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PHYSIOLOGICAL EVALUATION OF TWELVE WHEAT GENOTYPES TO DROUGHT

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ABSTRACT

The physiological response of 12 wheat genotypes to drought was investigated at EL-Giza Agricultural Research Station Farm during 2004/2005 and 2005/2006 winter seasons. Drought was imposed at either heading or grain filling stage by withholding irrigation. Data were collected on leaf area index (LAI), dry matter accumulation (DM), crops growth rate (CGR), stomatal resistance (SR), transpiration rate (TR) leaf temperature (LT), leaf relative water content (RWC), chlorophyll fluorescence in dark (Fo), maximal chlorophyll fluorescence (Fm), maximum quantum yield of the photosystem Π (Fv /Fm) physiological maturity date (PM), yield and yield components, water consumptive use (WCU), water use efficiency (WUE), drought sensitive (YR/SD), yield response factor (KY) and drought susceptibility index (S) .Drought at either heading or grain filling reduced LAI, DM, CGR, RWC, TR, Fm, Fv /Fm, plant height, number of spikes / m^2, grain and biological yields . Grain yield reductions reached 35.29 and 33.62 % at heading and grain filling, respectively corresponding to 9.27 and 10.88 % reduction in WCU .On the contrary, drought increased SR, LT, and FO. Wheat plants were more droughts sensitive at heading stage than grain filling stage. This was clear from YR/SD, KY and S data. Plants of the tested genotypes showed variation in the studied characters assessed at ether heading or grain filling stages. Data of drought sensitivity based on both yield, and water consumptive use (YR/SD & KY) and S (based on yield data only) revealed that 3 genotypes of Egyptian breading program, one introduced from ICARDA and one from CIMMYT are drought tolerant, could be grown at the end of water canals where irrigation water is scarce or at rain fed areas . Another genotype introduced from CIMMYT showed superior in yield when irrigation water was available.

Key words: ***Lea area index (LAI), Crop growth rate (CGR), Stomatal resistance (SR), Transpiration (TR), Leaf temperature (LT), Relative water content (RWC), Fluorescence (FO, FM and FV/FM), Physiological maturity (PM), Water consumptive use (WCU), Water use efficiency (WUE), Drought sensitivity (YR/SD), Yield response factor (KY) and Drought susceptibility index (S).***

INTRODUCTION

Water deficit occurs when water potentials in the rizospher are not sufficient for plant growth and development. On a global basis water deficit is a major cause of limiting productivity of agriculture crops and food production. (Boyer1982). He added, because of a biotic stress resulting from climate and soil conditions, the yield of field grown crops in USA is only 22 % of their genetic potential yield. In confirm to Boyer results, Abu-Grab and Hamada (2002) reported that withholding irrigation at tillering , heading or dough growth stages reduced grain yield by 13.6, 12 and 10.5 %, respectively corresponding to 10.1, 13.2 and 14.5 % reduction in the water consumption. They added that plants were more sensitive to water stress imposed at tillering stage. Sharma and Thakur (2004) tested 20 spring wheat genotypes under moisture stress and non-stress. They found that grain and biological yield showed maximum sensitivity as affected by moisture stress. They reported significant positive correlation between grain yield with biological yield and harvest index; significant negative correlation of grain yield with susceptibility index under water stress conditions and significant positive correlation of grains/spike and grain weight with grain weight/ spike under both stress and non-stress environments suggested that selection to withstand water stress must be exercised for high biomass , grain weight /spike and harvest index for yield improvement under dry land conditions. Moreover, Passioura (2004) stated that a good wheat cultivar must be characterized by the ability to capture more of the water supply for use in transpiration; exchange transpired water for Co_2 more effectively in producing biomass and convert more of the biomass into grains or other harvestable product. He added that the upper limit of water use efficiency in the field for the well managed diseases free water limited crops is 20 kg grain ha^{-1} mm^{-1}. Furthermore, Benmoussa and Achouch (2005) tested 25 barely varieties; one variety of durum wheat and one variety of triticale under dry land and irrigated conditions, They concluded that all agrophysiological characters (plant height, days to heading, lodging, number of spike /m^2, number of grain/spike and grain yield) were significantly affected by water deficit, grain yield decreased by 30 and 34 % in first and second season, respectively due to water deficit. More recently, Beltrano *et al* (2006) reported that water deficit and rewatering at watery ripe, milk and soft dough stages decreased flag leaf water content, chlorophyll and protein content. Water stress at the watery and milk stages reduced the final grain dry mass by 47 and 20%, respectively. This reduction was due to a decrease in grain filling period and to a significant reduction in the maximum rate of grain filling. Similar results were obtained by Yang and Zhang (2006) who stated that water stress during grain filling period induced early senescence, reduce photosynthesis and shortened grain filling period. However, it increased the remobilization of non-structural carbohydrates from vegetative tissues to the grain. Ali *et al* (2007) studied the effect of water deficit at different growth stages on yield, water productivity and net return of wheat. They reported that yield attributes not significantly differed in all cases by water deficit. They add that grain and straw yields were significantly affected by water deficit treatments.

The present work aims to use some physiological traits and parameters to evaluate some wheat genotypes for water stress under Giza governorate conditions.

MATERIALS AND METHODS

Two field experiments were conducted at Giza Agriculture Research Station, during 2004/2005 and 2005/2006 winter seasons to test the potency of some wheat genotypes to tolerate water stress at some growth stages. The experimental soil was clayey. Some of its physical characteristics are shown in Table (1).

Table1. Physical properties of the experimental site.

Soil depth (cm)	Field capacity (%)	Wilting point (%)	Bulk density (g/cm^3)
0-15	41.85	18.61	1.15
15-30	33.68	17.50	1.24
30-45	28.38	16.92	1.20
45-60	28.05	16.54	1.28

Water stress was created by withholding irrigation at heading or grain filling stage compared to unstressed (control) which had six irrigations at different growth stages. The name, pedigree and origin of the genotypes used in the experiments are presented in Table (2).

