Structural changes of the photosynthetic apparatus, morphological and cultivation responses in different wheat genotypes under drought stress condition

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ABSTRACT

To understand genotypic responses of wheat genotypes to drought stress, this project studied 64 different wheat genotypes under both irrigated and drought stress conditions, using simple lattice experimental design with two replication in research area of agricultural research station of Ardabil and research area and laboratory of genetic resources institute of Azerbaijan during two seasons 2006 to 2007.

Drought reduced wheat grain yield by 61.9% and stress intensity (SI) for wheat grain yield was 0.62. The genotypes studied were classified into three groups; tolerant, moderate tolerance and susceptible by genotypic responses of wheat genotypes under both irrigated and drought stress conditions and on the basis of values of SSI and STI indices. Results of germination capability of wheat genotypes evaluated under 16 atmosphere drought stress of PEG and control (water) treatments showed the same results as field experiments on the basis of the classifications of wheat genotypes for three classes; tolerant, moderate tolerance and susceptible. Results of changes of amounts of chlorophyll also showed significantly differences ($p<0.1$) between genotypes examined basis of amount of chl a, chl b, chl a+b and chl a/b under 20 atmosphere drought stress of PEG and control (water) treatments. Drought on average reduced amount of chl a, chl b and chl a+b, by 2.5, 6.6 and 2.5% respectively. However the amounts of reduction in chl a, chl b and chl a+b were different between genotypes studied, so that the amounts of chl a, chl b and chl a+b were increased in drought tolerant wheat genotypes. According to the depression degrees of chl a+b the classifications of wheat genotypes were also the same as the classifications of field experiments and germination capability under 16 atmosphere drought stress of PEG and control (water) treatments. The amount of chlorophyll was positively correlated ($r = 0.36^{**}$) with grain yield and with leaf area index ($r = 0.15$ns) of wheat genotypes. Drought reduced genotypic variation and heritability of wheat genotypes in most of examined characters. However heritability of grain yield and leaf area index was increased in drought stress condition. Finally according the studied characters the genotypes No. 6, 30, 37, 42, 43 and 44 were found to be tolerant genotypes.

INTRODUCTION

Under Iranian climatic conditions drought stress is a permanent problem of the wheat crop, often causing yield losses. Therefore improvement of cultivars for drought resistance is one of the main aims of wheat breeding programs. Photosynthesis, which is the most significant process influencing crop production, is also inhibited by drought stress (Bradford and Hsiao 1982). Little is known, however, about other structural changes in thylakoids under water stress conditions. Water deficiency causing the closure of stomata leads to a lowered internal concentration of CO_2, which in turn inhibits the Calvin-cycle, and the consequent shortage of reducible coenzymes gives photoinhibitory conditions (Horton et al. 1996). Structural parameters of chlorophyll were compared in different *Triticum aestivum* L. genotypes to characterize the water deficiency tolerance of their photosynthetic apparatus, and evaluate the morphological and cultivation responses of wheat genotypes.

MATERIALS AND METHODS

The 64 diverse wheat genotypes were studied in field experiments under both drought stress and normal conditions from 2006 to 2007 growing year. Each of experiment was laid out in a lattice design with two replications. Field experiments were planted on 15 November 2006 in a clay loam type of soil at the research area of Genetic Resources Institute of Azerbaijan National Academy of Science-Bako Republic of Azerbaijan and Agricultural and Natural Resources Research Station of Ardabil-Islamic Republic of Iran. Plants in normal condition were irrigated until they reached physiological maturity. Plants in normal condition received 672.4 mm of water (406 mm irrigation + 266.4 mm rain) and those in drought stress condition received 266.4 mm rainfall and plants in drought stress condition was not irrigated. In the growing season, the total amount of rainfall was 266.4 mm, close to the long-term average of the Ardabil region (long term average was 280 mm). However, of 266.4 mm of rainfall, 78.7 % was received before booting stage, 19.6 % received between booting and heading stage, and 1.7 % fell between heading and early grain-filling period. The absolute maximum and mean temperature in grain filling period were 27.6˚C and 8.0˚C, respectively. Each plot consisted of 2 rows, 2 m in length. Inter row spacing was 30 cm and interplant spacing was 3-5 cm. The land was fallowed the previous year and 100 kg ha^{-1} urea plus 150 ha^{-1} ammonium phosphate was incorporated into the soil before planting and 100 kg ha^{-1} urea was incorporated into the experiments at the tillering stage. Germination capability of wheat genotypes were evaluated under 16 atmosphere drought stress of PEG and control (water) treatments. Structural changes of photosythnetic apparatus of wheat genotypes were studied, by experimentally taking plant samples. Each plant sample contained 0.5 cm diameter segments of 15 ultimate leaves of wheat when the flag leaf was not completely extended. Chlorophyll contents of leaves were determined according to Porra et al. (1989). Chlorophyll a, b, a+b and a/b ratio were measured by Spectra photometer under E665 and E649 nm, respectively. Data were recorded from traits during growing season and plant development. Analysis of variance (ANOVA) was performed for each character measured or calculated for each year (SAS, 1988). The combined ANOVA was also performed across years.

