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Full Length Research Paper

Evaluation of yield potential and stress adaptive trait in wheat genotypes under post anthesis drought stress conditions

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Twenty winter wheat genotypes were evaluated under both post-anthesis drought stress and normal conditions in Ardabil Agricultural Research Station in two successive growing seasons 2005 - 2007 using randomized complete block design with three replications. The results showed that there were significant differences between genotypes in stem reserve under both normal and post anthesis drought stress conditions. Post-anthesis drought stress did not affect kernel numbers per spike. The rate of dry matter accumulation by kernels considerably decreased by water deficit. Dry weight of vegetative organs decreased in grain filling period under stress and normal conditions, contrasting anthesis stage. But, the rate of translocated dry matter was much higher in genotypes nos. 14, 15, 16, 18, 19 and 20 under drought stress condition. 1000 GW and weight of kernels per spike were more severely reduced by water deficit. The positive correlation of grain yield with grain weight per spike, 1000 GW, remobilization of dry matter, harvest index and stress tolerance index (STI) and significant negative correlation of grain yield with drought susceptibility index (SSI) revealed that selection must be exercised for high harvest index, grain weight per spike, 1000 GW, remobilization of dry matter and STI in stress condition. The negative correlation of 'STI' with 'SSI' indicated the efficiency of 'STI' as a selection criterion for identifying the drought tolerant with high yield potential in winter wheat genotypes.

Key words: Winter wheat, drought stress, dry matter, remobilization.

INTRODUCTION

In semi-arid areas of the world with a Mediterranean climate, rainfall decreases as soil evaporation increases in spring when bread wheat (*Triticum aestivum* L.) enters the grain-filling period (Ehdaie et al., 2006). Wheat crops often experience water deficit and heat stress during grain growth and development, which limit productivity (Ehdaie et al., 1988; Ehdaie and Waines, 1989). Wheat is grown on 6.9 million ha in Iran (Anonymous, 2003). About 36% of that is in irrigated and 64% in rainfed areas. Approximately 50 - 55% of wheat grown areas are planted by winter and facultative wheat varieties. Most winter wheat are grown under varied rainfed and water stressed conditions in the semiarid cold climate of Iran.

Year–to-year fluctuations in the amount (annual precipitation ranges between 280 – 300 mm), frequency and duration of rain is high. Other factors such as low temperature in winter (absolute minimum temperature is –30ºC), high temperature during the terminal grain filling period (+35ºC) and post-anthesis water deficit conditions in irrigated wheat, influence crop growth and yield (Sanjari, 2001). Grain growth and development in wheat depend on C from three sources: Current assimilates produced by photosynthesis in leaves and stems, mobilization of the stored carbohydrates and N containing compounds within these organs and their subsequent transport to the spike and growing kernels, and assimilates produced by the spike (Bradfor and Hasio, 1982). Under terminal drought, there is a rapid decline of photosynthesis after anthesis that limits the contribution of current assimilates to the grain (Johnson et al., 1981).

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The wheat canopy respires rapidly during grain filling (Gent and Kiyomoto, 1985; McCullough and Hunt, 1989). Flag leaf photosynthesis alone cannot support both respiration and grain growth under terminal stresses (Rawson et al., 1983). Therefore, a substantial amount of the carbohydrates used during grain filling in wheat must come from reserves assimilated before anthesis (Gent, 1994).

The estimated contribution of stored assimilates to grain yield in wheat depends on the genotype, experimental conditions and the method of measuring stored carbohydrates. Stored reserves and their contribution to grain can be estimated by measuring post-anthesis changes in internode dry matter (Hunt, 1979; Phelounng and Siddique, 1991; Borrell et al., 1993; Shakiba et al., 1996, Cruz-Aguado et al., 2000), and/or changes in internode water-soluble carbohydrate content during grain-filling period (Kiniry, 1993; Blum et al., 1994, Shakiba et al., 1996), or estimated by difference in canopy dry weight at anthesis and at maturity excluding the grains (Takani et al., 1990; Flood et al., 1995; Ehdaie and waines, 1996).

In most cereal grown under water limited conditions the crossover occurs at a yield level of around 2- 3 t/ha, which is approximately one-third of the yield potential. The main reason for a crossover under conditions of variable water supply is an inherent difference among the tested cultivars in drought resistance, beyond difference in their yield potential. This has also been observed in international wheat variety trials, where often stress environments were represented by mean yields of 4 - 5 t/ha as compared with a maximum yield of ~8 t ha^{-1} (Blum, 2005).

