mut.3	70.52	61.20	13.21	56.72	55.33	2.44	6.89	5.36	22.21	18.25	9.54	47.73	39.74	26.71	32.79
Mut.11	87.83	80.22	8.67	61.77	58.27	5.67	7.00	5.99	14.40	18.40	12.43	32.47	39.45	31.12	21.11
Mut.25	67.08	63.18	5.81	46.67	42.95	7.96	7.47	6.05	18.95	16.28	9.72	40.29	32.70	24.09	26.32
Mut.26	70.28	65.93	6.20	47.25	43.63	7.66	6.53	5.60	14.25	16.28	10.04	38.31	37.40	26.93	28.00
Mut.28	77.13	68.12	11.69	45.02	40.98	8.96	6.62	5.93	10.49	17.77	11.95	32.73	40.25	30.23	24.89
Mut.31	69.73	64.93	6.88	50.03	47.65	4.76	6.96	6.37	8.49	18.48	12.65	31.52	39.80	29.77	25.20
Mut.37	64.37	59.92	6.91	48.87	47.23	3.34	6.48	5.97	7.91	15.17	10.52	30.65	35.07	26.41	24.68
Mut.38	75.22	63.62	15.42	52.73	48.45	8.12	6.55	5.83	10.93	16.74	11.64	30.46	38.36	29.91	22.04
Mut.44	61.35	49.73	18.94	47.38	45.28	4.43	5.37	4.66	13.08	14.52	9.33	35.72	40.59	30.02	26.04
Mut.49	71.88	65.67	8.65	44.65	41.72	6.57	6.63	6.14	7.48	16.84	11.08	34.17	38.08	27.08	28.88
Mut.59	72.38	67.67	6.52	52.08	49.60	4.77	6.93	5.87	15.30	19.04	12.12	36.34	41.23	30.99	24.83
Mut.64	62.28	58.48	6.10	44.23	41.43	6.33	6.15	5.66	8.00	15.16	10.43	31.18	36.98	27.65	25.24
Mut.65	71.73	60.52	15.64	42.75	40.47	5.34	6.23	5.95	4.48	16.74	11.95	28.60	40.33	30.13	25.29
Mut.68	69.07	65.93	4.54	54.05	51.37	4.96	6.59	5.79	12.10	18.25	12.10	33.69	41.58	31.44	24.38
Mut.99	82.73	73.65	10.98	57.25	55.53	3.00	6.36	5.68	10.69	16.70	11.86	28.99	40.03	31.36	21.66
Mut.132	85.53	84.22	1.54	62.57	58.35	6.74	6.26	5.63	10.07	17.26	13.24	23.25	41.35	35.32	14.57
Mut.142	82.80	76.02	8.19	59.50	57.75	2.94	6.58	5.12	22.08	17.64	11.68	33.76	40.24	34.20	15.02
Mut.161	71.53	60.02	16.10	53.05	48.55	8.48	6.57	5.86	10.77	17.03	10.58	37.85	38.92	27.08	30.41
Mut.166	65.50	61.12	6.69	44.60	40.92	8.26	6.14	5.44	11.33	14.98	11.02	26.41	36.64	30.39	17.06
Mut.199	79.18	66.60	15.89	66.05	60.32	8.68	6.30	5.50	12.69	15.27	10.58	30.69	36.32	28.85	20.57
Gm11	72.68	60.75	16.42	58.92	56.05	4.87	6.52	5.15	21.05	16.77	9.21	45.08	38.62	26.84	30.50
Sd12	83.25	77.83	6.51	53.42	50.53	5.40	6.05	4.70	22.29	16.08	9.96	38.07	39.85	31.76	20.30
Sk93	63.03	60.65	3.78	49.07	44.57	9.17	5.37	4.99	6.95	14.81	9.91	33.06	41.42	29.77	28.12
Sk94	67.65	60.10	11.16	48.52	45.52	6.18	5.81	5.40	7.19	14.77	10.32	30.17	38.11	28.68	24.73
Yakora	62.12	51.93	16.39	44.62	40.93	8.26	4.13	3.82	7.58	14.53	9.23	36.46	45.48	36.26	20.27
Mean	**72.66**	**65.44**	**9.94**	**52.23**	**49.20**	**5.79**	**6.39**	**5.56**	**12.99**	**16.72**	**10.93**	**34.62**	**39.19**	**29.59**	**24.50**
L.S.D 0.5	**1.99**	**1.23**		**1.68**	**1.34**		**0.40**	**0.08**		**0.41**	**0.37**		**0.69**	**0.97**	

