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Growth Analysis and Yield Response of Barley as Affected by Irrigation Regimes

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THIS STUDY was conducted to evaluate twenty covered barley (*Hordeum vulgare* L.) genotypes for high yield potential and stable performance under two irrigation treatments (irrigated and water stressed). Total dry matter accumulation (TDM), leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR), relative growth rate (RGR), relative water content (RWC), relative chlorophyll content (RCC), grain yield and biological yield were evaluated during two successive seasons 2009/10 and 2010/11 at Sakha Res. Station. All parameters studied had a negative significant effects as a result of water stress in both growing seasons, except for relative chlorophyll content, which increased under stress conditions compared with the normal irrigation. Results showed that L4 and L8 genotypes had the heaviest biological yield and grain yield**,** where they had the highest values of TDM, LAI and CGR especially under stress condition, as well as possessed good values of NAR, RGR and RCC, revealing that these genotypes were more tolerant to water stress and more desirable genotypes for both stress and non-stress conditions.

Keywords : *Hordeum vulgare* L., Water stress, Irrigation regime, Growth analysis.

Abbreviations : TDM: Total dry matter accumulation, LAI: Leaf area index, CGR: Crop growth rate, NAR: Net assimilation rate, RGR: relative growth rate, RWC: relative water content, RCC: Relative chlorophyll content.

Barley (*Hordeum vulgare* L.) is the fourth grain crop both in area and production in the world after maize, wheat and rice. It has the potential to become one of the important cereal crops in Egypt.

Barley is the dominant cereal crop grown in North West Coast and North Sinai in Egypt. It is grown also in the new reclaimed lands. Most of these lands are suffering from water shortage and reduced soil fertility. The rainfed areas in Egypt cover about 120,000 hectares in the North West Coast and about 40.000 hectares in North-Sinai. Farming systems of these populations are livestock mainly sheep with barley as their main annual crop for fodder and bread-making (Noaman, 2008).

Development of barley cultivars having the ability to grow well under drought and other environmental stresses is needed. An additional avenue is cultivation of early maturing barley cultivars before cotton, to support wheat production in Egypt for bread making in order to overcome the gap between wheat consumption and wheat production. Because barley production areas are located in different environments, developing stable barley cultivars is one of the main objectives for barley breeders. In this respect, Katta *et al*. (2009) and Amer (2010) reported the possibility of developing some barley genotypes combining high yield potential under a wide range of environmental stresses.

Materials and Methods

Twenty covered barley genotypes (2 lines from ICARDA, 14 breeding lines and three local varieties, *i.e.*, Giza 121, Giza 126 and Giza 132 and Beacher Introduced from USA, locally named Giza118) were chosen for the study based on their reputed differences in yield performance under normal and stress conditions (Table 1). Experiments were conducted at the Experimental Farm of Sakha Agricultural Research Station, (ARC), Egypt, during the two successive seasons 2009/10 and 2010/11.

TABLE 1. Name, pedigree and origin of twenty barley genotypes.

Genotypes	Cross Name & Pedigree	Origin
Line 1	Giza 117/3/ACSAD 618//Aths/Lignee 686	Egypt
Line 2	Giza 117/4/Kenya Research/Belle//As46/Aths*2/3/Arar/19-3// WI2294	Egypt
Line 3	Ssn/Bda//Arar/3/Arabayan-01//CI07117-9/Deir Alla 106	ICARDA
Line 4	ACSAD1182/4/Arr/Esp//Alger/Ceres362-1-1/3/WI/5/ACSAD1180/3/ Mari/Aths*2//M-Att-73-337-1	Egypt
Line 5	Giza 117/4/Kenya Research/Belle//As46/Aths*2/3/Arar/19-3//WI2294	Egypt
Line 6	ACSAD1182/Harmal-02/Salmas/4/Lignee527/NK1272/3/Nacha2// Lignee 640/ Harma-01	Egypt
Line 7	HOR 1657/4/GLORIA-BAR/COME-B//LIGNEE 640/…/5/G2000	Egypt
Line 8	Lignee 527/Chn-01/Gustoe/5/Alanda-01/4/WI2291/3/Api/ CM67// L2966-69	ICARDA
Line 9	Alanda//Lignee527/Arar/5/Ager//Api/CM67/3/Cel/WI2269//Ore/4/ Hamra-1/6/ Lignee527/NK 1272/3/Nacha 2//Lignee 640/Harma-01	Egypt
Line 10	Giza 119/3/ESCOBA/BRB2//ALELI	Egypt
Line 11	Giza 119/4/TOCTE//CEN-B/2*CALI92/3/MARCO/SEN//CARDO	Egypt
Line 12	Giza 125/3/ACSAD 618//Aths/Lignee 686	Egypt
Line 13	CC 89/Saico	Egypt
Line 14	ACSAD1182/Harmal-02/Salmas/5/ACSAD1182/4/Arr/Esp//Alger/Ceres362-1-1/3/WI	Egypt
Line 15	ACSAD 1182/Harmal-02/Salmas/3/Saico	Egypt
Line 16	ACSAD1182/Harmal-02/Salmas/5/ACSAD1182/4/Arr/Esp//Alger/ Ceres362 -1-1/3/WI	Egypt
Beacher	Introduced to Egypt from USA and named Giza 118	USA
Giza 121	Baladi16/Gem	Egypt
Giza 126	BaladiBahteem/SD729-por12762-Bc	Egypt
Giza 132	Rihane-05//As46/Aths*2" Aths/ Lignee686	Egypt

Giza126 was the most drought tolerant variety. So, this variety was used as with the reference to compare the other genotypes.

Soil samples were randomly taken from the experimental area at a depth of 0 to 30 cm from soil surface before barley sowing. Soil properties are shown in Table 2. Water application was monitored *via* water meter as shown in Table 3.

TABLE 2. Soil analysis of the experimental field at Sakha Agricultural Research Station during 2009/10 and 2010/11 seasons.