Several studies have been conducted with spring and winter wheat to evaluate the effect of limited irrigations on crop quality and production. Stress was most critical during and after heading. Stress is likely to occur when the plants appear wilted and the leaves curl. Yield is reduced the most when stress starts during soft dough, flowering or heading. Stress during the maturing process results in about a 10% lower yield (Bauder, 2001). Hence, an important source of carbon for grain filling is stem reserve. Even under mild conditions, current assimilates may be limited for normal grain filling (Gent, 1994). Water deficit did not affect kernel number in wheat. The rate of dry matter accumulation by kernels was considerably decreased by water deficit in both studied wheat cultivars (Plaut et al., 2004). Rates of transport (probably of non-structural carbohydrates) from vegetative organs to kernels were much higher in Suneca than in Batavia wheat cultivars during drought stress conditions (Plaut et al., 2004). Plaut et al. (2004) also demonstrated that thousand-kernel weight (TKW) and weight of kernels per ear were severely decreased by water deficit than by heat in both wheat varieties, and more by water stress in Batavia than in Suneca wheat cultivars (Plaut et al., 2004).

The major purposes of this study were to investigate the accumulation of dry matter during pre-anthesis and grain filling periods as well as genotypic variation of stem reserves of bread wheat genotypes under post anthesis drought stress condition.

MATERIALS AND METHODS

The rates of remobilization of dry matter from vegetative organs (stem + leaves) into developing kernels and drought tolerance of 20 winter and facultative wheat (Table 1), were evaluated under both post anthesis drought stress (E_1) and normal (E_2) conditions in two successive cropping seasons (2005 - -2007) to understand the basis of genotypic differences in yield and yield contributing traits, using randomized complete block design with three replications.

Field experiments were planted on 24 October, 2005 and on 17 October, 2006 in a clay loam type of soil in Ardabil Agricultural Research Station, located at 38º 15´N, 48º 20´E, and an elevation of about 1350 m above sea level. Plants in normal condition were irrigated until they reached physiological maturity. Irrigation was terminated for plants in post anthesis drought stress condition, when 50% of plants in each plot reached late booting stage on 13 May, 2006 and on 10 May, 2007. In 2005 - 2006 growing season, plants in non-stress condition received 670.7 mm of water (466 mm irrigation + 204.7 mm rain) and those in post anthesis drought stress condition received 549.7 (345 mm irrigation + 204.7mm rain). In the 2006 - 2007 growing season, plants in non-stress condition received 661 mm of water (390.2 mm irrigation + 270.8 mm rain) and those in post anthesis drought stress condition received 543.5 mm water (272.7 mm irrigation + 270.8 mm rain) (data not shown). After irrigation was terminated in the post anthesis drought stress treatments, 1.6 and 4.2 mm of rain was received during grain-filling period in 2006 and 2007, respectively.

In the second growing season, the total amount of rainfall was 270.8 mm, which was close to the long-term perennial average of Ardabil region where long term average was 280 mm (data not shown). However, of 270.8 mm of rainfall, 67.5% was received before booting stage when plants were irrigated, 28.2% was received between booting and heading stage, and 4.2% fell between heading and early grain-filling period. The absolute maximum and mean temperature in grain filling period were 34.4 and 15.6°C, respectively (data not shown). In the first season, the total amount of rainfall was 204.7 mm, that is, was less than long term average of Ardabil region. From 204.7 mm of rainfall, 79.6% was received before booting stage when drought did not impose in drought treatment, 18.8% was received between booting and heading, and 1.6% was received between heading and early grain filling period. The absolute maximum and mean temperature in the first growing season were 32°C and 14.2°C, respectively (data not shown). The soil type at the experimental site was clay loam. Therefore, despite large differences in the amount of rainfall between first and second growing season, the percentage of reduction in stem weight at maturity was, 11.57 and 1.31% in 2005 - 2006 and 2006 - 2007 cropping seasons, respectively.

Individual plot was 5 m long with 6 rows spaced 20 cm apart and sown by a small-plot planter (Wintersteiger) and interplant spacing was 3 - 5 cm at a density of 450 seeds/m^2. The land was fallowed in the previous year and 100 kg ha^{-1} of urea plus 150 ha^{-1} phosphate and ammonium fertilizers were applied and incorporated into the soil before planting while 100 kg ha^{-1} of urea fertilizer was applied to the experiments at tillering stage. Data were analyzed, using SAS (1998) (Sanjari et al., 2006). In each plot, 20 main tillers were harvested randomly at anthesis and physiological maturity stages, respectively. The main tillers were harvested from soil surface.

