تقييم معايير التمثيل الضوئي وعلاقتها بالغلة الحبية لعدد من سلالات الشعير (*Hordeum vulgare* L.) الموسومة (RILs) تحت ظروف الإجهاد المائي

Evaluation of Photosynthetic Parameters in Recombinant Inbred Lines of Barley (*Hordeum vulgare* L.) in Relation To Grain Yield under Water-stress Conditions

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المُلَخَّص

يعد الجفاف أحد العوامل الرئيسة المحددة لإنتاج الشعير في العديد من الدول النامية في كافة أنحاء العالم. أجريت تجربة في البيت البلاستيكي لدراسة معايير التمثيل الضوئي وعلاقتها بالغلة الحبية تحت ظروف الجفاف المتباينة لنحو 40 سلالة موسومة (RILs) ناتجة عن تهجين الطرازين الوراثيين Arta و Keel. عرضت النباتات إلى ثلاث معاملات مائية خلال فترة امتلاء الحبوب وحتى النضج: (1) معاملة الري الجيد Well- watered (70 %) من الماء المتاح في التربة، (2) معاملة إجهاد الجفاف المعتدل Mild stress (35 %) من الماء المتاح في التربة، (3) معاملة الإجهاد المائي الشديد Severe stress (10 %) من الماء المتوافر في التربة. أخذت جميع القياسات في اليوم السابع من المعاملة. سببت ظروف الإجهاد المائي خلال مرحلة امتلاء الحبوب تراجعاً معنوياً في كل من معدل التمثيل الضوئي (Pn)، والغلة الحبية (GY). كان معدل التمثيل الضوئي، ومحتوى الماء النسبي (RWC)، والغلة الحبية للنباتات المروية بشكلٍ جيد أعلى منها في النباتات المعرضة لظروف الإجهاد المعتدل، والشديد، باستثناء الطراز الوراثي Keel، الذي كان يمتلك قيمة أقل من تركيز ثاني أكسيد الكربون داخل الأوراق (Ci) في معاملة الإجهاد المعتدل بالمقارنة مع معاملة الري والإجهاد المائي الشديد. كان التباين لجميع المؤشرات المدروسة معنوياً بين الطرز الوراثية (G)، والمعاملات (T) والتفاعل (GxT)، ولكن لم تكن هناك فروقات معنوية في محتوى الماء النسبي، والغلة الحبية في التفاعل بين الطرز والمعاملات. وكانت الفروقات معنوية بين متوسط معاملات إجهاد الجفاف لجميع المؤشرات المدروسة باستثناء تركيز CO_2 في السلالات، و معدل النتح (E)، والناقلية المسامية (gs)، وتركيز CO_2 في الطراز الوراثي Arta؛ حيث لم تكن هناك فروقات معنوية بين ظروف الإجهاد المائي المعتدل والشديد. سبب ازدياد شدة الجفاف انخفاضا في الغلة الحبية بمقدار 24 % و56 % تحت معاملة الإجهاد المائي المعتدل والشديد على التوالي، في حين انخفضت غلة الأبوين (Arta و Keel) بنسبة 31 % لكليهما تحت معاملة الإجهاد المائي المعتدل ، و61 % و46 % تحت معاملة الإجهاد الشديد لكل من الأبوين Arta

و Keel على التوالي. ارتبط معدل التمثيل الضوئي معنوياً مع الغلة الحبية تحت ظروف إجهاد الجفاف المتباينة، ولوحظ أن أعلى قيمة لمعامل الارتباط معاملة الإجهاد الشديد. انخفضت كفاءة التمثيل الضوئي بالعلاقة مع الغلة الحبية بتقليل كميات المياه المضافة للنباتات.

الكلمات المفتاحية: معايير التمثيل الضوئي، الغلة الحبية، محتوى الماء النسبي، الشعير، الإجهاد المائي.