Season	Particle size distribution			Texture class	EC ($ds.m^{-1}$)	OM %	Available N, P, K ($mg. kg^{-1}$ soil)		
	Sand %	Silt %	Clay %				N	P	K
2009/10	13.74	24.91	61.35	clayey	2.1	1.٦٥	١٧	١٣	٣١١
2010/11	15.53	23.95	60.52	clayey	2.9	1.٦٨	١٩	١٦	٣٢٠
Season	**Anions ($meq.L^{-1}$)**				**Cations ($meq.L^{-1}$)**				**pH**
	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+	
2009/10	٠,٠	٣,٥	١٤,٨	١,٣	٥,١	٢,١	١٢,٢	٠,٤	٧,٩
2010/11	٠,٠	٣,٨	١٥,٠	١,٢	٥,٣	٢,٠	١٤,٨	٠,٥	٨,2

TABLE 3. Amount of water supplied in $m^3. fed^{-1}$ at different critical growth stages of barley, rainfall amount and total water supplied in 2009/10 and 2010/11 seasons.

Irrigation treatments	Growth seasons	Growth stages			Irrigation			
		Sowing	Tillering	Booting	Total irrigated water (m^3)	Rainfall		Total supplied ($m^3.fed^{-1}$)
						(mm)	$m^3.fed^{-1}$	
Irrigated	2009/10	550	350	450	1350	28	117.6	1467.6
	2010/11	500	325	450	1275	120	504	1779
Stressed	2009/10	550	0	0	550	28	117.6	667.6
	2010/11	500	0	0	500	120	504	1004

In the first season, the maximum temperature was high and the relative humidity and rainfall were low compared with the second season (Table 4).

TABLE 4. Maximum and minimum temperature, average relative humidity and rainfall during the growing seasons of barley crop at Sakha Agricultural Research Station (ARC), Egypt.

Month	Temperature °(C)				Relative humidity (%)		Rainfall (mm)	
	2009/10		2010/11					
	Max.	Min.	Max.	Min.	2009/10	2010/11	2009/10	2010/11
Dec.	22.72	8.92	16.82	14.75	66.44	80.94	5.80	44.95
Jan.	21.77	7.77	14.73	12.49	71.48	87.74	0.00	28.21
Feb.	23.38	9.19	15.81	13.32	65.11	79.00	22.20	22.40
Mar.	23.92	9.18	18.24	15.09	62.09	77.97	0.00	13.95
Apr.	28.77	11.76	23.40	18.08	68.62	66.77	0.00	10.50

Grains were hand sowed at the recommended sowing rate of barley in the irrigated land (50 $kg.fed^{-1}$). Each genotype was sown in six rows of 3.5 m, spaced with 20 cm among rows. These experiments were laid out in a randomized complete block design with four replications. The first experiment was irrigated twice after sowing, 45 days after sowing at tillering stage and 75 days after sowing at booting stage (normal condition); the second experiment was received just sowing irrigation (drought stress condition). Sowing was done on November 15*th* in both seasons. All recommended culture practices were applied at proper time according to Ministry of Agriculture recommendations. The preceding crop was cotton in the two seasons.

Data recorded

Half long meter guarded tillers were randomly taken from the second inner rows of each plot at 45, 65 and 85 days after sowing to determine growth characters. Each sample was separated into stems and leaves, and then leaf area (blades area) was measured by portable area meter (Model LI-3000A). Tillers organs were dried separately in an electrical air-draft oven at 70°C until constant weight for determination of whole dry weight.

Growth characters were estimated as follows:-

Crop growth rate (CGR)

At an instant in time (t) is defined as the increase of tillers material per unit of time.

$$\text{CGR} = \frac{(w_2 - w_1)}{(t_2 - t_1)} \quad \text{g/m}^2\text{/week.}$$

where: $w_1$and w_2 refer to dry weight at time (t_1) and (t_2), respectively, in week according to Radford (1967).

Relative growth rate (RGR)

At an instant in time (t), is defined as the increase of plant material per unit of material present per unit of time.

$$\text{RGR} = \frac{(\text{Log}_e w_2 - \text{Log}_e w_1)}{(t_2 - t_1)} \quad \text{g/g/week.}$$

RGR was calculated according to Radford (1967).

Net assimilation rate (NAR)

At an instant in time (t), is defined as the increase of plant material per unit of material present per unit of assimilatory material per unit of time.

$$NAR = \frac{(w_2 - w_1)(Log_e A_2 - Log_e A_1)}{(A_2 - A_1)(t_2 - t_1)} \quad g/m^2/week.$$

where: w_1, A_1 and w_2, A_2, respectively, refer to dry weight and leaf area at time (t_1) and (t_2) in week according to Radford (1967).

Leaf area index (LAI)

It is defined as total area of leaves of the plants compared with the area of land occupied by the plants according to Watson (1952) as described by the following formula:

$$L.A.I = \frac{\text{Leaf area / tillers } (cm^2)}{\text{Tillers ground area } (cm^2)}$$

Relative chlorophyll content (RCC)

The relative chlorophyll content in the flag leaf was determined using a chlorophyll meter (SPAD-502, Japan).

Relative water content (RWC %)

It was determined by the method of Barrs (1968). To determine the relative water content (RWC), the harvested leaf was cut into 12 cm sections, and immediately weighed (FW), then sliced into 2 cm sections and floated on distilled water for 4 hr. The turgid leaf discs were then rapidly blotted to remove surface water and weighted to obtain turgid weight (TW). The leaf discs were then oven dried for 2 hr at 60^{o}C and dry weight (DW) was recorded. RWC was calculated by the formula:

$$RWC = \frac{FW - DW}{TW - DW} \times 100$$

where: FW = fresh weight of leaf. DW = dry weight. TW = full turgor.

Grain yield (kg/ fed)

It was recorded from the grains of harvested plants/plot after threshing and then converted to kg/fed.

Biological yield (kg /fed)

It was recorded from all harvested plants / plot and converted to kg/fed.

Results and Discussion

It is a well-established fact that plant structure is determined by growth parameters such as, total dry matter accumulation (TDM), leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), relative water content (RWC) and relative chlorophyll content (RCC).

These concepts not only involve the final crop yield and its components, but also probe into the physiological events that have occurred early in the growth stages causing variation in yield potential.

