Screening of bread wheat cultivars (Triticum aestivum L.) to water deficit stress under field conditions

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Abstract
Field trial was conducted during the growing season of 2011-2012 at the Research Field, Department of Biology, College of Science, Baghdad University to test the performance of wheat cv Rabyaa, Latifiya, Al-Iraq, Tummose 2, Abu-Graib 3, IPA 99 and Sham 6 grown under different soil water deficit stresses. Several agronomic and physiological traits and yield and yield components of the test cultivars were determined. The experiment was conducted in split plot design with five replications for each treatment. The cultivars were kept in the sub plot while water stress treatment was assigned as main plot. Water stress was applied by irrigated the plots to the soil field capacity (FC) then withheld next irrigation until the soil moisture of the respective plots depleted to 50 (control), 25 and 15% of FC.
Results indicated that the water deficit stress significantly reduced biological yield, grain yield and yield components, plant height and number of tillers. Also, drought significantly reduced leaf area and chlorophyll content and increased proline accumulation of the all test cultivars. In most cases, the reduction increased with the increased water stress. The results also showed significant differences among the test cultivars in most of the aforementioned parameters. Under higher drought stress, cultivars Rabyaa, Latifiya and Abu-Graib 3 were superior in grain and biological yields and most of yield components (number of spikes/m^2, number of grains/spike and 1000-grain weight) compared to other cultivars including Sham 6 and IPA 99 which recorded lower values of these traits. Subsequent analyses revealed the drought tolerant cultivars (Rabyaa, Latifiya and Abu-Graib 3) showed increased with high significant in grain and biological yields, yield components, plant height, number of tiller, leaf area, accumulation of proline and total chlorophyll content than non-tolerant cultivars (Sham 6 and IPA 99). This suggests that the these characters are useful criteria that may be used for screening wheat genotypes for drought tolerance.

Keyword: drought stress, wheat cultivars, grain and biological yields, proline accumulation, chlorophyll content.

غربلة أصناف من حنطة الخبز(Triticum aestivum L.) لتحمل شد نقص الماء تحت ظروف الحقل

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الخلاصة
أجريت دراسة حقلية خلال الموسم 2011 2012 –في حقل بحوث قسم علوم الحياة في كلية العلوم ، جامعة بغداد لاختبار تحمل أصناف الحنطة ربيعة و لطيفية و تموز 2 و العراق و أبو غريب 3 وإباء 99 و شام 6 لشدود مختلفة من نقص الماء تحت ظروف الحقل. إذ نفذت التجربة في حقل مزود بغطاء نافذ للضوء لوقاية التجربة من ماء المطر، وقد قسم الحقل إلى ألواح مساحة الواحد منها 1 × 2 م وزرعت فيها حبوب الأصناف في خطوط وحسب التوصيات الخاصة للمحصول. تم سقي النباتات في بداية التجربة إلى السعة الحقلية ثم

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حجبت السقية التالية إلى أن وصل ماء التربة إلى 50 (المقارنة) و 25 و15% من السعة الحقلية واستمر العمل بهذه الحالة إلى نهاية التجربة. نفذت التجربة وفق تصميم الألواح المنشقة وبخمسة مكررات، إذ تمثلت الأصناف بالألواح الثانوية في حين تمثلت معاملات الجفاف بالألواح الرئيسة.

أظهرت النتائج أن الجفاف اختزل معنويا الحاصل البيولوجي وحاصل الحبوب ومكونات الحاصل وارتفاع النبات وعدد الأشطاء لجميع الأصناف، وبشكل عام ازداد الاختزال بزيادة الشد ألجفافي، كما اختزل الجفاف المساحة الورقية ومحتوى الأوراق من الكلوروفيل وزاد من محتوى الأوراق من البرولين. بينت النتائج أن هنالك تباينا معنويا في معظم الصفات المشار إليها بين الأصناف، إذ سجلت أصناف ربيعة ولطيفية وأبو غريب 3 أعلى قيم في الحاصل البيولوجي وحاصل الحبوب تحت شد الجفاف العالي، في حين سجل صنفي شام 6 و إباء 99 اقل قيم في تلك الصفات. ولوحظ إن الأصناف المتحملة للجفاف أظهرت زيادة معنوية في حاصل الحبوب والحاصل البيولوجي ومكونات الحاصل وارتفاع النبات وعدد الأشطاء والمساحة الورقية و محتوى الأوراق من البرولين والكلوروفيل تحت ظروف الجفاف مقارنة بالصنفين شام 6 و إباء 99، الأمر الذي يشير إلى إمكانية استخدام تلك المؤشرات كمعايير في دراسة تحمل الجفاف في أصناف الحنطة.