Abstract

Drought stress is one of the major factors limiting barley yields in many developing countries worldwide. A greenhouse experiment was conducted to study the photosynthetic parameters in relation to grain yield under water stress conditions on 40 recombinant inbred lines (RILs) developed from the cross between the cultivars Arta and Keel. Plants were exposed to three water treatments during the period of grain filling until grain maturity as follow: (1) well-watered at 70% available water in the soil, (2) mild stress at 35% available water in the soil, and (3) severe stress at 10% available water in the soil. All measurements were taken after 7 days of treatment. Water stress conditions during grain filling significantly decreased photosynthesis (Pn) and grain yield (GY). Well-watered plants of RILs and two parents had higher photosynthetic activity, (GY) and relative water content (RWC) than plants in mild and severe stress treatments; only intercellular CO_2 concentration (Ci) for genotype Keel under mild stress treatment had smaller value comparing with well-watered and severe stressed plants. The differences among genotypes (G), treatments (T) and (GxT) interaction were significant in all studied traits but were not significant in relative water content and grain yield when genotypes and treatments had been interacted. In all studied traits there were significant differences among the three water stress treatment for the parameter Ci for mean of RILs and Ci, transpiration (E), stomatal conductance (gs) of Arta; In which differences between mild and severe stress conditions were not significant. By increasing the severity and duration of drought stress, grain yield of RILs decreased 24% and 56% under mild and severe stress treatments respectively, while for the parents decreased 31% for both of them under mild stress and 61%, 46% in Arta and Keel respectively under sever stress condition. Photosynthesis was found to be significantly correlated to grain yield under water stress conditions and the higher correlations were found for severe stress treatment. Photosynthetic activity in relation to grain yield decreased by limiting the quantities of water supplied to plants.

Keywords: Photosynthetic parameters, Grain yield, Relative water content, Barley, Water stress.

Introduction

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops in many countries including Syria. In many developing countries it is a typical crop of marginal, low input, stressful environments because it is adapted to a severe stress water regime compared with other cereals (Ceccarelli, 1984). In many of these countries, barley is often the only possible rainfed crop that farmers can grow, and it is often subjected to extreme water deficit during the dry season (Ceccarelli et al., 2007). The effect of water deficit has been investigated on physiological mechanisms, such as net photosynthesis, leaf water status (Basnayke et al., 1996). Although there is no consensus on the utility of water relation parameters as drought tolerance selection criteria (Sinha, 1987), selection criteria must be identified that are associated with improved yield under drought stress, have a high heritability and that can be measured simply and accurately in large populations.

Water stress limits grain yield in many crops including cereals (Iqbal et al., 2005), reducing average yields by 50% and more. Like other cereals barley is also affected by water stress since its grain yield (Urchei and Rodrigues, 1994) and net photosynthesis rate are reduce significantly by intense dry developmental stage. Therefore, drought stress is a serious challenge for barley in these areas, because it affects simultaneously many traits through morphological, physiological and metabolic modifications occurring in all plant organs leading to a decrease in yield (Cochard et al. 2002). According to Katerji et al., (2009), drought affected barely water status during the ear formation and flowering stages. It reduced the grain (37%) and straw (18%) yields. These reductions were not related to the soil salinity levels. There were fewer ears per plant, explaining the decrease in crop productivity and water use efficiency in drought conditions.

Photosynthesis is an essential process to maintain crop growth and development. It is well known that photosynthetic systems in higher plants are more sensitive to drought stress (Falk et al., 1996), as well the limitation of photosynthetic carbon metabolism has been analyzed in certain crop plants (Griffiths and Parry, 2002). According to Xu & Shen, (1994) photosynthesis capacity during the reproductive stage is positively correlated with crop yield. Chen et al., (1995) summarized the studies on the relation between photosynthesis and yield, and deduced that elevating photosynthetic rate is beneficial to dry matter production and yield. Relative water content is closely related to cell volume, and it may closely reflect clearly the balance between water supply to the leaf and transpiration rate (Farquhar et al., 1989). The effect of water stress on photosynthesis has been a subject of controversy among plant physiologists for many years, and conflicting results have been reported depending on the plant material, and plant procedures used for investigations (Cornic and Massacci, 1996). The effect of water stress could be due to different events, such as an inhibition of electron transport activity limiting the generation of reducing power or limitation in the metabolic activity (Guo and Al-Khatib, 2003). When the water deficit in plant tissue increases develops, it will lead to a significant inhibition of photosynthesis, and consequently the photosynthesis activity is hampered. In such condition one of the earliest plant responses includes stomatal closure, which limits CO_2 diffusion to chloroplast (Muller and Whisitt, 1996) and reduced photosynthetic activity substantially causes yield reduction. However, the relative importance of stomatal conductance (gs) in resterecting the supply of CO_2 to metabolism (stomatal limitation), and of metabolic impairment which decreases the potential of photosynthesis rate (Pn). Stomatal limitation is considered to decrease both Pn and CO_2 concentrations in the intercellular spaces of the leaf (Ci), which inhibits metabolism (Cornic, 2000). For instance, restricted CO_2 availability could lead to increased the susceptibility to photo-damage (Valentini et al.,1995), controversially other studies (Epron et al., 1992; Gamon and Pearcy, 1990) found that photo-damage does not generally occurs during water stress under natural conditions. Despite of the fact that photosystem II (PSII) is highly drought resistant (Yordanov et al., 2003). Under water stress, photosynthetic electron transport to O_2 and increased quenching of excitation energy in the PSII may be unable to dissipate the excess excitation energy in the PSII and thus causes photodamage of PSII, consequently, increased dissipation of this energy as heat occurs in order to minimize photodamage to PSII reaction centers (Baker, 1993). Although many studies on PSII have been done, the mechanism by which water stress affects its photosynthetic activity remains to be elucidated. It has been shown that plants in drying soil can have reduced rates of growth and gas exchange while showing no clear perturbation in leaf water relation (Kutschera and Kohler, 1993).