Total dry matter accumulation (TDM)

This trait was significantly affected by water stress (Table 5). In general, increasing irrigation increased TDM. TDM increased slowly at the early stages of growth and then increased rapidly with the advancement of plant age (Fig.1). The cause of rapid increase of TDM at the later stages was possibly due to the development of a considerable number of late tillers, plant height and leaf area. These results are in harmony with those of Alam (2003), Mollah & Paul (2008) and Vaezi *et al*. (2010). Giza 132, L4, L5, L6 and L8 gave the highest values for TDM compared to Giza 126 in the three samples. Highly significant interaction between barley genotypes and irrigation treatments was found in the three samples. Giza 132, L4 and L8 gave the highest values of TDM compared to Giza 126 under both treatments in the three samples, which they had high values of LAI in the three samples, CGR and NAR in both growth intervals.

TABLE 5. Dry matter accumulation (TDM) means as affected by irrigation treatments and barley genotypes as well as its interaction at three growth stages in combined data of both growing seasons.

Total dry matter accumulation (TDM) (kg. fed^{-1})			
Effect of irrigation treatments			
Treatment	Sample 1 (45 days)	Sample 2 (65 days)	Sample 3 (85 days)
Irrigated	634.56	1285.57	2676.64
Stressed	590.96	1185.82	2308.04
LSD 0.05	2.51	3.03	10.75
Reduction%	7	8	14

Effect of barley genotypes												
Genotype	**Means**			**Interaction**								
				Sample 1			**Sample 2**			**Sample 3**		
	Sample 1	**Sample 2**	**Sample 3**	**Irrigated**	**Stressed**	**Reduction %**	**Irrigated**	**Stressed**	**Reduction %**	**Irrigated**	**Stressed**	**Reduction %**
L 1	553	1158	2307	583	522	10	1215	1101	9	2444	2170	11
L 2	610	1210	2458	595	624	-5	1235	1184	4	2586	2330	10
L 3	598	1233	2477	641	555	13	1329	1138	14	2709	2246	17
L 4	720	1388	2753	725	714	2	1400	1375	2	2909	2597	11
L 5	660	1288	2584	693	628	9	1345	1231	8	2789	2380	15
L 6	655	1277	2575	675	636	6	1320	1234	7	2756	2394	13
L 7	604	1218	2466	650	557	14	1281	1155	10	2665	2267	15
L 8	674	1336	2670	681	667	2	1361	1312	4	2827	2513	11
L 9	613	1247	2527	638	588	8	1287	1207	6	2736	2318	15
L 10	533	1149	2375	552	513	7	1209	1089	10	2558	2192	14
L 11	627	1260	2509	643	611	5	1302	1218	6	2701	2316	14
L 12	517	1139	2340	527	507	4	1205	1074	11	2510	2170	14
L 13	582	1211	2416	592	571	4	1251	1171	6	2573	2259	12
L 14	606	1201	2442	652	561	14	1274	1127	12	2665	2220	17
L 15	616	1234	2501	635	597	6	1277	1190	7	2693	2309	14
L 16	594	1167	2414	648	541	17	1243	1092	12	2652	2175	18
Beacher	570	1158	2384	568	571	-1	1195	1121	6	2601	2167	17
Giza 121	626	1251	2546	638	613	4	1284	1218	5	2750	2343	15
Giza 126	640	1274	2478	666	615	8	1316	1232	6	2590	2366	9
Giza 132	659	1315	2626	689	629	9	1383	1247	10	2821	2430	14
LSD 0.05	7.92	9.57	34	11.2		--	13.53			48.08		--

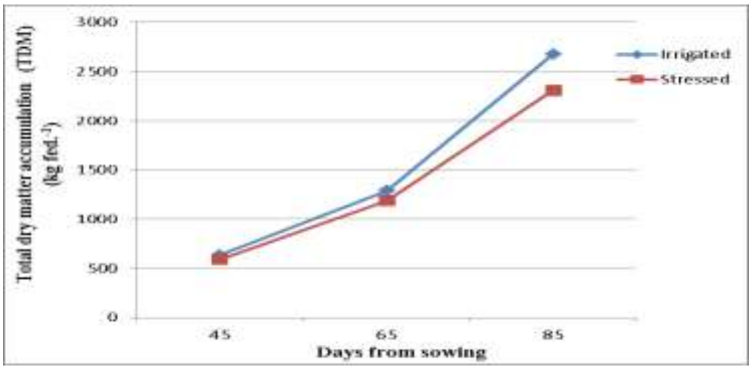

Fig. 1. Trend of total dry matter accumulation under irrigated and stressed conditions.

Leaf area index (LAI)

Leaf area index decreased with decreasing irrigation application (Table 6). The irrigated treatment had higher LAI than the stressed one. LAI (3.97, 7.87 and 5.85 at 45, 65 and 85 days, respectively) exhibited the highest value under irrigated treatment and corresponding lowest value obtained from the stressed treatment (3.85, 7.31 and 4.67 at 45, 65 and 85 days, respectively). The reduction percentage was 3, 7 and 20% at 45, 65 and 85 days, respectively.

LAI reached in a maximum value in the second sample and then declined with plant age in the third sample (Fig. 2). The increase of LAI occurred due to the increase of leaf expansion in the irrigated plants. Increase in soil moisture resulted in increased turgor pressure in the cells and turgor forces played a part in the process of leaf expansion (Alam, 2003; Jazy, 2007; Mollah & Paul, 2008 and Moayedi *et al.*, 2011).

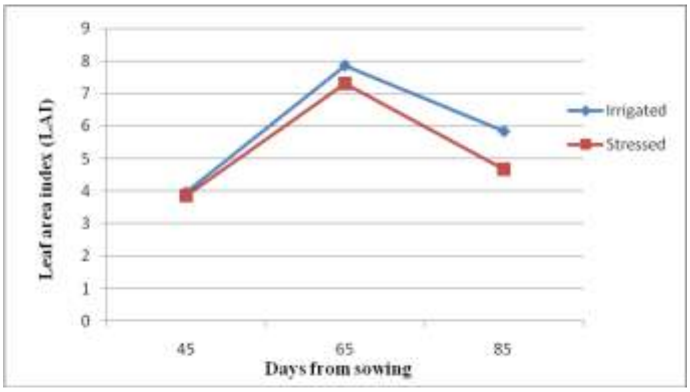

Fig. 2. Trend of leaf area index under irrigated and stressed conditions.

TABLE 6. Leaf area index (LAI) means as affected by irrigation treatments and barley genotypes as well as its interaction at three growth stages in combined data of both growing seasons.