RESULTS AND DISCUSSION

All characters studied of the wheat genotypes had different responses under both irrigated and drought stress conditions. There were significant differences ($p<0.01$) between the studied wheat genotypes in all characters examined. Drought reduced all the characters studied, however, the amounts of reductions were different in genotypes examined. For example highly drought tolerant wheat genotypes showed higher amount of leaf area index, amount of water per dry weight of leaf and amount of water per wet weight of leaf than other genotypes studied. Drought reduced wheat grain yield, by 61.9% and stress intensity (SI) for wheat grain yield was 0.62. Genotypes studied of wheat were classified in to three groups; tolerant, moderate tolerance and susceptible by genotypic responses of wheat genotypes under both irrigated and drought stress conditions and on the basis of values of stress susceptibility index (SSI) and stress tolerance index (STI) indices. Results of germination capability of wheat genotypes evaluated under 16 atmosphere drought stress of PEG and control (water) treatments showed the same results as field experiments on the basics of the classifications of wheat genotypes for three classes; tolerant, moderate tolerance and susceptible. Chl content and Chl a/b ratio of leaves are widely used to characterize the general state of the photosynthetic apparatus. Although Chl content per leaf area changed during drought stress probably due to differences in level of drought tolerance of wheat genotypes, but the changes related to the control were moderate. In the case of the Sardary land race of Iran and land race of Azerbaijan, 20 atmosphere drought stress of PEG treatment increased the Chl content per leaf area, by contrast the susceptible wheat genotypes, that was decreased Chl content per leaf area in susceptible wheat genotypes. This may be explained by the restricted ability of the cells in susceptible wheat genotypes to elongate when PEG inhibited water uptake, which was increased water uptake when the osmotic stress treatment was used in tolerant genotypes. The change in Chl a/b ratio provides further information about modification processes taking place in the photosynthetic apparatus under osmotic stress. There are notable differences in the variations of the Chl a/b ratio under PEG treatment in the examined genotypes.

Changes of amounts of chlorophyll also showed significantly differences ($p<0.1$) between genotypes examined based on the amount of chl a, chl b, chl a+b and chl a/b under 20 atmosphere drought stress of PEG and control (water) treatments. Drought on average reduced the amount of chl a, chl b and chl a+b, by 2.5, 6.6 and 2.5% respectively. The results of this section were in close agreement with the results of Laszelo et al. (2002). However the amounts of reduction in chl a, chl b and chl a+b were different between genotypes studied, so that the amounts of chl a, chl b and chl a+b were increased in drought tolerant wheat genotypes. According to the depression degrees of chl a+b the classifications of wheat genotypes were also same as the classifications of field experiments and germination capability under 16 atmosphere drought stress of PEG and control (water) treatments. The amount of chlorophyll was positively correlated ($r = 0.36^{**}$) with grain yield and with leaf area index ($r = 0.15$ns) of wheat genotypes. Drought reduced genotypic variation and heritability of wheat genotypes in most of examined characters. However heritability of grain yield and leaf area index was increased in drought stress condition. Finally according the studied characters the genotypes No. 6, 30, 37, 42, 43 and 44 were found to be tolerant genotypes.

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Table 1- Germination capability of wheat seeds under control (water), 16 atm. Drought stress of PEG and seed depression degrees (SDD), chlorophyll content per unit leaf area under control (water) and 20 atm. Drought stress of PEG and chlorophyll depression degrees (CDD), leaf area index (LAI) under irrigated and drought stress conditions.