Introduction

Wheat (Triticum spp.) is one of the most important food crops in the world in terms of the area harvested, production, and nutrition; as it supplies about 19% of the calories and 21% of the protein to the world's population [1]. Wheat is mostly grown under the rain fed conditions. In 2000,70% of world's wheat harvested area was under rain fed condition [2]. Drought and high temperature are two important environmental factors that adversely affect performance and yield of several crops [3 and 4]. Several investigators have reported that considerable variations in drought resistance have been observed among crop species and even within cultivars of the same species [5].

In recent years, several genotypes of wheat have been released in Iraq due to better agronomic traits such as yield and yield components. However, their response to drought stress has not been evaluated. Therefore, the present study was conducted to study the performance of the test cultivars under different water stress regimes, and identify the most tolerant one (s) and to find out if the possible differences among the test cultivars are related to some physiological parameters.

Materials and Methods

Experiment was conducted on (2011-2012) at the research field of the Department of Biology, College of Science, Baghdad University, Baghdad, Iraq. Seven bread wheat cultivars namely Rabyaa, Latifiya, Tummose 2, Al-Iraq, Abu-Graib 3, IPA 99 and Sham 6 were provided by Seed Technology Center, Ministry of Science and Technology. Field plots (1×2 m) were randomly made in the field equipped with rain fall transparent shed to avoid the rains. The plots were separated from each other by a plastic sheet inserted vertically in the soil to 35 cm depth in order to prevent the possible horizontal movement of irrigated water. Grains of wheat cultivars were sown manually in their respective plots in rows of one meter each with a distance of 20 cm between rows (10 rows per plot) and at seed rate of 3 g per row (150 kg/ha). Fertilizers used were urea (46% N) at 200 kg ha^{-1} and triple super phosphate (46% P_2O_5) at 100 kg ha^{-1}. All phosphorus fertilizer was applied at planting during seed bed preparation, while urea was divided into three equal amounts. The first amount was added during the land preparation prior to planting, the

second was added 30 days after sowing (during the early tillering stage) and the final amount was added at panicle initiation [6].Water stress was applied by irrigated the plots to the soil field capacity then withheld next irrigation until the soil moisture the respective plots reached 50 (control), 25 and 15% of soil field capacity. All weeds were hand weeded during the course of study. Soil moisture of the plots was recorded by weight basis method.

At booting stage, samples of leaves were randomly taken from plants of each plot and analyzed for leaf area [7], total chlorophyll content [8] and proline content [9].

At the physiological maturity of crop, number of tillers per m^2, plant height (cm), numbers of spikes per m^2, number of grains per spike, 1000-grain weight (g), biological yield (t/ha) and grain yield (t/ha), were determined following standard procedures.

The experiment was conducted in split plot design with five replications for each treatment. The cultivars were kept in the sub plot while water stress treatment was assigned as main plot. The data were analyzed using analysis of variance (ANOVA). The least significant differences test was used to compare the averages of treatments [10].

Results

Effect of water deficit stress on proline content and total chlorophyll of leaves of several wheat cultivars

Results presented in table 1 exhibited that average proline content was significantly increased by water deficit stress. Expose of plants to 25 and 15% of FC water stress led to increase proline content of leaves by 63.82 to 72.64 % of control respectively.

Average of proline content was significantly different among the test cultivars. The highest proline content (12.82 µmole/g) was recorded by Latifiya, Rabyaa (12.10 µmole/g) and Abu-Graib 3 (12.07 µmole/g), while IPA 99 and Sham 6 recorded the least proline content (6.12 and 6.14 µmole/g, respectively).