Leaf area index (LAI)			
Effect of irrigation treatments			
Treatment	Sample 1	Sample 2	Sample 3
Irrigated	3.97	7.87	5.85
Stressed	3.85	7.31	4.67
LSD 0.05	0.02	0.02	0.02
Reduction%	3	7	20

Effect of barley genotypes												
Genotype	**Means**			**Interaction**								
				Sample 1			**Sample 2**			**Sample 3**		
	Sample 1	**Sample 2**	**Sample 3**	**Irrigated**	**Stressed**	**Reduction %**	**Irrigated**	**Stressed**	**Reduction %**	**Irrigated**	**Stressed**	**Reduction %**
L 1	4.05	7.37	5.05	4.08	4.02	2	7.55	7.18	5	5.67	4.42	22
L 2	3.79	7.51	5.27	3.82	3.75	2	7.76	7.25	7	5.92	4.62	22
L 3	4.08	7.58	5.19	4.13	4.03	2	7.81	7.35	6	5.77	4.61	20
L 4	4.31	7.81	5.67	4.36	4.27	2	7.95	7.67	3	6.21	5.14	17
L 5	3.95	7.72	5.56	4.06	3.85	5	7.89	7.56	4	6.09	5.02	18
L 6	3.94	7.67	5.40	4.01	3.86	4	7.98	7.36	8	5.95	4.85	19
L 7	3.60	7.75	5.06	3.68	3.53	4	8.10	7.39	9	5.72	4.39	23
L 8	3.93	7.88	5.55	3.96	3.90	2	7.89	7.88	0	6.15	4.95	20
L 9	3.89	7.42	5.27	3.96	3.83	3	7.69	7.15	7	5.83	4.71	19
L 10	3.79	7.41	5.22	3.90	3.68	6	7.81	7.00	10	5.83	4.61	21
L 11	3.89	7.47	5.17	3.93	3.86	2	7.93	7.01	12	5.83	4.50	23
L 12	3.72	7.63	5.19	3.78	3.66	3	8.06	7.20	11	5.79	4.60	21
L 13	4.05	7.69	5.31	4.06	4.05	0	8.06	7.33	9	5.94	4.67	21
L 14	3.82	7.55	5.06	3.87	3.76	3	8.10	7.00	14	5.69	4.42	22
L 15	3.75	7.65	5.01	3.76	3.74	1	7.93	7.36	7	5.61	4.42	21
L 16	3.86	7.59	5.12	3.94	3.79	4	8.06	7.13	11	5.64	4.61	18
Beacher	3.91	7.36	4.97	3.98	3.83	4	7.43	7.30	2	5.62	4.32	23
Giza 121	3.94	7.58	5.19	4.01	3.87	3	7.62	7.54	1	5.64	4.74	16
Giza 126	3.93	7.52	5.36	4.00	3.86	3	7.84	7.19	8	5.89	4.83	18
Giza 132	3.99	7.60	5.55	4.04	3.94	2	7.88	7.32	7	6.17	4.92	20
LSD 0.05	0.11	0.08	0.07	--		--	0.10			0.90		--

For mean values of the twenty barley genotypes, results showed highly significant differences existed between barley genotypes. Giza132, L4 and L18 had higher values especially under the stressed treatment compared to Giza 126.

Crop growth rate (CGR)

Crop growth rate means had been significantly lower in the stressed treatment than the irrigated treatment (Table 7). CGR changes resembled in both treatments, but the irrigated treatment had superiority over that of the stressed treatment during all the stages. Reduction of the CGR under water stress condition was due to reduction of the LAI and the NAR (Jazy, 2007; Mollah & Paul, 2008 and Moayedi *et al.*, 2011). Giza 132, L4 and L8 had the highest values in the first growth intervals, while, most genotypes exceeded Giza 126 in the second growth intervals, especially Giza 132, L4 and L8. L4 and L8 had the highest values in the two growth intervals under the stressed treatment compared to Giza 126, where they had the highest values of TDM in the three samples.

TABLE 7. Crop growth rate (CGR) means as affected by irrigation treatments and barley genotypes as well as its interaction at two growth intervals in combined data of both growing seasons.

Crop growth rate (CGR) ($g.m^{-2}.week^{-1}$)		
Effect of irrigation treatments		
Treatment	CGR 1	CGR 2
Irrigated	217	463.69
Stressed	198.28	374.07
LSD 0.05	1.39	3.65
Reduction%	9	19

Effect of barley genotypes								
Genotype	**Means**		**Interaction**					
			CGR 1			**CGR 2**		
	CGR 1	**CGR 2**	**Irrigated**	**Stressed**	**Reduction%**	**Irrigated**	**Stressed**	**Reduction%**
L 1	202	383	211	193	9	410	356	13
L 2	200	416	213	187	12	450	382	15
L 3	212	415	229	194	15	460	369	20
L 4	223	455	225	220	2	503	407	19
L 5	209	432	217	201	7	481	383	20
L 6	207	433	215	199	7	479	387	19
L 7	205	416	210	199	5	461	371	20
L 8	221	445	226	215	5	489	401	18
L 9	212	427	217	206	5	483	370	23
L 10	205	409	219	192	12	450	368	18
L 11	211	416	220	202	8	467	366	22
L 12	208	400	226	189	16	435	366	16
L 13	210	402	219	200	9	441	363	18
L 14	198	414	208	189	9	463	364	21
L 15	206	422	214	198	7	472	373	21
L 16	191	415	198	184	7	470	361	23
Beacher	196	409	209	183	12	469	348	26
Giza 121	209	432	215	202	6	489	375	23
Giza 126	211	401	217	206	5	425	378	11
Giza 132	219	437	231	206	11	479	394	18
LSD 0.05	4.38	11.53	6.19		--	16.31		--

Net assimilation rate (NAR)

The trend in NAR had a high similarity with both irrigated treatments, in which it increased at the second growth interval more than the first growth interval. This period was corresponding with the maximum LAI and dry mater accumulation period (Mollah & Paul, 2008 and Moayedi *et al.*, 2011). A lower NAR was found in the stressed treatment than in the irrigated treatment (Table 8). It appears that a severe decline in NAR under water stress condition was related to the high reduction in LAI and CGR, which consequently caused a severe reduction in RGR and TDM in the same phase. Under irrigated treatment, Giza 132, L3, L8 and L12 had the highest values in the first growth intervals, while, all genotypes exceeded Giza126 in the second growth intervals. Under the stressed treatment, all genotypes were lower than Giza126, except L9 and L11 were exceeded in the first growth interval, while, there insignificant different between genotypes in the second growth interval.

