Effect of different levels of water deficit on yield and amount of osmotic regulator in tetraploid and hexaploid wheat genotypes

Farshad Sorkhi[1*], Saeid Khomari[2]

(1. Department of Agronomy and Plant Breeding, Miandoab Branch, Islamic Azad University, Miandoab, Iran. Post Box: 433
2. Department of Agronomy and Plant Breeding, University of Mohaghegh Ardabili, Ardabil, Iran. Postal Code: 56199-13131)

Abstract: For study the effect of water deficit stress on yield and osmotic regulator of tetraploid and hexaploid wheat genotypes, an experiment was carried out at the Research Station of Islamic Azad University of Miandoab in 2015. The soil texture of experimental site was sandy loam. The research field was located in a semi-arid region. This experiment was conducted as factorial based on a completely randomized block design with three replications. Water deficit levels were A: control (normal condition), B: no irrigation of fertilization stage, C: no irrigation of the grain filling stage. Studied genotypes were hexaploid of bread wheat 'Sabalan' and 'Zarrin' and tetraploid of durum wheat 'Syrian-4' and 'Zardak'. Plant density was 400 plants m^{-2}. In the present experiment data showed that under severe water deficit (non-irrigated stage of pollination) situations, the highest and the lowest grain yield belonged to tetraploid genotype of durum wheat 'Zardak' and hexaploid genotype of bread wheat 'Zarrin'. Under severe water deficit conditions, the highest decrease in grain yield as well as concomitant increase in proline content was seen in bread wheat of 'Sabalan' and 'Zarrin'. However, the highest amount of grain yield and proline content were observed in durum wheat of 'Syrian-4' and 'Zardak'. In total, water deficit had adverse effects on yield of wheat genotypes had negligible potential to compensate the deteriorating effects of water deficit condition and these condition tetraploid durum wheat for the cultivation and production of superior hexaploid wheat bread.

Keywords: grain yield, osmotic regulator, water stress, wheat genotypes

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1 Introduction

Biotic and abiotic stresses are of the main problems of agricultural systems (Zarei et al., 2007; Zhang et al., 2008). Water stress is one of the most important abiotic stresses adversely affects crop production in many regions of the world (Gupta et al., 2001; Secenji et al., 2005). In most cereal crops under-grown in water deficiency conditions, water deficit affects approximately one-third of the yield potential of plants (Blum, 2005). The main reason for a crossover under conditions of variable water supply is an inherent difference between the tested cultivars in drought resistance, beyond differences in their yield potential (Shangguan et al., 2000; Farshadfar et al., 2002). This was also observed in international wheat variety trials where stress environments often were represented by mean yield of 4-5 t ha^{-1} as compared with a maximum yield of 8 t ha^{-1} in common wheat production areas (Blum, 2005; Secenj et al., 2005). A study on the effects of water stress on wheat bread and durum wheat bread was observed that the effects of stress on more than Durum wheat (Gupta et al., 2001).

Osmotic adjustment is a common physiological response of plants to most stress conditions where it is regulated by the accumulation of free amino acids, proline and sugars in the roots and shoots of stress affected plants. Proline accumulation is a widespread

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***Corresponding author: Farshad Sorkhi,** Department of Agronomy and Plant Breeding, Miandoab Branch, Islamic Azad University. Email: farsorkh@gmail.com.

plant response to environmental stresses such as low water availability. Proline has a unique role as an osmoticum under abiotic mainly water deficit conditions. In particular, because of its zwitterionic status and high hydrophilic characteristics, proline acts as a “compatible solute”, i.e. one that can accumulate to high concentrations in the cell cytoplasm without interfering with cellular structure and/or metabolism (Samaras et al., 1995; Rauf et al., 2007). It was reported that osmotic power setting and increase the osmotic regulated substance in tetraploid durum wheat more than hexaploid bread wheat (Heuer, 1999; Kuznetsov and Shevyakova, 1999).

There is presently no clear agreement about the function of drought-induced proline accumulation, although a role in osmo-regulation seems likely (Samaras et al., 1995). Other functions of proline accumulation have also been proposed, including stabilization of macromolecules, a sink of carbon and nitrogen for use after relief of drought stress conditions (Secenji et al., 2005), radical detoxification (Smirnoff and Cumbes, 1989). The aim of the present study, effects of water deficit on yield and osmotic regulator of tetraploid and hexaploid wheat genotypes.

