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Full Length Research Paper

The contribution of remobilization of storage materials in wheat yield as affected by potassium iodide (KI)

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This investigation was conducted to study the accumulation and remobilization of storage materials (carbohydrate) and their contribution to wheat yield by using a split plot design in agricultural and natural resources research station of Torogh, Mashhad in the 2006 to 2007 growing season. The experiment included two levels of water status: 1-normal conditions (full irrigation) and 2- terminal water stress as main plot, 8 new wheat genotypes as sub plots, and 2 photosynthesis treatments: 1) using of current photosynthesis and 2) inhibition of current photosynthesis by applying a 0.4% solution of KI after spike appearance in sub-sub plots. Results showed that under terminal water stress condition, the percentage of storage material remobilization increased compared with the normal condition. Genotypes 9212, 9116 gave the highest biological (total dry matter yield) and grain yield and amount of reserve use was moderate, while genotypes C-81 - 10, 9103 had the highest percentage of storage remobilization.

Key words: Wheat genotype, water stress, remobilization, solution, potassium iodide (KI).

INTRODUCTION

Pollination and grain filling are critical stages of wheat development with regard to water stress in which wheat shows the highest sensitivity to lack of water. Two weeks before pollination, grain crops including wheat are susceptible to drought (Machado et al., 1995). In recent years, increasing the potential yield of new wheat cultivars is due mainly to increased harvest index. New cultivars are more capable of mobilizing assimilates to grains. However, the balance between source and sink and the allocation of more material from vegetative to productive organs affects harvest index (Ghodsi, 2004). Current photosynthesis as an important carbon source for grain filling is dependent on the effective light absorption by the green area of the plant after pollination stage. This source is also limited generally by natural leaf aging and different stresses. At the same time, demands for photosynthesis material for grain filling and for keeping respiration for live plant biomass increase (Blum, 1996). Thus, one important source of carbon for grain filling is stem reserve. Even without stress photosynthesis products from current photosynthesis may not be adequate for grains filling (Blum 1996; Gent 1994).

In most studies on the small grain cereals, it was determined that stems and leaf sheaths contained most of the stored assimilates (Dubois et al., 1990; Wardlaw and Willenbrink 1994). Improving the capacity of grain filling using stem reserves is one of the most important goals of wheat and other small grains breeding under abiotic stress such as drought and heat, as well as biotic stress. However, there are genetic differences that affect various aspects of grain filling using stem reserves. Cultivars with high yield potential compared with cultivars with low yield potential have less stem reserves, but under water stress, their reductions of grain yield do not have significant statistical difference from each other. In other words, the results of these studies show that there is no interaction between grain yield potential and use of stem reserves (Blum et al., 1994).

Tahmasebi (1998) concluded that remobilization of carbohydrates and nitrogen from the aerial organs of

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Table 1. Interaction of water condition, Amount of Remobilized Dry Matter (ARDM) and Remobilization Efficiency (REE) in photosynthesis condition.

Water condition	Using of current photosynthesis		Inhibition of current photosynthesis	
	ARDM (mg/plant)	REE (%)	ARDM (mg/plant)	REE (%)
Normal condition	3334[a]	70.2[a]	856 [b]	22.8 [b]
Water stress condition	2805[a]	62.3[a]	1198 [b]	31.8 [b]

wheat and barley grains during filling stage was affected by water stress and remobilization of both elements decreased under in stress. It seems that in end-stage development, current photosynthesis is affected by numerous biotic and abiotic factors that reduce yield. Awareness of the capacity of wheat cultivars in terms of synthesis and remobilization of photosynthetic material in conditions of both water stress and without stress condition will help selection of new cultivars. Current photosynthesis as an important carbon source for grain filling is dependent on effective absorption of light by green leaves after pollination (Naderi and Moshref, 1991; Araus et al., 2002). Blum (1996) suggests using methods that prevent current photosynthesis, by using chemicals, for screening advanced lines and even screening early wheat generation. Thus, information about remobilization of photosynthesis material in grains under normal and terminal water stress conditions is of great importance.

The aim of this study was to estimate the contribution of remobilization of storage materials to wheat yield by potassium iodide (KI) and studying the rate of photosynthetic re-use of materials reserved in the stem of new wheat genotypes under normal and water stress conditions. In this regard, genetic differences in terms of accumulation of photosynthetic material in the stem and their remobilization to the grains under normal and water stress conditions at the end of the growing season were assessed. These reserves in both normal and water stress conditions are of significant importance for grain filling.

MATERIALS AND METHODS

This research was conducted using split plot designs based on a randomized completely block design (RCBD) with three repetitions, during 2006 to 2008 at the Torogh research station in Mashhad. In main plots, two water treatments were applied: 1) Full irrigation as a control treatment and; 2) Water stress from anthesis to maturity by providing no irrigation. In sub plots there were 8 new wheat genotypes, including genotypes number 9103 and 9116 from AYT-D1 experiment and genotypes number 9203, 9205, 9207 and 9212 from AYT-D2 experiment in agricultural year 2005 to 2006 that were drought tolerant genotypes in addition to the dry resistant genotype C-81-10 and "Cross Shahi" cultivar as sensitive cultivar, that their dry resistance and sensitivity were analyzed before (Ghodsi, 2004).