TABLE 8. Net assimilation rate (NAR) means as affected by irrigation treatments and barley genotypes as well as its interaction at two growth intervals in combined data of both growing seasons.

Net assimilation rate (NAR)) (kg.m^2.week^{-1})		
Effect of irrigation treatments		
Treatment	**NAR 1**	**NAR 2**
Irrigated	6.56	11.88
Stressed	6.34	11.15
LSD 0.05	0.05	0.10
Reduction%	3	6

Effect of barley genotypes								
Genotype	**Means**		**Interaction**					
			NAR 1			**NAR 2**		
	NAR 1	**NAR 2**	**Irrigated**	**Stressed**	**Reduction %**	**Irrigated**	**Stressed**	**Reduction %**
L 1	6.29	10.93	6.42	6.16	4	10.87	10.98	-1
L 2	6.32	11.52	6.59	6.05	8	11.59	11.44	1
L 3	6.46	11.49	6.83	6.09	11	11.90	11.08	7
L 4	6.52	11.87	6.50	6.54	-1	12.48	11.26	10
L 5	6.40	11.47	6.51	6.29	3	12.10	10.85	10
L 6	6.37	11.69	6.41	6.33	1	12.07	11.30	6
L 7	6.52	11.54	6.43	6.60	-3	11.74	11.34	3
L 8	6.68	11.70	6.83	6.52	5	12.23	11.17	9
L 9	6.67	11.79	6.64	6.69	-1	12.55	11.02	12
L 10	6.55	11.46	6.69	6.40	4	11.59	11.33	2
L 11	6.63	11.62	6.62	6.65	0	11.92	11.32	5
L 12	6.55	11.08	6.87	6.23	9	11.05	11.12	-1
L 13	6.36	10.91	6.48	6.25	4	11.07	10.75	3
L 14	6.24	11.61	6.23	6.25	0	11.82	11.41	3
L 15	6.48	11.80	6.58	6.37	3	12.26	11.33	8
L 16	5.97	11.55	5.93	6.02	-1	12.07	11.03	9
Beacher	6.19	11.66	6.52	5.87	10	12.61	10.71	15
Giza 121	6.46	11.93	6.60	6.31	4	12.95	10.91	16
Giza 126	6.59	11.00	6.54	6.63	-1	10.84	11.17	-3
Giza 132	6.72	11.75	6.92	6.52	6	11.99	11.51	4
LSD 0.05	0.15	0.33	0.21		--	0.46		--

Relative growth rate (RGR)

Relative growth rate exhibited the highest value in the irrigated treatment and the lowest value obtained from the stressed treatment (Fig. 3). The reduction percentage was 1 and 9% at 45-65 and 65-85 days, respectively. The smaller TDM and CGR may be responsible for the significant decrease in RGR. These results are in agreement with those obtained by Alam (2003) and Moayedi *et al.* (2011). L10 and L12 had the highest values in the two growth intervals under the stressed treatment compared to Giza 126 (Table 9).

TABLE 9. Relative growth rate (RGR) means as affected by irrigation treatments and barley genotypes as well as its interaction at two growth intervals in combined data of both growing seasons.

Relative growth rate (RGR) ($g.g^{-1}.week^{-1}$)		
Effect of irrigation treatments		
Treatment	**RGR 1**	**RGR 2**
Irrigated	0.102	0.106
Stressed	0.101	0.096
LSD 0.05	0.0007	0.0007
Reduction%	1	9

Effect of barley genotypes

Genotype	Means		Interaction					
			RGR 1			RGR 2		
	RGR 1	RGR 2	Irrigated	Stressed	Reduction%	Irrigated	Stressed	Reduction%
L 1	0.107	0.100	0.106	0.108	-2	0.102	0.098	3
L 2	0.099	0.103	0.106	0.093	12	0.107	0.098	9
L 3	0.105	0.101	0.106	0.105	1	0.104	0.099	5
L 4	0.095	0.099	0.095	0.095	0	0.106	0.092	13
L 5	0.097	0.100	0.096	0.097	-1	0.106	0.095	10
L 6	0.097	0.101	0.097	0.096	1	0.107	0.096	10
L 7	0.102	0.102	0.098	0.106	-8	0.106	0.098	8
L 8	0.099	0.100	0.100	0.098	2	0.106	0.094	11
L 9	0.103	0.102	0.102	0.104	-2	0.109	0.094	14
L 10	0.111	0.105	0.113	0.109	4	0.109	0.101	7
L 11	0.101	0.099	0.102	0.100	2	0.106	0.093	13
L 12	0.114	0.104	0.120	0.109	9	0.106	0.102	4
L 13	0.106	0.100	0.108	0.104	4	0.105	0.095	9
L 14	0.099	0.103	0.097	0.101	-5	0.107	0.098	8
L 15	0.100	0.102	0.101	0.100	1	0.108	0.096	11
L 16	0.098	0.105	0.095	0.102	-8	0.110	0.100	9
Beacher	0.103	0.104	0.108	0.098	9	0.113	0.095	16
Giza 121	0.100	0.102	0.101	0.099	2	0.110	0.095	14
Giza 126	0.100	0.095	0.099	0.101	-2	0.097	0.094	3
Giza 132	0.100	0.100	0.101	0.099	2	0.104	0.097	7
LSD 0.05	0.002	0.002	0.003		--	0.003		--

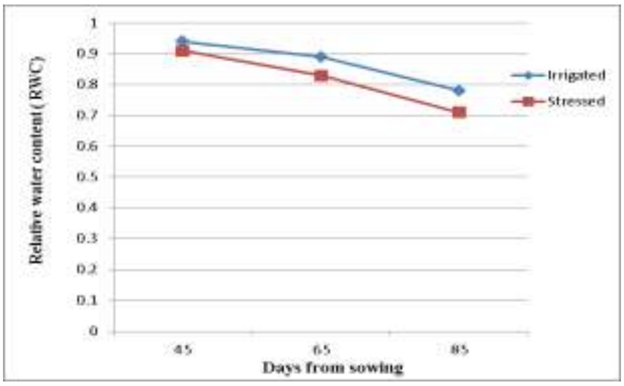

Fig. 3. Trend of relative water content under irrigated and stressed conditions.

