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Effect of terminal drought stress on the germination and growth potential wheat cultivars seeds

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Abstract

In order to study the germination and growth potentials of seeds of bread wheat cultivars produced under terminal drought stress condition, seeds for five cultivars namely Sabalan, Rasad, Azar-2, Sardari and Zaare' produced both under terminal drought stress and normal irrigation conditions were subjected to a factorial experiment in the form of Randomized Complete Blocks (RCB) design with three replications. The first factor of the experiment included the type of seed production (rainfed and irrigated), the second factor included drought condition using Polyethylene Glycol 6000 (0^{mp}, -3^{mp}, -6^{mp} levels), whereas the third factor included cultivars. In addition, traits such as germination within 10 days (using Al-Mudaris method, 1998), germination after 10 days, wet weight and germination percentage were measured during the experiment. Furthermore, during in vitro germination experiment indices such as coefficient of velocity of germination (CVG), germination rate index (GRI), final germination percentage (FGP), germination index (GI), mean germination time (MGT), germination stress index (GSI) and seedling traits were measured. Samples subjected to -6^{mp} level of drought stress ceased growth at germination stage, while the remaining samples grew into stem stage. Results from the experiment showed that stress applied by polyethylene glycol 6000 had impact on traits such as coleoptile length, shoot length, shoot weight, germination percentage and germination rate index at 1% probability level. Likewise, types of seed production had impact on germination percentage, GRI, GI, and GSI. Finally, all the cultivars differed for the abovementioned traits except for shoot weight and GSI.

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Introduction

Wheat fields in arid and semiarid regions invariably encounter drought stress during germination, vegetation as well as terminal growth stages in rainfed agriculture. For such regions, it is highly important to select cultivars that are both drought tolerant during germination and vegetation stages and produce high yield (Saeidi *et al.*, 2007).

In Iran, seeds for rainfed regions are produced in irrigated fields, since seeds produced in this way are characterized with high vigor, which ensure their desired quality at the time of plantation under normal condition. However, as the most important challenge favorable weather condition dictates the time of plantation in rainfed cultivation, as it totally relies on rainfall. More specifically, unstable weather conditions combined with late plantation will lead to decreased germination and consequently to decreased final yield (Espigares and Peco, 1993; McArtour and Rongdier, 1996; McCreary, 1998). It appears that terminal drought stress may prove beneficial in seed production for rainfed regions, since any decrease in the yield as a result of terminal drought stress is more than compensated for by the accumulation of some drought related substances in the seed. Thus, this experiment focuses on germination and early growth of these seeds under drought stress condition as compared by seeds produced under normal condition. It is known that impact of drought on plant growth depends upon the intensity and time of stress, not to mention upon the growth stage at which it occurs. Germination stage is one of the most sensitive stages at which drought stress can occur; consequently improvement in traits associated with germination is one of the most important breeding goals in regions where plant establishment is challenged by drought stress (Blam *et al.*, 1980; Rauf *et al.*, 2007; Bayomi *et al.*, 2008). Fortunately, various quantitative indices have been proposed for selection of genotypes with respect to their yields under stressed and without stress conditions (Jiang *et al.*, 2007; Farshadfar *et al.*, 2008).

Germination of seed in polyethylene glycol, measurement of root length and stem growth in various smoticom are experimental techniques in measuring physiological traits, which can be used in various osmotic solutions as well as in decreasing stress in plant tissues. These techniques can also be used to select genotypes tolerant against drought (Emmerich and Hardegree, 1990; Kocheva *et al.*, 2004; Farshadfar *et al.*, 2002).

The objective of this study on effect of terminal drought stress on quality of the produced seed (germination indices of bread wheat) and Study on germination percentage of seeds obtained from previous crop (normal and rainfed conditions).