In subplots, photosynthesis treatment was done in two levels: 1) using current photosynthesis (Normal situation) and; 2) preventing current photosynthesis by applying potassium iodide (KI) for 10 to 12 days after spike appearance, which was synchronized with the end of lag phase and starting linear increment of the grain filling. A 4% KI solution was sprayed on all parts of plants including stems, leaves and spike, to prevent current photosynthesis by destroying chlorophyll to investigate the role of reserve material remobilization in grain filling. In order to study the rate of remobilization of assimilates the dry weight of 20 randomly selected stems from each plot at the stages of anthesis and physiological maturity was obtained. Then the amount of remobilized dry matter (ARDM), remobilization efficiency (REE) and remobilization percentage (REP) were determined using the following equations (Cox et al., 1986; Papakosta and Gagianas, 1991; Arduini et al., 2006):

ARDM (mg/plant) =DMSHT (Ant)-DMSHT (Mat)
REE% = ARDM (mg/plant)/ DMSHT (Ant)$\times$ 100
REP%= ARDM (mg/plant)/ GY (mg/plant)$\times$ 100

Where, ARDM is the amount of remobilized dry matter (g/plant); DMSHT (Ant) is above-ground dry matter of plant parts at anthesis stage (g); DMSHT(Mat) is above ground dry matter of plant parts at maturity stage (g),except grain weight (g); REE is remobilization efficiency (%); REP is remobilization percentage; and GY is grain yield (g/plant).

The test of normality and analysis of variance over grain yield and other grain features were calculated using the MSTATC software, and the comparison of means were realized through Duncan multiple range test.

RESULTS AND DISCUSSION

Genotypes 9212 and 9116 had the highest yield and Cross-Shahi had the lowest yield (Figure 1). There was no significant difference between genotypes C-81-10 and 9103 with the two above genotypes. However, genotypes 9212 and 9116 had the highest and Cross-Shahi cultivar had the lowest amount of biological yields (total dry matter yield). To increase potential yield, the amount of dry matter produced should be increased (Blum, 1996). Results indicated that inhibition of current photosynthesis decreased the amount of remobilized dry matter for both normal water conditions and under water stress condition. Inhibiting current photosynthesis under water stress, the amount of remobilized dry matter (ARDM) was higher than the normal condition, but differences were not significant (Table 1). Under the condition of decreasing the amount of current photosynthesis during grain filling, the demand for consuming the stem reserves increases (Bonnett and Incoll, 1992).

Our results showed that under water stress the remobilization efficiency (REE) decreased. On the other hand, under water stress and inhibited current

Table 2. Grain yield of wheat genotypes (Kg/ ha) under normal and water stress conditions for stem reserves utilization.

Genotype or Cultivar	Normal water condition			Water stress condition		
	Using of current photosynthesis	Inhibition of current photosynthesis	Percentage of reserves utilization	Using of current photosynthesis	Inhibition of current photosynthesis	Percentage of reserves utilization
C1:9103	6567 ^{ab}	1900 $^{h-j}$	28.9	5200 $^{a-e}$	1733 $^{i-j}$	33.3
C2:9116	7033 ^{a}	2167 $^{g-i}$	30.8	4967 $^{b-e}$	2467 $^{f-j}$	49.7
C3:9203	6400 ^{ab}	1933 $^{h-j}$	30.2	3967 $^{d-g}$	1933 $^{h-j}$	48.7
C4:9205	5000 $^{b-e}$	1867 $^{h-j}$	37.3	4867 $^{b-e}$	1967 $^{h-j}$	40.4
C5:9207	6067 $^{a-e}$	2367 $^{g-j}$	39	4300 $^{c-f}$	1967 $^{h-j}$	45.7
C6:9212	6967 ^{a}	1677 $^{i-j}$	24.1	5567 $^{a-d}$	1933 $^{h-j}$	34.7
C7:C-81-10	5167 $^{a-e}$	3767 $^{d-h}$	72.9	3467 $^{e-i}$	2300 $^{g-j}$	66.3
C8:Cross-shahi	4267 $^{c-f}$	1933 $^{h-j}$	45.3	4367 $^{c-e}$	1333 ^{j}	30.5
Average	5934 ^{a}	2201 ^{c}	37.1	4588 ^{b}	1954 ^{c}	42.6