The interaction between water deficit treatments and wheat cultivars significantly affected proline content of leaves. At normal irrigation (control treatment), cultivars Rabyaa and Latifiya have statistically higher leaves proline content than the other cultivars. However, under water stress condition, differential response in terms of leaves proline content has been observed. Maximum proline content (18.67 µmole/g) was found in Latifiya, Abu-Graib 3 (18.66 µmole/g) and Rabyaa (17.73 µmole/g) by the higher water deficit, while Sham 6 and IPA 99 remained lower in their proline content although it increased in both cultivars.

Average chlorophyll content was significantly decreased by water deficit stress and the reduction was significantly increased with increased of water deficit stress (Table 1). Chlorophyll content appeared to be reduced by 16.10 and 29.70 % of control when plants exposed to 25 and 15% water deficits, respectively.

Average of chlorophyll content was also significantly different among the test cultivars. The highest chlorophyll content (7.04 mg/g) was recorded by Rabyaa and Abu-Graib 3 (6.64 mg/g), while Sham 6 and IPA 99 were recorded the least chlorophyll content (4.64 mg/g) followed by Al-Iraq and Tummose 2 cultivars.

The interaction between water deficit treatments and wheat cultivars were significantly affected chlorophyll content. At a control treatment of water stress, the highest of chlorophyll content was recorded by Rabyaa and Abu-Graib 3 (8.50 mg/g and 7.33 mg/g, respectively) followed by Latifiya (6.80 mg/g), while the lowest chlorophyll content was recorded by IPA 99, Sham 6 and Tummose 2 cultivars. However, at higher water stress level, differential reduction in chlorophyll content has been observed among the test cultivars. Maximum reduction in chlorophyll content was observed in Al-Iraq followed by IPA 99, while least reduction was recorded in Abu-Graib 3 followed by Latifiya.

Table 1- Effect of water deficit stress (W) on proline content and total chlorophyll of test wheat cultivars (CV).

Cultivars	Water deficit (% of field capacity)			
	Control*	25	15	Average
	Proline content (µmole/g fresh weight tissue)			
Rabyaa	5.23	13.33	17.73	12.10
Latifiya	4.3	15.5	18.67	12.82
Al-Iraq	4.13	10.2	12.73	9.02
Tummose 2	3.97	9.07	12.03	8.36
Abu-Graib 3	3.63	13.87	18.67	12.06
IPA 99	2.83	5.93	9.6	6.12
Sham 6	2.83	6.57	9.03	6.14
Average	3.85	10.64	14.07	
LSD ≤ 0.05	W = 0.75	CV = 0.51	W × CV = 1.00	
	Total chlorophyll (mg/g fresh weight tissue)			
Rabyaa	8.50	6.73	5.90	7.04
Latifiya	6.80	5.90	5.20	5.97
Al-Iraq	5.87	5.60	4.17	5.21
Tummose 2	6.80	5.77	3.93	5.50
Abu-Graib 3	7.33	6.53	6.07	6.64
IPA 99	5.93	4.30	3.70	4.64
Sham 6	5.57	4.43	3.93	4.64
Average	6.69	5.61	4.70	
LSD ≤ 0.05	W = 0.33	CV = 0.55	W × CV = 0.92	

*Control = 50% of field capacity

Effects of water deficit on leaf area, plant height and number of tillers

Results presented in table 2 exhibited that averages of leaf area, plant height and number of tillers were significantly affected by water deficit treatments. Leaf area, plant height and number of tillers were reduced by 26.95, 8.52 and 3.98% of control, respectively by 25% water deficit treatment and by 36.98, 17.09 and 10.77%, respectively by 15% water deficit treatment.

Averages leaf area, plant height and number of tillers were significantly affected by wheat cultivars. Cultivars Rabyaa and Latifiya recorded the highest leaf area and plant height, while Abu-Graib 3 recorded the highest number of tillers. Cultivars IPA 99 and Sham 6 showed the least values of most aforementioned agriculture traits.

The interaction between water deficit treatments and wheat cultivars significantly affected the average leaf area, plant height and number of tillers. At the higher water stress, The highest leaf area and plant height was recorded by Rabyaa and Latifiya cultivars, while the highest number of tillers per m^2 was found in Abu-Graib 3 followed by Latifiya cultivar. The least value of leaf area was recorded by Sham 6 and Tummose 2, while the least values of plant height and number of tillers per m^2 were recorded by Sham 6 and IPA 99, respectively.