Drought tolerance indices

To differentiate between drought resistant genotypes, several selection indices have been performed to identify drought resistant genotypes considering grain yield potential in both favorable and stress conditions, **Bahar and Yildirim, (2010)**. Stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), harmonic mean (HM), yield index (YI), tolerance index (Tol), stress susceptibility index (SSI), sensitive drought index (SDI), yield stability index (YSI) and relative drought index (RDI). According to the STI was more useful index in order to select favorable cultivars under stressful and stress-free conditions **(Moghaddam and HadiZadeh, 2002)**. Mut.31, Mut.59, Mut.132, Mut.11, Mut.1 and Mut.68 had the largest STI, YP and YS, indicating, they might be the best promising tolerant, whereas genotypes cultivar Yakora, mut.44 and cultivar Sk93 showed the smallest STI were the most susceptible genotypes. These finding are in adherence to **Farshadfar, et. al., (2013), Abdelghany, et. al., (2016)**, **Manal and Sabry (2019)** and **El-Hosary et al. (2019)**. The term mean productivity (MP) was coined by **Rosielle and Hambin (1981)**, referring to the average yield of genotypes between stress and non-stress conditions. The mutants with high values of MP were considered tolerant mutants. According to this index, the Mut.59 (15.58), Mut.31 (15.56), Mut.1 (15.47), Mut.11 (15.41), Mut.132 (15.25) and Mut.68 (15.18) were having higher values. On the other side, cultivar Yakora (11.88), mut.44 (11.92) and cultivar Sk93 (12.36) were having lower values (Table 7). Mutants with highest GMP and HM values were preferred under stress conditions. Based on these current indices, genotypes number 31, 59, 11, 132, 1, 68 exhibited the highest values for these indices, indicating tolerant these mutants genotypes, whereas genotypes cultivar Yakora, mut.44 and cultivar Gm11 were the most sensitive genotypes. Mutants No. 31, 59, 132, 11, 1 and 68 were drought tolerant mutants based on STI, MP, GMP, and HM indices.

Table 7: Mean values of drought tolerance indices and grain yield under normal and stress water conditions for 27 tested genotypes over two years.