Table 2. The names and pedigree the parental varieties and lines evaluated

Entry no.	Variety of cross and pedigree	Origin
1	CMH 74A.630/SX//SERI 82/AGENT/3/Chil/WUH3	Egypt
2	Gem 5/CNH*@-694/2*ACO89	Egypt
3	F134-71/Crow's'//TPZ,Bc4/3Gem 3	Egypt
4	SIBIA/Sids 4	Egypt
5	Bcr/Lks4 /Sids 4	Egypt
6	Tow's'/Pews	ICARDA
7	Naama 9	ICARDA
8	Angra/2*Cazo	CIMMYT
9	Kavko/Cmh82-493	CIMMYT
10	Mri//Gem9	Egypt
11	Gemmeiza 10	Egypt
12	Gemmeiza 5	Egypt

A split plot design in a complete block arrangement with three replicates was adopted. The water stress treatments occupied the main plots whereas the test genotypes were randomly distributed in the subplots. Each plot was 10 rows, each 4 m long with 20 cm between rows.

Wheat grains were planted on 20 and 25 November in the first and second seasons, respectively. The other cultural practices, expect irrigation, were carried out as recommended for wheat production .Two plant samples, of 20 cm long, were taken from the two outer rows of every plot, on two days before the end of drought cycle at heading stage and 15 days before harvest, then the following data were recorded.

1- Total dry matter (TDM) plant samples were oven dried to constant weight, and expressed as kg/m^2.

2- Leaf area index (LAI) i.e. the ratio between the area of leaves/plant to the area of ground occupied by the plant (Daughtry and Hollinger 1984) Leaf area was measured as length x width x 0.7 .

3- Crop growth rate (CGR): the increase of plant material per unit of time (Watson 1952). During the same period of measuring growth parameters, a portable steady state porometer Model LI 1600) USA was used to determine leaf and air temperature LT & AT; photosynthetic photon flux density (PPFD); stomatal resistance (SR) and transpiration (TR). Also chlorophyll fluorescence was measured using Optiscince OS-30 chlorophyll fluoremeter during the same period. Leaves relative water content (RWC) was determined according to Barrs and Weatherley (1962) equation : RWC = (Fw- Dw)/(Tw-Dw) x 100 --------------------**(1)**
Where FW is fresh weight of the leaf sample, DW is the dry weight of leaf sample; TW is the weight of fresh leaf floated in distilled water for 8 hrs. Besides, number of days to physiological maturity was also recorded.

Water consumptive use (WCU) was determined gravimetrically (Israelson and Hansen 1962) according to the following equation

$WCU = (\emptyset_2 - \emptyset_1 \times Bd \times 600)/100$ --------------------------------------**(2)**

Where: $\emptyset_2$ and $\emptyset_1$ are soil moisture %, 48 hrs. after irrigation and just before the next irrigation, respectively, Bd = Bulk density for the soil layer (g/cm^3); WCU=water consumptive use in mm. Drought sensitivity (RYR/SD) was estimated according to Hiller and clark (1971) where RYR are relative yield reduction = $1\text{-}yd/y_c$------------**(3)**
Where Yd and Yc are yield of stressed and control treatment, respectively
SD are number of stressed days = 1- (Ed/Ec) N -----------------------**(4)**
Where Ed and Ec are evapotranspiration from fully irrigated and drought treatment, respectively and N is the number of the days in the period.Yield response factor (ky) was calculated according Doorenbos and Kassam (1979) $Ky = (1-Y_d/Y_c) / (E_d/E_c)$ ------------**(5)**

The drought susceptibility index (S) was calculated for the yield data according to the formula of Fisher and Maurer (1978)

$S= (1-Y_d/Y_c) / D$ --(6)

Where D = drought intensity = 1-mean of Y_d of all genotypes / mean of Y_c of all genotypes.

At harvest time, plant height was measured then the plants of the inner rows of every sub-plot were used to determine biological and grain yield. Number of spike per square meter, and 1000 grain weight were also recorded .Combined analysis for the two studied seasons data has been done according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Growth

Growth parameters i.e. dry matter /m^2, leaf area index (LAI) and crop growth rate (CGR) are presented in Table (3).

Table 3. Leaf area index (LAI), total dry matter (TDM) and crop growth rate (CGR) as affected by drought and grown genotypes (combined data of 2004/2005 and 2005/2006 seasons).

Treatment	LAI	TDM kg/m^2	LAI	TDM Kg/m^2	CGR g/m^2 /day
Irrigation	At heading stage		At grain filling stage		
Control	13.462	1.524	5.841	2.255	22.857
Drought	10.426	1.251	3.229	1.824	9.437
F. Test	**	*	**	**	**
Genotypes					
1	8.002	1.458	2.312	1.723	5.732
2	11.373	1.413	4.502	1.988	15.367
3	11.692	1.375	6.284	1.990	17.188
4	10.102	1.357	3.816	2.030	18.690
5	12.188	1.298	3.575	2.282	22.970
6	14.227	1.530	4.883	2.225	19.428
7	12.502	1.197	5.414	1.853	15.002
8	16.303	1.528	2.860	2.000	9.273
9	11.197	1.422	3.842	2.190	22.710
10	12.485	1.333	4.537	1.853	13.645
11	14.548	1.373	5.224	2.278	17.137
12	8.563	1.368	3.508	2.062	13.282
$LSD_{0.05}$	1.810	n.s	0.993	0.169	3.860

n.s = not significant

From the table it can be seen that imposing drought at either heading or grain filling time resulted in highly significant reduction in most growth parameters studied. This trend was clearly found in CGR which decreased more than two folds compared to non stressed (control) plants. The obtained results agree with those of Lu *et al* (1999) who reported that water deficit reduced shoot growth of two barley genotypes (on dry weight basis) by 74.8 to 85.2 % compared with the control plants.

