Effect of Drought on Different Physiological Characters and Yield Component in Different Varieties of Syrian Durum Wheat

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Abstract

Tolerant and susceptible durum wheat varieties were grown in the 1st and 2nd settlement zone under rainfed conditions inDaraa province-Syria, In order to expose plants to different level of water regime, since the two zones differ in total amount of rainfall during the growing season. Plants were suffered from terminal drought stress in both zones, however, the drought was more sever in the 2nd settlement zone. All measured parameters: chlorophyll content, MSI, RWC, Fv/Fm decreased significantly in the 2nd compared to the 1st zone at all growth stages, however more reduction was recorded in drought susceptible varieties. Yield all yield components also affected negatively and drought tolerant varieties have maintained good performance in the 2nd zone. Our results proved that Chlorophyll content, MSI, RWC and Fv/Fm are good physiological indices of drought tolerance and can be used for improvement drought tolerance in wheat.

Keywords: Wheat, Drought, Chlorophyll content, Membrane stability index, Relative water content, Chlorophyll fluorescence

1. Introduction

Wheat is the most important cereal crop, it's stable diet for more than one third of the world population and contributes more calories and protein to the world diet than any other cereal crop (Abd-El-Haleem*et al*., 2009). Drought is the most severe stress and the main cause of significant losses in growth and productivity of crop plants (Ludlow and Muchow, 1990).Drought induces significant alterations in plant physiology and biochemistry. Some plants have a set of physiological adaptations that allow them to tolerate water stress conditions. The degree of adaptations to the decrease of water potential caused by drought may vary considerably among species (Save *et al*., 1995)**.** Plant response to water stress include morphological and biochemical changes and later as water stress become more sever to functional damage and loss of plant parts (Sangtarash, 2010). Researchers linked various physiological responses of plant to drought with their tolerance mechanisms, such as: pigment content and stability and high relative water content (Clarke and McCaig, 1982).Drought tolerant wheat species can be characterized by growth response, changes in water relations of tissues exposed to low water potential, stomatal conductance, ion accumulation and changes in the fluorescence induction parameters under water stress (Blum, 1988).In recent years, the screening of plant fluorescence signatures is developing as a specific tool which could be applied to detect the functioning and health status of plants (Lichtenthaler*et al.*, 1999; Samson *et al*., 2000). The ability of plants to maintain membrane integrity under drought is what determines tolerance towards drought stress (Vieira Da Silva *et al*., 1974).Membrane stability is a widely used criterion to assess crop drought tolerance (Premachandra and Shimada, 1988). Understanding of physiological mechanisms that enable plants to adapt to water deficit and maintain growth and productivity during stress period could help in screening and selection of tolerant genotypes and using these traits in breeding programs (Zaharieva*et al*., 2001). The main objective of this study was to determine the effect of water stress- imposed by planting different durum wheat varieties in different settlement zones (differ in total annual rainfall)- on various physiological parameters and yield components in and to find out the best and most simple tool which could be used for screening wheat varieties for drought tolerance.

2. Materials and Methods

2.1 Plant materials

Seven drought tolerant and susceptible durum wheat varieties viz., Sham3, Sham5, Hourani and Doma1 (drought tolerant), ACSAD65, Bohouth7 and bohouth11 (moderately susceptible to Drought) were used in this study. Seeds were obtained from Crop Research Directorate, GCSAR, and sown under rainfed conditions in the field on 20th Nov.2009 in the first settlement zone (Izra research station, annual rainfall 291mm) and second settlement zone (Jelean research station annual rainfall 400mm). Crops were sown at an adjusted rate of 300 viable seeds/m^2 in three replications. Normal agronomic practices were performed and relevant metrological parameters were obtained from the observatory at each research station and daily minimum and maximum temperature and rainfall were recorded. Chlorophyll content (chl), membrane stability index (MSI), relative water content (RWC), chlorophyll fluorescence Fv/Fm were estimated on the first fully expanded leaf (third from top) at vegetative stage and flag leaf at anthesis and grain filling stage.