The present study aims to determine the performance of photosynthesis rate in relation to grain yield under three water conditions in forty recombinant inbred lines (RILs) derived from the cross between Arta and Keel in which the parents differ for drought tolerance.

Material and Methods

Plant material and growth conditions:

Forty randomly chosen lines of 501 F7 recombinant inbred lines (RILs) of the cross Arta/Keel were used for this experiment. The population was developed by single-seed descent at ICARDA. Arta is a high yielding pure line selected from the Syrian white-seed landrace 'Arabi Abid', is well adapted to Syrian conditions, and combines high number of tillers and high kernel weight, but is susceptible to lodging under high yielding conditions and becomes very short under dry conditions. Keel is an Australian breeding line resistant to lodging, combines early flowering, high yielding, and plant height and with adaptation to sever drought stress. Both parents are well adapted to low rainfall conditions (250-375 mm) and are characterized by high yield stability. The main objective of this cross was to develop lines combining tillering ability of the Arta with plant height and the adaptation to sever drought stress conditions of Keel (Grando et al., 2001).

A greenhouse experiment including 40 F7 RILs and two parents was arranged in a randomized incomplete-block design with three treatments (well-water, mild stress and severe stress) and four replicates for each one under controlled conditions in a greenhouse at the International Center for Agriculture Research in the Dry Areas (ICARDA) (Tel Hadya, Aleppo, Syria). Three seedlings each of three-four weeks vernalized seedlings of the same entry were transplanted into a 2.5 kg pot (15 cm in height and 16 cm in diameter) filled with 2 kg of sterilized soil, which contain about 6% of water. Field capacity, wilting point and available water content (AWC) of the soil were measured at ICARDA soil laboratory according to protocol described by Ryan et al., (2001). At the beginning of the grain-filling period plants were subjected to three drought stress conditions, the values: 70%, 35% and 10% of AWC in the soil were considered for barley as well-water, mild stress and sever stress conditions, respectively (Doorenbos and Pruit, 1977). For one treatment one RILs and its parents were planted in four pots with a total of twelve plants; all plants were grown with 16 h/ 8 h day/night at 27 ^{o}C/18 ^{o}C day /night under control conditions. Drought treatments were imposed from the beginning of grain filling. Pots were weighed daily and maintained at the desired soil moisture content. The days for drought stress were counted after the AWC in the soil reached the desired percentage to allow measurements at precise determined intervals.

Measurements of photosynthetic activity:

Photosynthetic activity like Photosynthetic rates (pn), stomatal conductance (gs), transpiration (E) and intercellular CO_2 concentrations (Ci) were measured starting from the 7th day after water stress on fully expended flag leaf for one plant per pot per treatment for all replicates as a total four plants for each RILs and two parents using CIRAS 2 infrared gas analyzer system manufactured by PP-system (UK). According to PP-system company the equipment was calibrated with the following specifications/adjustments: leaf surface area 4.50 cm^2, ambient CO_2 concentration (Cref) 360 lmol mol^{-1}, temperature of leaf chamber

(Cuvette) varied from 19.9 to 25.2 °C, temperature of leaf varied from 21.4 to 25.9, leaf chamber gas flow rate (v) 288 ml min^{-1}. Ambient pressure ranged from 967-973 m bar, PAR (Qleaf) at leaf surface was maximum up to 1003 l mol m^{-2} s^{-1}.

Relative water content:

Relative water content (RWC) was measured using leaf pieces that were taken from the flag leaf of one plant per one pot per treatment for all replicates as a total four plants for each RILs and two parents after imposing drought conditions. Immediately after cutting the base of lamina, leaves were sealed within plastic bags and transferred quickly to the laboratory. Fresh weights (FW) were determined within 2 h after excision. Turgid weights were obtained after soaking leaves in distilled water in test tubes for 24 h in the fridge at 4°C and in the dark. After soaking leaves were quickly and carefully blotted dry with tissue paper in preparation for determining turgid weight. Dry weights were obtained after oven drying the leaf sample for 48 h at 80°C (Molnár er al., 2004). The relative water content was calculated according to (Barrs and Watherley, 1968) as in the flowing formula:

$$RWC = [(FW-DW) / (TW-DW)]*100$$

Data analysis:

Mean and standard errors were calculated according to the standard statistical procedure laid down by Gomez and Gomez, (1984). Analysis of variance (ANOVA) was performed to examine treatment effects on genotype by using GENSTAT software v. 11.1 to determine the significance of variation for all traits measured for this study. A mixed model, with genotypes as random effects and treatments as fixed effects was used. Correlation analysis was performed to express the relationship among variable of interest.