Genotype no. 8 recorded the Except DM at heading the test genotypes showed differences in growth parameters at either heading or grain filling stages (Table 3). In this respect, genotypes no. 6 and 8 recorded high LAI and DM at heading stage although the data of DM were not significant. At grain filling stage genotype no. 5 showed the highest DM accumulation rate with the highest CGR followed by genotypes 6, 9&11. Similar results were obtained by Lu *et al* (1999) who found significant differences in shoot dry weight of two barley genotypes under water deficit (-0.4 Mpa) conditions.

highest LAI with the highest DM accumulation rate at heading stage under control conditions, whereas genotype no. 6 recorded the highest DM accumulation rate under water stress condions although the data were not significant. At grain filling period Gemmeiza 10 cv. and genotypes 5and 6 recorded high DM and CGR. Under control conditions, whereas genotypes no. 9 and 5 recorded the highest DM and CGR under water stress conditions (Table 4). As for LAI, genotypes no. 3 and no. 6 recorded the highest LAI at grain filling period under control and water stress conditions, respectively. Obtained results refer that genotypes 9 and 5 were more drought tolerant. In this respect Lu *et al*. (1999) tested two barley genotypes one tolerant and the other non-tolerant under water deficit. They reported that drought tolerant one (Wadi Qitt 23-39) showed full osmotic adjustment in the last full expanded leaf tissues compared to 62.5% only for another cultivar (Mona).

Porometer parameters and relative water content (RWC)

Water stress significantly decreased with RWC and TR (Table 5). Vice versa was found with (SR) and (LT). This trend was clearly showed at both heading and grain filling stages. This result confirm those of Abu-Grab and Hamada (2002) on wheat who reported that stressed plants were less transpired water whereas SR and LT were increased, Beltrano *et al* (2006) who stated that RWC of flag leaves was significantly lower for stressed wheat plants compared to control.

Table 4. Interaction effect of drought treatments and grown genotypes on leaf area index (LAI), total dry matter (TDM) and crop growth rate (CGR). (Combined data of 2004/2005 and 2005/2006 seasons).

Treatment	LAI	TDM Kg/m^2	LAI	TDM Kg/m^2	CGR g/m^2 /day
Irrigation X Genotypes	At heading stage		At grain filling stage		
Control					
1	8.997	1.540	2.553	1.823	8.857
2	13.400	1.497	6.543	2.273	24.273
3	12.973	1.440	9.777	2.313	27.293
4	11.083	1.423	3.290	2.160	23.020
5	13.473	1.440	4.047	2.630	37.190
6	16.468	1.603	5.093	2.587	30.730
7	13.270	1.373	7.087	1.977	18.853
8	18.640	1.720	3.223	2.143	13.230
9	13.783	1.463	4.003	2.277	25.420
10	15.630	1.417	6.437	2.04	19.480
11	14.927	1.730	6.860	2.693	30.107
12	8.903	1.637	3.853	2.143	15.833
Drought					
1	7.007	1.377	2.070	1.623	2.607
2	9.347	1.330	2.460	1.703	6.460
3	10.410	1.310	2.790	1.667	7.083
4	9.120	1.290	4.343	1.900	14.900
5	10.903	1.157	3.103	1.933	15.417
6	110987	1.457	4.673	1.863	8.127
7	11.733	1.020	3.740	1.730	11.150
8	13.967	1.337	2.497	1.857	5.317
9	8.610	1.380	3.680	2.103	20.000
10	[illegible].340	1.250	2.637	1.667	7.810
[illegible]	14.17	1.017	3.587	1.863	4.167
1[illegible]	8.223	1.100	3.163	1.980	10.730
[illegible]D $_{0.05}$	[illegible]	n.s.	1.405	0.238	5.456

Table 5. Stomatal resistance (SR), transpiration rate (TR), leaf temperature (LT) and relative water content (RWC) as affected by drought and grown genotypes (Combined data of 2004/2005 and 2005/2006 seasons).

Treatment	SR s/cm	TR mg $H_2o/m^2/s$	LT C°	RWC %	SR s/cm	TR mg H_2o m^2/s	LT C°	RWC %
Irrigation	At heading stage				At grain filling stage			
Control	2.67	9.54	23.72	87.89	4.36	4.51	25.11	70.01
Drought	7.03	3.44	23.82	75.44	8.05	2.71	26.69	51.43
F. Test	**	**	n.s.	**	**	**	*	**
Genotypes								
1	6.20	4.75	24.93	81.25	7.32	2.77	25.93	52.50
2	5.10	6.11	24.57	79.00	5.61	3.80	25.73	66.00
3	4.59	7.04	24.18	80.50	6.02	3.62	26.00	61.75
4	4.71	6.70	24.28	79.00	6.41	2.87	26.00	55.25
5	4.44	5.77	23.87	80.50	5.73	3.73	25.85	54.25
6	5.40	6.90	23.85	80.25	5.94	3.41	25.90	59.75
7	4.03	6.80	23.83	82.25	7.11	3.39	25.95	64.50
8	3.85	7.20	24.32	84.50	6.23	3.84	26.05	59.75
9	5.54	6.50	24.03	83.00	6.64	3.86	26.00	63.75
10	5.85	6.03	24.03	80.85	6.25	3.81	25.71	64.75
11	4.27	7.08	23.57	84.50	5.40	4.10	25.77	66.33
12	4.75	7.07	23.53	84.42	5.85	3.96	25.78	66.08
$LSD_{0.05}$	0.42	0.44	n.s.	3.02	0.44	0.39	n.s.	7.24

The tested genotypes differed significantly in their leaves SR, TR and RWC (Table 4) In this respect, the genotype no. 1 recorded the highest SR and the lowest TR and RWC (Table 5). This trend was clearly found in the two assisted intervals. Genotype no. 8, 11 and 12 recorded low SR, LT and high RWC, TR., at heading stage. On grain filling stage, plants of genotypes no. 11 and 12 attained low SR, high LWC and Tr. rate whereas LT did not significantly differ between the tested genotypes. The variation between genotypes in stomatal resistance and transpiration rate was also reported by Gummuluru *et al* 1989, Darwish (1998) and Abu-Grab and Hamada (2002).

Significant interaction was found between the tested genotypes and drought imposing time (Table 6). it is obvious from the table that, plants of both genotypes no. 8 and no. 11 might be have the potency to increase their

Table 6. Interaction effect of drought treatments and grown genotypes on stomatal resistance (SR), transpiration (TR), Leaf temperature (LT) and relative water content (RWC) combined over 2004/2005 and 2005/2006 seasons.

