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Effects of water deficit on dry matter remobilization and grain filling trend in three spring barley genotypes

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Abstract

To investigate the effects of water deficit stress on dry matter remobilization and grain filling trend in barley a split-plot experiment based on Randomized Complete Block (RCB) design with three replications was conducted at Agricultural Research Station of Ardebil, Iran, in 2004. Water deficit treatments included no-stress (full irrigation), water withholding after anthesis and severe water deficit stress (no irrigation), substituted in main plots, and barley genotypes, LB-Iran, N-81-7 and N-81-14, were placed in sub-plots. With increase in water deficit severity, the amount of dry matter remobilization from various organs of plant to grain was increased. The contribution of dry matter remobilization in severe stress and water deficit sress after anthesis was 82.5 and 36.5 percent relative to full irrigation treatment. This result showed that water deficit stress had a direct effect on reduction of the grain yield. The LB-Iran genotype in all of three water deficit stresses had higher value than other genotypes, although the grain yield of this genotype under water stress condition was 60 percent lower than under full irrigation condition.

Key words: Barley grain filling, remobilization, water deficit.

Introduction

Before grain filling the amounts of photosynthetic products are greater than plant growth demands. Therefore, these substances can be stored in organs called secondary sources. Depending on environmental conditions, a portion of these materials redistributes to developing grains, so-called sinks. In other words, the process of redistribution of these stored substances from transient sources to sinks is called remobilization [7]. The amount of dry matter accumulation in secondary sources depends on cultivar and environmental conditions and varies from 58 to 48 percent in favorable and unfavorable conditions respectively. A major portion of dry matter accumulation is occurred before anthesis. The contribution of pre-anthesis photo-assimilates in grain weight varies from 4 to 24.2 percent [11], whereas the contribution of photosynthetic substances redistributed from shoot in grain weight is 6-75%. This value reaches to 100 percent in severe stress condition [1-4, 6, 8-11], and the reasonable factor in yield loss of some spring cultivars of barley is consumption of major portion of pre-anthesis photo-assimilates in organs other than grain during anthesis and maturing stage [12]. If the adapted cultivar in short growth season region completes the vegetative growth before anthesis, it is able to do more effective dry matter redistribution to grain in stress conditions. Otherwise photo-assimilates produced during grain filling play the major role in grain weight. Water deficit stress after anthesis reduces photo-assimilates, so the grain yield is closely related to water availability and redistribution capacity of cultivar during the grain filling period [15]. The difference between leaves for dry matter remobilization capabilities and redistribution rate of photo-assimilates in second leaf is significantly lower than in flag leaf [16]. In a greenhouse study, water deficit stress reduced the grain filling period in barley and hence decreased the grain yield [14]. The aim of our study was to investigate the effects of water deficit stress on dry matter remobilization and grain filling trend in a field trial on barley.

Material and Methods

This experiment was conducted at Agricultural Research Station of Ardebil in 2004. The experiment was carried out in split-plot on Randomized Complete Block (RCB) with three replications. The water deficit stress levels included full irrigation, water withholding after anthesis and severe water deficit stress placed in main plots. Barley genotypes, LB-Iran, N-81-7 and N-81-14, were substituted in sub-plots. The trial was carried out in a field and the traditional agronomic practices were done.

In order to measure the photosynthetic substances remobilization at each plot, 20 plants were selected randomly at anthesis and maturity. Then the leaves and stems were removed from samples. In both sampling phases for obtaining the stable dry matter weight, the samples were placed in an oven at 70-72°C. The dry matter remobilization before anthesis can be evaluated based on dry matter remobilization (DMT t ha^{-1}) and the contribution of photosynthates in grain before anthesis:

$$DMT = \frac{TDM_{anthesis} - \left(TDM_{maturity} - Seedweight\right)}{\left(TDM_{maturity} - Seedweight\right)} \times 100$$

To measure the grain filling trend and rate during grain filling period, sampling was done with 3-4 day intervals during reproductive phase. Then spikes were dried in oven in temperature between 72 and 75°C. The dried barley grains were separated from other spike parts. For obtain the best regression model based on accumulated growth degree-days, 100 grains from each sample were selected randomly. Data were subjected to analysis of variance by SAS software and means were separated by multiple Duncan test. Figures were drawn by Excel software.