Result

Phenotypic variation among genotypes:

All source of variation for 40 genotypes and their parents (Arta and Keel) showed a highly significant ($P > 0.001$) genotype (G) and water stress treatment (T) effects for all the studied traits (Table 1). ‘GxT’ interaction was also significant for all traits except for stomatal conductance (gs) was found significant ($P > 0.05$) and not significant in grain yield (GY) and Relative water content (RWC) indicating a difference among RILs in the responses to drought, these differences displayed in (Fig 1) depending on the five highest yielding genotypes (HYGs) under three water stress. The variations among HYGs were high under well-watered (WW) condition and low under mild (MS) and severe stress (SS) condition except Ci parameter, which was high under MS condition. Under WW condition, genotype (AK-9) had highest value in GY comparing to others genotypes, while the genotype AK-12 should superiority in remnant traits, which were RWC 66%, 72% for genotypes AK- 9 and AK-12 respectively. GY increased by coinciding with RWC under MS and SS condition for genotypes AK-2 and Keel respectively. Photosynthesis parameters were the highest in genotype (AK-6) compare to other genotypes under MS and SS s Phenotypic performance of photosynthetic parameters in relation to grain yield for RILs and the two parents under three water regimes after 7th days after withholding water are summarized in (Table 2). The differences between two parents Arta and Keel at the same treatment were not significant for all traits except intercellular CO_2 concentration (Ci), photosynthesis rate (Pn), gs, GY under well- watered condition; Ci under mild stress condition and RWC, GY, Ci under severe stress condition.

Table 1. Mean Square values for different parameters of 40 RILs and their two parents grown under three water stress treatments.

S.O.V	d.f	Photosynthetic rate	Stomatal conductance	Transpiration	intercellular CO_2 concentrations	Relative water content	Grain yield
Geno (G)	41	2.0428***	1201***	0.16746***	11302***	0.012794***	0.4244 ***
Treatment (T)	2	628.3862***	230530.2***	23.84405***	215037***	1.960677***	63.8114***
G x T	82	1.4781***	890.4*	0.12308***	6221***	0.004436 ns	0.2274 ns
Error	375	0.7557	627.9	0.04402	2314	0.005842	0.1956
Total	500						