Dates of heading, anthesis and physiological maturity were

Table 1. Growth habit and days to heading of the bread wheat genotypes under non-stress and post-anthesis drought stresses.

No.	Genotypes	Days to heading (DHE) from first of January			Days to maturity from first of January	
		Stress	Stress	Normal	Normal	GH
1	Shahriar	137	190	192	137	W
2	Toos	139	191	193	139	F
3	Tx62A4793-7/Cb809//Vee 'S'/3/Shi#44140	136	190	191	136	W
4	1-67-122/4/1-32-1317//II-5017/Y50E/3/..	137	189	193	138	W
5	Alvd/5/Gds/4/Anza/3/Pi/Nar//	139	190	194	140	F
6	1-60-1//Emu's'/Tjb84/3/1-	137	192	192	137	W
7	1-66-49/1-66-44	140	193	195	140	F
8	Hys//Drc*2/7C/3/2*Rsh/5/1-	140	193	194	137	W
9	Icwha81-1473/5TI/4/La/3/Fr/Kad//Gd	137	191	194	139	W
10	Recital Own-3Wm-Owm	138	192	193	137	W
11	Ymh/Tob//Mcd/3/Lira (Bdme-.	140	193	193	139	W
12	Ae.Ventricosa//T.turgidum/2*.	140	193	195	141	F
13	Darunok	140	193	195	140	W
14	Nal60/Hn7//Buc/3/Falke	137	190	194	137	F
15	362.111/6/Nkt/5/Tob/Cno67//Tob/8156/..	137	189	192	137	F
16	Kinaci97 951327 Swmi2289-	139	193	194	140	W
17	Eryt 1554.90 (Donskayapoi-	139	192	193	139	W
18	Cham4/Tam200/Del483 (960185..	140	193	192	140	S
19	494J6.Ll/Roller (960040 Cm..	138	194	192	136	F
20	1-27- 275/Cf/Cf1770/5/ Ghods/4/Anza/3/Pi/Nar//Hys	137	191	192	136	F
Mean		138	191	193	138	-

W = Winter wheat, F = facultative wheat, S = spring wheat, GH = growth habit, Stress = post anthesis drought stress condition.

scored in each plot as: when 50% of spikes partially emerged from the flag leaf sheaths, when 50% of spikes had extruded anthers, and when 50 % of the spikes lost their green color, 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 (Steel et al., 1997). The combined ANOVA was also performed across years. Relationships between characters were examined by correlation analysis. Means were compared using the LSD test (Steel et al., 1997). Stress susceptibility index (SSI) (Fischer and Maurere, 1978) and stress tolerance index (STI) (Fernandez, 1992) were used to evaluate the genotypes. A mechanistic model was used in order to analyze the collected data and calculate the remobilization and evaluation of stored assimilates from the stem and leaves to developing kernels (Ehdaie et al., 2006).

RESULTS AND DISCUSSION

Analysis of variance on yield and related traits revealed significant differences among the genotypes under both stress and normal conditions in each year (results not shown). The combined analysis of variance (ANOVA) (Table 2) indicated significant difference ($P < 0.01$) between the year for total dry matter per stem at maturity, dry matter of vegetative organs (stem plus leaves, spike remove) at anthesis and at maturity and grain number per spike under normal and post anthesis drought stress conditions. However, the effect of year for grain weight per spike and 1000 grain weight was found significant just in normal condition and for remobilization of dry matter just in stress condition. Results also showed significantly genotypic effect for all the traits both in normal and stress conditions (Table 2). Also genotype × year of interaction was significant for all the traits under both normal and stress conditions except for harvest index under both conditions, grain number per spike under normal condition, and for remobilization of dry matter under stress condition. These findings are in agreement with the results of Shafazadeh et al. (2004) and Ehdaie et al. (2006). The significant genotype × year of interactions was mainly due to differences in changes of genotypes mean rather than in ranking of the genotypes in different years. Only for a few genotypes, changes in rank for some traits were observed under stress and normal conditions.

Since there was genotypic variation in phonological periods, the mean of days to heading was similar in post anthesis drought stress and normal conditions, but the mean of days to maturity was different in both stress and normal; that is, 191 and 193 days, respectively (Table 1).