Relative water content (RWC)

The relative water content was demonstrated to be a relevant screening tool of drought tolerance in cereals, as well as a good indicator of plant water-status relative to their fully turgid condition. During the drought stress, relative growth rates were more reduced. Maintenance of relative water content contributes to the increased yield and yield stability under drought, in cereals.

Results showed highly significant differences on RWC due to irrigation treatments at both growth intervals (Table 10). In general, the RWC means in the stressed treatment were significantly lower than the irrigated treatment, where the RWC reduction as the result of water stress. RWC changes resembled in both treatments, but the irrigated treatment had superiority over that of the stressed treatment during all the stages. These results are in agreement with those obtained by Klar & Santos (2008), Sorin *et al.* (2008) and Vaezi *et al.* (2010). Genotype Giza132 had a higher value under the stressed treatment compared to Giza 126.

TABLE 10. Relative water content (RWC) means as affected by irrigation treatments and barley genotypes as well as its interaction at three growth stages in combined data of both growing seasons.

Relative water content (RWC)			
Effect of irrigation treatments			
Treatment	**Sample 1**	**Sample 2**	**Sample 3**
Irrigated	0.94	0.89	0.78
Stressed	0.91	0.83	0.71
LSD 0.05	0.003	0.004	0.007
Reduction%	3	7	9

Effect of barley genotypes												
Genotype	**Means**			**Interaction**								
				Sample 1			**Sample 2**			**Sample 3**		
	Sample 1	Sample 2	Sample 3	Irrigated	Stressed	Reduction %	Irrigated	Stressed	Reduction %	Irrigated	Stressed	Reduction %
L 1	0.92	0.88	0.73	0.96	0.91	5	0.90	0.86	5	0.78	0.67	14
L 2	0.92	0.88	0.70	0.97	0.92	5	0.90	0.86	5	0.75	0.66	12
L 3	0.94	0.84	0.75	0.94	0.90	4	0.90	0.78	13	0.77	0.73	6
L 4	0.92	0.88	0.78	0.93	0.91	2	0.90	0.85	6	0.82	0.74	9
L 5	0.92	0.87	0.77	0.93	0.92	1	0.89	0.86	3	0.81	0.73	10
L 6	0.93	0.88	0.73	0.95	0.93	2	0.89	0.86	3	0.78	0.68	13
L 7	0.94	0.78	0.68	0.86	0.80	7	0.82	0.73	11	0.71	0.65	8
L 8	0.83	0.82	0.79	0.93	0.92	1	0.86	0.79	8	0.80	0.77	4
L 9	0.93	0.86	0.74	0.94	0.90	4	0.88	0.83	5	0.81	0.67	17
L 10	0.92	0.88	0.77	0.95	0.94	1	0.89	0.86	3	0.78	0.76	2
L 11	0.93	0.91	0.79	0.95	0.90	5	0.92	0.89	3	0.84	0.74	12
L 12	0.92	0.85	0.69	0.93	0.92	1	0.87	0.83	5	0.74	0.64	14
L 13	0.94	0.86	0.71	0.97	0.90	7	0.88	0.83	6	0.73	0.68	7
L 14	0.92	0.87	0.73	0.96	0.88	8	0.88	0.85	4	0.78	0.67	14
L 15	0.92	0.86	0.70	0.93	0.91	2	0.88	0.83	6	0.73	0.68	7
L 16	0.94	0.87	0.74	0.95	0.93	2	0.91	0.83	9	0.77	0.71	8
Beacher	0.93	0.85	0.73	0.93	0.90	3	0.90	0.80	11	0.78	0.68	13
Giza 121	0.92	0.84	0.81	0.93	0.92	1	0.86	0.82	4	0.82	0.80	3
Giza 126	0.95	0.85	0.77	0.95	0.92	3	0.89	0.81	9	0.82	0.72	12
Giza 132	0.95	0.88	0.83	0.95	0.89	6	0.89	0.87	2	0.84	0.81	3
LSD 0.05	0.01	0.01	0.02	0.02		--	0.02		--	0.03		--

Relative chlorophyll content

The stressed treatment resulted in higher RCC, compared with the irrigated treatment in three growth stages (Fig. 4). Photosynthesis per unit leaf area was not initially reduced by stress, particularly in the more-tolerant genotypes, as the chlorophyll per unit area was higher under stress than under non-stress conditions (the leaves were narrower, the cells were smaller, and so the chloroplast density was greater) (Munns *et al.*, 2006). For mean values, Giza 132, Giza 121, L2, L4, L8, L10 and L12 genotypes gave the highest values for relative chlorophyll content compared to Giza 126 (Table 11). While, Giza 121, L4, L8 and L12 had higher values under the stressed treatment in the three samples. These results agreed with Ali *et al.* (2009).

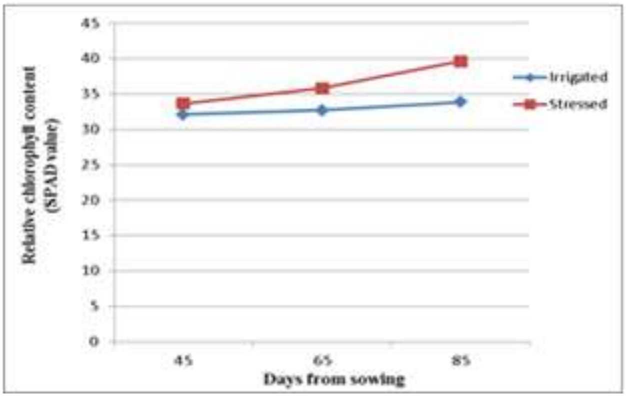

Fig. 4. Trend of relative chlorophyll content under irrigated and stressed conditions.

Grain yield

As drought stress severity increased, grain yield decreased for all genotypes in both seasons (Table 12). The percentage of reduction in grain yield by the severe drought stress treatment was 37 %, 36 % and 36 % in the first, the second season and combined analysis, respectively. Average yields in irrigated treatment varied from 3150 to 4143 kg. fed^{-1}, and in the stressed treatment, they varied from 1999 to 2639 kg. fed^{-1} in the first and the second seasons, respectively. Under both water stress and irrigated conditions, L4 revealed the highest grain yield for two years. These results agreed with Bagheri *et al.* (2007) Santos *et al.* (2008) Samarah *el al.* (2009), Refay (2010) and Vaezi *el al.* (2010).