ns: no significant; * $P < 0.05$; *** $P < 0.001$

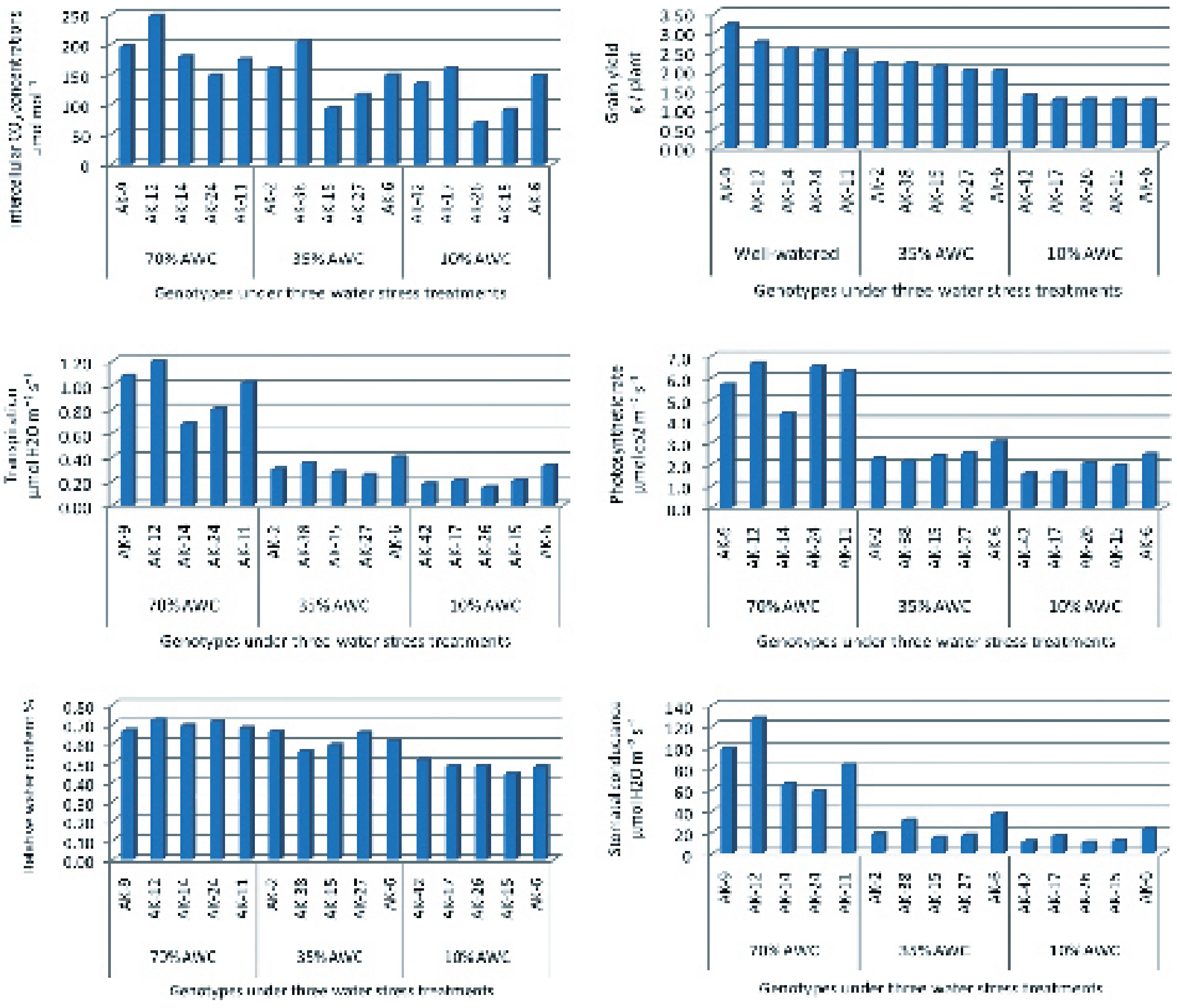

Fig. 1. Phenotypic differences among five highest grain yield genotypes under three water stress treatments.

Table 2. Means, standard deviation and ranges of the 40 RILs and their parents for Pn, gs, E, Ci, RWC and GY in the 7 day after beginning of treatment for barely plants under three water stress treatments imposed during the period of grain filling until grain maturity

Traits	Treatment	Parents			RILs		
		Arta	Keel	[e]significance	Mean	Max	Min
Pn	WW	5.5 ± 0.88 a ‡	4.2 ± 1.28 a	*	5.60 ± 0.78 a	7	4.15
	MS	2.8 ± 0.22 b	2.8 ± 1.43 b	ns	2.93 ± 0.67 b	4.45	1.48
	SS	2.2 ± 0.55 c	1.6 ± 0.58 c	ns	1.84 ± 0.43 c	2.68	1.1
GS	WW	37.8 ± 11.87 a	66.8 ± 58.03 a	*	83.55 ± 25.47 a	139.5	37.8
	MS	16.5 ± 3.70 b	22.8 ± 9.39 b	ns	25 ± 8.50 b	55.3	12.5
	SS	12 ±1.83 b	10.8 ± 4.11 c	ns	14.97 ± 4.90 c	30.3	6.3
E	WW	0.60 ± 0.35 a	0.70 ± 0.23 a	ns	0.95 ± 0.29 a	1.55	0.55
	MS	0.25 ± 0.06 b	0.38 ± 0.15 b	ns	0.38 ± 0.11 b	0.75	0.2
	SS	0.25 ± 0.06 b	0.18 ± 0.05 c	ns	0.24 ± 0.07 c	0.4	0.08
Ci	WW	116 ± 34.04 a	167.5 ± 127.11 a	*	196.08 ± 49.17 a	278.8	102
	MS	81.8 ± 74.09 b	179.8 ± 9.15 b	*	130.71 ± 36.09 b	204	74
	SS	81.8 ± 94.55 b	133.8 ± 23 c	*	138.2 ± 47.05 b	255.5	69.3
RWC	WW	0.69 ± 0.07 a	0.70 ± 0.04 a	ns	0.70 ± 0.03 a	0.76	0.55
	MS	0.65 ± 0.09 b	0.63 ± 0.04 b	ns	0.62 ± 0.03 b	0.7	0.56
	SS	0.45 ± 0.21 c	0.51 ± 0.07 c	*	0.48 ± 0.05 c	0.56	0.26
GY	WW	1.979 ± 0.43 a	2.477 ± 0.94 a	*	2.21 ± 0.28 a	3.18	1.69
	MS	1.374 ± 0.29 b	1.713 ± 0.39 b	ns	1.67 ± 0.30 b	2.19	0.97
	SS	0.778 ± 0.43 c	1.349 ± 0.16 c	*	0.98 ± 0.22 c	1.35	0.39

‡ Treatment means followed by letter a, b and c in the same column indicate significant differences according to the Least ignificant Difference (LSD) test probability level 0.05.