Treatment	SR	TR	LT	RWC	SR	TR mg H_2o m^2/s	LT C°	RWC %
Irrigation X Genotype	At heading date				Grain filling stage			
Control								
1	3.65	6.83	24.67	85.00	4.51	3.64	25.10	65.50
2	3.41	8.94	24.33	90.00	4.37	4.57	25.20	76.50
3	2.52	10.75	24.27	86.00	4.01	4.52	25.20	72.5
4	2.36	9.94	23.97	88.50	5.24	3.51	25.10	66.00
5	2.70	8.07	23.87	84.50	4.38	4.57	25.13	61.50
6	2.25	10.63	23.53	85.00	4.27	4.25	25.10	71.50
7	2.58	9.93	23.47	84.00	4.88	4.31	25.13	75.00
8	2.30	10.57	23.80	90.50	4.14	4.75	25.20	71.00
9	2.54	9.34	23.40	40.00	4.12	4.93	25.20	74.50
10	2.88	8.67	23.27	87.2	4.05	4.78	25.13	71.00
11	2.38	10.40	23.07	88.00	4.04	5.00	25.17	74.17
12	2.42	10.46	22.97	91.00	4.34	4.93	24.60	73.00
Drought								
1	8.75	2.66	25.20	77.5	10.13	1.90	26.77	39.50
2	6.79	3.27	24.80	68.00	6.84	3.02	26.27	55.50
3	6.63	3.32	24.10	75.00	8.03	2.73	26.80	51.00
4	7.05	3.45	24.60	69.50	7.57	2.24	26.97	44.50
5	6.18	3.46	24.30	76.50	7.09	2.88	26.57	47.00
6	8.56	3.17	24.17	75.50	7.60	2.57	26.70	48.00
7	5.47	3.66	24.2	75.00	9.33	2.48	26.77	54.00
8	5.39	3.83	24.83	79.00	8.32	2.92	26.90	48.50
9	7.53	3.67	24.67	76.00	9.17	2.80	26.97	53.00
10	8.81	3.39	24.80	74.50	8.44	2.83	26.30	58.50
11	6.15	3.75	24.07	81.00	6.76	3.21	26.90	58.50
12	7.08	3.67	24.10	77.80	7.37	2.99	26.37	59.17
$LSD_{0.05}$	0.59	0.62	n.s.	4.56	0.63	n.s.	n.s.	10.23

osmotic adjustment at the stomata guard cells, hence enhancing photosynthesis and assimilates accumulation on one hand, or they has a good root system to get the water from the deeper root zones on the other.

Chlorophyll fluorescence

Water stress induced significant increase in chlorophyll fluorescence at dark FO. This trend existed when water stress was imposed at either heading or grain filling stage (Table 7). Vice versa was found in the maximal chlorophyll fluorescence (Fm) and Fv/Fm ratio which represents the maximal quantum yield of the primary photochemical reaction for the photosystem two (PSII) in dark adapted leaves. The obtained results partially agree with those of Zlatev and Yordanove (2004) working on bean plant, who reported that drought stress induced an increase in FO accompanied by a decrease in Fm. They added that Fv/Fm ratio, practically, was not changed and showed a slight tendency to decrease.

Table 7. Chlorophyll fluorescence at dark (FO), maximal chlorophyll fluorescence (FM) and quantum yield of PSII (FV/FM) as affected by drought and grown genotypes (combined data of 2004/ 2005 and 2005/2006 seasons).

Treatment	Fo	Fm	Fv/Fm	Fo	Fm	Fv/Fm
Drought	At heading			At grain filling		
Control	355.31	1752.78	0.800	219.05	1202.34	0.817
Drought	455.89	1670.44	0.734	270.00	1173.05	0.768
F. Test	**	*	*	*	*	*
Genotypes						
1	490.17	1651.33	0.706	213.93	1015.13	0.794
2	532.00	1464.17	0.728	229.75	1046.21	0.832
3	399.00	1816.67	0.778	235.88	1289.63	0.789
4	349.83	1591.17	0.782	224.13	1225.33	0.863
5	391.33	1768.33	0.778	239.81	1141.50	0.830
6	572.17	1784.17	0.754	306.76	1306.56	0.805
7	435.83	1733.17	0.751	226.18	998.83	0.825
8	348.67	1705.17	0.792	271.38	1239.88	0.824
9	469.00	1885.67	0.752	237.90	1286.93	0.854
10	366.67	1653.17	0.794	263.75	1291.34	0.801
11	283.67	1575.67	0.818	255.55	1274.81	0.831
12	316.17	1410.67	0.771	229.30	1136.21	0.800
$LSD_{0.05}$	119.96	198.75	N.s.	55.65	183.29	n.s.

Genotypes showed significant differences in FO and FM chlorophyll fluorescence (Table 7). But no significant differences were found among the test genotypes in Fv/Fm ratio at either heading or grain filling stages. The results agree with those of Lu and Zhang (1999) who found that water stress showed no effects on the maximum quantum yield of PSII photochemistry (Fv/Fm).

No significant interaction, between the test cultivars and drought stress was reported at either heading or grain filling stages on Fo/Fm and Fv/Fm, thus its related data were discarded.

Number of day to physiological maturity (PM)

Earliness expressed as number of days to physiological maturity (PM) as affected by water stress are seen in Table (8). It is quite clear from the table that water stress significantly shortened the number of days from planting to PM .In this respect, withholding irrigation at grain filling period hastened maturity significantly more than withholding irrigation during heading. This is mainly due to shortening grain filling period through increasing the remobilization of non structural carbohydrates from vegetative tissues to the grain. The results obtained are in accordance with those of Beltrano *et al* (2006), and Yang and Zhang (2006). They found that drought during grain filling induced early senescence, reduced photosynthesis and shortened grain filling period.

Table 8. Number of days to physiological maturity, yield, yield components as affected by drought and grown genotypes (combined data of 2004/2005 and 2005/2006 seasons).