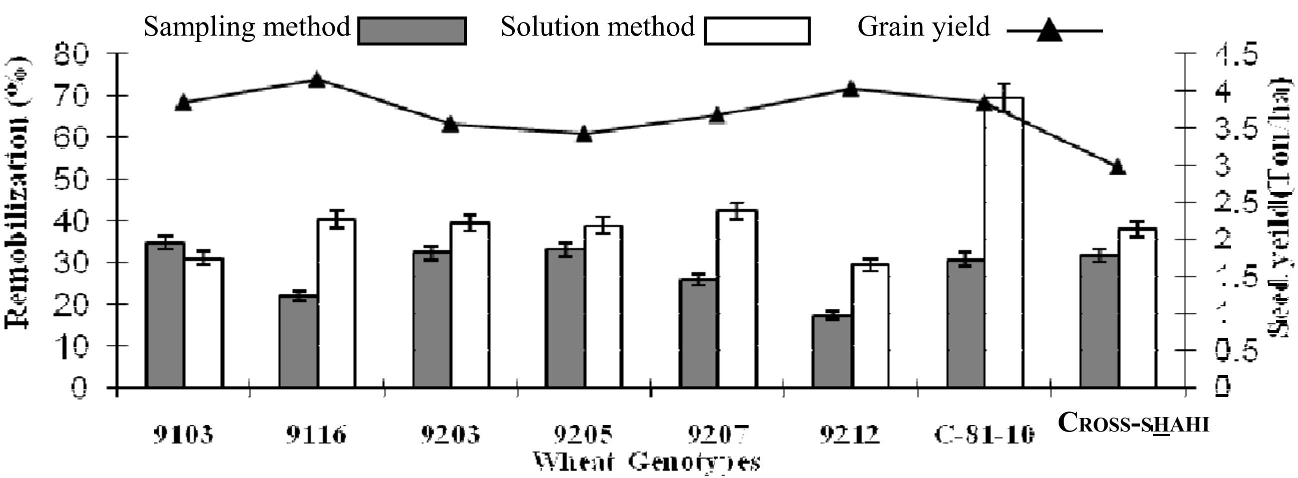

Figure 1. Seed yield and wheat genotypes remobilization percentage of photosynthesis materials.

photosynthesis, the REE increased (Table 1). However, these differences were not statistically significant. Under water stress conditions and different photosynthetic conditions (current photosynthesis and inhibited current photosynthesis) compared to full irrigation, the remobilization percentage, the amount of remobilized dry matter and remobilization efficiency increased, which are in agreement with other reports (Blum et al., 1994; Blum 1996; Tahmasebi, 1998; Ghodsi, 2004) in this field. The mean remobilization percentage of studied genotypes under normal water condition was 37.1% and it was increased to 42.6% under water stress (Table 2). On the other hand, this study showed that the genotypes 9103 and 9212 had the highest and the lowest remobilization percentage respectively (Figure 1). C-81-10 had a high remobilization percentage but it had no significant difference with genotypes 9103. Cultivars tolerant to drought must have suitable storage capacity for grain filling.

In this study, to prevent current photosynthesis and to estimate the contribution of the storage photosynthetic material remobilization, in addition to solution method (using potassium iodide), the conventional sampling method was used as well. In conventional sampling method by using 20 stems randomly from each plot and measuring dry matter weights of samples in stages of anthesis and maturation, the amount of photosynthesis material remobilization was obtained. The results of comparing these two methods to estimate the contribution of remobilization represented a relatively equal trend of both methods to estimate the share of remobilization. C-81-10 had the highest remobilization percentage (72.9%) compared with other genotypes when solution method was used and also its differences with other genotypes were significant (Figure 1).

However, there were some differences observed between the two methods to estimate the share of the remobilization.

Also, solution method with potassium iodide to evaluate the contribution of remobilized dry matter in wheat was a simpler and more precise method than conventional sampling method (Figure 1).

Conclusion

Among the studied genotypes, the promising line C-81-10 had the highest capacity to use stem reserves for grain filling in both the normal and water stress conditions. Under normal conditions, more than 72% of the seed yield of the genotype C-81-10 was due to remobilization of the photosynthesis materials and more than 66% of the grain contents of this line were due to using stem reserves (Table 1). These percentages were higher than other lines and wheat cultivars. However, the GY performance of the line C-81-10 in both normal and water stress conditions showed no significant statistical difference with the other genotypes (Table 1). Generally, in the grain filling stage, the current photosynthesis will be affected by several biotic and abiotic stresses. In this stage, remobilization of the stem reserves as a supporting process can largely compensate the yield reduction (Blum et al., 1994). This source is also limited generally by natural leaf aging and different stresses.

Based on the results of this experiment, by using current photosynthesis under both normal and water stress conditions, genotypes 9116 and 9212 had the highest grain yield GY. However, under normal condition with inhibition of current photosynthesis the genotype C-81-10 had the highest yield and under water stress and with inhibition of current photosynthesis, the genotype 9116 had the highest GY. Therefore, the genotypes 9116, 9212 were best under normal conditions due to current photosynthesis and C-81-10 was a good performer under water stress due to remobilization (Table 1).

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