Results and Discussion

Water deficit stress had significant effects on dry matter remobilization from leaves, shoot, peduncle and stem. With increasing water deficit stress, genotypes showed significant difference for dry matter remobilization from peduncle and stem. Dry matter remobilization from shoot to grain had higher value (82.5%) under severe water stress than in other treatments with water deficit stress after anthesis (36%). Before anthesis the amount of photosynthetic substances is greater than plant demand, therefore additional photo-assimilates accumulate in shoot and eventually these assimilates are stored in secondary sources, such as stem, peduncle and leaves. These stored assimilates can be used during grain filling period for economical yield. The occurrence of environmental stresses such as drought, especially during grain filling, decreases the photosynthesis, and the importance of secondary sources in grain filling are more pronounced. In general, each factor which limits the photosynthesis after anthesis, especially during grain filling, can be effective on remobilization from secondary sources.

With increase in water deficit stress, the allocation of dry matter from peduncle to grain is also increased (Table 1). The interaction of water deficit stress and genotype on dry matter allocation from leaves, stem and shoot were significant (Fig. 1). In respect to source-sink relationship for dry matter allocation, mainly the closest source plays important role. Peduncle serves as close source for grain, therefore when the environmental stress is occurred, the dry matter of peduncle can be translocated to grain easily. The significant difference between genotype for dry matter remobilization from peduncle implies on physiological and morphological differences of them for dry matter accumulation and remobilization of these assimilates to grain (Table 1). Also

Table1. Effect of water deficit treatments on remobilization of dry matter from several shoot organs (mg per plant).

		Means of remobilization from shoot organs			
	Treatment	Peduncle	Leaf	Shoot	Total
Water deficit severity	No-stress	78.89 b	244.44 b	333.33 b	656.67 b
	Severe water deficit	115.56 a	314.44 a	456.11 a	886.11 a
	Water deficit after anthesis	65.56 b	318.89 a	393.33 ab	777.78 ab
Genotype	LB-Iran	66.67 b	310.00 a	475.00 a	851.67 a
	N-81-7	97.78 a	275.56 a	332.22 b	705.56 b
	N-81-14	95.56 a	292.220 a	375.56 b	763.33 ab