Treatment	Days to maturity	Plant height (cm)	Spikes /m^2	GY (ton /fed)	BY (ton /fed)	1000 grain wt (gm)	WCU (mm)	WUE Kg/mm/fed
None drought	143.75	92.51	337.31	3.063	4.595	40.49	487.12	6.29
Drought at H.	139.18	85.42	306.69	1.983	4.667	34.22	441.95	4.48
Drought at G.F.	136.88	88.59	311.22	2.033	4.491	32.44	434.13	4.68
LSD $_{0.05}$	0.29	1.95	7.24	0.074	0.087	2.59	—	—
Genotypes								
1	137.89	86.57	262.22	2.142	4.484	35.71	455.40	4.70
2	142.89	89.06	256.33	2.166	4.572	35.32	451.35	4.80
3	141.33	83.08	263.11	2.309	4.886	34.60	443.25	5.21
4	138.56	92.84	316.67	2.225	4.817	32.76	440.43	5.05
5	137.33	92.55	371.56	2.268	4.736	35.50	466.43	4.86
6	136.89	90.46	274.22	2.117	4.937	34.08	455.87	4.64
7	140.00	93.60	367.11	2.391	4.880	35.52	463.41	5.16
8	138.44	93.65	375.00	2.692	5.139	36.41	440.95	6.11
9	142.89	81.89	286.22	2.203	4.950	36.82	453.25	4.86
10	142.89	91.73	375.77	2.292	4.851	35.77	442.41	5.18
11	144.11	84.53	378.44	2.846	5.075	39.96	460.48	6.18
12	140.56	94.12	364.22	2.625	5.169	41.14	465.16	5.64
LSD $_{0.05}$	0.58	3.90	14.55	0.149	0.173	1.49	—	—

H = heading stage, G.F. = grain filling stage, BY= Biological yield, GY =grain yield

The tested genotypes could be classified into two categories according to PM (Table 8). Early category which needs 136.89-138.56 days to reach PM this group includes genotypes 1,4,5,6 and 8. Late category which needs 140.0–144.11 days to reach PM includes genotypes no. 2,3,7,9,10,11 and 12. In this respect, Benmoussa and Achouch (2005) tested 25 barley varieties, one variety of durum wheat and one triticale variety. They found that days to heading (DTH) were significantly affected by water deficit.

Genotypes no. 1, 4, 5 and 6 showed earliness under non stressed conditions (140.33–140.67 DTPM). When water stress was imposed at heading or grain filling stages genotypes no. 1,4,5,6 and 8 showed earliness (134.00–137.67 DTPM) as it is clear from (Table 9). In contrast genotype no. 11 showed late maturity as its plants reached the physiological maturity after 148.66, 141.66 and 140.67 days under non stressed conditions or when water stress was imposed at heading and grain filling period, respectively. A variation between genotypes in earliness was also reported by Benmoussa and Achouch (2005).

Yield and yield components

Data of yield and its components are presented in (Table 8). Water stress significantly reduced plant height, number of spikes per square meter and 1000-grain weight which was reflected in decreasing both biological and grain yields. In this respect, water stress at heading stage was more effective in reducing all yield components studied than water stress at grain filling period, (grain yield reductions were 35.29 and 33.62 due to water stress at heading and grain filling stages, respectively). One exception was found, i.e., 1000-grain weight was more influenced by water stress at grain filling period than at heading stage. The obtained results confirm those of Abu-Grab and Hamada (2002), Sharma and Thakur (2004), Beltrano *et al.* (2006) and Yang and Zhang (2006).

Plants of genotypes no. 11, 12 and 8 generally surpassed those of other genotypes significantly in number of spikes/m^2, 1000-grain weight, plant height which reflected on grain and biological yields (Table 8). In contrast genotypes no.1 and 2 recorded lower grain and biological yields than the other test genotypes, mainly due to their poor number of fertile tillers (low number of spikes/m^2). The obtained results could be explained as plants of genotypes no. 11, 12 and 8 has the ability to use the water from the soil under drought conditions through enhancing osmotic adjustment in the guard cells of their stomata, hence decreasing stomatal resistance and increasing transpiration and photosynthesis rates see (Table 5) From such table it can be seen that these genotypes has recorded low SR and high TR. as well as RWC, on one hand. On the other hand these genotypes may have

Table 9. Interaction effect of drought and grown genotypes on No. of days to physiological maturity and yield and yield components (Combined data of 2004/2005 and 2005/2006 seasons)

Drought x Genotypes	Days to heading	Days to maturity	Plant height (cm)	Spikes/ m^2	GY, ton/ fed	BY, ton/ fed	1000-grain wt.(g)	UCU, mm	WUE, Kg/ mm fed
Control									
1	77.67	140.67	93.73	280.0	2.600	4.676	39.73	489.29	5.31
2	79.33	146.33	95.97	281.0	2.700	5.015	39.77	480.24	5.62
3	88.33	143.66	86.43	271.33	3.101	5.630	39.10	475.48	6.66
4	86.33	140.33	97.73	333.33	2.925	5.400	34.93	468.67	6.24
5	75.00	140.66	96.13	399.67	2.880	5.205	41.37	510.95	5.64
6	77.33	140.33	88.27	294.67	2.801	5.510	37.20	490.24	5.71
7	82.00	143.00	93.23	396.67	3.150	5.441	37.10	508.57	6.19
8	78.00	143.67	101.93	410.0	3.600	5.765	44.63	467.38	7.70
9	82.33	147.66	84.20	290.00	2.850	5.525	44.03	495.00	5.76
10	82.33	146.66	101.21	394.00	3.075	5.600	41.40	469.38	6.55
11	81.67	148.66	86.13	401.67	3.575	5.951	45.13	495.00	7.22
12	76.67	143.33	103.18	375.33	3.500	5.850	45.43	499.29	7.01
Drought at heading date									
1	72.67	137.67	82.73	251.66	1.775	4.350	36.73	443.57	4.00
2	78.33	142.33	78.53	231.66	1.850	4.400	34.03	440.48	4.20
3	80.00	141.00	77.83	256.67	1.901	4.650	32.83	428.33	4.44
4	78.00	137.67	83.67	308.33	1.775	4.526	32.50	427.86	4.15
5	71.67	136.67	90.78	351.67	1.976	4.650	33.57	456.19	4.33
6	73.67	136.33	88.87	257.67	1.751	4.850	34.73	445.95	3.93
7	79.00	138.33	92.83	353.00	1.925	4.625	36.00	439.29	4.38
8	71.33	137.67	92.57	355.33	2.125	4.976	33.00	429.05	4.95
9	80.33	140.67	75.97	298.33	1.985	4.700	33.10	431.90	4.60
10	70.33	141.66	88.70	363.00	1.875	4.550	32.73	427.86	4.38
11	76.00	143.00	86.37	367.33	2.576	4.650	36.97	453.57	5.68
12	75.33	139.66	86.13	266.00	2.171	4.081	39.40	454.29	4.78
Drought at grain filling period									
1	72.34	135.33	83.23	2.55	2.051	4.425	30.67	433.33	4.73
2	77.67	140.00	92.67	256.67	1.950	4.301	32.17	445.48	4.38
3	79.67	139.33	84.97	261.33	2.025	4.376	31.87	425.95	4.75
4	77.67	135.67	91.13	308.33	1.976	4.526	30.83	424.76	4.65
5	70.33	134.67	90.73	363.33	1.950	4.350	31.57	432.14	4.51
6	73.67	134.00	94.23	270.33	1.800	4.451	30.30	431.43	4.17
7	80.00	138.67	94.73	351.67	2.100	4.575	33.47	442.38	4.75
8	72.67	134.00	86.47	359.67	2.350	4.676	31.60	426.43	5.51
9	80.67	140.33	85.50	270.33	1.875	4.625	33.33	432.86	4.33
10	71.00	140.33	85.27	370.33	1.925	4.400	31.17	430.00	4.48
11	77.67	140.67	81.10	366.33	2.385	4.625	37.77	432.86	5.51
12	75.100	138.67	93.03	351.33	2.205	4.575	38.60	441.90	4.99
$LSD_{0.05}$	3.30	1.61	6.76	25.2	0.257	0.300	2.52	——	——