Table 2- Effect of water deficit on leaf area (cm^2)' plant height (cm) and number of tillers per m^2 of several wheat cultivars.

Cultivars	Water deficit (% of field capacity)			
	50 (Control)	25	15	Average
	Leaf area (cm^2)			
Rabyaa	60.30	44.80	40.00	48.37
Latifiya	54.80	45.40	38.40	46.20
Al-Iraq	55.40	39.00	30.10	41.50
Tummose 2	49.10	39.80	28.20	39.03
Abu-Graib 3	40.10	31.50	31.30	34.30
IPA 99	55.80	32.80	30.60	39.73
Sham 6	43.20	28.70	27.40	33.10
Average	51.24	37.43	32.29	
LSD ≤ 0.05	W = 0.94	CV = 1.04	W x CV = 1.79	
	Plant height (cm)			
Rabyaa	130.03	114.80	102.30	115.71
Latifiya	103.30	96.40	93.10	97.60
Al-Iraq	101.50	92.20	80.10	91.27
Tummose 2	100.60	91.70	82.00	91.43
Abu-Graib 3	101.50	96.20	84.50	94.07
IPA 99	95.70	83.10	80.30	86.37
Sham 6	88.40	85.20	75.50	83.03
Average	103.00	94.23	85.40	
LSD ≤ 0.05	W = 2.20	CV = 1.51	W x CV = 2.94	
	Number of tillers per m^2			
Rabyaa	541.00	473.33	423.00	479.11
Latifiya	510.00	472.00	462.00	481.33
Al-Iraq	450.00	456.00	412.00	439.33
Tummose 2	488.00	478.00	424.00	463.33
Abu-Graib 3	546.67	529.00	518.00	531.22
IPA 99	418.00	366.00	360.00	381.33
Sham 6	425.00	470.00	416.00	437.00
Average	482.67	463.48	430.71	
LSD ≤ 0.05	W = 3.34	CV = 12.20	W x CV = 19.70	

*Control = 50% of field capacity

Effects of water deficit stress on yield components of test wheat cultivars

Results indicated that averages of number of spikes per m^2, number of grains per spike and 1000-grain weight were significantly decreased by water deficit treatments and the reduction increased with the increased water deficit (Table 3). At higher water stress level, the number of spikes per m^2, number of grains per spike and 1000-grain weight were reduced by 11.04, 21.49 and 7.05 % of control, respectively.

Averages of number of spikes per m^2, number of grain per spike and 1000-grain weight were significantly different among the test cultivars. The highest number of spike per m^2 (521.22) was recorded by Abu-Graib 3, while the least number of spike per m^2 (360.00) was observed in IPA 99. The highest number of grains per spike (46.47) was recorded by Latifiya, followed by Rabyaa (40.48), while the least number of grains per spike (31.77) was noticed in Sham 6. Maximum 1000-grain weight (33.68 g) was observed in Rabyaa, while the lowest 1000-grain weight (20.98 g) was found in Sham 6 .

The interaction between water deficit treatments and wheat cultivars significantly affected the number of spike per m^2, number of grain per spike and 1000-grain weight. Abu-Graib 3 which scored higher number of spikes per m^2 (540.00) at control treatment remained higher in this trait when grown at higher water stress (498.67), while Rabyaa cultivar which has number of spikes per m^2 equal to 508.33 in control treatment showed a reduction in this trait up to 466.11 spikes per m^2 at higher water stress. The least number of spikes per m^2 (332.00) was observed in IPA 99 at higher water deficit stress .The highest number of grain per spike (52.3) was recorded by IPA 99 in control treatment, However, it reduces drastically (up to 42.26 % of control) at higher water deficit stress level, while the number of grains per spike was reduced up to 16.47 and 7.35% of control in Rabyaa and Latifiya.

Rabyaa cultivar scored the superior weight of 1000 grains in control treatment as well as in the drought stress treatments, followed by Latifiya, while Sham 6 scored the least value in this trait in all water stress levels including control.