2.2 Chlorophyll content estimation

Chlorophyll estimation was done by incubating 50 mg of the leaf material in 10 ml of dimethyl sulphoxide (Hiscox and Israelstam, 1979) for 4 hours at 65 ^{0}C. The absorbance of the clear solvent was recorded at 663 and 645 nm (Arnon, 1949).

2.3 Membrane stability index

Membrane stability index was determined by recording the electrical conductivity of leaf leachates in double distilled water at 40 and 100^{o}C (Deshmukh*et al.,* 1991). Leaf samples (0.1 g) were cut into discs of uniform size and taken in test tubes containing 10 ml of double distilled water in two sets. One set was kept at 40^{o}C for 30 minutes and another set at 100^{o}C in boiling water bath for 15 minutes and their respective electric conductivities C_1 and C_2 were measured by Conductivity meter

Membrane stability index = $[1- (C_1/C_2)] \times 100$

2.4 Relative Water Content

Relative water content was determined by the method described by Barrs and Weatherley, (1962). 100 mg leaf material was taken and kept in double distilled water in a petridish for two hours to make the leaf tissue turgid. The turgid weights of the leaf materials were taken after carefully soaking the tissues between the two filter papers. Subsequently this leaf material was kept in a butter paper bag and dried in oven at 65 ^{0}C for 24 hours and their dry weights were recorded. The RWC was calculated by using the formula.

$$\text{RWC (\%)} = \frac{\text{(Fresh weight – Dry weight)}}{\text{(Turgid weight – Dry weight)}} \times 100$$

2.5 Chlorophyll fluorescence

For the estimation the polyphasic rise of fluorescence transients of intact leaves of non-stressed and water stressed plants were measured by a Plant Efficiency Analyzer (PEA, Handsatech Instruments Ltd., King's Lynn, UK) according to Strasser*et al*., (1995). For the measurement of the chlorophyll fluorescence all the samples were covered with clips, kept in dark for 30 minutes before fluorescence measurements. The transients were induced by red light of 3000 μmol m^{-2} s^{-1} provided by an array of six light emitting diodes (peak 650nm), which focused on the sample surface to give homogenous illumination over exposed area of sample surface and maximal quantum yield of PS II (Fv/Fm) measured, readings were taken from 9 plants.

On mid Jun plants harvested from m^2 and used for recording number of tillers, seed number per ear, 1000 grain weight, total biomass and grain yield. Data analyzed statistically and analysis of variance (ANOVA) for split plot design was work out using CoStat6.311 Cohort software.

3. Results and Discussion

Reduced plant productivity due to drought is a major concern for wheat grown in arid and semiarid areas. In these areas, most wheat is grown under rainfed conditions where drought may occur at any time. About 37 % of the world wheat is grown in semiarid areas where moisture is the most serious production constraint (Osmanzai, *et al*., 1985).

Data on mean maximum and minimum temperatures recorded during all growth stages showed marginal or no differences in both zones (Table 1). Total rainfall was well distributed uptoanthesis stage, indicated that enough water was available for fast and rapid emergence of seeds (10-13 days after sowing). The total amount of the rainfall in the 2nd zones was 28% less than that in the 1st zone i.e., 299mm and 418mm respectively (Table 2). Terminal drought stress experienced by the varieties in both zones, however the drought was more sever in case of 2nd settlement zone and enough water was available in the soil for the varieties in the 1st one for good tillering and spike emergence.

3.1 Chlorophyll content

Highchlorophyll content is a desirable characteristic because it indicates a low degree of photoinhibition of photosynthetic apparatus, therefore reducing carbohydrate losses for grain growth(Farquhar et al., 1989).According to Ityrbc*et al.,* (1998)water stress condition caused reduction in chlorophyll content. Our findings indicate that chlorophyll content differ significantly among varieties and between the two zones, however, highest amount of total chlorophyll was recorded at anthesis stage, and more chlorophyll content was recorded in the 1st compared to 2nd zone, these findings are in agreement with Araus et al., (1998) who reported that drought treatment caused a 20% reduction in leaf chlorophyll content. The greatest reduction in total chlorophyll in the 2nd compared to 1st zone was observed in Bohouth11 and Bohouth7 at anthesis and grain filling stage i.e. 27, 36% respectively (Table 3). Highest chlorophyll a/b ratio was recorded at vegetative stage and lowest value at anthesis stage in both zones, however this ratio increased in the 2nd zone (Table 3).