good root system to get the water from deeper soil zones. In this connection Edwin *et al* (1991) and Abu-Grab and Othman (1999) reported that the relationship between grain yield and SR as well as TR. rates are consistent suggesting it may be useful as yield predictor. Also, the variation between wheat genotypes in yield and yield components was reported by Abu-Grab and Hamada (2002), Sharma and Thakur (2004) and Benmoussa and Achouch (2005).

Genotypes no. 8, 11 and 12 exceeded the other tested genotypes in grain and biological yields under non stressed conditions (Table 9). This is mainly due to the high number of spikes/m^2 and the high 1000-grain weight recorded by these genotypes in addition to genotypes no. 8 and 12 were taller than the other tested genotypes. The same trend was found when drought was imposed at grain filling stage .When drought was imposed at heading stage, genotypes no. 9,11 and 12 recorded highest grain yield whereas genotypes no. 5,6,8,9 and 11 recorded the high biological yield compared with the other tested genotypes. The variation between genotypes in yield and yield components could be explained on genetical basis. The variation between wheat cultivars under water stress was also reported by Abu-Grab and Hamada (2002) and Sharma and Thakur (2004) who tested 20 spring wheat under moisture stress, and found significant positive correlation between grain yield with biological yield and harvest index.

Water consumptive use (WCU)

Non stressed treatment (control) plants recorded the highest water consumptive use compared with stressed plant at either heading or grain filling stages (Table 8 and Fig. 1). The reduction in WCU due to withholding irrigation at heading and grain filling stages was 9.27 and 10.88 %, respectively. The obtained results confirm those obtained by Abu-Grab and Hamada (2002) and Moussa and Abdel Maksoud (2004).

The tested genotypes also differed in their WCU (Table 8 and Fig. 1). In this respect, genotype no. 5 followed by both genotypes no. 12 and no. 7 recorded high WCU rate whereas genotype no. 3, 4, 8, and 10 recorded low WCU. The diversity between genotypes in WCU was also reported by Abu-Grab and Hamada (2002). They reported that Gemmeiza 7 and Gemmeiza 9 cvs. recorded high WCU where Sids1 and Gemmeiza 3 cvs. recorded the lowest WCU. A variation in WCU between wheat cultivars was also reported by Moussa and Abdel Maksoud (2004).

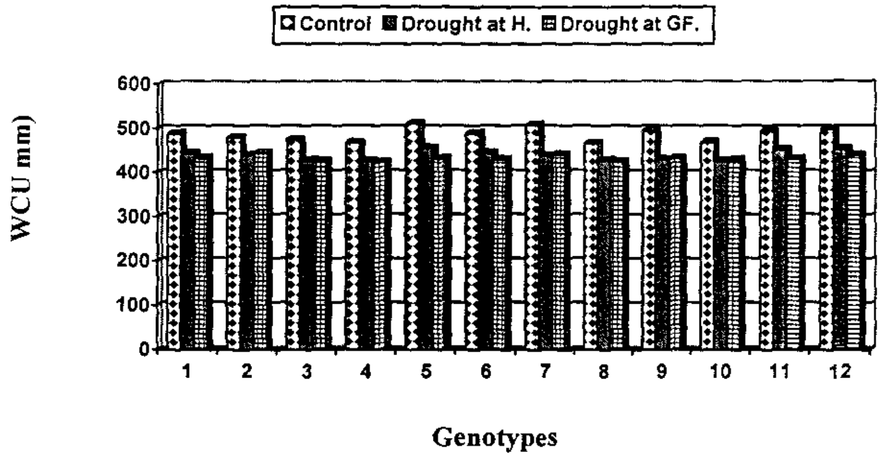

Fig. 1. Water consumptive use WCU as affected by drought and genotypes

Plants of genotype no. 5 in non stressed plots attained the highest WCU (510.95 mm) whereas those of genotype no. 8 subjected to water stress at heading stage recorded the lowest WCU (Table 9).Varietals variation in WCU was also by Khater *et al* (1997), Abu-Grab and Hamada (2002) and Moussa and Abdel Maksoud (2004).

Water use efficiency (WUE)

Non stressed plants attained the highest WUE (Table 8 and Fig. 2). The reduction in WUE due to missing one irrigation at heading or at grain filling stages were 28.77 and 25.60%, respectively. The obtained results are in accordance with those of Abu-Grab and Hamada (2002).

The maximum (6.18 kg/fed/mm) WUE was recorded with genotype no. 11. The minimum WUE rate was obtained with genotypes no. 6, 1 and no. 2, respectively. Their WUE rates were 4.64, 4.70 and 4.80 kg/fed/mm in the same order. Variation among wheat cultivars in WUE was also reported by Abu-Grab and Hamada (2002), and Passioura (2004). The later stated that the upper limit of WUE in the field for well managed disease–free water limit crop is 20 kg /ha/mm.