[e] Significant differences between two parents Arta and Keel

ns, not significant; * $P < 0.05$

Mean values for RILs and their parents were significant differences for all discussed traits under three water stress conditions except Ci for mean of RILs and Ci, transpiration (E), gs of Arta; there were no significant differences between mild .

and severe stress conditions .In general, the range of variation was higher for the well-watered RILs compared to the stressed one. The values obtained for all traits are higher for well-watered RILs compared to mild and severe stressed ones. As an example, the mean of Pn was 5.60 in well-watered RILs when was RWC 70%, while the Pn, RWC in mild stress and severe stress were 2.93, 62% and 1.84, 48% respectively (Table 2). By increasing the severity and duration of drought stress after 7 days from drought, RWC of RILs decreased around 11% under mild stress and 49% under sever stress conditions comparing to well-watered treatment, while in the two parents Arta and Keel they decreased around 7%, 10% under mild stress and 35%, 27% under sever stress conditions respectively.

Decreasing RWC caused a decrease of gs and Pn in parallel, approximately, by the resulted decreasing E and Ci, although at small values of RWC, gs reacheed a minimum but Pn may continue to decease. However, when stomata closed, to protected the plant against water loss they simultaneously restricted carbon assimilation by the plant (Fig. 2).

The differences in net photosynthetic rate values influenced on grain yield. Water stress treatments during grain filling significantly decreased GY and Pn (Fig. 2).