Materials and methods

Study area

The study was conducted in Agronomical Research Station of Jahad-e Keshavarzi organization of Ardabil Province and in Biotechnical Lab of Islamic Azad University, Ardabil branch, during 2012-2013 years. In order to study germination and growth potentials of seeds for bread wheat cultivars produced in fields under terminal drought stress condition by using genetic method, in the first year of the experiment seeds for five bread wheat cultivars namely Sabalan, Rasad, Azar2, Sardari and Zaare' were sown in the form of CRB design, with three replications, under terminal drought stress and normally irrigated conditions. During the second year, seeds from the first year of the experiment were subjected to an in vitro factorial experiment in the form of CRB design with three replications; while the first factor included the type of seed production (diem and irrigated), the second factor included drought condition applied by using Polyethylene Glycol 6000 (-6^{mp}, -3^{mp}, 0^{mp} levels), whereas the third factor included the cultivars. Prior to in vitro plantation of the seeds, as many as 25 seeds were selected for each cultivar and disinfected for 10 minutes in sodium hypochlorite 5% solution diluted with distilled water with a ratio of 1 to 5. Then, they were washed three times with distilled water in order to avoid any damage from the solution to the embryo of the seeds. Seeds for each cultivar were spread between two layers of filter papers before each being put into separate already disinfected culture dishes, followed by adding 7 mL distilled water or PEG solution to each dish.

Physiological traits

After the rootlets broke out of the chloriz membrane and became about 4mm in length, they were considered as physiologically germinated seeds in this experiment. Then, the germination seeds were counted during ten days and the germination indices were calculated using Al-Mudaris method (1998).

Traits of seedlings

In order to measure the seedling traits, germinated seeds were counted in daily basis, then as many as 10 seedlings were randomly selected from each dish and traits such as shoot length, coleoptile length and shoot weight and their mean values were used as data for each plot.

Germination indices

The germination indices included coefficient of velocity of germination (CVG), germination rate index (GRI), final germination percentage (FGP), germination index (GI), mean germination time (MGT), germination stress index (GSI).

Coefficient of velocity of germination (CVG)

This index was estimated based on the number of the germinated seeds in a given day by using the following equation:

$$CVG = 100 \times \frac{\sum Ni}{\sum NiTi}$$

Ni = number of germinated seeds in a given day

Ti = number of day since the beginning of the experiment

Germination index (GI): this index was estimated based on the number of germinated seeds in a given day by using the above equation:

$$GI = (24 \times N_1) + (23 \times N_2) + \cdots + (1 \times N_{24})$$

Where, N1, N2 and ... is the number of germinated seeds in first day, second day and so forth; whereas numbers 24, 23 and ... are weights applied on number of germinated seeds in first day, second day and so forth.

Germination rate index (GRI)

This index was estimated based on percentage of seeds germinated in a given day and by using the following equation:

G2 = germination percentage in second day and so forth

G1 = germination percentage in first day

$GRI =$

Mean germination time (MGT)

This index was estimated based on number of seeds germinated in a given day and by using the following equation:

Where, Ti= number of day since the beginning of the experiment

Ni= number of seeds germinated in a given day

MGT

Final germination percentage (FGP)

This index was estimated by using the following equation:

Ng = total number of germinated seeds Nt= total number of seeds being evaluated

FG

Germination stress index (GSI)

$GSI(\%$

PI= nd2(1.00)+nd4(0.80)+nd6(0.6)+nd8(0.40)+nd10(0.20).

Nd2, nd4, nd6, nd8, nd10 represent the percentage of germinated seeds in second, fourth, sixth, eighth, and tenth days, respectively; whereas subscripts *n* and *s* for PI represent PI under stressed and without stress conditions, respectively.

Data analysis

After the simple analysis of variance and mean comparison, germination indices were used to determine drought tolerance of the cultivars cultivated under normal irrigation and drought stress conditions.

Results and discussion

Results from the experiments were subjected to analysis of variance, then mean comparison was accomplished by using Duncan method at P<0.05.

Table 1. Results of mean comparison on levels of polyethylene glycol 6000 with respect to morphological traits.

Polyethylene glycol 6000	Mean				
	gri	fgp	Wet weight of shoot(gr)	Shoot length (cm)	Coleoptile length(cm)
0MP	118.05a	82.93 a	0.17 a	16.90 a	5.19 a
-3MP	76.24 b	48.66 b	0.02 b	3.13 b	1.99 b

Different letters indicate a significant difference at P<0.05 by Duncan's test.

Coleoptile length

Results from this experiment showed that cultivars differed significantly for coleoptile length (Table 4) under drought stress applied by polyethylene glycol 6000 (P<0.01). In addition, effect of polyethylene glycol on cultivars was significant at P<0.05; which indicates variation among the cultivars as well as effect of applied drought on them.