The grain yield under stress environments is dependent upon stress susceptibility yield potential. The susceptibility of a plant genotype to stress in the product of many physiological and morphological traits for which effective selection criteria have not yet been developed (Fisher & Maure, 1978). Therefore, grain yield and attributes remain as major selection criteria for improved adaptation to stress environments in many breeding programs.

TABLE 11. Relative chlorophyll content (SPAD value) means as affected by irrigation treatments and barley genotypes as well as its interaction at three growth stages in combined data of both growing seasons.

Relative chlorophyll content (SPAD value)												
Effect of irrigation treatments												
Treatment	**Sample 1**					**Sample 2**				**Sample 3**		
Irrigated	32.11					32.72				33.85		
Stressed	33.64					35.81				39.62		
LSD 0.05	0.35					0.31				0.37		
Reduction%	-5					-9				-17		
Effect of barley genotypes												
Genotype	**Means**			**Interaction**								
				Sample 1			**Sample 2**			**Sample 3**		
	Sample 1	**Sample 2**	**Sample 3**	**Irrigated**	**Stressed**	**Reduction %**	**Irrigated**	**Stressed**	**Reduction %**	**Irrigated**	**Stressed**	**Reduction %**
L 1	32.47	34.24	37.26	31.00	33.93	-9	33.70	34.78	-3	34.10	40.43	-19
L 2	33.43	35.01	37.30	31.40	35.47	-13	33.40	36.63	-10	34.80	39.80	-14
L 3	32.88	33.01	34.43	32.00	33.77	-6	31.10	34.93	-12	31.25	37.60	-20
L 4	33.72	37.41	38.33	33.23	34.20	-3	35.73	39.10	-9	37.65	39.00	-4
L 5	31.67	34.16	35.15	30.80	32.53	-6	32.78	35.55	-8	31.08	39.23	-26
L 6	33.98	32.66	35.08	33.93	34.03	0	30.98	34.35	-11	32.05	38.10	-19
L 7	31.08	31.71	35.01	30.43	31.73	-4	30.45	32.98	-8	33.00	37.03	-12
L 8	35.22	35.61	39.30	34.50	35.93	-4	33.08	38.15	-15	36.48	42.13	-15
L 9	32.27	32.59	36.06	32.07	32.47	-1	30.38	34.80	-15	33.88	38.25	-13
L 10	34.67	34.93	37.16	33.97	35.37	-4	33.23	36.63	-10	33.98	40.35	-19
L 11	31.57	31.84	36.35	30.17	32.97	-9	29.50	34.18	-16	32.65	40.05	-23
L 12	32.68	35.45	38.75	31.47	33.90	-8	33.65	37.25	-11	32.73	44.78	-37
L 13	31.95	34.38	37.68	29.87	34.03	-14	32.93	35.83	-9	33.95	41.40	-22
L 14	33.43	32.86	34.01	32.90	33.97	-3	31.85	33.88	-6	32.30	35.73	-11
L 15	32.83	37.06	39.01	32.44	33.22	-2	35.96	38.16	-6	36.66	41.37	-13
L 16	33.05	33.31	37.10	32.37	33.73	-4	31.50	35.13	-12	35.28	38.93	-10
Beacher	31.13	33.56	34.85	30.45	31.81	-4	30.85	36.28	-18	30.65	39.05	-27
Giza 121	34.57	36.23	37.47	34.43	34.70	-1	35.48	36.98	-4	34.43	40.50	-18
Giza 126	31.90	34.27	36.14	31.23	32.57	-4	33.70	34.84	-3	34.21	38.08	-11
Giza 132	32.97	35.02	38.29	31.33	34.60	-10	34.26	35.78	-4	35.90	40.68	-13
LSD 0.05	1.11	0.97	1.16	1.57		--	1.37		--	1.65		--

As a result of water stress condition, the average of grain yield for these genotypes decreased. Several authors reported that, drought stress reduced photosynthesis and translocation rates and increased respiration, which reduced available assimilates for grain filling and finally decreased grain yield (El-Naggar, 2010 and Zare *el al.,* 2011).

TABLE 12. Mean values of the effect of irrigation treatments, comparison among barley genotype means and effect of the interaction between barley genotypes and irrigation treatments on grain yield (kg. fed $^{-1}$) in both growing seasons and combined.

Effect of irrigation treatments			
Treatment	2009/10	2010/11	Comb.
Irrigated	3150	4143	3647
Stressed	1999	2639	2319
LSD 0.05	77	152	85
Reduction %	37	36	36

Effect of barley genotypes												
Genotype	**Means**			**Interaction**								
				2009/10			**2010/11**			**Comb.**		
	2009/10	**2010/11**	**Comb.**	**Irrigated**	**Stressed**	**Reduction %**	**Irrigated**	**Stressed**	**Reduction %**	**Irrigated**	**Stressed**	**Reduction %**
L 1	2361	3194	2777	3108	1615	48	4225	2163	49	3666	1889	48
L 2	2617	3613	3115	3184	2050	36	4375	2850	35	3780	2450	35
L 3	2285	3094	2689	2883	1687	41	3963	2225	44	3423	1956	43
L 4	3018	4250	3634	3536	2500	29	4925	3575	27	4231	3037	28
L 5	2687	3625	3156	3262	2112	35	4400	2850	35	3831	2481	35
L 6	2768	3744	3256	3409	2128	38	4613	2875	38	4011	2501	38
L 7	2341	3106	2723	2863	1819	36	3863	2350	39	3363	2084	38
L 8	2812	3725	3268	3372	2252	33	4300	3150	27	3836	2701	30
L 9	2570	3381	2976	3000	2140	29	3888	2875	26	3444	2507	27
L 10	2275	2963	2619	2726	1823	33	3475	2450	29	3101	2136	31
L 11	2794	3725	3259	3511	2077	41	4638	2813	39	4074	2445	40
L 12	2473	3125	2799	3152	1795	43	4025	2225	45	3588	2010	44
L 13	2502	3163	2832	3085	1918	38	3838	2488	35	3461	2203	36
L 14	2479	3206	2842	3188	1770	44	4125	2288	45	3656	2029	45
L 15	2514	3356	2935	3052	1975	35	4063	2650	35	3557	2313	35
L 16	2556	2963	2759	3071	2041	34	3788	2138	44	3429	2089	39
Beacher	2447	3069	2758	2911	1984	32	3638	2500	31	3274	2242	32
Giza 121	2640	3488	3064	3204	2075	35	4200	2775	34	3702	2425	34
Giza 126	2682	3519	3100	3240	2123	34	4238	2800	34	3739	2462	34
Giza 132	2671	3513	3092	3246	2097	35	4288	2738	36	3767	2417	36
LSD 0.05	243	482	269	--		--	--		--	--		--