3.2 Membrane stability index

Water stress caused water loss from plant tissues which seriously impair both membrane structure and function (Cave, 1981; Buchanan *et al*., 2000). Cell membrane is one of the first targets of plant stresses (Levitt, 1972) and the ability of plants to maintain membrane integrity under drought is what determines tolerance towards drought (Vieira da Silva *et al.,* 1974). Significant reductions in MSI in the 2nd zone in all varieties were recorded. Bohouth7 and 11 showed highest MSI value in the 1st zone at all growth stages, while drought tolerant varieties Douma1 and Sham5 showed highest MSI in the 2nd zone. ACSAD65, Bohouth7 and 11 showed maximum reduction in MSI at anthesis stage i.e., 41%, 35% and 36 % respectively and grain filling stage i.e., 58%, 53% and 47% respectively (Table 4). The results from electrolyte leakage measurements showed that membrane integrity was conserved for tolerant compared to susceptible varieties, this is in agreement with the conclusion of Martin *et al*., (1987) and Vasquez Tello*et al*., (1990) that electrolyte leakage was correlated with drought tolerance. The leakage was due to damage to cell membranes which become more permeable (Senaratna and Kersie, 1983). This shows the importance of this test in discriminating among tolerant and susceptible varieties.

3.3 Relative water content

Leaf RWC is proposed as a more important indicator of water status than other water potential parameters under drought stress conditions. During plant development drought stress significantly reduced RWC values (Siddique and Islam, 2000). Significant differences in RWC was observed between variety at various stages and our results showed reduction in RWC in 2nd zone at all stages of growth and more reduction were recorded in drought susceptible varieties (Table 4). This deviation in RWC may be attributed to differences in the ability of the varieties to absorb more water from the soil and or the ability to control water loss through the stomata's. It may also be due to differences in the ability of the tested varieties to accumulate and adjust osmotically to maintain tissue turgor and hence physiological activities. Highest RWC was recorded at vegetative stage and decreased gradually and the highest RWC value observed in drought tolerant varieties Douma1 and Sham5 in the 2nd zone at various growth stages (Table 4).

3.4 Chlorophyll fluorescence

It is known that all of the environmental constraints affected chlorophyll fluorescence parameters(Havaux, 1993; Schreiberg*et al*., 1995).Under this stress usually a water deficit in plant tissues develops, thus leading to a significant inhibition of photosynthesis. The ability to maintain the functionality of the photosynthetic machinery under water stress, therefore, is of major importance in drought tolerance(Mohammadi*et al*., 2009).The maximum photochemical efficiency of PSII was calculated by the ratio Fv/Fm, however, drought stress imposed by growing plants in the 2nd zone affected this ratio (Table 4) and the drastic changes in chlorophyll fluorescence measurement most probably indicates the physical dissociation of PSII reaction centers from light harvesting complex, a substantial accumulation of inactivated PSII centers as well as photoinhibition. Ma *et al*., (1995) reported that higher photochemical efficiency played important role in drought tolerance. This phenomenon is a criterion for thylacoide membrane integrity and electron transfer efficiency from photosystemII to photosystemI (Mamnoue, 2006). Significant reduction in chlorophyll fluorescence Fv/Fm value was observed in all varieties grown in the 2nd compared to 1st zone, while there was minimal reduction in this ratio in drought tolerant varieties and highest Fv/Fm value were recorded in Douma1 and Sham5 at anthesis and grain filling stage in the 2nd zone (Table 4). According to Mamnoue (2006) The photochemical efficiency of photosystem II is determined by the Fv/Fm ratio which is decreased significantly during drought stress. Chlorophyll fluorescence analysis may provide a sensitive indicator of stress conditions in plants. It can also be used to estimate the activity of thermal energy dissipation in photosystem II, which protects photosynthesis from the adverse effects of light and heat stress. For this reason, chlorophyll fluorescence has often been proposed as a useful tool for screening durum and bread wheat for drought (Flagella *et al.*, 1995).

