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Effect of drought stress on yield and osmotic regulator of tetraploid and hexaploid wheat genotypes

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Abstract

For Study the effect of drought stress on yield and osmotic regulator of tetraploid and hexaploid wheat genotypes an experiment was carried out at Research Station of Islamic azad university of Miandoab in 2012. The soil texture of experimental site was sandy clay loam. The research field was located in a semi-arid region. This experiment was conducted as factorial based on completely randomized block design with three replications. Drought levels were A: control (normal condition), B: no irrigattion of fertilization stage, C: no irrigattion of grain filling stage. Studied genotypes were hexaploid of bread wheat 'Sabalan' and 'Zarrin' and tetraploid of durum wheat 'PGS 01-60-335' and 'IDW 01-61-130'. Plant density was 400 plants m^{-2}. In the present experiment data showed that under severe drought stress (non-irrigated stage of pollination) situations, the highest and the lowest grain yield belonged to tetraploid genotype of durum wheat 'IDW 01-61-130' and hexaploid genotype of bread wheat 'Zarrin'. Under severe drought conditions, the highest decrease in grain yield as well as concomitant increase in proline content were seen in bread wheat of 'Sabalan' and 'Zarrin'. However, the highest amount of grain yield and proline content were observed in Durum wheat of 'PGS 01-60-335' and 'IDW 01-61-130'. In total, drought stress had adverse effects on yield of wheat genotypes had negligible potential to compensate the deteriorative effects of drought condition and these condition tetraploid durum wheat for the cultivation and production of superior hexaploid wheat bread.

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Introduction

Biotic and abiotic stresses are of 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; Secenj *et al*, 2005). In most cereal crops under-grown in water deficiency conditions, drought stress affects approximately one-third of the yield potential of plants (Blum, 2005). The main reason for a cross-over under conditions of variable water supply is an inherent difference among the tested cultivars in drought resistance, beyond difference 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 as compared with a maximum yield of 8 t/ha 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 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 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 water deficit conditions (Sminrnoff and Stewart, 1985; Secenji *et al*, 2005), radical detoxification (Smirnoff and Cumbes, 1989) and regulation of cellular redux status (Hare and Cress, 1997). The aim of the present study, effects of drought stress on yield and osmotic regulator of tetraploid and hexaploid wheat genotypes**.**

Material and methods

In the study, the effect of drought stress on yield and osmotic regulator of tetraploid and hexaploid wheat genotypes an experiment was carried out at Research Station of Islamic azad university of Miandoab in 2013. The soil texture of experimental site was sandy clay loam. The research field was located in a semi-arid region. This experiment was conducted as factorial based on completely randomized block design with three replications. Drought stress levels were A: control (normal condition), B: no irrigattion of fertilization stage, C) no irrigattion of grain filling stage. Studied genotypes were hexaploid of bread wheat 'Sabalan' and 'Zarrin' and tetraploid of durum wheat 'PGS 01-60-335' and 'IDW 01-61-130'. Plant density was 400 plants m^{-2}.

Grain yield

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

Proline content

Free proline accumulation was determined by using Bates *et al* method (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.

Statistical analysis

The mean values of grain yield and proline content were taken from the measurements of three replicates and the "standard error" of the means was calculated. One-way ANOVA was applied to determine the significance of the results among different treatments and then least significant differences ($LSD_{5\%}$) were evaluated. All the statistical analyses were done using the Statistical Package for Social Sciences (SPSS) for windows (version 13) and MSTATC softwares.

Results and discussin

grain yield

The results showed that the effect of drought stress levels was significant at the 1% and the effects of genotype and interaction genotype with drought levels were significant at the 5% level (Tab 1). Average grain yield in hexaploid bread wheat genotypes were greater than tetraploid durum wheat genotypes (Tab 2). Average grain yield of genotypes were significantly higher in the control relative to the other levels of drought stress (Tab 3). Investigate the interactions between genotype with drought levels that with increasing severity of drought stress significantly decreased seed yield and the lowest grain yield in tetraploid and hexaploid obtained the treatment of non-irrigated the stage of pollination (Tab 4). 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 treatment of non-irrigated stage of pollination in tetraploid durum wheat genotypes especially 'IDW 01-61-130' genotype of 1943.02 kg ha^{-1} (Tab 4).