Genotype	Yp m	Ys m	STI	MP	GMP	HM	TOL	SSI	YI	YSI	SDI	RDI
Mut.1	19.28	11.67	0.81	15.47	15.00	14.54	7.61	1.14	1.07	0.61	0.39	0.92
Mut.2	18.36	10.31	0.68	14.34	13.76	13.21	8.05	1.27	0.94	0.56	0.44	0.86
Mut.3	18.25	9.54	0.62	13.89	13.19	12.53	8.71	1.38	0.87	0.52	0.48	0.80
Mut.11	18.40	12.42	0.82	15.41	15.12	14.83	5.98	0.94	1.13	0.68	0.32	1.03
Mut.25	16.28	9.72	0.57	13.00	12.58	12.17	6.56	1.17	0.89	0.60	0.40	0.91
Mut.26	16.28	10.04	0.59	13.16	12.78	12.42	6.24	1.11	0.92	0.62	0.38	0.94
Mut.28	17.77	11.95	0.76	14.86	14.57	14.29	5.82	0.95	1.09	0.67	0.33	1.03
Mut.31	18.48	12.65	0.84	15.56	15.29	15.02	5.83	0.91	1.16	0.68	0.32	1.05
Mut.37	15.16	10.52	0.57	12.84	12.63	12.42	4.64	0.89	0.96	0.69	0.31	1.06
Mut.38	16.74	11.64	0.70	14.19	13.96	13.73	5.10	0.88	1.06	0.70	0.30	1.06
Mut.44	14.51	9.33	0.49	11.92	11.64	11.36	5.18	1.03	0.85	0.64	0.36	0.98
Mut.49	16.83	11.08	0.67	13.96	13.66	13.36	5.75	0.99	1.01	0.66	0.34	1.00
Mut.59	19.04	12.12	0.83	15.58	15.19	14.81	6.92	1.05	1.11	0.64	0.36	0.97
Mut.64	15.15	10.43	0.57	12.79	12.57	12.36	4.72	0.90	0.95	0.69	0.31	1.05
Mut.65	16.74	11.95	0.72	14.35	14.14	13.95	4.79	0.83	1.09	0.71	0.29	1.09
Mut.68	18.25	12.11	0.79	15.18	14.87	14.56	6.14	0.98	1.11	0.66	0.34	1.01
Mut.99	16.67	11.86	0.71	14.26	14.06	13.86	4.81	0.84	1.08	0.71	0.29	1.09
Mut.132	17.25	13.24	0.82	15.25	15.11	14.98	4.01	0.67	1.21	0.77	0.23	1.17
Mut.142	17.63	11.68	0.74	14.66	14.35	14.05	5.95	0.98	1.07	0.66	0.34	1.01
Mut.161	17.03	10.58	0.65	13.80	13.42	13.05	6.45	1.10	0.97	0.62	0.38	0.95
Mut.166	14.98	11.02	0.59	13.00	12.85	12.70	3.96	0.77	1.01	0.74	0.26	1.12
Mut.199	15.27	10.58	0.58	12.92	12.71	12.50	4.69	0.89	0.97	0.69	0.31	1.06
Gm11	16.77	9.21	0.55	12.99	12.43	11.89	7.56	1.31	0.84	0.55	0.45	0.84
Sd12	14.77	10.32	0.55	12.54	12.35	12.15	4.45	0.87	0.94	0.70	0.30	1.07
Sk93	14.81	9.91	0.53	12.36	12.11	11.87	4.90	0.96	0.91	0.67	0.33	1.02
Sk94	16.08	9.96	0.57	13.02	12.66	12.30	6.12	1.10	0.91	0.62	0.38	0.95
Yakora	14.53	9.23	0.48	11.88	11.58	11.29	5.30	1.06	0.84	0.64	0.36	0.97
Mean	**16.72**	**10.93**	**0.66**	**13.82**	**13.50**	**13.19**	**5.79**	**1.00**	**1.00**	**0.66**	**0.34**	**1.00**

Based on the same four indices cultivar Yakora, mut.44 and cultivar Gm11 were the most susceptible genotypes. Therefore, STI, MP, GMP and HM considered as more efficient indices in identify high yielding genotypes under normal and drought stress conditions. Similar resulted were reported by **Mursalova et, al., (2015), Ali and El-Sadek (2016) and Manal and Sabry (2019)**.