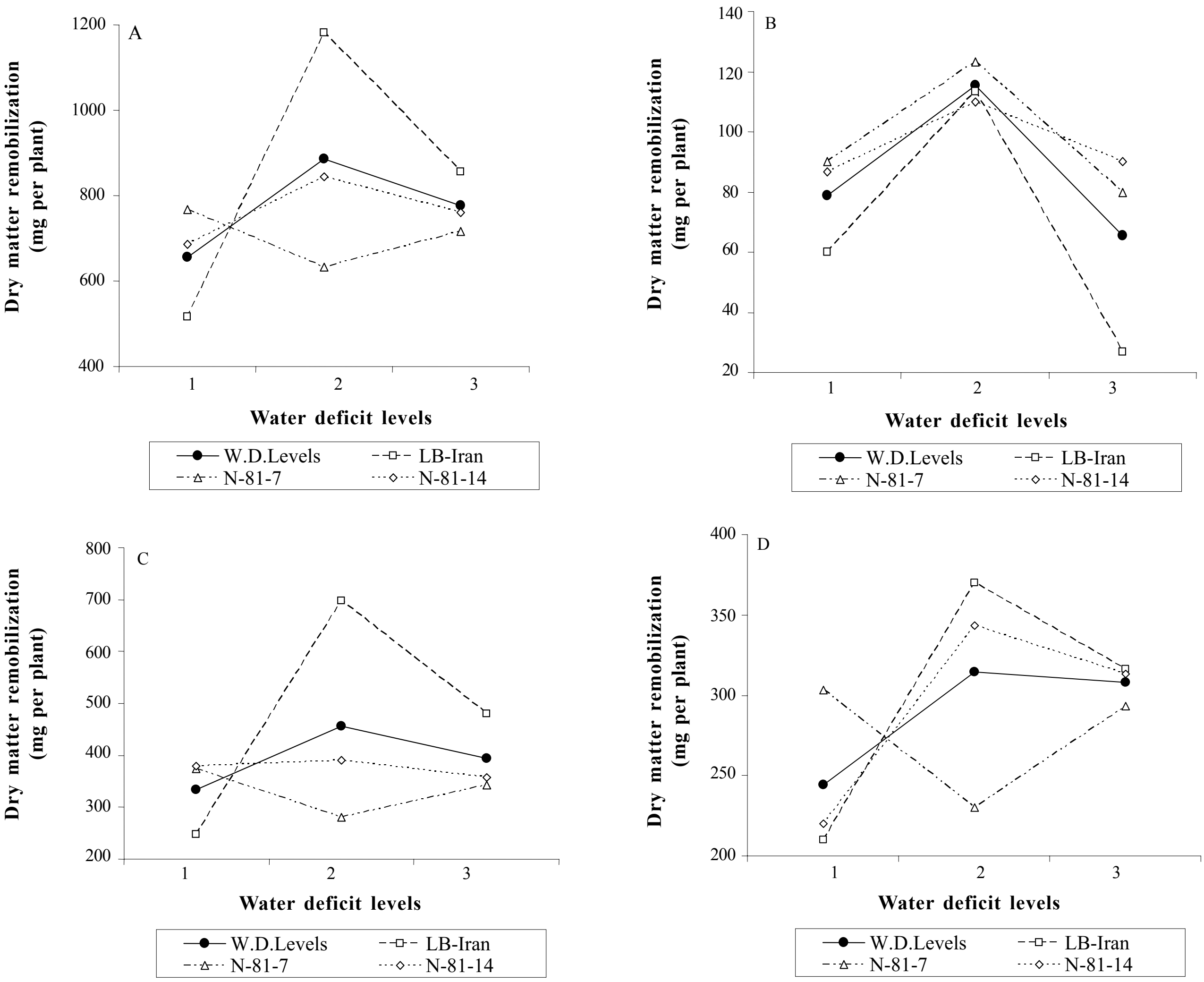

Figure 1. Interaction between drought intensities and barley genotype in dry matter remobilization from total (a), peduncle (b), stem (c) and leaves (d).

other researchers reported that peduncle before internode and leaf sheath are the major reserves for dry matter accumulation and redistribution to grain [5]. Genotypes N-81-7 and N-81-14 in respect to dry matter remobilization from peduncle to grain obtained higher value (Table 1).

Increase in water deficit stress enhanced the amount of dry matter remobilization from leaves to grain, and the difference between severe deficit stress and water deficit stress after anthesis were not significant, but remobilization of dry matter in these treatments was significantly higher than in non-stressed treatment (Table 1). The contribution of remobilization from leaves in grain yield was 29 and 14 percent for severe stress and withholding water after anthesis respectively (Table 1). Although leaves are the main organ for CO_2 absorption and photosynthesis process, in some cases they serve as transient sources for dry matter accumulation. These substances can be remobilized to grain during filling period. The promotion of leaves senescence after anthesis increases the importance of dry matter remobilization in grain filling stage.

Dry matter redistribution from stem increased with increase in water stress severity (Table 1). The highest amount of remobilization obtained from severe stress (42.5%) was followed by withholding water after anthesis (18.4%), whereas this value for non-stressed treatment was low (13.4%). The genotypes showed significant difference for dry matter remobilization from stem, LB-Iran had the highest value, followed by N-81-14 and N-81-7 respectively (Table 1).

The time of arresting of dry matter accumulation or obtaining maximum stem dry weight depends on genotype and environmental condition. Hence water deficit stress caused the translocation of carbon from tillers to main spike at grain filling period, so the relative contribution of stem dry matter remobilization to final grain weight varies from 6 to 100 percent based on genotypes and environmental conditions [2, 3, 5, 8-11]. The results obtained from current investigation for remobilization of photo-assimilates stored in secondary sources before anthesis to grain is consistent with findings of other researchers [15]. The grain filling trend in all water deficit treatments followed a sigmoidal model which includes three stages (lag, linear and maturity) (Fig. 2). Water stress promotes the maturity of barley grain and reduces the grain filling period in comparison to no-stress condition [14]. In general, we concluded that the occurrence of environmental stress such as water deficit in grain filling period causes the increase of grain filling rate and whereas reduces the grain filling period, which