Table 2. Combined analysis of variance for studied traits of wheat genotypes.

Characters	Environments	Mean	Mean squares				
			Years	Error (a)	Genotype	Geno*year	Error (b)
TDMA (mg)	E1	1974	68224432.8**	132137.5	281966.4**	151780.8**	35800.3
	E2	2042	33655022.9**	496486.9	349435.2**	190952.1**	45112.5
TDMM (mg)	E1	3057	40864448.9**	631085.4	673640.7**	384478.0**	157899.8
	E2	3485	33538615.4**	538360.6	923839.4**	378399.6**	146373.8
GW/S (mg)	E1	1234	3294889.3 ns	530420.0	107538.9**	122495.0**	43634.4
	E2	1559	4491135.1**	157737.6	197986.2**	104372.4**	43414.7
GN/S	E1	36	5341.8**	82.6	130.3**	35.4**	16.8
	E2	36	5967.8**	44.4	87.3**	22.2 ns	17.4
DMVOA (mg)	E1	1460	43520592.7**	97152.3	155255.2**	105713.3*	26477.5
	E2	1530	22715702.6**	384290.8	187087.2**	114527.5**	32702.0
DMVOM (mg)	E1	1271	13678876.2*	112984.3	244858.8**	82579.1 *	46968.9
	E2	1360	8474767.9**	103624.4	259603.7**	142585.5*	80832.7
1000 GW (g)	E1	35.0	379.561ns	148.659	71.018**	38.238**	16.192
	E2	44.1	1192.5*	95.9	120.5**	21.7**	6.9
HI (%)	E1	40.9	645.034ns	259.465	78.598**	38.795ns	28.794
	E2	45.1	169.2ns	26.2	64.1**	35.3ns	23.1
Grain yield (t/ha)	E1	5.983	42.530ns	6.487	1.623*	1.941**	0.769
	E2	7.920	0.538ns	1.016	2.276**	2.201**	0.612
RDM (mg)	E1	150.8	77723.936**	2890.32	1749.748**	754.202ns	629.536
	E2	116.4	18266.868ns	4011.735	1120.297**	813.534*	431.671
(STI)	-	0.761	2.720ns	0.916	0.147*	0.117ns	0.074
(SSI)	-	0.552	0.961*	0.061	0.061**	0.069**	0.022

E1= Post anthesis drought stress condition, E2= normal condition. *, ** = Significant at 5 and 1% of probability level, respectively. ns= non-significant. TDMA = Total dry matter per stem at anthesis (stem + spike) (mg), TDMM = total dry matter per stem at maturity (stem + spike) (mg), GW/S = grain weight per spike (mg), GN/S = grain number per spike, DMVOA = dry matter of vegetative organs at anthesis (mg), DMVOM = dry matter of vegetative organs at maturity (mg), 1000 GW= 1000 grain weight (g), HI = harvest index (%), RMD = remobilization of dry matter (mg), STI = stress tolerance index, SSI = stress susceptibility index.

This finding was closely in agreement with the experimental results, respectively by Blum (2005) which allowed genotypes maturation 2 to 3 days earlier under drought stress than normal conditions.

Dry weight of vegetative organs (stem plus leaves, spike removed) decreased during grain filling stage in both normal and stress conditions, (probably due to export of non-structural carbohydrates to grain (Figure 1 and Table 2).

Post anthesis water deficit did not affect grain number per spike (Table 3). The average grain numbers per spike of wheat genotypes were similar in both stress and non stress environments (36.09 and 35.77 grain spike^{-1}) (Table 3). Rate of dry matter accumulation by grains considerably decreased in post anthesis water deficit, in all the genotypes (Table 3). But reduction of dry matter accumulation by grains in genotype no. 8 was more severe (49.3 and 34.3 g in normal and post anthesis drought stress conditions, respectively) in comparison with genotype no. 17 in which the reduction of dry matter accumulation was very low (44.3 and 40.1 g for 1000 grain weight in normal and post anthesis drought stress conditions respectively) (results not shown). The results here correspond with Plaut et al. (2004) study. 1000 GW and weight of grains per spike were more severely reduced by water deficit in all genotypes. The average grain weight per spike was 1559.2 and 1233.9 mg under normal and post anthesis drought stress conditions, respectively. The reduction of grain weight per plant in genotype no. 7 was more severe (1935 and 1378 mg /spike in normal and post anthesis drought stress conditions, respectively), in comparison with genotype no. 2 in which the reduction of grain weight per spike was very low (1352 and 1246 mg spike^{-1} in normal and post anthesis drought stress conditions, respectively) (Table 3). The reduction of dry weight of vegetative organs (stem plus leaves, spike removed) was 11.1 and 12.9% in normal and stress conditions, respectively. Remobilization of dry matter from vegetative organs also increased by 29.5% under drought stress condition than in normal condition (116.4 and 150.8 mg under normal and stress conditions respectively) (Table 4). The rate of translocation of dry matter was much higher in genotypes nos. 9, 14, 15, 16, 18, 19 and 20 under drought stress