The highest Tol values were related to genotypes Mut.3, Mut.2, and Gm11 which recorded values of 8.71, 8.95 and 7.61, respectively. Therefore, high amount of Tol is a sign of genotypes susceptibility to stress **(Parchin et al., 2013)** and **(Manal and Sabry 2019).** While, Mut.166, Mut.132, cultivar Sk94, Mut.37 and Mut.199 which recorded low values 3.98, 4.01, 4.45, 4.64 and 4.69 were considered a tolerant genotypes. Similar results were found by **Mahdi, Z. (2012)** and **Raman et al., (2012).** The genotypes which showed stress susceptibility index SSI values <1 could be considered as drought tolerant compared with theses of stress susceptibility index > 1. As shown in (Table 7) SSI ranged from 0.67 for Mut.132 to 1.38 for Mut.3. The lowest values were 0.67, 0.77, 0.83, 0.84 and 0.87 for Mut.132, Mut.166, Mut.65, Mut.99 and Sk94, respectively. So, theses mutants were considered more tolerant to drought than the other wheat genotypes. These current mutants had the same tend to SDI. These results are in harmony with **Kumar et al., (2012).** Whereas Mut.3, cultivar Gm11 and Mut.2 with high SSI values of 1.38, 1.31 and 1.27, respectively, can be considered susceptible to drought and only suitable for normal irrigation conditions. These results are in harmony with the same tend to SDI. Similar results were found by **Abdi et al., (2013), Raman et al., (2012), Manal and Sabry (2019)** and **Afiah et al. (2019).** Mutants with highest YI values recoded for Mut.132, Mut.31, Mut.11, Mut.59, Mut.68 and Mut.65 (1.21, 1.16, 1.13, 1.11 and 1.11, respectively), indicating tolerant mutants. Regarding to the highest YSI values were recorded for Mut.132, Mut.166, Mut.65, Mut.99 and Sids12 (0.77, 0.74, 0.71, 0.71 and 0.70, respectively). These current mutants had the same tend to RDI. These finding are cooperated with **Karimizadeh and Mohammadi (2011)** and **Ghohodi et al., (2012).**

Correlation analysis

To determine the most desirable drought tolerant criteria, the correlation coefficient between YP, YS and other quantitative indices of drought tolerance were calculated (table 8). Positive significant correlation was observed between YP and YS (r = 0.584**) which means that high yielding genotypes can be selected based on them under both stress and non-stress conditions (Table 8). Similar results were obtained by **Nazari and Pakniyat (2010)** on barley. In other words, correlation analysis between grain yield and drought tolerance indices can be a good criterion for screening the best cultivars and indices used. Grain yield under stress conditions (YS) was significantly and positively correlated with STI (r=0.916**), MP (r=0.860**), GMP (r= 0.913**), HM (r=0.952**), YI (r=0.996**), YSI (r=0.594**) and RDI (r= 0.596**) and significantly negative correlated with Tol (r= -0.236), SSI (r= -0.600**) and YSI (r=-0.594**). Yield under normal water conditions (YP) was significantly and positively correlated with STI (r=0.858**), MP (r=0.917**), GMP (r=0.864**), HM (r=0.804**), Tol (r=0.651**), YI (r=0.587**). **Golabadi et al., 2006** stated that the best suitable index for drought tolerant genotypes is an index that is highly correlated with grain yield under both stress and optimum conditions**.** Results reveled that STI, MP, GMP, HM and YI indices that were significantly and positively correlated with grain yield under two conditions (Table 8) and they can be the appropriate indices for screening wheat genotypes. These findings are in according with the results **Mohammadi et al., (2011)** in bread wheat. The significant correlations between quantitative drought resistance indices such as MP, GMP, STI and HM with yield under stress and normal conditions are consistent with those reported by **Mardeh et al., (2006)** in bread wheat. **Farshadfar et al., (2018)** and **Manal and Sabry (2019)** also observed that STI, MP, GMP, HM and YI indices highly correlated with grain yield under two condition and during both years.

Table 8: Correlation coefficients between grain yield and drought indices for 27 wheat genotypes under normal and drought stress conditions.

	Yp m	Ys m	STI	MP	GMP	HM	TOL	SSI	YI	YSI	SDI	RDI
Yp m	1											
Ys m	.584**	1										
STI	.858**	.916**	1									
MP	.917**	.860**	.991**	1								
GMP	.864**	.913**	.999**	.993**	1							
HM	.804**	.952**	.994**	.975**	.994**	1						
TOL	.651**	-.236	.171	.293	.181	.073	1					
SSI	.296	-.600-**	-.231	-.109	-.222	-.326	.916**	1				
YI	.587**	0.9996**	.917**	.861**	.914**	.952**	-.233	-.597-**	1			
YSI	-.302	.594**	.225	.103	.216	.320	-.918-**	-.998-**	.591**	1		
SDI	.302	-.594-**	-.225	-.103	-.216	-.320	.918**	.998**	-.591-**	-.999-**	1	
RDI	-.301	.596**	.225	.104	.217	.321	-.918-**	-.999-**	.593**	.997**	-.997-**	1

