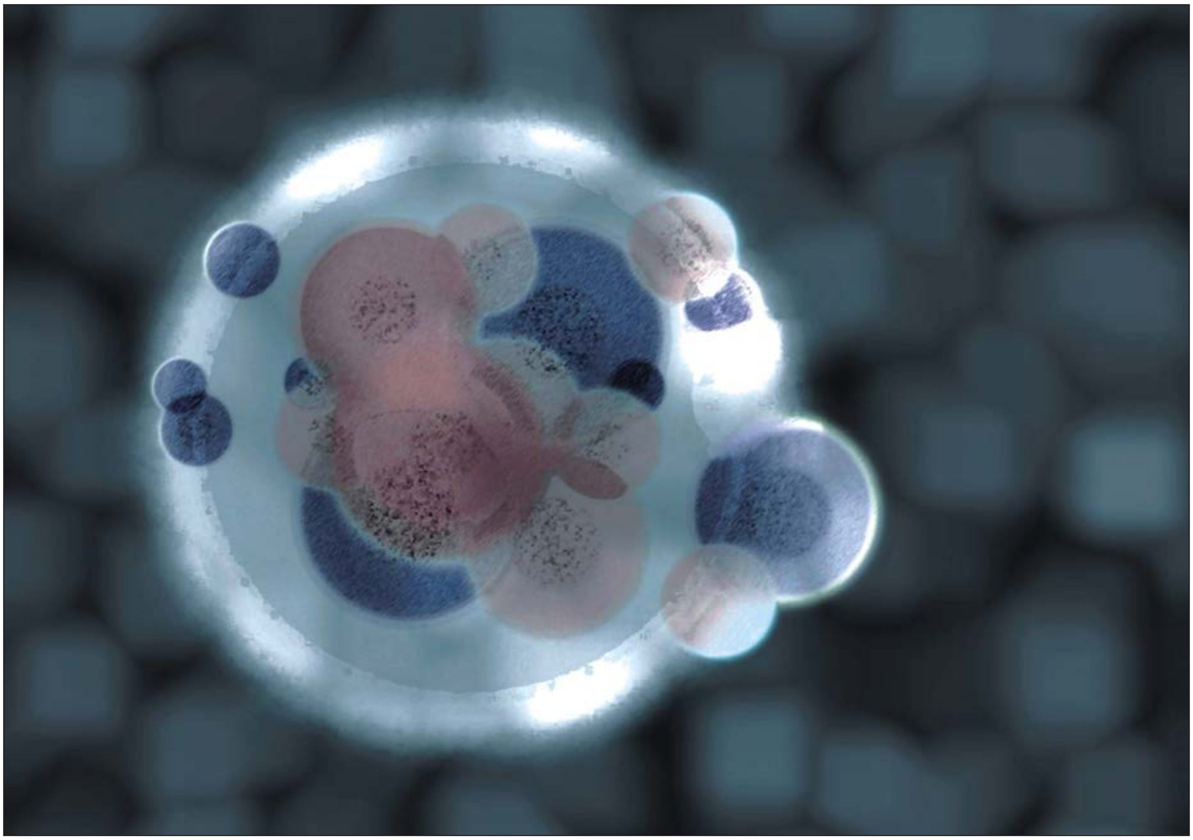

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Effects of Post-Anthesis Drought Stress on the Stem-Reserve Mobilization Supporting Grain Filling of Two-Rowed Barley Cultivars at Different Levels of Nitrogen

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Abstract: The objectives of this research were to determine the contribution of stem reserves to grain development under drought stress conditions that were created at post-anthesis by chemical desiccant application and to determine the drought-resistant varieties grown at four levels of nitrogen under the ecological conditions found in Bursa, Turkey, in 2003 and 2004. Ten varieties of two-rowed barley were used as plant materials in the experiment. In this study, various parameters-such as Dry Matter Translocation (DMT), Dry Matter Translocation Efficiency (DMTE), Rate of Grain Weight Reduction (RGWR), Mean Productivity (MP) and Seed Yield Tolerance (SYT) of varieties were determined. The highest values of DMT and DMTE were found in the Serifehanim-98 and Balkan-96 varieties and the lowest values in the Angora variety, according to the 2-year study results. The other varieties varied between these values. On the other hand, Serifehanim-98 and Suleymanbey-98 had the highest MP and the lowest SYT values that are considered ideal for growth under dry conditions.

Key words: Drought stress, two-rowed barley, stem-reserve mobilization, nitrogen, post-anthesis, chemical desiccant

INTRODUCTION

Drought is one of the most significant stress factors of the environment. It threatens agricultural production on 20×10^8 ha dry farming areas in the world, especially in developing countries. The effects are also becoming more prominent with time. It also impairs the balance of food production (McWilliam, 1986).