2 Material and methods

In the study, the effect of water deficit stress on yield and osmotic regulator of tetraploid and hexaploid wheat genotypes an experiment was carried out at the Research Station of Islamic Azad University of Miandoab in 2015. The soil texture of experimental site was sandy loam (Table 1).

Table 1 Soil properties (0-30 cm) before plant sowing

Soil Texture	Silt (%)	Clay (%)	Sand (%)	Total N (%)	K (mg kg^{-1})	P (mg kg^{-1})	OC (%)	EC (ds m^{-1})	pH
Sandy loam	31.5	47.9	20.6	0.08	357.23	12.68	0.79	1.36	7.21

The research field was located in a semiarid region. This experiment was conducted as factorial based on a completely randomized block design with three replications. Water deficit levels were A: control (normal condition), B:_no irrigation of fertilization stage, C: no irrigation of the grain filling stage. Studied genotypes were hexaploid of bread wheat ‘Sabalan’ and ‘Zarrin’ and tetraploid of durum wheat ‘Syrian-4’ and ‘Zardak’. Plant density was 400 plants m^{-2}. Wheat genotypes were supplied from the Center of Agricultural Services, Tabriz city, East Azarbaijan Province, Iran.

2.1 Grain yield

After threshing, each spike was separated from the seeds and the weight of seeds was calculated based on kg ha^{-1}.

2.2 Proline content

Free proline accumulation was determined by using the method of (Bates et al., 1973). 0.5 g dry weight of root crown, flag leaf and flag leaf internode were homogenized with 3% sulfosalicylic acid for 72 h. Thereafter, the homogenate was centrifuged at 3000 g for 20 min. The supernatant was treated with acetic acid and ninhydrin, and boiled for one hour. Then the absorbance was read at 520 nm by a spectrophotometer (Biochrom S 2100). Content of proline was expressed as mg g^{-1} DW of plant material.

2.3 Statistical analysis

Statistical analysis of the collected data was carried out using MSTATC software and the means were compared by Duncan's multiple range test at $p \leq 0.05$.

3 Results and discussion

3.1 Grain yield

The results showed that the effect of water deficit levels was significant at the 1% and the effects of genotype and interaction genotype with water deficit levels were significant at the 5% level (Table 2). Average grain yield in hexaploid bread wheat genotypes was greater than tetraploid durum wheat genotypes (Table 3). Average grain yield of genotypes was significantly higher in the control relative to the other levels of water deficit (Table 4). Investigate the interactions between genotype with drought levels that with increasing severity of water deficit significantly decreased seed yield and the lowest grain yield in tetraploid and hexaploid obtained the treatment of non-irrigated the stage of pollination (Table 5). The highest grain yield in the control treatment obtained in hexaploid bread wheat genotypes, especially genotype 'Sabalan' with the 4981.37 kg ha^{-1} and the highest grain yield in the treatment of non-irrigated stage of pollination in tetraploid durum wheat genotypes especially 'Zardak' genotype of 1943.02 kg ha^{-1} (Table 5).

Table 2 Mean square analysis variance of traits

SV	df	Grain yield (kg ha^{-1})	Proline content (mg g^{-1} DW)
Rpeat	2	1417.08 ^{ns}	2.45 ^{ns}
Water deficit	2	38393.15**	8.79**
Genotypes	3	20498.31*	6.60*
Genotypes * Water deficit	6	24683.66*	5.01 *
Error	22	6591.09	1.41
C.V (%)		11.16	6.72

Note: ns, * and ** : non-significant, significant at 5% and 1% respectively.

Table 3 Effect of cultivar on traits

Genotypes	Grain yield (kg ha^{-1})	Proline content (mg g^{-1} DW)
Sabalan	3120.24 a	2.945 b
Zarrin	2942.29 b	2.539 b
Syrian-4	2787.09 c	4.217 a
Zardak	2640.31 c	4.874 a

Note: Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Duncan.

Table 4 Effect of Water deficit on traits

	Treatment	Grain yield (kg ha-1)	Proline content (mg g-1 DW)
Water deficit	Control (normal condition)	4272.73 a	0.450 c
	no irrigattion of grain filling stage	2666.69 b	3.313 b
	no irrigattion of fertilization stage	1677.97 c	7.168 a

Note: Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Duncan.