**. Denote significant differences at the 0.01 level.

Cluster analysis

Wheat breeder have been evaluating wheat genotypes in irrigated and stress conditions to discriminate genotypes regarding to level of drought tolerance with many drought indices. **Fernandez (1992)** reported that genotypes can be divided in to four group according to their yield under stress and normal conditions. Genotypes that have high yield under both stress and non-stress (group A), genotypes with high yield response under non-stress (group B), or stress conditions (group C) and the last genotypes with low yield performance under both normal and stress conditions (group D).

In order to classify of wheat genotypes, cluster analysis on ward's Method is used. The results of cluster analysis on all of the drought tolerance indices (figure 1) showed that studied 27 wheat genotypes classified in 4 classes.

Cluster 1 contained sensitivity genotypes that had high values of stress susceptibility (SSI) and low values of tolerance indices (STI, MP, GMP, HM, and YI) and separated into two groups. First group comprised genotypes Mut.37, Mut.64, Mut.199, Mut.166, Sakha94 and Sakha93. Second group contained genotypes Mut.44 and Yakora.

Cluster 2 contained semi sensitive genotypes: Mut.2, Mut.3, Mut.26, Sids12, Mut.25 and Gm11 were recommended for irrigation conditions and separated into two groups. First group comprise genotypes Mut.2 and Mut.3. Second group contained genotypes Mut.26, Sids12, Mut.25 and Gm11.

Cluster 3 contained semi tolerant genotypes: Mut.65, Mut.99, Mut.38, Mut.49 and Mut.161 were identified for stress conditions.

Cluster 4 contained tolerant genotypes that had low values of stress susceptibility and high value of tolerance indices genotypes Mut.1, Mut.59, Mut.28, Mut.142, Mut.11, Mut.31, and Mut.68. Where, genotype Mut.132 separated only in cluster 4.