Biological yield

Results show highly significant differences among irrigation treatments in both seasons, where the irrigated treatment outyielded the stressed treatment (Table 13). The reduction percentage was 41, 46 and 44% at the first season, the second and combined, respectively. These results are confirmed by Bayoumi (2004), Bagheri *et al.* (2007) and Refay (2010). Biological yield differences were related to low plant height, leaf area and tiller numbers; grain yield differences were caused by a reduction in spikes/plant and grains/spike. Genotypes Giza132, L4 and L8 produced the highest values compared with Giza 126, while Beacher, L1, L10 and L12 recorded the lowest genotypes in both seasons.

TABLE 13. Mean values of the effect of irrigation treatments, comparison among barley genotype means and effect of the interaction between barley genotypes and irrigation treatments on biological yield (kg. fed $^{-1}$) in both growing seasons and combined.

Effect of irrigation treatments			
Treatment	2009/10	2010/11	Comb.
Irrigated	9100	11550	10325
Stressed	5394	6199	5796
LSD 0.05	174	379	211
Reduction %	41	46	44

Effect of barley genotypes												
Genotype	Means			Interaction								
				2009/10			2010/11			Comb.		
	2009/10	2010/11	Comb.	Irrigated	Stressed	Reduction %	Irrigated	Stressed	Reduction %	Irrigated	Stressed	Reduction %
L 1	6426	7950	7188	8825	4028	54	11250	4650	59	10038	4339	57
L 2	7015	8275	7645	8665	5366	38	10450	6100	42	9558	5733	40
L 3	7236	9275	8256	9283	5189	44	12500	6050	52	10892	5620	48
L 4	8159	10163	9161	9820	6498	34	12625	7700	39	11222	7099	37
L 5	7459	9638	8548	9064	5853	35	12400	6875	45	10732	6364	41
L 6	7512	9350	8431	9367	5658	40	12000	6700	44	10683	6179	42
L 7	7190	8900	8045	9311	5068	46	11950	5850	51	10630	5459	49
L 8	7928	9988	8958	9929	5927	40	12625	7350	42	11277	6639	41
L 9	7053	9038	8045	8546	5560	35	11200	6875	39	9873	6217	37
L 10	6419	7700	7060	8005	4833	40	9725	5675	42	8865	5254	41
L 11	7234	9275	8255	9292	5177	44	11950	6600	45	10621	5888	45
L 12	6440	7425	6932	8104	4776	41	9750	5100	48	8927	4938	45
L 13	7130	8438	7784	9188	5073	45	11250	5625	50	10219	5349	48
L 14	7152	8738	7945	9054	5251	42	11375	6100	46	10215	5675	44
L 15	7140	8738	7939	8868	5413	39	11350	6125	46	10109	5769	43
L 16	7627	8175	7901	9346	5907	37	10750	5600	48	10048	5754	43
Beacher	6755	7975	7365	8468	5042	40	10200	5750	44	9334	5396	42
Giza 121	7354	8925	8139	9107	5600	39	11600	6250	46	10354	5925	43
Giza 126	7607	9225	8416	9339	5875	37	12000	6450	46	10669	6163	42
Giza 132	8102	10300	9201	10420	5783	45	14050	6550	53	12235	6166	50
LSD 0.05	550	1198	666	--		--	--		--	942		--

The interaction between the irrigated treatments and barley genotypes was non-significant in both growing seasons. These results are confirmed by Khayatnezhad *el al.* (2010), Refay (2010), Mollah & Paul (2011) and Zare *el al*. (2011).

Conclusion

Generally, all the studied characteristics were significantly affected by water stress at both growing seasons, except for total chlorophyll content. Grain yield was the highest in Giza132, L2, L4, L5, L6, L8 and L11compared with Giza126 (as a check). L4 and L8 genotypes had the highest values of TDM, LAI and CGR especially under stress condition, as well as possessed high values of NAR, RGR and RCC.

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تحليل النمو وإستجابة محصول الشعير تحت تأثير نظم الرى

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لتقدير تحمل أربعه أصناف وستة عشر سلالة من الشعير للإجهاد المائى، تم قياس صفات تراكم المادة الجافة الكلية، دليل مساحة الأوراق، معدل نمو المحصول، معدل الكفاءة التمثيلية، معدل النمو النسبى، محتوى الماء النسبى، محتوى الكلوروفيل النسبى، المحصول البيولوجي ومحصول الحبوب، وذلك فى محطة البحوث الزراعية بسخا فى موسمى ٢٠١٠/٢٠٠٩، ٢٠١١/٢٠١٠. وقد تأثرت جميع الصفات المدروسة سلبيا وبشكل كبير نتيجة للإجهاد المائى فى كل من الموسمين، ماعدا صفة محتوى الكلوروفيل النسبى فقد زاد تحت ظروف الإجهاد. وقد أظهرت السلالتان ٤ و ٨ قيما مرتفعة لمحصول الحبوب والمحصول البيولوجى حيث اعطيتا اعلى القيم فى كل من المادة الجافة الكلية، دليل مساحة الأوراق ومعدل نمو المحصول خاصة تحت ظروف الاجهاد، كما اعطيتا قيما جيدة لمعدل الكفاءة التمثيلية، معدل النمو النسبى، محتوى الماء النسبى، محتوى الكلوروفيل النسبى. فكلتا السلالتان تمثلان أكثر التراكيب الوراثية المرغوبة والمتحملة للإجهاد، وكذلك تحت ظروف عدم الاجهاد.