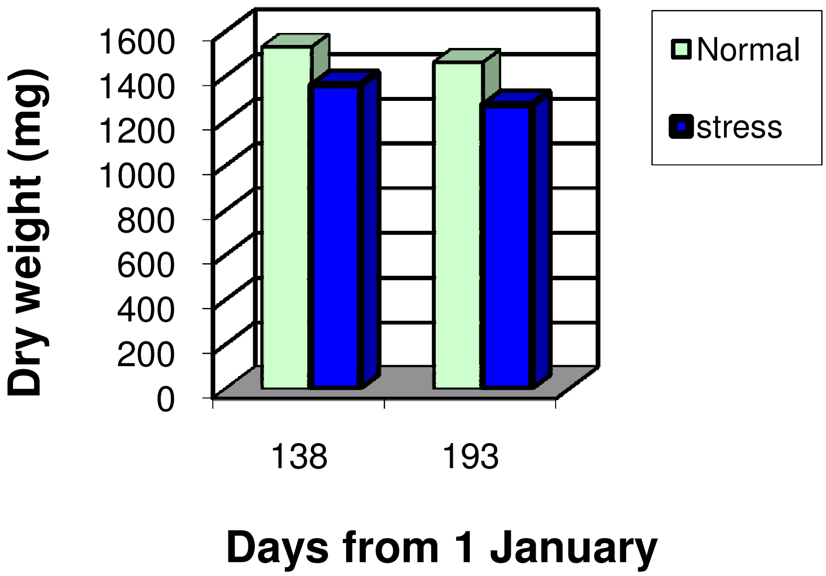

Figure 1. Dry weight of vegetative organs (stem plus leaves) (excluding roots and spike removed) of wheat genotypes under normal and post-anthesis drought stress conditions.

Table 3. Studied characters of wheat genotypes under normal and post-anthesis drought stress conditions.

No.	Normal condition				Drought stress condition			
	Total dry matter of vegetative organs mg)		Grain/ spike	Grain yield /spike (mg)	Total dry matter of vegetative organs (mg)		Grain/spike	Grain yield/ spike(mg)
	Anthesis	Maturity			Anthesis	Maturity		
1	1464	1339	36	1492	1484	1276	34	1065
2	1499	1581	35	1309	1526	1577	36	1088
3	1547	1050	33	1352	1447	1423	39	1246
4	1545	1379	37	1403	1394	1231	38	1177
5	1537	1075	34	1658	1295	1134	30	1070
6	1759	1397	46	1893	1602	1547	47	1573
7	1526	1358	40	1935	1438	1528	37	1378
8	1647	1507	32	1576	1497	1316	33	1134
9	1673	1939	32	1770	1791	1565	29	1249
10	1201	1254	40	1499	1380	1186	39	1117
11	1366	1169	32	1278	1162	1112	33	1076
12	1763	1573	43	1753	1548	1477	44	1418
13	1409	1126	34	1548	1263	1083	36	1354
14	1633	1318	32	1448	1413	1188	31	1239
15	1619	1439	37	1580	1731	1301	30	1164
16	1274	1193	34	1404	1319	956.4	35	1242
17	1350	1413	34	1472	1354	1337	31	1248
18	1345	1269	35	1513	1446	918.1	36	1202
19	1534	1277	37	1623	1399	1022	40	1264
20	1911	1548	36	1678	1726	1262	36	1375
Mean	1530.1	1339.4	36.09	1559.2	1460.7	1272	35.77	1233.9
LSD 5%	207.9	326.9	4.8	239.6	187.1	249.2	4.7	240.2
Changes of dry matter under drought stress condition					-4.5	-5.0	0.0	-20.9

Total dry matter of stem=all internodes weight (excluding root), total dry matter of vegetative organs=stem plus leaves (excluding spike).