3.5 Yield components

The stress factors especially drought negatively affects plant growth and development and causes a sharp decrease of plants productivity (Pan *et al.,* 2002). Blum and Pnuel (1990) reported that yield and yield components of twelve spring wheat varieties were significantly decreased when they received minimum annual precipitation**.** The effect of drought stress on wheat grain yield may be analyzed in terms of yield components, some of which can assume more importance than others, depending upon the stress intensity and growth stage at which it develops (Giunta*et al* 1993). Yield and yield component decreased significantly as variety experienced drought stress in the 2nd zone. Seed number/ear decreased upto 64% as in ACSAD65. 1000 grain weight decreased also but the influence of growing zone has less effect on this character than seed number/ear. Lowest reduction in 1000 grain weight 5% was reported in Sham5 (Table 5). Present investigation showed that number of grains per main spike, 1000-grain weight, number of tillers per plant, biological yield per plant and grain yield per plant were decreased under stressed environment which is also reported by Chandler and Singh (2008). Number of tillers/m^2 also affected by the settlement zone and significant reduction in all varieties was observed in the 2nd zone and highest tiller number/m^2 recorded in Bohouth11 and ACSAD65 in the 1st zone and in Douma1 and Sham5 in the 2nd zone. Grain yield in all varieties also significantly reduced in the 2nd zone. This reduction in productivity is brought about by a delay or prevention of crop establishment, weakening or destruction of established crops, predisposition of crops to insects and diseases, alteration of physiological and biochemical metabolism in plants (Larson and Eastin, 1971). However, lowest reduction in grain yield recorded in Sham5 and Hourani i.e., 45% and 52% respectively. Significant differences in total biomass between all varieties were observed and great reduction was observed in the 2nd zone. Lowest reduction in biomass value recorded in Sham5 and Douma1 i.e., 70% and 71% respectively. The worldwide losses in crop yield from water stress exceed the losses from all other classes combined (Kramer, 1980). Even a temporary drought can cause a substantial loss in crop yields and sometimes can amount to many million dollars (Moseley, 1983).

4. Conclusions

Growth and photosynthesis are two of the most important processes abolished, partially or completely, by water stress (Kramer and Boyer, 1995), and both of them are major cause of decreased crop yield. The best option for crop production, yield improvement, and yield stability under soil moisture deficient conditions is to develop drought tolerant crop varieties. A physiological approach would be the most attractive way to develop new varieties rapidly (Turner and Nicolas, 1987). Looking overall results, it is clear that these parameters could explain some of the mechanisms which indicate tolerance to drought; however, their relevance in describing the varietals variability is significant.

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Table 1. Mean maximum and minimum temperature 0C in the 1st and 2nd settlement zones at different growth stages

	Max. Temperature °C		Min. Temperature °C		Mean Temperature °C	
Growth stage	1st	2nd	1st	2nd	1st	2nd
Vegetative	16	16	6	6	11	11
Anthesis	26	26	10	9	16.5	17.5
Grain filling	31	30	14	13	23	21.5

Table 2. total amount of rainfall (mm) every month during the growing season in the1st and 2nd settlement zones

	Rainfall mm	
Month	1st	2nd
Sep.2009	25	12.6
Oct.2009	8.8	12.6
Nov.2009	75.8	80.1
Dec.2009	104.2	65.1
Jan. 2010	97.5	73.7
Feb.2010	72.7	54.9
Mar.2010	34	0.3
Apr.2010	0	0
May.2010	0	0
Jun.2010	0	0
Total	418	299.3

Table 3. Effect of drought stress imposed by planting wheat varieties in different settlement zones on total chlorophyll (mg g^{-1} fw) and chlorophyll a/b ratio of tolerant and susceptible wheat varieties at vegetative anthesis and grain filling stage