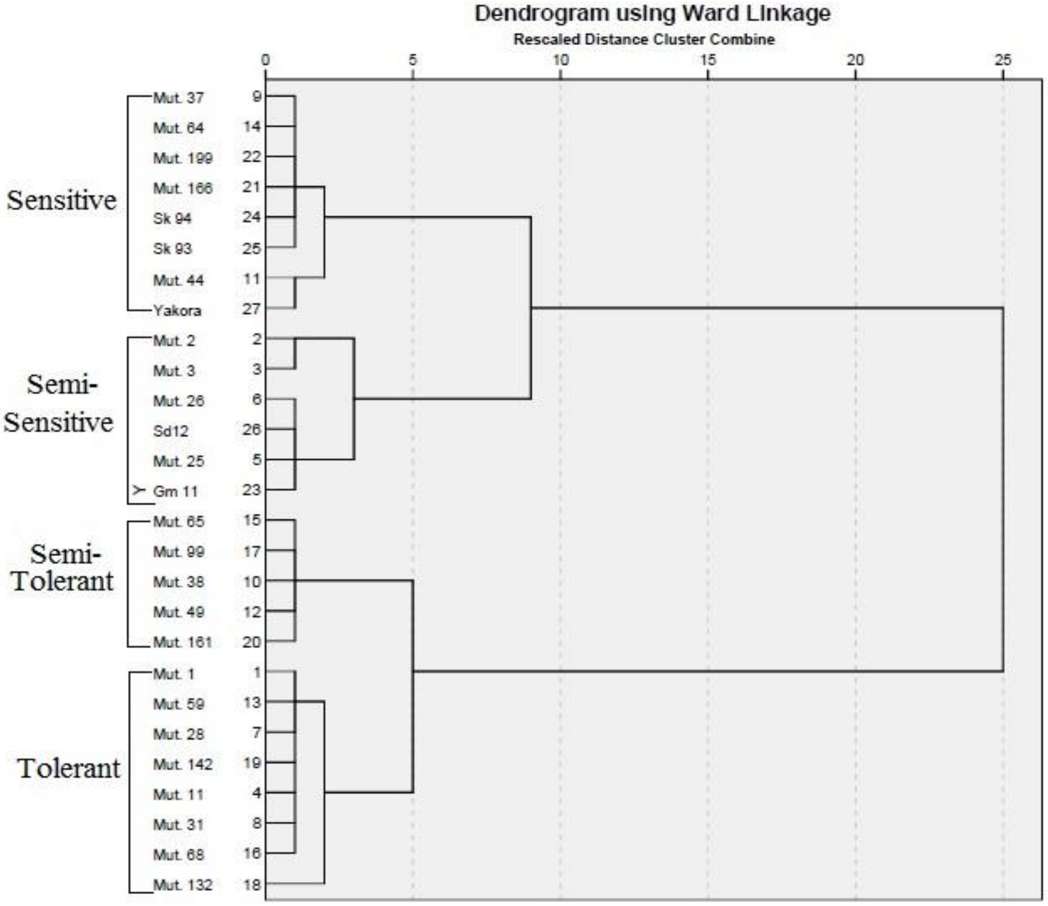

Fig. 1: Dendrogram using ward method between groups showing classification of cultivars based on resistance/tolerance indices.

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تقييم بعض طفرات قمح الخبز لمؤشرات تحمل الجفاف تحت ظروف الري العادي والجفاف.

محمد أحمد عفيفي [1]، علي عبدالمقصود الحصري[2]، صبيح السيد سليمان صبيح[1]، جابر يحيي همام[2]، أسامة أحمد بعلط[3]، خالد فؤاد العزب[1]

[1]قسم البحوث النباتية – مركز البحوث النووية – هيئة الطاقة الذرية – القاهرة – مصر.

[2]قسم المحاصيل – كلية الزراعة – جامعة بنها.

[3]قسم بحوث أمراض القمح – معهد بحوث أمراض النباتات – مركز البحوث الزراعية – الجيزة – مصر.