Table 2. Results of mean comparison on types of seed production with respect to morphological traits.

Type of seed production	Mean			
	gsi	Gi	gri	fgp
Irrigated	314.46a	557.23a	86.58b	60.93b
Rainfed	217.07b	268.67b	107.70a	70.6a

Different letters indicate a significant difference at P<0.05 by Duncan's test.

Furthermore, results from mean comparison with respect to coleoptile length by using Duncan method (Table) at P<0.05 showed that the size of coleoptile was higher under 0MP than under -3MP level of polyethylene glycol; which reflects the effect of drought. In addition, under the applied drought size of the coleoptile of cultivars such as Sardari, Azar-2, Sabalan and Rasad was greater than that of Zaare' cultivar (Table 3); which appears to be due to the very nature of the cultivars, as Zaare' is produced for regions under normal irrigation. Moreover, mean comparison was not accomplished for types of seed production, as the difference was insignificant for this trait.

Table 3. Results of mean comparison on cultivars with respect to morphological traits.

Cultivar	Mean							
	Coleoptile length(cm)	Shoot length (cm)	gsi	Gi	gri	fgp	mgt	cvg
Sardari	3.86a	10.29a	292.78a	561.17a	64.99c	58B-c	6.96a	14.41c
Azar-2	4.24a	10.83a	233a	489a-b	112.27b	76a	6.55b	15.26b
Sabalan	3.81a	10.87a	268.94a	364.33a-b	119.50a-b	69.33a-b	6.50b	15.45a-b
Rasad	3.70a	10.75a	241.98a	354.50b	134.03a	74a	6.34b	15.76b
Zaare	2.34b	7.33b	292.13a	295.75b	54.93c	51.66c	6.97a	14.36c

Different letters indicate a significant difference at P<0.05 by Duncan's test.

Results of mean comparison on types of seed production and levels of drought stress with respect to coleoptile length (Diag. 1) showed that cultivars such as Sardari and Rasad, with their seeds produced under drought stress, produced longer coleoptile when grown under normal irrigation; similarly these cultivars, with their seeds produced under normal irrigation condition, produced longer coleoptile when grown under drought stress condition. Moreover, Azar-2 cultivar, with its seed produced under normal irrigation condition; and cultivars such as Sabalan and Zaare', with their seed produced under drought stress; will produce longer coleoptile under both normal and drought stressed conditions. Long coleoptile improves seedling establishment under stressed conditions, which is one of the main factors determining the final yield of the plant (Balouchi, 2010).

Table 4. Results of analysis of variance on morphological traits.

Sources of variation	Degree of freedom	Mean squares							
		Coleoptile length(cm)	Shoot length (cm)	Wet weight of shoot(gr)	Gi	gri	fgp	mgt	cvg
Polyethylene glycol 6000	1	153.952**	2846.53**	0.35**	6344.81 ns	26223.57**	17613.06**	0.22*	0.85*
Condition of seed production	1	0.667 ns	7.59 ns	0.018 ns	1249060.81**	6689.74**	1421.06*	0.008 ns	0.001ns
Cultivar	4	6.375**	27.66**	0.020ns	141802.8*	14714.52**	1333.06**	0.98**	4.77**
Polyethylene glycol × condition of seed production	1	0.795 ns	25.07**	0.04 ns	263608.8*	132.05 ns	60.0 ns	0.12 ns	0.45 ns
Polyethylene glycol × cultivar	1	2.160*	11.043*	0.02 ns	61358.23 ns	301.13 ns	213.06 ns	0.14*	0.55 ns
Condition of seed production × cultivar	4	1.153 ns	1.035 ns	0.03 ns	64629.9 ns	10304.72**	1150.4**	0.98**	4.99**
Polyethylene glycol × condition of seed production × cultivar	4	1.280 ns	8.36*	0.03 ns	37706.93 ns	417.17 ns	338.66 ns	0.017 ns	0.04 ns
Error	38	0.72	2.89	0.025	52206.357	486.71	235.27	0.05	0.24
Coefficient of variation		23.59	16.96	154.25	55.33	22.70	23.31	3.35	3.25

ns: non-significant **: significant at P=< 0.01 *: significant at P=<0.05.

Continued Table 4. Results of analysis of variance on morphological traits.