Table 4. Studied characters of wheat genotypes under normal and post-anthesis drought stress conditions.

No	Normal condition				Drought stress condition			
	Total dry matter/stem (mg)		Grain yield/ spike (mg)	RDM (mg)	Total dry matter/stem (mg)		Grain yield/ spike (mg)	RDM (mg)
	Anthesis	Maturity			Anthesis	Maturity		
1	1976	3429	1492	+39	2025	2912	1065	+178
2	2045	3561	1309	-207	2061	3260	1088	-111
3	2086	2936	1352	+502	2007	3354	1246	-101
4	2090	3362	1403	+130	1903	3084	1177	-4.0
5	2119	3316	1658	+461	1775	2728	1070	+117
6	2423	3993	1893	+323	2236	3811	1573	-2.5
7	2080	4007	1935	+8.3	1941	3476	1378	-156
8	2128	3672	1576	+32	1944	2934	1134	+144
9	2183	4404	1770	-451	2384	3389	1249	+244
10	1576	3226	1499	-151	1842	2838	1117	+121
11	1799	2934	1278	+143	1590	2664	1076	+1.0
12	2311	3934	1753	+129	2094	3598	1418	-85
13	1835	3046	1548	+337	1683	2863	1354	+174
14	2210	3304	1448	+354	1964	2916	1239	+287
15	2089	3609	1580	+60	2249	2983	1164	+431
16	1727	3100	1404	+31	1805	2686	1242	+361
17	1785	3408	1472	-150	1772	3019	1248	+1.7
18	1789	3238	1513	+64	1911	2628	1202	+485
19	2028	3383	1623	+268	1895	2758	1264	+401
20	2558	3833	1678	+403	2397	3242	1375	+530
Mean	2046.8	3484.7	1559.2	+116.4	1973.9	3057.1	1233.9	+150.8
LSD 5%	244.2	439.9	239.6	-	217.6	456.9	240.2	-
Changes of dry matter under drought stress condition					-3.6	-12.3	-20.9	29.5

RMD = Remobilization of dry matter (mg). Standard error of mean in remobilization of dry matter was 45.8 and 44.9 under normal and post-anthesis drought stress, respectively. - = The pre-anthesis assimilates did not translocate from vegetative organs to developing kernels. + = The pre-anthesis assimilates translocated from vegetative organs to developing kernels.

condition and these genotypes were also of high yielding and drought tolerance (Table 4).

The average grain yield of the genotypes was 7.90 and 5.98 t/ha in normal and post anthesis drought stress conditions, respectively (Table 5). But the reduction of grain yield was more severe in genotype no. 12 (7.88 and 5.56 t/ha in normal and stress conditions respectively), in comparison with genotypes nos. 2 and 20, in which the reduction of grain yield was very low (5.90 and 5.24, 7.83 and 7.13 t/ha, respectively) in normal and stress conditions. Tolerance and susceptibility indices showed that genotypes nos. 10, 13 and 20 were more drought tolerant and of high yield potential (Table 5). Selection based on stress tolerance index (STI) also favored genotypes nos. 10, 13 and 20. TOL index could select genotypes with low yield but tolerant to drought stress as well as genotype No. 2 under post-anthesis drought stress condition (Table 5). These findings are in accordance with results of Sanjari and Yazdansepas (2008). Selection based on stress susceptibility index (SSI) favored genotypes nos. 2, 14, 15 and 20 in post-anthesis drought stress (Table 5). However, SSI failed to identify the high yielding and stress tolerant genotypes under both water deficits and non-stress conditions. These findings are in accordance with results of Snjari et al. (2006). Based on STI, genotypes nos. 10, 13 and 20 were also more drought tolerance and produced higher yield potential under both well watered and drought stress conditions, but on the basis of SSI, genotypes nos. 20, 14, 15 and 16 were more drought tolerant and they produced high yield under drought stress condition (Tables 3 and 5).

Overall, results showed that an important component for success of a plant breeding program in stressed environments is optimized performance of genotypes under severe stress condition and high yield under optimum condition. Therefore, in this study three high yielding, and drought tolerant genotypes that is, genotypes nos. 10, 13 and 20 were identified as suitable

Table 5. Tolerance and susceptibility indices of wheat genotypes under non-stress and post-anthesis drought stress conditions.