	Vegetative stage				Anthesis stage				Grain filling stage			
	Total chl (mg g^{-1} fw)		Chl a/b		Total chl (mg g^{-1} fw)		Chl a/b		Total chl (mg g^{-1} fw		Chl a/b	
Variety	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Buhouth11	1.67	1.56	1.94	4.7	2.49	1.83	1.49	1.49	2.04	1.46	1.47	1.98
Buhouth7	1.96	1.38	2.59	4.21	2.18	1.8	1.52	1.52	2.15	1.38	1.86	1.84
ACSAD65	1.88	1.72	1.34	3.05	2.30	1.73	1.41	1.41	1.77	1.39	1.83	1.95
Douma1	1.70	1.13	2.65	3.37	2.18	1.98	1.44	1.44	2.01	1.73	1.87	1.95
Sham3	1.76	1.16	1.97	5.43	2.15	1.75	1.61	1.61	1.71	1.37	1.95	1.87
Sham5	1.60	1.05	2.46	4.79	2.12	1.86	1.63	1.63	1.67	1.53	1.94	2.01
Hourani	1.65	1.44	1.72	3.32	1.99	1.70	1.47	1.47	1.67	1.35	1.79	1.76
LSD at 5 %		0.07		0.51		0.11		0.09		0.14		0.16

Table 4. Effect of drought stress imposed by planting wheat varieties in different settlement zones on membrane stability index (%), relative water content (%) and maximum quantum yield of PSII as measured Fv/Fm of tolerant and susceptible wheat varieties at vegetative anthesis and grain filling stage

	MSI						RWC						Fv/Fm					
	Vegetative		anthesis		Grain filling		Vegetative		anthesis		Grain filling		Vegetative		anthesis		Grain filling	
Variety	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Buhouth11	269	123	211	135	255	133	85	62.8	68.6	59.2	61.8	53.2	0.67	0.57	0.87	0.66	0.7	0.49
Buhouth7	268	103	214	138	275	127	78.7	60.9	67.5	58.6	62.6	52.7	0.75	0.56	0.81	0.61	0.67	0.48
ACSAD65	231	100	199	118	238	100	87.6	58.7	65.7	56.5	58.7	49.2	0.73	0.64	0.79	0.52	0.54	0.45
Douma1	235	111	181	169	269	158	76.2	62.8	63.8	59.3	62.6	56.9	0.68	0.49	0.77	0.72	0.75	0.58
Sham3	218	109	183	123	211	110	76.3	60.3	65.5	57.4	58.7	51.2	0.69	0.54	0.73	0.58	0.66	0.46
Sham5	222	155	178	141	205	132	73.5	64.1	62.1	59.7	58.1	53.4	0.66	0.48	0.74	0.71	0.74	0.57
Hourani	182	108	175	132	210	168	64.3	58.5	61.4	56	58.4	51.8	0.65	0.56	0.72	0.57	0.54	0.45
LSD at 5 %		18		15		17		1.6		1.6		1.5		0.02		0.03		0.05

Table 5. Effect of drought stress imposed by planting wheat varieties in different settlement zones seed number per ear, tiller number/m^2, 1000 grain weight (g), grain yield m^2 and total biomass m^2 (g) of tolerant and susceptible wheat varieties

	seed no/ear		tiller no./m^2		1000 grain wt (g)		grain yield (g/ m^2)		total biomass (g/ m^2)	
Variety	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Buhouth11	50	23	371	127	42	38	828	334	4991	1058
Buhouth7	55	28	332	115	40	36	838	314	3164	756
ACSAD65	52	19	371	113	42	35	799	294	4795	1115
Douma1	48	20	369	147	45	40	825	323	3451	1006
Sham3	53	22	352	117	39	36	791	303	2769	752
Sham5	46	24	349	135	41	39	756	415	990	990
Hourani	26	18	307	121	42	38	470	227	730	730
LSD at 5 %		1.2		28		1.15		18		47.3