Sources of change	Degree of freedom	Mean squares gsi
Condition of seed production	1	71138.03**
Cultivar	4	4611.09ns
Condition of seed production × cultivar	4	19783.77ns
Error	18	83337.38
Coefficient of variation		108.62

ns: non-significant **: significant at P=< 0.01 *: significant at P=<0.05.

Shoot length

Results for shoot length showed (Table 4) that levels of drought applied by using polyethylene glycol 6000 as well as cultivars differed significantly for shoot length (P<0.01). Furthermore, interaction of "polyethylene glycol levels × treatment" as well as interaction of "polyethylene glycol levels × treatment × type of seed production" differed significantly for this trait at P<0.05.

Moreover, results from mean comparison by using Duncan method at 5% probability level showed that shoot length was greater under 0MP level than under -3MP level of polyethylene glycol (Table 1), which was due to drought. In addition, all the cultivars except for Zaare' produced longer shoot under drought condition (Table 3). Mean comparison was not accomplished for the types of seed production, as difference between them was insignificant.

Results from mean comparison (Diag. 2) on types of seed production and levels of drought stresses applied by polyethylene glycol with respect to this trait showed that all the cultivars except for Zaare' in order to produce longer shoot when grown under normal irrigation, their seeds must be produced under drought stress; whereas in order to produce longer shoot when grown under drought stress condition, their seeds must be produced under normal irrigation condition. Furthermore, in order for Zaare' cultivar to produce longer shoot under both normal irrigation and drought stress conditions, its seed must be produced under normal irrigation condition.

Table 5. Simple correlation between the morphological traits.

	Coleoptile length(cm)	Shoot length (cm)	Wet weight of shoot(gr)	Gi	gri	fgp	mgt	cvg
Coleoptile length(cm)	1							
Shoot length (cm)	0.919**	1						
Wet weight of shoot(gr)	0.441**	0.470**	1					
Gi	0.065	-0.025 ns	-0.050 ns	1				
gri	-0.034	0.047 ns	0.048 ns	-0.995**	1			
fgp	0.723**	0.707**	0.325*	0.266 ns	-0.194 ns	1		
mgt	0.577**	0.513**	0.191 ns	0.704**	-0.671**	0.814**	1	
cvg	0.078	0.046	0.017 ns	-0.124 ns	0.102 ns	-0.193ns	-0.995**	1

ns: non-significant **: significant at P=< 0.01 *: significant at P=<0.05.

Prisco *et al.* (1992) believed that accumulation of dry matters in shoot tissue of tolerant cultivar increases under stressed condition; while cultivars that are capable of increasing their shoot length under stressed condition or suffer lower loss of shoot length with increased drought stress, are considered as resistant against drought at seedling stage. Interestingly, shortening of rootlet and shoot as a result of increasing drought stress has been demonstrated by other researchers on wheat, which confirms the results from this study (Bayoumi *et al.*, 2008; Rauf *et al.*, 2007).

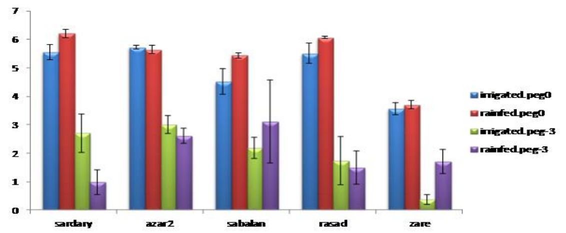

Fig. 1. Mean value and standard deviation for coleoptile length of the cultivars under seed production conditions and drought stress.

Drought stress conditions

Wet weight of shoot

Results from the experiment showed (Table 4) that levels of drought applied by using polyethylene glycol 6000 differed significantly for wet weight of shoot at P<0.01; while the other parameters did not produce any difference.

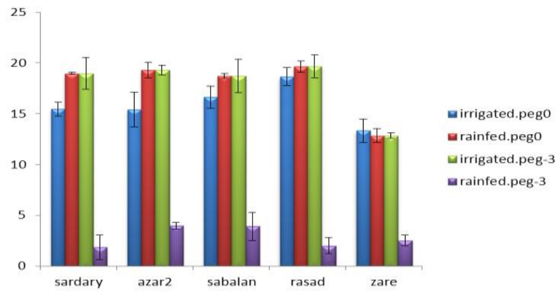

Fig. 2. Mean value and standard deviation for shoot length for the cultivars under seed production and drought stress conditions.