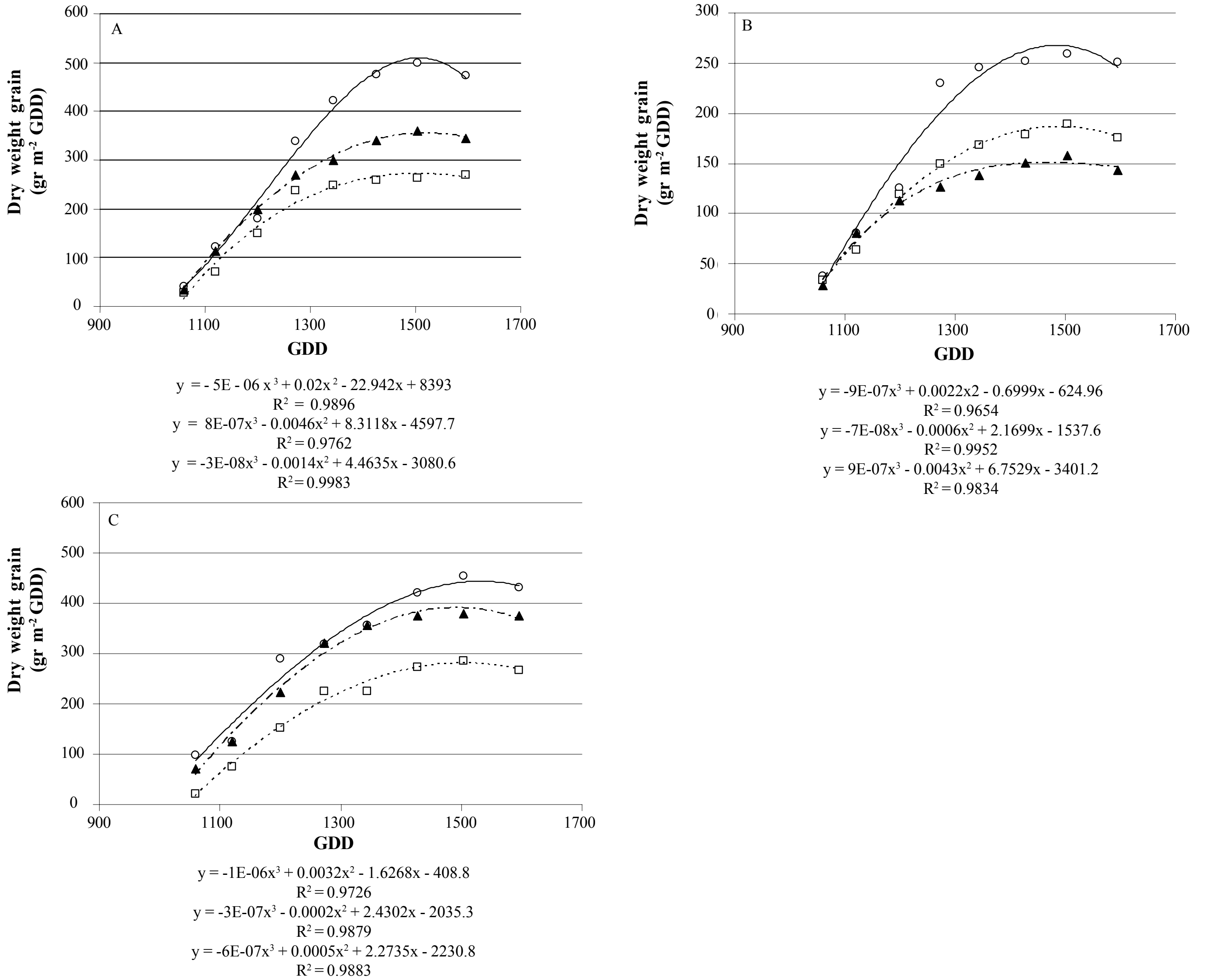

Figure 2. Dry matter accumulation trend in barley genotypes in three water deficit stress: No stress (a), severe stress (b) and water deficit after anthesis (c).

led to decrease in the final grain yield, while in no-stress condition the higher yields were obtained because of increases in grain filling period and grain filling rate.

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