Effects of water deficit stress on grain and biological yields of test wheat cultivars

Results presented in table 4 exhibited that averages of grain and biological yields were significantly decreased by water deficit stresses and the reduction was significantly increased with increased water deficit stress. Yield of grain was reduced by 18.48 and 31.91% and biological yield was reduced by 26.44 and 40.97% of control by application of 25 and 15% of FC water deficits, respectively.

Average grain and biological yields were significantly different among the test cultivars. The highest grain yield (6.24 t ha^{-1}) was recorded by Rabyaa followed by Latifiya (5.37 t ha^{-1}), while the least grain yield (2.60 t ha^{-1}) was observed in Sham 6 followed by IPA 99 (3.53 t ha^{-1}). The highest biological yield (16.96 t ha^{-1}) was recorded by Rabyaa followed by Latifiya cultivar (14.43 t ha^{-1}), while the least biological yield (9.09 t ha^{-1}) was observed in Sham 6 followed by Al-Iraq (10.85 t ha^{-1}) and IPA 99 (10.94 t ha^{-1}).

The interaction between water deficit treatments and wheat cultivars significantly affected grain and biological yields. The highest grain yield (7.73 t ha^{-1}) and biological yield (22.30 t ha^{-1}) was recorded by Rabyaa cultivar in control treatment, followed by Latifiya then Abu-Graib 3, while the least grain (2.10 t ha^{-1}) and biological yields (6.80 t ha^{-1}) was observed in Sham 6 cultivar. Interestingly, at high drought level, the response of the above test cultivars are similar to that observed in control treatment. The order of grain yield and biological yield of the above test cultivars was in the order of Rabyaa > Latifiya > Abu-Graib 3, while the least grain and biological yields was observed in Sham 6 followed by IPA 99. The other test cultivars did not show significant differences among them in grain yield.

Table 3- Effect of water deficit stress (W) on yield components of test wheat cultivars (CV).

Cultivars	Water deficit (% of field capacity)			
	Control*	25	15	Average
	Number of spikes per m^2			
Rabyaa	508.33	470.00	420.00	466.11
Latifiya	490.00	465.00	455.00	470.00
Al-Iraq	441.00	409.00	395.00	415.00
Tummose 2	475.00	470.00	415.00	453.33
Abu-Graib 3	540.00	525.00	498.67	521.22
IPA 99	403.00	345.00	332.00	360.00
Sham 6	409.00	396.00	390.00	398.33
Average	466.62	440.00	415.10	
LSD ≤ 0.05	W = 4.96	CV = 10.99		W × CV = 17.95
	Number of grain per spike			
Rabyaa	46.33	36.40	38.70	40.48
Latifiya	49.00	45.00	45.40	46.47
Al-Iraq	41.00	40.10	33.10	38.07
Tummose 2	42.50	39.80	31.30	37.87
Abu-Graib 3	41.50	38.20	37.33	39.01
IPA 99	52.30	32.90	30.20	38.47
Sham 6	37.50	30.30	27.50	31.77
Average	44.31	37.53	34.79	
LSD ≤ 0.05	W = 1.02	CV = 1.78		W × CV = 2.94
	1000-grain weight (g)			
Rabyaa	34.50	33.70	32.83	33.68
Latifiya	26.30	25.30	24.20	25.27
Al-Iraq	24.30	22.70	22.50	23.17
Tummose 2	24.30	23.60	22.10	23.33
Abu-Graib 3	25.40	24.40	23.10	24.30
IPA 99	24.10	23.80	23.10	23.67
Sham 6	21.70	21.23	20.00	20.98
Average	25.80	24.96	23.98	
LSD ≤ 0.05	W= 0.953	CV = 0.984	W × CV = 1.72	

*Control = 50% of field capacity

Table 4- Effects of water deficit stress (W) on grain and biological yields of test wheat cultivars (CV).