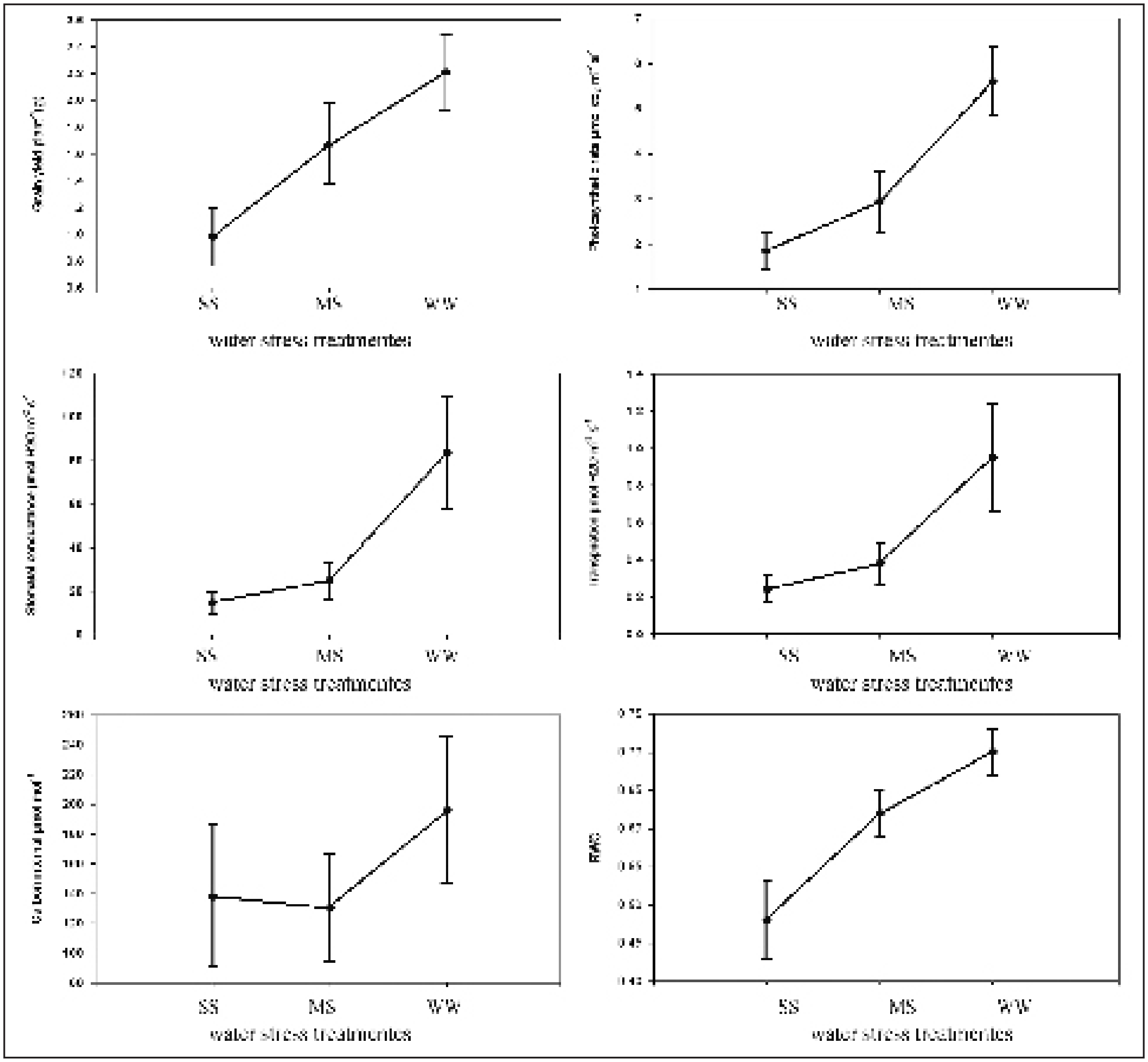

Fig. 2. means of grain yield and photosynthesis activity for 40 RILs and two parents in barley exposed to three water treatment. Bars indicate the standard error of the mean.

The percentage of decreasing grain yield of RILs was 24% under mild stress and 56% under sever stress conditions comparing to well-watered condition, while the parents Arta and Keel decreased by 31% for both of them under mild stress and 61%, 46% respectively under sever stress condition for (Fig 3).

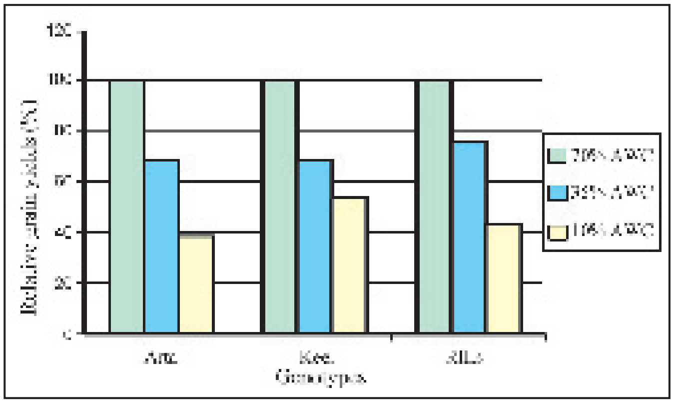

Fig. 3. Relative grain yields of two parents (ArtaKeel) and 40 RILs under three water stress treatments.

Relationship among photosynthesis activity and grain yield:

Photosynthesis was found to be positively correlated to grain yield under water stress, however the greatest value of correlation between photosynthesis and grain yield (r = 0.62) was found in severe stress condition.

In the present study the correlations among Ci, E, gs, GY, Pn and RWC were positively and highly significant (*P* > 0.01), except the relationship between RWC and Ci was found significant (*P* > 0.05) under mild stress conditions and not significant under severe stress conditions (Table 3).

Table 3. phenotypic correlation coefficients between photosynthesis activity and grain yield for 40 RILs and two parents under three water conditions

Treatments	Traits	Ci	E	GS	GY	PN
70%	Ci					
	E	0.6165 **				
	GS	0.6129 **	0.9624 **			
	GY	0.3038 **	0.5181 **	0.4725 **		
	PN	0.2700 **	0.8409 **	0.8090 **	0.5719 **	
	RWC	0.2617 **	0.4766 **	0.4334 **	0.4367 **	0.4683 **
35%	Ci					
	E	0.7585 **				
	GS	0.7386 **	0.8277 **			
	GY	0.2684 **	0.2279 **	0.4164 **		
	PN	0.5677 **	0.8083 **	0.8022 **	0.3453 **	
	RWC	0.2010 *	0.2891 **	0.3260 **	0.2134 **	0.3960 **
10%	Ci					
	E	0.5464 **				
	GS	0.5101 **	0.9015 **			
	GY	0.2828 **	0.6264 **	0.6027 **		
	PN	0.2517 **	0.8367 **	0.8324 **	0.6211 **	
	RWC	0.1291 ns	0.5707 **	0.5697 **	0.5309 **	0.6491 **

ns, not significant; * $P < 0.05$; ** $P < 0.01$

Discussion

Photosynthesis is an important factor controlling growth and yield production in plants. Photosynthetic rate, transpiration rate, stomatal conductance and intercellular CO_2 concentration got reduced under lower water regime conditions (Fig. 2). The present findings are in agreement with the results reported by Bakhtenko, (2001). Plant growth depend on photosynthesis is sensitive to both biotic and a biotic streses. Water stress influences the sensitivity of the photosynthetic apparatus to photoinhibition (Ferrar and Osmond, 1986; Osmond, 1994), probably because of the induced stomatal closure and consequent reduction of CO_2 uptake (Ludlow and Powles, 1988). The differences in all studying traits among genotypes, treatments and their interaction were significant, but it is not the case in relative water content and grain yield (Ashraf et al., 2006) (Table 1).