One of the methods that was approved as effective for the selection of cereal varieties that are resistant to drought and that is widely used is the chemical desiccant application. In fact, conducted research has proven that the determination of varieties that have stable grain weights that are reliable in drought conditions was created by the application of chemical desiccants. A lot of researchers who used the method mentioned above obtained successful results in different varieties of cereal (Hossain *et al*., 1990; Nicolas and Turner 1993; Blum *et al*., 1994; Cseuz and Erdei, 1996; Djekoun *et al*., 1996; Cseuz *et al*., 2002).

Leaf photosynthesis often decreases markedly after anthesis in grain crops due to various stresses (drought, heat and leaf diseases) and then the grain growth depends increasingly on the contribution of vegetative reserves (Rawson and Evans, 1971; Davidson and Birch, 1978; Austin *et al*., 1980; Hall *et al*., 1989) and the photosynthesis of the relatively stress-tolerant ear tissues (Evans *et al*., 1972; Johnson and Moss, 1976; Blum, 1985). In general, the genotypes that can store a large amount of non-structural carbohydrates that are assimilated in the periods before fertilization and that transport these carbohydrates effectively into developing grains may give higher yields than those that do not have these properties under drought conditions (Ozturk and Akten, 1996). Whan *et al*. (1991) reported that the most important drought-resistant mechanism is resistance to post-anthesis drought stress and that the photosynthesis products produced in this period were transported into grain in the grain-filling period. In addition, about 40-60% of grain yield was obtained by remobilization of assimilants that had been reserved in pre-anthesis.

Bidinger *et al*. (1977) estimated, in barley, that the relative contribution of post-anthesis assimilation to grain growth increased from 13% under irrigation to 27% under drought conditions. However, Austin *et al*. (1980)

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reported that the barley grains received more than 50% of their carbohydrate requirements from stem reserves in drought conditions, but that in cool and rainy years this rate was only 14%.

Blum *et al.* (1983a) reported that, in a study on four wheat cultivars, kernel weight was the least reduced by chemical desiccant in the two cultivars that showed a greater loss of stem dry matter under desiccation relative to the controls. They suggested that varieties that translocate more carbohydrate reserves to the grains are better able to maintain a stable kernel weight under desiccation conditions. In addition, in other studies conducted on the same subject, the reduction in grain weight resulting from chemical desiccation of plants correlated significantly with the reduction in grain weight due to natural drought (Blum *et al.*, 1983b; Nicolas and Turner, 1993).

Barley is a crop that is not tolerant to a long or extremely dry period. In a study in greenhouse conditions, the effects of different nitrogen (N) rates and post-anthesis moisture stress on the grain yield of barley cultivars were tested. In this study, it was determined that the amount of reserve matters translocated to grain indicated the variation among cultivars and that the net remobilization of dry matter was increased by stress but not by N treatment (Fathi *et al.*, 1997).

This study was conducted with two-rowed barley cultivars that had been grown under different N regimes in order to determine the contribution of reserve matters to grain filling under dry conditions that had been created by a chemical desiccant (4% potassium chlorate) at post-anthesis and then in order to define the cultivar(s) that are tolerant to drought.

MATERIALS AND METHODS

This study was carried out at the Research and Application Center of the Agricultural Faculty, Uludag University, Bursa, Turkey, as field experiments in 2003 and 2004.

The total precipitation (461.5 mm) in the first year of the experiment during the vegetation season was lower than the normal value (555.6 mm), but it was approximately the same as the normal value in the second year (555.7 mm). The average temperature (10.5°C) in the first year was lower than the normal temperature (11.6°C), but it was close to normal in the second year (11.1°C). Both in the first year (67.0%) and in the second year (68.1%), the relative moisture was lower than the normal amount (70.9%). The soil of the experimental area was clayey textured, almost without salt (0.095%), rich in K (1410 kg ha^{-1}), neutral in pH (7.2) and poor in organic matter (1.50%).

The experiment was set up according to the Split-Plots Design of the Randomized Block with three replications. Bilgi-91, Cumhuriyet-50, Cildir-02 and Kalayci-97 cultivars of two-rowed barley were used in the experiment; these were obtained from the Anatolia Agricultural Research Institute; Bornova-92, Suleymanbey-98 and Serifehanim-98 varieties were obtained from the Aegean Agricultural Research Institute; and Balkan-96, Angora and Sladoran varieties were obtained from the Trache Agricultural Research Institute.

In each year of the experiment, sowings were made using an ojord-type sowing machine in November. The size of the plots was 3×1.2 m. Each plot was sown in eight rows, with row spacings of 15 cm. After sowing, a hand-driven roller was used to allow the seeds to come into contact with the soil. Four levels (0, 50, 100 and 150 kg ha^{-1}) of N were used in the experiment. One-third of the nitrogen fertilizer was applied immediately after the sowing and two-thirds of it at the jointing stage. The N fertilizer contained 26% ammonium nitrate.