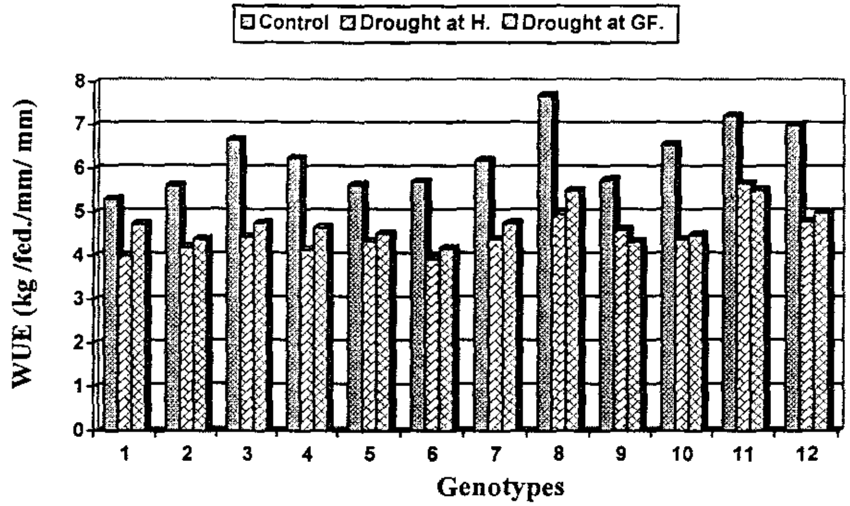

Fig. 2. Water use efficiency as affected by drought and genotypes.

Unstressed plants of genotypes no. 8, 11 and 12 recorded high WUE (7.70, 7.22and 7.01 kg/fed /mm, respectively) (Table 9). Whereas plants of genotype no. 6 subjected to water stress at heading stage recorded the lowest (3.93 kg/fed /mm) WUE.

Drought sensitivity (YR/SD)

The ratio of relative yield reduction to the number of stressed days (YR/SD) was used by Hiller and Clark (1971) and Mogensen *et al* (1985) to compare drought sensitivity at various growth stages.

Data of YR/SD are shown in Table (10). The YR/SD values were 0.024 and 0.020 when drought was imposed at heading and grain filling, respectively, corresponded to 35.20and 33.51 % reduction in grain yield for the respective drought stages compared with the control. It could be concluded that heading stage is a greater drought sensitive stage as YR/SD was associated with low WUE. Similar results were obtained by Mogensen *et al* (1985), Abu-Grab and Hamada (2002) who reported that heading was more drought sensitive stage and Sharma and Thakur (2004) who reported that grain and biological yield showed maximum sensitivity as affected by water stress.

Genotype no. 10 showed maximum YR/SD value (0.031) followed by genotypes no. 8 which recorded (0.030) YR/SD whereas genotypes no. 1,5,7,9 and 11 were less sensitive to water stress as they recorded 0.018, 0.016 , 0.018 , 0.018 and 0.020 YR/SD, respectively (Table 10) .

Table 10. Relative yield reduction (YR) stressed days (SD), drought sensitivity (YR/SD), yield response factor (KY) and susceptibility index (S) as affected by drought treatments and grown genotypes (combined data of 2004/2005 and 2005/2006 seasons).

Treatment	YR	SD	YR/SD	KY	S
Drought treatment					
Drought at heading (D1)	0.3520	14.50	0.024	3.80	1.00
Drought at grain filling (D2)	0.3351	16.48	0.020	3.18	0.98
Cultivars					
1	0.2731	15.59	0.018	2.63	0.77
2	0.2963	11.64	0.025	3.82	0.86
3	0.3670	15.25	0.024	3.61	1.06
4	0.3588	13.55	0.026	3.98	1.04
5	0.3184	19.61	0.016	2.44	0.92
6	0.3662	15.77	0.023	3.48	1.06
7	0.3611	19.98	0.018	2.71	1.05
8	0.3784	12.72	0.030	4.46	1.10
9	0.3404	18.98	0.018	2.69	0.99
10	0.3821	12.63	0.030	4.53	1.11
11	0.3061	15.69	0.020	2.93	0.89
12	0.3749	15.38	0.024	3.66	1.09

Genotypes no. 8 and 10 showed more sensitivity when drought was imposed at heading and grain filling stages, respectively (Table 11). On the other hand genotypes no. 7 and 9 were less sensitive to drought at heading stage whereas genotypes no. 1,5,7 and 11 showed drought tolerant at grain filling stage (Table 11). The diversity of genotypes in drought sensitivity was also reported by Mogensen *et al* (1985), Abu-Grab and Hamada (2002) and Sharma and Thakur (2004).

Yield response factor (KY)

Data of KY are present in (Table 10). Mean KY values were 3.80 and 3.18 when drought was imposed at heading date and grain filling stages, respectively. The results revealed that, wheat plants were more sensitive to drought imposed at heading than at grain filling. Similar results were reported by Mogensen *et al.* (1985), Abd EL-Gawad *et al* (1993), and Abu – Grab and Hamada (2002).

Table 11. Interaction effect of drought and grown genotypes on relative yield reduction (YR), stressed days (SD), drought sensitivity (YR/SD), yield response factor (KY) and susceptibility index (S) (combined data of 2004/2005 and 2005/2006 seasons).