Table 1. 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}
drought stress	2	38393.15**	8.79**
Genotypes	3	20498.31*	6.60*
genotypes * drought stress	6	24683.66*	5.01*
error	22	6591.09	1.41
cv(%)		11.16	6.72

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

Table 2. 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
PGS 01- 60-335	2787.09 c	4.217 a
IDW 01- 61-130	2640.31 c	4.874 a

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 higher seed yield compared to durum wheat. However, under drought stress 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 drought stress. Between durum wheat, Durum 'IDW 01-61-130' was resistant. Agarwal and Sinha (1984) reported the negative effects of drought on the seed yield of different wheat genotypes. In their research any decreases in seed yield was closely related to water deficiency about 10-69 days before pollination. Recorded decrease was

37-86% compared to the control treatment. Demir and haw (1990) pointed out that, water stress encountered in pollination stage of corn plant decreased the seed yield up to 50 percent. 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).

Table 3. Effect of drought stress on traits.

	Treatment	Grain yield (kg ha^{-1})	Proline content (mg g^{-1} DW)
drought stress	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

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

Proline content

Results indicated that the effect of drought levels was significant at the 1% and the effects of genotype and interaction genotype with drought levels were significant at the 5% level (Tab 1). Average proline content in tetraploid durum wheat genotypes were greater than hexaploid bread wheat genotypes and between hexaploid genotypes of bread and between tetraploid genotypes of durum was found non significant difference (Tab 2). Average proline content of genotypes were significantly lower in the control relative to the other levels of drought stress (Tab 3). Study effects of the interactions between genotype with drought levels showed that with increasing severity of drought stress significantly increased proline content and the highest proline content in genotypes obtained the treatment of non-irrigated the stage of pollination (Tab 4). The highest proline content in treatments of control and non-irrigated stage of pollination observed in tetraploid durum wheat genotypes especially 'IDW 01-61-130' with 0.538 and 5.637 respectively (Tab 4).

Table 4. Iinteraction effect of cultivar and drought stress on traits.

drought stress	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
	PGS 01- 60-335	3981.57 c	0.445 g
	IDW 01- 61-130	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
	PGS 01- 60-335	2543.25 f	4.015 e
	IDW 01- 61-130	2456.87 f	4.295 e
	Sabalan	1507.82 h	5.637 e
no irrigattion of fertilization stage	Zarrin	1424.60 h	5.055 d
	PGS 01- 60-335	1836.46 g	8.191 b
	IDW 01- 61-130	1943.02 g	9.790 a

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

High levels of proline could be related to osmosis regulation and furthermore it can be a source of carbon and nitrogen available to use after stress alleviation. As mentioned above, proline content was affected by watering levels. High proline content under drought conditions in Durum cultivars especially Durum IDW 01-61-130 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 drought stress. Kuznetsov and Shevyakova (1999) have been pointed out the role of proline in adaptation of plants to the stress conditions due to its diverse biological effects such as osmosis 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 dry weight). The absolute amount of this compound beyond drought stress may be up to 50 mg/g 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 osmoticum 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).

Conclusion

In the present experiment data showed that under severe drought stress (non-irrigated stage of pollination) situations, the highest and the lowest grain yield belonged to tetraploid genotype of durum wheat 'IDW 01-61-130' and hexaploid genotype of bread wheat 'Zarrin'. Under severe drought stress conditions, the highest decrease in grain yield as well as concomitant increase in proline content were seen in bread wheat of 'Sabalan' and 'Zarrin'. However, the highest amount of grain yield and proline content were observed in Durum wheat of 'PGS 01-60-335' and 'IDW 01-61-130'.

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