Cultivars	Water deficit (% of field capacity)			
	Control*	25	15	Average
	Grain yield (t ha^{-1})			
Rabyaa	7.73	5.90	5.08	6.24
Latifiya	6.10	5.20	4.80	5.37
Al-Iraq	4.10	3.50	2.70	3.43
Tummose 2	4.70	3.90	2.80	3.80
Abu-Graib 3	5.47	4.80	4.60	4.96
IPA 99	4.80	3.40	2.40	3.53
Sham 6	3.10	2.60	2.10	2.60
Average	5.14	4.19	3.50	
LSD ≤ 0.05	W = 0.18	CV = 0.30		W × CV = 0.50
	Biological yield (t ha^{-1})			
Rabyaa	22.30	15.47	13.10	16.96
Latifiya	17.53	13.47	12.30	14.43
Al-Iraq	13.90	10.77	7.87	10.85
Tummose 2	16.60	11.60	8.47	12.22
Abu-Graib 3	15.70	12.30	10.90	12.97
IPA 99	15.13	10.50	7.20	10.94
Sham 6	11.60	8.87	6.80	9.09
Average	16.11	11.85	9.51	
LSD ≤ 0.05	W = 0.53	CV = 0.51		W × CV = 0.90

*Control = 50% of field capacity

Discussion

Screening for drought tolerance is useful tool to select the most drought tolerant genotypes. This can be done under laboratory, green house in pots and under field condition; however, of the all of these methods, field condition bioassay is the most successful and effective method for screening since the evaluation can cover all stages of plant growth and development and thus the data is more realistic than using the other methods [11].

Results of the present work exhibited differential response of the test cultivars of wheat to water deficit stress. This suggests that these differences were due to genetical variations among the test cultivars to water deficit stress since all treatments were carried out under similar conditions. The differential response of genotypes of several crops including wheat to drought stress has been reported and well documented by several investigators [12,13 and 14]. The present study demonstrated that Rabyaa, Latifiya and Abu Ghraib 3 are the most tolerant cultivars since it had the highest values of grain and biological yields at high water deficit stress, while IPA 99 and Sham 6 were the most drought sensitive cultivars since lower grain and biological yields were obtained when grown at high level of water deficit stress. Subsequent data analyses revealed that the drought tolerant cultivars appeared superior in yielding, number of tillers, spikes per m^2, grains per spikes, 1000-grain weight, leaf area, plant height, Chlorophyll and proline content compared to the drought sensitive cultivars (IPA 99 and Sham 6). Several investigators showed that all yield components are significantly reduced by water deficit stress and crop genotypes with high tolerance to drought showed higher values in yield components . Vaezi et al. [11] mentioned that 1000-grain weight was the yield component most affected by drought. Others reported that the responses of different crop genotypes to drought during grain filling lead to differences in individual grain weight [15,16,17 and 18]. The number of grains per spike of many crop cultivars was significantly greater in the irrigated than in the water stress conditions (like IPA 99, Sham 6 and Tummoze 2 in recent study). Giunta et al. [16] found that the severe drought stress caused a reduction in all the yield components of wheat, but particularly in the number of fertile spike per unit area (60%) and in the number of grains per spike (48%).

Plant height is directly linked to the productive potential of plant in terms of grain yield [19] since it represents a good storage organ (sink) for photosynthetic metabolites. In the present study, a significant reduction in plant height was noticed due to water stress; however, tolerant cultivars attained more plant height. This suggests that more metabolites expect to move from higher stem height cultivars to grains than from lower plant height cultivars.

The opinion shared by many scientists that proline might be involved in drought tolerance of plants is confirmed in present study. The drought tolerant cultivars accumulate more proline than drought sensitive ones. It has been believed that proline plays a major role in maintaining the membrane stability and thereby decreasing nutrients leakage and water loss of the cell grown under drought stress medium. No attempt was made to study the membrane stability of the test genotypes; however, relative water content appeared to be superior in drought tolerant cultivars, suggesting the possibility of possessing these cultivars higher membrane stability.

Finally, It can be concluded from this study that the performance of the test wheat cultivars is different under water deficit stress. The drought tolerant cultivars were Rabyaa, Latifiya and Abu-Graib 3 while least drought tolerance was IPA 99 and Sham 6 cultivars. Interestingly, at higher water deficit stress, the responses of the above test cultivars are similar to that observed in control treatment. The other test cultivars did not show significant differences among them in grain and biological yields.

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