The variation among five highest genotypes in grain yield was high under well-water condition and low under mild and severe stress conditions (Fig 1). Under well-water condition tolerant genotypes with high grain yield have high photosynthesis activity and relative water content. Ashraf et al., (1994) found that wheat genotypes with higher RWC were more drought tolerant.

The highest values of photosynthesis activity under mild and severe stress conditions for tolerant genotype was found with less value of grain yield comparing to highest grain yield genotypes, because these genotypes are more flexible for maintaining a higher PSII activity at similar RWC during dehydration. There is unanimous agreement for the facts that yield of the plant in the drying soils get reduced even in the tolerant genotype (Ashraf, 1998b; Iqbal et al., 2005).

In this study, there were significant differences in mean of RILs and two parents for all traits under three water stresses except mildly stressed plants that were not significantly different in the total of Ci for RILs and Ci, E, gs for Arta to severely stressed plants, this attributed to the role of gs in restricting the supply of CO_2 to metabolism, and impairment metabolic. The variations were bigger in well-watered than mild and severe stress treatments (Table 2). However the importance of stomatal closure in regulating photosynthesis under water stress was recognized by the numerous findings of parallel reduction of Pn and E as drought develops (Kozlowski, 1982). Metabolic limitation is correlated with loss of ATP content, which starts to decrease with mild stress (Flexas and Medrano, 2002). In additional, when drought is moderate stomatal responses can be more closely linked to soil drying rather than to leaf water status (Zhang and Davies, 1989). Therefore, analyses of photosynthetic parameters are considered as an important approach to evaluate the health or integrity of the internal apparatus during photosynthesis process within a leaf (Abbate et al., 2004).

The reduction in RWC under mild and severe stress conditions affect the photosynthesis and other metabolic activity (Ashraf et al., 1994). Photosynthetic metabolism is more sensitive to changing RWC and cellular conditions in some types of plants than the others (Lawlor, 2002).

(Urchei and Rodrigues, 1994) showed that grain yield is reduced significantly under water stress. The percentages of decreasing grain yield of RILs were less than those of the two parents under mild stress, while they were lower than Arta and higher than Keel under sever stress conditions comparing to well-watered condition (Fig 3). As consequence, 40 RILs are more suitabile for high grain production under mild stress conditions than other treatments. Arta is affected by drought more than Keel, where the later can tolerate drought for long time (Grando et al., 2001). Many reports indicated that a short duration water deficit cycle reduce the plant growth and yield (Ashraf et al., 1992; Azhar et al., 2005). Reduction in growth and yield may be due to disturb in nutrient uptake efficiency and photosynthetic translocation within plant (Iqbal et al., 1999). Photosynthesis was found to be positively correlated to grain yield under water stress, which's corresponding to the results as with indicated by (Xu and Shen, 1994). According to Ashraf et al., (2006) the correlations among photosynthetic activity, grain yield and relative water content were significant and positive, except the relationship between RWC and Ci was found significant not significant under severe stress conditions (Table 3).

Conclusion

Drought stress during the grain filling period reduced photosynthesis and grain yield. There were significant differences for all parameters that were examined in this experiment between genotypes, treatments and considering the relationship between genotype and treatment interaction, except for grain yield and relative water content when genotype interacted to treatment. The variations among five highest grain yield genotypes under well-water treatment were higher than mild and severe stress treatments. Also the values of photosynthesis and grain yield under well-water treatment were higher than mild severe stress treatments as a consequence of increased relative water content, stomatal conductance, transpiration and intercellular CO_2 concentration for plants under normal condition. Photosynthesis was related to grain yield under water stress conditions. In all studying traits there were significant differences under three water stresses except intercellular CO_2 concentration for mean of RILs and intercellular CO_2 concentration, transpiration, stomatal conductance of Arta; that were not significantly different between mild and severe stress conditions. The performance of photosynthesis in relation to grain yield decreased by limiting of supplied water amount for plants. The percentages of decreasing grain yield of RILs were less than the two parents under mild stress, but lower than Arta and higher than the tolerant genotype Keel under sever stress conditions comparing to well-watered condition. In present experiment the correlation between photosynthesis and grain yield was significant and the higher value of correlation were found in severe stress treatment. Photosynthetic activity in relation to grain yield decreased by limiting the amounts of water to plants.

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