The chemical desiccant potassium chlorate (4%) was used to create drought stress conditions after anthesis. The desiccant was sprayed 15 days after anthesis of each variety. For comparison, a 0.84 m^2 area of each plot was used as a control. The green parts of the plants that had been exposed to potassium chlorate completely dried in the 48 h after the desiccant had been sprayed. Fifteen days after anthesis of each variety, 15 spikes from each plot were taken to determine the grain weight at that time. Cultivars reached their harvesting maturity in the second half of June in each year. At the harvesting time, 15 spike samples were taken from each plot in which the chemical desiccant had been applied or not applied (control). Spike samples were dried at 68°C for 48 h, they were then threshed with a single-spike thresher and, after weighing at a sensible balance, their dry weights were determined. After these procedures, grains of sample plants of each plot were counted and then their average dry weights (mg $grain^{-1}$) were calculated. By using the values determined above, some new parameters, such as dry matter translocation (DMT; mg $grain^{-1}$), dry matter translocation efficiency (DMTE; %), rate of grain weight reduction (RGWR; %), mean productivity (MP; t ha^{-1}) and seed yield tolerance (SYT; kg ha^{-1}) were calculated. The following equations were used in the calculation of these parameters:

Dry Matter Translocation (DMT; mg $grain^{-1}$) =
(Grain dry matter of plants treated with potassium chlorate)− (Grain dry matter of plants sampled 15 days after anthesis) (Kalayci *et al.*, 1998; Przulj and Momciloviv, 2001).

Dry Matter Translocation Efficiency (DMTE; %) = [DMT/(Grain dry matter of plants sampled 15 days after anthesis)]×100 (Przulj and Momciloviv, 2001).

Rate of Grain Weight Reduction (RGWR; %) = [(Grain dry weight of control plants−grain dry weight of desiccated plants)/(Grain dry weight of control plants)]×100 (Borner *et al*., 2002).

Mean Productivity (MP; t ha^{-1}) = (Yield of control + Yield of stress)/2 (Hossain *et al*., 1990).

Seed Yield Tolerance (SYT; kg ha^{-1}) = Yield of control−Yield of stress (Hossain *et al*., 1990).

The values of the 2 years were combined and then subjected to statistical analysis. The values obtained from these experiments were analysed using ANOVA, according to the Split Plot Design of Randomized Block. Probability levels of 1 and 5% were used for tests of significance. Means were tested by the Least Significant Difference (LSD) at p<0.05. MINITAB and MSTAT-C programmes were used for all the calculations.

RESULTS AND DISCUSSION

According to the results of variance analysis of 2-year average values, cultivars indicated significant differences at the 1% level in respect of DMT, DMTE, RGWR, MP and SYT (Table 1). On the other hand, N doses significantly affected DMT and SYT of varieties at p<0.01, but MP and DMTE at p<0.05. Variety×N interaction had a significant effect on DMTE, RGWR and SYTs of varieties at p<0.01.

The amounts of DMT of barley varieties ranged from 9.61 to 13.48 mg grain^{-1} (Table 1). There were significant differences among varieties in respect of DMT. The Balkan-96 and Serifehanim-98 varieties had the highest amount of DMT, whereas the Angora variety had the lowest. The other varieties were lined up between these extreme values. The effects of N doses on DMT were found to be statistically different. However, this difference occurred in a decreasing way only at 50 kg N ha^{-1}. The reason why this N dose decreased DMT was not understood. In a study related to this subject, it was stated that the N applications did not have any effect on DMT (Fathi *et al*., 1997). In general, the results of this study indicate that the tested varieties had different DMT values under drought stress conditions that were created artificially. Present results are generally in accordance with those of the other researchers (Fathi *et al*., 1997; Kalayci *et al*., 1998).

Table 1: Dry Matter Translocation (DMT), Dry Matter Translocation Efficiency (DMTE), Rate of Grain Weight Reduction (RGWB), Mean Productivity (MP) and Seed Yield Tolerance (SYT) values of two-rowed barley varieties grown on different nitrogen doses (%)