Drought response	Line No	Germination capability			Chlorophyll content per leaf unit area						CDD %	LAI %	
		Control (Water)	PEG (16 atm)	SDD %	Control (water)			PEG 20 atm					
					Chl. a	Chl b	Chl a+b	Chl. a	Chl b	Chl a+b		Droughted	Irrigated
Tolerant	9	100	81.0	19.0	5.1 ac	0.42af	5.5 ad	5.2 a	0.45 a	5.7 a	+3.2	14.1 bm	21.3do
	30	100	96 ad	4.0	3.8 jo	0.30 fq	4.0 ls	4.6 af	0.41 ad	5.0 af	+50	12.4 jm	15.4o
	44	100	90.7 et	7.5	3.9 hn	0.40 ai	4.2 jq	4.5 ah	0.28 dl	4.9 bi	+22	14.0 bm	19.8eo
	13	100	77.0 qr	23.0	2.6 vw	0.16 r	2.8 v	2.8 pr	0.16 lm	3.0 d	+25	16.84 ak	18.2be
	42	100	93.0 dg	7.0	3.1 sw	0.22 or	3.3 tv	3.5 lq	0.25 fl	3.8 lo	+13	12.37 jm	15.6o
	23	100	84.7 kn	15.4	4.3 dj	0.33 ep	4.4 ho	4.6ag	0.39 ae	5.0 ag	+14.3	19.11 ab	28.3ad
	20	100	88.5 hk	10.4	3.8 jo	0.32 fq	4.1 lr	4.0 dl	0.32 aj	4.3 el	+11	13.0 em	19.6eo
	19	100	77.5 pq	22.5	3.6 ks	0.28 jq	4.0 ls	3.9 fl	0.42 ac	4.4 dl	+9	14.4 am	21.7be
Moderate tolerant	2	100	77.0 qr	23.0	4.0 gm	0.33 ep	4.3 ho	4.2 cl	0.36 ah	4.5 ck	+5.5	15.0 am	24.3 bm
	26	100	85.5 jn	14.5	3.5 lt	0.30 hq	3.8 nt	3.6 jo	0.27 el	3.9kn	+6	14.8 am	23.0co
	16	100	61.0 v	39.0	4.5 dh	0.35 cm	4.6 fk	4.6 ag	0.33 aj	4.9 bh	+6	14.2 am	22.8co
	21	100	89.0 gj	10.5	3.9 hn	0.33 eo	4.4 ho	3.6 kp	0.36 ah	4.6 ck	+4	15.4 al	18.3 io
	15	100	61.0 v	39.0	3.9 hn	0.33 eo	4.4 ho	4.3 bk	0.27 dl	4.6 ck	+4	16.70 ak	26.0bi
	6	100	95.7 ad	4.4	3.4 lt	0.29 iq	3.7 ot	3.7 jn	0.32 aj	4.0 kn	+6.7	15.83 al	22.7co
	43	100	98.0 ac	2.0	4.0 gl	0.34 dn	4.4 ho	4.2 cl	0.36 ah	4.5 ck	+4.1	18.1 ag	27.0bg
Susceptible	28	100	37.0 yz	63.0	3.4 mt	0.27 lr	3.6 pt	1.7 t	0.11 m	1.8 r	-51	12.6 im	21.3do
	33	100	52.0 w	48.0	3.2 qv	0.21 pr	3.4 rv	3.6kp	0.32 aj	3.9 kn	-44	12.6 hm	16.6 mo
	34	100	52.7 w	47.4	4.9 ad	0.42 ag	5.4 ae	2.9nr	0.11 m	3.0 op	-43	14.9 am	16.2no
	35	100	61.0 v	39.0	2.9 tw	0.33 eo	3.3 tv	1.8 t	0.19 jm	2.0 qr	-43	13.2 cm	18.0jo
	25	100	50.3 w	45.2	3.9 hn	0.30 hq	4.3 hp	3.7 jm	0.24 gm	4.5 cl	-28	13.0 em	18.7io
	48	100	81.5 np	18.5	3.9 hm	0.34 dn	4.2 ip	2.8 qr	0.27 el	3.1 op	-38.2	10.6 lm	18.4 io
	40	100	86.7 im	13.4	3.3 ou	0.27 kq	3.5 qu	2.7 st	0.22 im	2.9 p	-18	12.8 fm	21.9co
LSD 5 %		-	-	-	0.607	0.115	0.688	0.764	0.136	0.751	-	4.299	6.369