Results of mean comparison by using Duncan method at 5% probability level showed that due to drought, wet weight of shoot was higher under 0MP level than under -3MP level of polyethylene glycol (Table 1). Mean comparison was not accomplished for the types of seed production and treatments, as difference between them was insignificant.

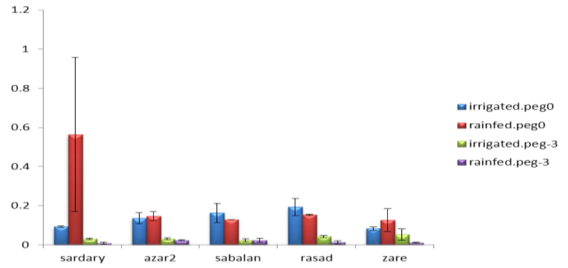

Fig. 3. Mean value and standard deviation for wet weight of shoot of cultivars under seed production and drought stress conditions.

Results of mean comparison on types of seed production and levels of drought stress with respect to this trait (Diag. 3) showed that cultivars such as Sabalan and Rasad, with their seed produced under normal irrigation condition, will produce higher wet weight of shoot under both normal and drought stress conditions. Due to the stress, cultivars such as Sardari, Azar-2 and Zaare', with their seeds produced under drought stress condition, produced higher wet weight of shoot under normal irrigation condition; which is in contrast with regions under drought stress condition.

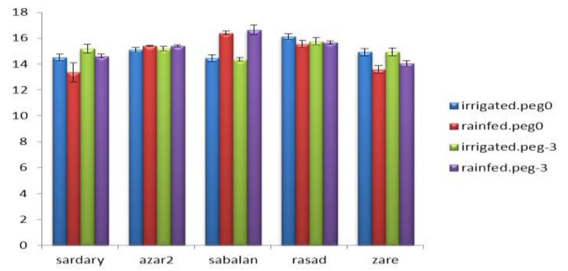

Fig. 4. Mean value and standard deviation for CVG of the cultivars under seed production and drought stress conditions.

Moreover, increased drought intensity led to decreased wet weight and increased dry weight of shoots of the cultivars; which is in line with results by Nagashiro and Shibata (1995) and Bakhshayeshi *et al.* (2011). In addition, some of the researchers argued that accumulation of dry matters in tissues of rootlet and shoot was higher in tolerant than in sensitive cultivars (Prisco *et al.*, 1992; De and Kar, 1994; Bakhshayeshi *et al.*, 2011) and the amount of dry matters accumulated in seedlings was directly and positively related with final grain yield (Turner and Nicolas, 1987; Bakhshayeshi *et al.*, 2011).

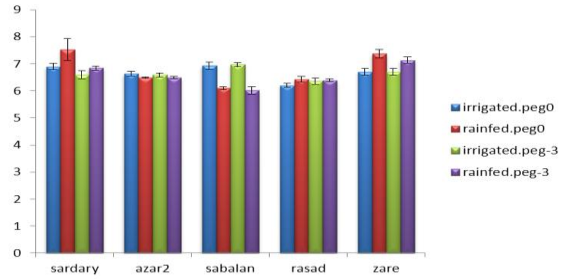

Fig. 5. mean value and standard deviation for MGT under seed production and drought stress conditions .

Coefficient of velocity of germination

Results from this study showed (Table 4) that cultivars as well as interaction of "types of seed production × cultivars" differed significantly for CVG at P<0.01; which represents variation among the cultivars and impact of type of seed production on this trait.

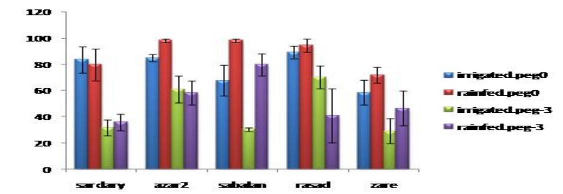

Fig. 6. Mean value and standard deviation for germination percentage of the cultivars under seed production and drought stress conditions.