Genotypes	Yp (t/ha)	Ys (t/ha)	(TOL)	(MP)	(SSI)	(STI)
1	7.45 c	5.45 df	2.00	6.45	1.10	0.65
2	5.90 d	5.24 f	0.66	5.57	0.45	0.50
3	8.14 ac	5.21 f	2.93	6.68	1.48	0.68
4	7.14 ac	5.28 ef	1.86	6.41	1.07	0.60
5	8.37 ab	5.62 df	2.75	6.99	1.35	0.75
6	8.26 ac	6.06 bf	2.20	7.16	1.10	0.80
7	7.92 ac	5.90 bf	2.02	6.91	1.05	0.75
8	8.17 ac	6.25 ae	1.92	7.21	0.97	0.82
9	7.67 bc	5.62 cf	2.05	6.64	1.10	0.69
10	8.73 a	6.63ac	2.10	7.68	0.99	0.93
11	8.20 ac	6.06 bf	2.14	7.13	1.07	0.80
12	7.88 ac	5.56 df	3.32	6.72	1.21	0.70
13	8.72 a	6.67 ab	2.05	7.70	0.97	0.93
14	7.53 bc	6.31 ad	1.22	6.92	0.67	0.76
15	7.67bc	6.41 ad	1.26	7.04	0.68	0.79
16	7.58 bc	6.09 bf	1.49	6.84	0.81	0.73
17	8.22 ac	6.38 ad	1.84	7.30	0.92	0.84
18	8.62 a	5.83 bf	2.79	7.22	1.33	0.81
19	7.99 ac	5.94 bf	2.05	6.97	1.06	0.76
20	7.83 ac	7.133 a	0.70	7.48	0.37	0.89
Mean	7.90	5.98	1.92	6.95	0.97	0.76
LSD 5%	0.8996	1.008				

Means followed by the same letter within columns are not significantly differences at LSD test ($p < 0.05$). Yp = yield under normal condition, Ys =yield under stress condition, TOL= Tolerance, MP= mean productivity, SSI= stress susceptibility index and STI= stress tolerance index. For TOL and SSI, lower values are desirable; For MP and STI, higher values are desirable. Standard error of mean for TOL, MP, SSI and STI were 0.13, 0.09, 0.06 and 0.02, respectively.

genotypes for both non-stress and drought stress environments, with relatively high remobilization of dry matter under drought stress condition (Tables 3, 4 and 5).

Significant and positive correlation of harvest index with remobilization of dry matter and grain yield under normal; and stress conditions (data not shown) revealed that selection must be exercised for high remobilization of dry matter and high harvest index which will result in high grain yield in both conditions. Also, positive and significant correlation between grain yield and STI under normal and stress conditions indicated that STI can be a reliable index for relation of high yielding genotypes under both conditions. These findings are in close agreement with Sanjari et al. (2006).

REFERENCES

Anonymous (2003). Detail results of public agricultural statistics of country. Management and programming organization of country. Center of statistic of Islamic Republic of Iran, p. 302.

Bauder J (2001). Irrigating with limited water supplies. Montana State University Communications Services. Montana Hall. Bozeman, MT 59717. USA.

Blum A, Sinmena B, Mayer J (1994). Stem reserve mobilization supports wheat-grain filling under heat stress. Aust. J. Plant Physiol., 21: 771-781.

Blum (2005). Drought resistance, water-use efficiency, and yield potential-are they compatible, dissonant, or mutually exclusive? Aust. J. Agric. Res., 56: 1159-1168.

Borrell A, Incoll LD, Dalling MJ (1993). The influence of the Rht1 and Rht2 allels on the deposition and use of stem reserve in wheat. Ann. Bot. (London), 71: 317-326.

Bradford KJ, Hasio TC (1982). Physiological responses to moderate water stress. In:Lange. O.L., Nobel, P.S., Osmond, C.P. Ziegler, H. (Eds.), Encyclopedia of plant physiology. New Series: Physiological Plant Ecology. II. Water relations and Carbon Assimilation , vol. 12B. Springer Berlin.

Cruz-Aguado JA, Rodes R, Perez IP (2000). Morphological characteristics and yield components associated with accumulation and loss of dry matter in internodes of wheat. Field Crops Res., 66: 129-139.

Ehdaie B, Alloush GA, Madore MA (2006). Genotypic variation for stem reserves and mobilization in wheat: I. Post-anthesis changes in internode dry matter. Crop Sci., 46: 735-746.

