Mobilization of dry matter and its relations with drought stress in wheat genotypes

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ABSTRACT

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. Post-anthesis drought stress did not affect kernel number per spike. The rate of dry matter accumulation by kernels was considerably decreased by water deficit. Dry weight of vegetative organs decreased in grain filling period under stress and normal conditions, by contrast, in anthesis stage. But, the rate of translocated dry matter was much higher in genotypes No 14, No 15, No 16, No 18, No 19 and No 20 under drought stress condition. The 1000GW and weight of kernels per spike were more severely reduced by water deficit. The positive correlation of grain yield with grain weight per spike, 1000GW, 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, 1000GW, 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 drought tolerant winter wheat genotypes with high yield potential.

INTRODUCTION

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 is 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 280-300mm), frequency and duration of rain are 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). 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). 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).

In most cereal grown under water limited conditions a "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 was 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 (Blum, 2005).

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 more severely decreased by water deficit than by heat in both wheat varieties, and more by water stress in Batavia than in Suneca wheat cultivars.

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

MATERIALS AND METHODS

Twenty promising wheat genotypes were evaluated under both stress and normal conditions in two successive cropping seasons (2000-2002) to understanding the basis of genotypic differences in yield and yield contributing traits, using randomized complete block design with three replications.

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 the previous year and 100 kg ha^{-1} of urea plus 150 ha^{-1} ammonium phosphate were applied and incorporated into the soil before planting and 100 kg ha^{-1} of urea was applied to the experiments at tillering stage. In each plot, 20 main tillers were harvested randomly at both anthesis and physiological maturity. The main tillers were harvested from the soil surface.

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. Relationships between characters were examined by correlation analysis. Means were compared using the LSD test (SAS, 1988). Stress susceptibility index (SSI) (Fischer and Maurere, 1978) and stress tolerance index (STI) (Fernandez, 1992) were used to evaluate the genotypes.

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. The combined analysis of variance (ANOVA) indicated significant difference ($P<0.01$) between the years 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 significant only in normal condition and for remobilization of dry matter only in the stress condition. Results also showed significantly genotypic effect for all the traits both in normal and stress conditions. Also genotype×year 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 rate of dry matter accumulation by grains was considerably decreased by post anthesis water deficit, in all genotypes. But the reduction of dry matter accumulation by grains in genotype No 8 was more severe (49.3 g 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 g and 40.1 g for 1000 grain weight in normal and post anthesis drought stress conditions respectively) (table 5). The results of this sectio corresponded to those of Plaut *et al*. (2004). The 1000GW 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).

There were significantly 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 was considerably decreased by water deficit (Table 1). Dry weight of vegetative organs decreased in grain filling period under stress and normal conditions, by contrast, in anthesis stage, but, the rate of translocated dry matter was much higher in genotypes No 14, No 15, No 16, No18, No 19 and No. 20 under drought stress condition. The 1000GW and weight of kernels per spike were more severely reduced by water deficit. The positive correlation of grain yield with grain weight per spike, 1000GW, 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, 1000GW, 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.

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Sanjari, P. A. and A. Yazdansepas, 2008, Evaluation of wheat (*T. aestivum* L.) under pre and post anthesis drought stress conditions. Journal of Agricultural Science and Technology (JAST), Vol. 2

Table 1-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.