Results of mean comparison by using Duncan method at 5% probability level (Table 3) shows that Sabalan cultivar is the most superior cultivar in terms of this trait and it had the highest coefficient; though, it did not differ significantly from cultivars such as Azar-2 and Rasad. Furthermore, the lowest coefficient for CVG belonged to Sardari and Zaare'. Types of seed production as well as levels of applied drought stress did not differ significantly for this trait, so that mean comparison was not accomplished for them.

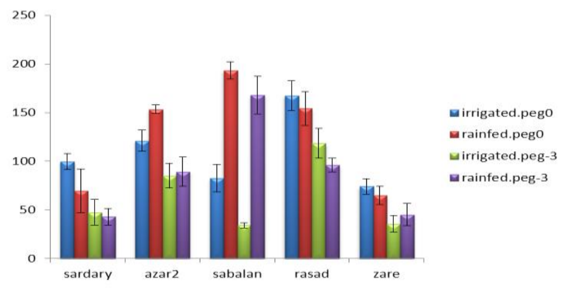

Fig. 7. Mean value and standard deviation for GRI of cultivars under seed production and drought stress conditions.

Results of mean comparison on types of seed production and levels of drought stress with respect to CVG (Table 4) shows that cultivars such as Sardari, Rasad and Zaare', with their seeds produced under normal irrigation condition, are suitable for cropping in both normal irrigation and drought stress conditions. In contrast, cultivars such as Sabalan and Azar-2, with their seed produced under drought stress condition, are suitable for cropping in both normal irrigation and drought stress conditions; curiously, this is because of accumulation of substances in the seed.

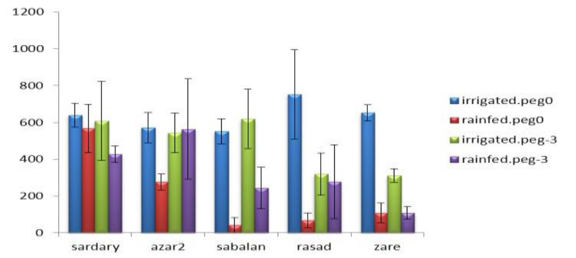

Fig. 8. Mean value and standard deviation for GI of cultivars under seed production and drought stress conditions.

Drought stresses can prove effective in decreasing germination velocity, while insufficient humidity in upper layers of the soil required for germination followed by drought stress during seedling stage are important factors that cause failure of plant to establish properly in arid regions (Paulsen, 1987), which is consistent with results reported by Nikkhah and Niloufar Taherian. CVG is one index for evaluation of drought tolerance; more specifically, cultivars with higher germination velocity under stressed condition have comparatively higher chance of greening (Pessaraki, 1996; Ashraf and Shokran, 1978). High germination velocity is among the most desirable features required for seed of crops in arid and semiarid regions (Saeidi *et al.*, 2007). In spite of high rainfall at the time of plantation, in some conditions as humidity evaporates and subsequently upper soil surface dries out, germination and greening of the plant encounter problems (Emmerich and Hardgree, 1994; Singh and Afria, 1985). This is of special importance in arid regions where high rainfall fluctuation occur either as gradual decrease in amount of rainfall or as lengthening of intervals between consecutive rainfalls (FAO, 2004).

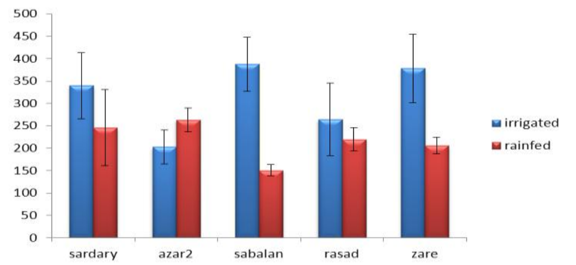

Fig. 9. Mean value and standard deviation for GSI of the cultivars under seed production and drought stress conditions.

Mean Germination Time (MGT)

Based on mean values obtained for MGT (Table 4) there was a significant difference between the cultivars and impact of type of seed production; which indicate variation among the cultivars in terms of germination time and effect of drought stress on germination time.

Based on results of mean comparison with respect to MGT by using Duncan method at $P<0.05$ (Table 3) Sardari and Zaare' were the most superior cultivars in terms of this trait, which had the highest mean value, followed by Azar-2, Sabalan and Rasad cultivars. This indicates variation among the cultivars in terms of germination time of the seeds. Furthermore, type of seed productions and their cropping under normal irrigation or stressed conditions did not have any impact on germination time.