Table 5 Interaction effect of cultivar and Water deficit in traits

Water deficit	Genotypes	Grain yield (kg ha^{-1})	Proline content (mg g^{-1} DW)
Control (normal condition)	Sabalan	4981.37 a	0.413 g
	Zarrin	4607.16 b	0.405 g
	Syrian-4	3981.57 c	0.445 g
	Zardak	3521.06 d	0.538 g
no irrigattion of grain filling stage	Sabalan	2871.53 e	2.785 f
	Zarrin	2795.13 e	2.157 f
	Syrian-4	2543.25 f	4.015 e
	Zardak	2456.87 f	4.295 e
no irrigattion of fertilization stage	Sabalan	1507.82 h	5.637 e
	Zarrin	1424.60 h	5.055 d
	Syrian-4	1836.46 g	8.191 b
	Zardak	1943.02 g	9.790 a

Note: Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Duncan.

It seems that under suitable circumstances regarding water use efficiency, bread wheat was more suitable ones with a higher seed yield compared to durum wheat. However, under water deficit conditions, water use efficiency and grain yield of durum wheat was more than bread wheat. Meanwhile, between two genotypes of bread wheat, 'Zarrin' was more sensible than 'Sabalan' to the water deficit. Between durum wheat, 'Zardak' was resistant. Agarwal and Sinha (1984) reported the negative effects of drought on the seed yield of different wheat genotypes. Some factors such as climate and management practices such as crop rotation, drainage and watering are of main significance in response of field crops (Fathi et al., 1997).

3.2 Proline content

Results indicated that the effect of drought levels was significant at the 1% and the effects of genotype and interaction genotype with water deficit levels were significant at the 5% level (Table 2). Average proline content in tetraploid durum wheat genotypes was greater than hexaploid bread wheat genotypes and between hexaploid genotypes of bread and between tetraploid genotypes of durum was found no significant difference (Table 3). The average proline content of genotypes was significantly lower in the control relative to the other levels of water deficit (Table 4). Study effects of the interactions between genotype with water deficit levels showed that with increasing severity of water deficit significantly increased proline content and the highest proline content in genotypes obtained the treatment of non-irrigated the stage of pollination (Table 5). The highest proline content in treatments of control and non-irrigated stage of pollination observed in tetraploid durum wheat genotypes especially 'Zardak' with 0.538 and 5.637 respectively (Table 5).

High levels of proline could be related to osmotic regulation and furthermore, it can be a source of carbon and nitrogen available to use after stress alleviation (Ramond and Smirnoff, 2002). High proline content under drought conditions in Durum cultivars, especially Durum 'Zardak' compared with bread wheat indicates the high capacity of durum wheat in osmotic regulation and keeping the slope of water potential and at last more resistance to the water deficit. Kuznetsov and Shevyakova (1999) have been pointed out the role of proline in the adaptation of plants to the stress conditions due to its diverse biological effects such as osmotic regulation, antioxidant action, energy transfer and, carbon and nitrogen source. Usually, the amount of proline in plants under normal growing conditions is very low (0.2 to 0.6 mg g^{-1} dry weight). The absolute amount of this compound beyond drought stress may be up to 50 mg g^{-1} dry weight based on severity of water deficit severity and plant type (Rajinder, 1987). Although proline accumulates in any organ of plants, its major accumulation occurs in leaves (Heuer, 1999). Increased proline accumulation acts as an osmotic for lessening of osmotic potential and increases water availability for many of fundamental biochemical pathways ongoing in plants and hence induces drought resistance (Ramond and Smirnoff, 2002).

4 Conclusion

In the present experiment data showed that under severe water deficit (non-irrigated stage of pollination) situations, the highest and the lowest grain yield belonged to tetraploid genotype of durum wheat 'Zardak' and hexaploid genotype of bread wheat 'Zarrin'. Under severe water deficit conditions, the highest decrease in grain yield as well as concomitant increase in proline content was seen in bread wheat of 'Sabalan' and 'Zarrin'. However, the highest amount of grain yield and proline content were observed in Durum wheat of 'Syrian-4' and 'Zardak'.

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