	DMT (mg grain^{-1})	DMTE (%)	RGWR (%)	MP (t ha^{-1})	SYT (kg ha^{-1})
Varieties					
Angora	9.61c[1]	35.99c	22.64a	3.21f	846.3a-c
Balkan-96	13.48a	53.55a	20.22ab	3.74de	840.0a-c
Bilgi-91	11.17bc	52.70a	20.41ab	4.61ab	1043.2a
Bornova-92	10.53bc	43.35bc	19.81a-c	4.76ab	1047.4a
Cumhuriyet-50	11.48b	48.54ab	18.05bc	3.20f	663.5c
Cildir-02	11.14bc	48.20ab	16.41c	3.70e	648.3c
Kalayci-97	11.35b	48.86ab	20.64ab	3.61ef	803.1bc
Sladoran	9.99bc	39.62c	19.03a-c	4.83a	1015.0ab
Suleymanbey-98	10.68bc	48.38ab	20.20ab	4.15cd	948.7ab
Serifehanim-98	13.25a	55.18a	18.34bc	4.36bc	850.6a-c
LSD (5%)	1.716	8.286	3.663	0.45	230.2
N Doses (kg ha^{-1})					
0	11.52ab	49.30a	19.94	3.00c	674.3c
50	10.41c	44.29b	18.71	4.07b	844.8b
100	11.00bc	45.79ab	19.56	4.31b	941.9ab
150	12.13a	50.37a	20.09	4.68a	1021.3a
LSD (5%)	1.021	4.819	ns	0.25	121.6
Significance					
Variety	**	**	**	**	**
N doses	**	*	ns	*	**
Varieties×N	ns	**	**	ns	**

[1]: Means followed by the same letter was not significantly different at 0.05 level using LSD test; *,**: F-test significant at p<0.05 and p<0.01, respectively; ns: not significant

It can be said that the varieties with a high DMT (Dry Matter Translocation) used their stem reserves effectively under drought stress conditions that were encountered at post-anthesis and had more stable grain yields. Because of these abilities, they can be grown safely in regions in which post-anthesis drought stress occurs.

The varieties showed significant differences in respect of DMTE (Dry Matter Translocation Efficiency). The highest values were found in the Serifehanim-98 (55.18%), Balkan-96 (53.55%) and Bilgi-91 (52.70%) varieties, while the lowest values were obtained from Angora (35.99%) and Sladoran (39.62%). At the same time, these two varieties had the highest and the lowest values, respectively, according to DMT (Table 1). The effects of N doses on DMTE were significant. Only the 50 kg ha^{-1} N dose caused a reduction of DMTE, but the other doses did not show any differences from the control (Table 1).

Among the mean RGWR (Rate of Grain Weight Reduction) of varieties, significant differences were found. It is accepted that the lower the RGWR of a plant, the more the plant resists to stress. From this point of view, Cildir-02 was the most advantageous of the tested varieties due to its lowest RGWR. However, considering this parameter only can lead us to wrongly proposing a variety. In fact, the yield of a variety under stress conditions depends on its yield potential under non-stress conditions and also RGWR under stress conditions or its translocation capacity. On the other hand, the variety that was most affected by stress (in other words, the variety having the highest RGWR value) was the Angora variety. Such a result might be due to the lower values of DMT and DMTE of this variety than those of the others.

In the studies on wheat, sodium chlorate ($NaClO_3$) and potassium iodide (KI) have been used as inhibitors of photosynthesis and have produced results similar to those produced under drought conditions. For example, Nicolas and Turner (1993) reported that the reduction in grain weight due to KI treatment varied from near zero to 32% (1985) or 21% (1986) compared with the controls. In the same way, Cseuz *et al.* (2002) analysed the effects of $NaClO_3$ on 55 genotypes of wheat. Also, in this research, the applications of desiccant affected the rate of grain weight reduction of genotypes differently and the reduction rates ranged between 11 and 61% according to the varieties. These results indicate that the chemical desiccants that are used for the inhibition of photosynthesis might give results close to those of natural drought conditions and they might be used in genotype selection for drought resistance. Also, some other researchers reported that, after desiccant application, there have been fewer changing rates in the grain weight of varieties and that the varieties having less reduction in grain weight were more resistant (Hossain *et al.*, 1990; Borner *et al.*, 2002).

Mean Productivity (MP) values of 2-year data ranged between 3.20 and 4.83 t ha^{-1}. The highest MP appeared in the Sladoran variety and this was followed by the Bornova-92 and Bilgi-91 varieties, respectively (Table 1). The effect of N doses on MP was found to be statistically significant. In general, the values of MP increased depending on the increasing N doses.

According to the average values of the 2-year results, varieties differed significantly in SYT (Seed Yield Tolerance) values. The SYT values of the Bornova-92 and Bilgi-91 varieties were the highest. Cildir-02 and Cumhuriyet-50, on the other hand, were the lowest in this respect (Table 1). ANOVA results showed that the effects of N dose on SYT were significant. The tolerance value at N_0 (control) was 674.3 kg ha^{-1} but at the 150 kg N ha^{-1} level it increased up to 1021.3 kg ha^{-1} (Table 1).

MP and SYT were calculated to identify the varieties that have desirable high MP or low SYT values. From this point of view, the Serifehanim-98 variety had the most desirable traits, followed by Suleymanbey-98.

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