Treatment	YR	SD	YR/SD	KY	S
Drought at heading date (D1)					
1	0.3173	14.02	0.023	3.39	0.90
2	0.3148	12.42	0.025	3.80	0.89
3	0.3870	14.87	0.026	3.90	1.10
4	0.3932	13.06	0.030	4.51	1.11
5	0.3139	16.08	0.020	2.93	0.89
6	0.3749	13.55	0.028	4.15	1.06
7	0.3889	20.43	0.020	2.86	1.10
8	0.3819	12.30	0.031	4.66	1.16
9	0.3035	19.12	0.016	2.38	0.86
10	0.3408	13.27	0.029	4.41	1.11
11	0.2794	12.55	0.022	4.34	0.79
12	0.3797	13.52	0.028	4.21	1.08
Drought at grain filling period (D2)					
1	0.2289	17.16	0.013	2.00	0.63
2	0.2778	10.86	0.026	3.84	0.83
3	0.3470	15.63	0.022	3.33	1.03
4	0.3244	14.05	0.023	3.61	0.06
5	0.3229	23.14	0.014	2.09	0.96
6	0.3574	17.99	0.020	2.98	1.06
7	0.3333	19.52	0.017	2.56	0.99
8	0.3750	13.14	0.029	4.28	1.03
9	0.3421	18.83	0.018	2.73	1.02
10	0.3740	12.00	0.030	4.67	1.11
11	0.3329	18.83	0.018	2.65	0.99
12	0.3700	17.24	0.021	3.22	1.10

It is obvious that genotypes no. 1, 5, 7, 9 and 11 were less drought sensitive than other tested genotypes (Table 10) .The results could be explained as these genotypes are differ in their SR, TR and RWC (Table 5), WCU and WUE (Table 8) which was reflected on variation in KY factor. Obtained results agree with those of Gummulur *et al* (1989), and Abu-Grab and Hamada (2002) who found variation in such characters in tolerant and susceptible wheat cultivars.

Genotypes no. 8 recorded the highest KY value at heading whereas genotype no. 10 was more sensitive to drought at grain filling stage. In these respect genotypes no. 9 and no. 7 were more tolerant to drought at heading and grain filling (Table 11).

Drought susceptibility index (S)

Drought susceptibility index (S) differ than both YR/SD and KY in that it was computed depend on yield data whereas the other two parameters were computed from both yield and water consumptive use data. However, data of S values are shown in (Table 10). From the data, it can be seen that wheat plants at heading stage were more sensitive to drought than grain filling stage as S values were 1.00 and 0.98 when drought was imposed at heading and grain filling stage, respectively.

Four genotypes bred in Egypt including commercial cultivar (Gemmeiza 10) showed higher drought tolerant (S values were 0.77–0.92). The highest S value was obtained, however for genotype no.9 from CIMMYT (S = 0.99).

Genotypes no. 8 and 10 were the most drought susceptible genotypes (Table 10) their S values were 1.10 and 1.11, respectively whereas genotypes no. 1,2,5,9 and 11were more drought tolerant, S values for these genotypes were 0.77, 0.86, 0.92, 0.99 and 0.89, respectively. In this respect, Abu-Grab and Hamada (2002) and Moussa and Abdel maksoud (2004) found similar variation among some wheat cultivars.

Genotype no. 8 was more susceptible to drought when it was imposed at heading stage, whereas genotypes no. 10 was more susceptible to drought at grain filling stage (Table 11) as S values were 1.16 and 1.11, respectively. In this respect genotypes number 9 and number 1 were less susceptible to drought when it was imposed at heading and grain filling, respectively (S values were 0.86 and 0.63 in the same order). In this field Ceccarelli (1987) reported that genotype which has a low S value indicates drought resistance.

This work recommends planting drought tolerant genotypes at the end of irrigation canals or at rain fed areas were water is scarce and planting genotype no. 8 (showed superior in yield) where irrigation water is available.

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التقييم الفسيولوجي لأثني عشر تركيبا وراثيا للقمح تحت ظروف الجفاف

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٤- قسم الأصول الوراثية- معهد المحاصيل الحقلية - مركز البحوث الزراعية- مصر

تم دراسة الاستجابة الفسيولوجية لاثني عشر تركيبا وراثيا من القمح للجفاف تحت ظروف محافظة الجيزة خلال موسمي ٢٠٠٤/٢٠٠٥ ، ٢٠٠٥/٢٠٠٦ وذلك بوقف الري أثناء طرد السنابل أو مرحلة امتلاء الحبوب وتم اخذ بيانات عن دليل مساحة الورقة ، وتراكم المادة الجافة ومعدل النمو المحصولي . كذلك تم اخذ بيانات على مقاومة الثغور للنتح ومعدل النتح والمحتوى النسبي للأوراق من الماء ودرجة حرارة الورقة ومعدل تفلور الكلورفيل فى الظلام وأقصى معدل لتفلور الكلوروفيل فى الضوء، وعائد الكوانتم للنظام الصبغى الثانى PS) (II فى عملية التمثيل الضوئي ، وميعاد النضج الفسيولوجي والمحصول ومكوناته وكفاءة استخدام ماء الرى (WUE) وحساسية النباتات للعطش وتم استخدام ثلاثة مقاييس لذلك هي معامل الحساسية للعطش (YR/SD) ، ومعامل استجابة المحصول (KY) وهذان القياسان يعتمدان على المحصول والاستهلاك المائي والمعامل الثالث وهو معامل الإصابة بالعطش S ويعتمد على المحصول فقط . وتبين النتائج ما يلى :-

أدى التعطيش فى مرحلة طرد السنابل (أو الجفاف عموما) إلى نقص فى دليل مساحة الورقة وتراكم المادة الجافة ومعدل النمو المحصولي ومعدل النتح والمحتوى النسبي للأوراق من الماء والمحصول ومكوناته وقد بلغ النقص فى محصول الحبوب ٣٥,٢٩ ، ٣٣,٦٢ % عند إجراء التعطيش فى مرحلتي طرد السنابل و مرحلة امتلاء الحبوب على التوالى فى مقابل نقص قدرة ٩,٢٧ %، ١٠,٨٢% فى الاستهلاك المائى وعلى العكس من ذلك أدى العطش إلى زيادة مقاومة الثغور وزيادة حرارة الورقة واقل معدل لتفلور الكلوروفيل فى الظلام .

أظهرت التراكيب الوراثية تباينا في الصفات المدروسة حيث خلصت الدراسة إلي تحمل ٥ تراكيب وراثية ثلاث منها من برنامج التربية المصري و واحد مستورد من ال ICARDA و آخر مستورد من برنامج ال CIMMYT قدرتهم علي تحمل العطش بحيث يمكن زراعتها في المناطق شحيحة الماء مثل نهايات الترع او في الزراعات المطرية ، كما أثبت تركيب وراثي آخر مستورد من ال CIMMYT تفوقه في المحصول ولكن تحت ظروف توفر الماء.

المجله المصريه لتربية النبات ١٢ (١): ١٣٥ ـ ١٥٦ (٢٠٠٨)