Ehdaie B, Waines JG (1989). Adaptation of landrace and improved spring wheat genotypes to stress environments. J. Genet. Bread., 43: 144-156.

Ehdaie B, Waines JG (1996). Genetic variation for contribution of pre-anthesis assimilates to grain yield in spring wheat. J. Genet. Breed., 50: 47-56.

Ehdaie B, Waines JG, Hall AE (1988). Differential responses of landrace and improved spring bread wheat genotypes to stress environment, Crop Sci., 28: 838-842.

Fernandez GCJ (1992). Effective selection criteria for assessing plant stress tolerance. p. 257-270. In proceeding of the international symposium on adaptation of vegetative and other food crops in temperature and water stress. Taiwan 13-19 Aug.

Fischer RA, Maurere R (1978). Drought resistance in spring wheat cultivars. (I-Grain yield responses) .Aust. J. Agric. Res., 29: 897-912.

Flood RG, Martin PJ, Gardener WK (1995). Dry matter accumulation and partitioning and its relationships to grain yield in wheat. Aust. J. Exp. Agric., 35: 495-502.

Gent MPN (1994). Photosynthate reserves during grain filling in winter wheat. Agro. J., 86: 159-167.

Gent MPN, Kiyomoto RK (1985). Comparison of canopy and flag leaf net carbon dioxide exchange of 1920 and 1977 New York winter wheats. Crop Sci., 25: 81-86.

Hunt LA (1979). Stem weight changes during grain filling in wheat from diverse sources. In S. Ramanujam (ed.) Proceed. 5th International Wheat Genetics Symposium. Feb. 2328, 1978. Indian Society of Genetics and Plant Breeding. Indian Agricultural Research Institute. New Delhi, India.

Johnson RC, Witters RE, Ciha AJ (1981). Daily patterns of apparent photosynthesis and evapotranspiration in a developing winter wheat crop. Agro. J., 73: 414-418.

Kiniry JR (1993). Nonstructural carbohydrate utilization by wheat shaded during grain growth. Agro. J., 85: 844-849.

McCullough DE, Hunt LA (1989). Respiration and dry matter accumulation around the time of anthesis in field stands of winter wheat (*Triticum aestivum L.*). Ann. Bot. (London), 63: 321-329.

Phelounng PC, Siddique KHM (1991). Contribution of stem reserve to grain yield in wheat cultivars. Aust. J. Plant Physiol., 18: 53-64.

Plaut Z, Butow BJ, Blumenthal CS (2004). Transport of dry matter into developing wheat kernels and its contribution to grain yield under post-anthesis water deficit and evaluated temperature. Field Crops Res., 86: 185-198.

Rawson HM, Hindmarsh JH, Fischer RA (1983). Changes in leaf photosynthesis with plant ontogeny and relationships with yield per ear in wheat cultivars and 120 progeny. Aust. J. Plant Physiol., 10: 503-514.

Sanjari PA (2001). Relation among yield potential drought tolerance and stability of yield in bread wheat varieties under water deficit conditions. Proceeding of the 10th Australian Agronomy Conference. Hobart.

Sanjari PA, Valizadeh M, Majidi I, Shiri M (2006). Evaluation of new bread wheat genotypes under different drought stress conditions for grain yield and some important agronomic and physiologic characters. Agricultural Science. Sci. J. Fac. Agric. Univ. Tabriz, 16(3): 97-112.

Sanjari PA, Yazdansepas A (2008). Evaluation of wheat (*T. aestivum* L.) under pre and post anthesis drought stress conditions. J. Agric. Sci. Technol. (JAST), 10: 109-121.

SAS (1988). SAS/STAT user, guide. Release 6.03 SAS Inst. Inc. Cary. USA.

Shafazadeh MK, Yazdansepas A, Amini A (2004). Study of terminal drought tolerance in promising winter and facultative wheat genotypes using stress susceptibility and tolerance indices. Seed and Plant, 20(1): 57-71.

Shakiba MR, Ehdaie B, Madore MA (1996). Contribution of internode reserves to grain yield in a tall and semidwarf spring wheat. J. Gent. Breed., 50: 91-100.

Steel RGD, Torrie JH, Dickey DA (1997). Principles and procedures of statistics, 3rd ed., McGraw-Hill. New York,

Takami S, Kobata T, Bavel CHM (1990). Quantitative method for analysis of grain yield in rice. Agro. J., 82: 1149-1153.