يعتبر قمح الخبز غذاء اساسي لأكثر من 40 دولة بما فيهم مصر علي مستوي العالم. استخدمت في هذه الدراسة 22 طفرة و5 أصناف محلية من قمح الخبز في الجيل الخامس والسادس. وتمت زراعة التجارب الحقلية في المزرعة التجريبية المتابعة لقسم البحوث النباتية، شعبة تطبيقات النظائر المشعة – مركز البحوث النووية – هيئة الطاقة الذرية، أنشاص مصر. قيمت مواد الدراسة في الجيل الخامس (M_5) 2018/2017 والجيل السادس (M_6) 2019/2018. تحت ظروف الري العادي وظروف نقص المياه في تجارب منفصلة. وكانت معاملة الري العادي الري كل 10 ايام ومعاملة الجفاف الري كل 20 يوم.تهدف الدراسة الي 1 – تحديد التراكيب الوراثية في قمح الخبز العالية في المحصول والمتحملة للجفاف تحت ظروف الري العادي ونقص الماء. 2 – تقييم التراكيب الوراثية في قمح الخبز المتحملة للجفاف باستخدام مقاييس التحمل للجفاف.ويمكن تلخيص النتائج المتحصل عليها كما يلي: وفقا لصفات التراكيب الوراثية في قمح الخبز تحت ظروف الجفاف لمتوسط سنتين كانت نسبة النقص 6.19% لصفة عدد الايام حتي الطرد، 6.25% لصفة عدد الايام حتي النضج، 11.60% لصفة طول النبات ، 8.79% لصفة طول السنبلة، 23.27% لصفة عدد السنابل في المتر المربع، 9.94% لصفة عدد الحبوب في السنبلة، 5.79% لصفة وزن الالف حبة، 34.62% لصفة محصول الحبوب (أردب /فدان)، 12.99% لصفة المحصول البيولوجي (طن/فدان) و 24.50% لصفة دليل الحصاد. تحت ظروف الري العادي كان هناك ارتفاع في محصول الحبوب (أردب/فدان) في الطفرات 1 و 59 و 31 و 11 و 2 و 68. في حين تحت ظروف الجفاف كان هناك ارتفاع في محصول الحبوب (أردب / فدان) في الطفرات 132 و 31 و 11 و 59 و 68 و 65. تشير النتائج الي ان الطفرات 31 و 132 و 11 و 59 و 68 و 1 أظهرت قيم مرتفعة لمقياس متوسط الانتاجية (MP) ومقياس متوسط الانتاج الحسابي (GMP) ومقياس متوسط التوافقية (HM) تحت ظروف الري العادي (YP) والاجهاد (YS) وتشير تلك الطفرات الي تحملها للجفاف. في حين الصنف ياكورا والطفرة 44 والصنف جميزة 11 أظهرت قيم منخفضة لمقياس متوسط الانتاجية ومقياس متوسط الانتاج الحسابي ومقياس متوسط التوافقية وتعتبر هذه التراكيب حساسة للجفاف.ارتبط محصول الحبوب تحت ظروف الجفاف (YS) ارتباط موجب ومعنوي مع مقياس تحمل الجفاف STI (r = 0.916**) ومقياس متوسط الانتاجية (MP) (r = 0.860**) ومقياس متوسط الانتاج الحسابي (GMP) (r = 0.913**) ومقياس متوسط التوافقية (HM) (r = 0.953**) ومقياس المحصول الناتج (Yi) (r = 0.996**) ومقياس ثبات المحصول الناتج YSI (r = 0.599*) ومقياس مقاومة الجفاف RDI (r = 0.596**) وكان الارتباط سالب ومعنوي مع مقياس القابلية للاجهاد SSI (r = −0.660**) ومقياس ثبات المحصول YSI (r=0.594**). كان الارتباط موجب ومعنوي بين محصول الحبوب تحت ظروف الري العادي (YP) و مقياس تحمل الجفاف STI (r = 0.858**) ومقياس متوسط الانتاجية (MP) (r = 0.917**) ومقياس متوسط الانتاج الحسابي (GMP) (r = 0.864**) ومقياس متوسط التوافقية (HM) (r = 0.804**) ومقياس التحمل TOL (r = −0.236) ومقياس المحصول الناتج (Yi) (r = 0.996**) . أظهرت النتائج أن مقاييس التحمل للجفاف وهي STI, MP, GMP, HM and YI كان ارتباطها موجب ومعنوي مع المحصول العالي تحت ظروف الجفاف والري العادي. أظهرت نتائج التحليل التجميعي لمؤشرات تحمل الجفاف أن دراسة 27 تركيب وراثي من القمح قسمت الي 4 أقسام. احتوي القسم الأول علي تراكيب القمح الحساسة للجفاف وهي الطفرات أرقام (37، 64، 199، 166 ، 44، والاصناف سخا94 وسخا93 وياكورا. واحتوي القسم الثاني علي تراكيب القمح متوسطة الحساسية للجفاف وهي الطفرات 2، 3، 25، 26 والاصناف سدس 12 وجميزة11 وتضمن القسم الثالث تراكيب القمح متوسطة التحمل للجفاف وهي الطفرات 65، 99، 28، 49 و161. وتضمن القسم الرابع تراكيب القمح المتحملة للجفاف حيث كانت القيم منخفضة لمقاييس القابلية للجفاف SSI ومرتفعة لقيم مقاييس تحمل الجفاف في الطفرات أرقام 1، 59، 28، 142، 11، 31 و 68 وكانت الطفرة 132 منفصلة فقط في القسم الرابع.