Results of mean comparison on types of seed production and levels of drought stress with respect to this trait (Diag. 5) shows that cultivars such as

Sardari, Rasad and Zaare', with their seeds produced under terminal drought stress, are suitable for cropping under both normal irrigation and drought stress conditions.

Al-e Ebrahim (1999); Ashraf (1990); Di (1994); Jajermi (2007 and 2012); Masoumi (2008) and Akhondi (2010) reported that as the drought stress levels increases so does mean germination time.

It is known that cultivars with lower MGT are of higher germination velocity, this especially affect the accelerated establishment of plant under low humidity conditions (Irannejad and Shahbazian, 2004). With crops such as wheat, which are sown in early autumn, lower germination time may cause accelerated growth of seedling and subsequently leads to accelerated flowering of the plant, which ensures its resistant against cold during winter season (Jamshidi, 2006; Rahimian, 1999).

Final Germination Percentage (FGP)

Results from calculation of germination percentage in the experiment (Table 4) showed that levels of drought stress applied by polyethylene glycol 6000, cultivars as well as interaction of "types of seed production × cultivars" differed significantly for this trait at $P<0.01$; whereas types of seed production differed significantly for this trait at $P<0.05$. This indicates variation among the cultivars in terms of germination vigor and, impact of drought on germination. Furthermore, results of mean comparison by using Duncan method at 5% probability level (Table 1) showed that germination percentage was higher under 0MP level than under -3MP level of polyethylene glycol; while germination percentage was higher in seeds subjected to terminal drought stress during their production (Table 2). In addition, cultivars (Table 3) such as Azar-2 and Rasad had the highest mean values for this trait, though not significantly different from Sabalan cultivar; whereas Zaare' had the lowest mean value for this trait and not so different from Sardari.

Results from mean comparison on types of seed production and levels of drought stress (Diag. 6) with respect to this trait showed that cultivars such as Sabalan, Azar-2 and Zaare', with their seed produced under drought stress condition, germinated in comparatively higher percentage under both normal irrigation and drought stress conditions. Furthermore, with Sardari cultivar the higher germination percentage will be possible with its seed produced under normal irrigation and grown under normal condition; and its seed produced under terminal drought stress condition and grown under drought stress condition. Interestingly, this is in complete contrast with results obtained for Rasad cultivar.

Based on reports by Paulsen (1987) drought stresses are effective on decreasing germination percentage, which is in line with results reported by Nikkhah and Taherian. Decreased germination percentage in wheat cultivars under drought stress condition represents the sensitively of the cultivars against stress, which has been reported by Heidari and Heidarizadeh (2002) and Saeidi *et al.* (2007) on wheat genotypes. Abdul-Bake and Anderson (1970) in their study on barley argued that germination velocity is more sensitive to water stress than germination percentage, while it decreases more intensively than germination percentage under higher osmotic potentials. High germination percentage is considered as a desirable feature for seeds of crops grown in arid and semiarid regions (Saeidi *et al.*, 2007).

Germination Rate Index (GRI)

Results from this experiment shows (Table 4) that levels of drought stress applied by polyethylene glycol 6000, types of seed production as well as cultivars differed for GRI at $P<0.01$; whereas interaction of "types of seed production × cultivar" differed significantly for this trait at $P<0.01$. Results from mean comparison by using Duncan method at 5% probability level showed that GRI was higher under 0MP level than under -3MP level of polyethylene glycol (Table 1); while values for this trait is higher. Rasad cultivar had the highest mean value for this trait, though did not have a significant difference with Sabalan; whereas Sardari and Zaare' had the lowest mean value for this trait.

Results of mean comparison on types of seed production and levels of drought stress with respect to this trait (Diag. 7) shows that cultivars such as Sabalan and Azar-2, with their seeds produced under drought stress condition, are suitable for cropping under both normal irrigation and drought stress conditions. In contrast, cultivars such as Sardari and Rasad, with their seeds produced under normal irrigation condition, are suitable for cropping under both normal irrigation and drought stress conditions. Furthermore, in order for Zaare' cultivar to have higher value for this trait when grown under normal irrigation condition, its seed must be produced under normal irrigation, whereas in order to have higher value for this trait when grown under drought stress condition, its seed must be produced under terminal drought stress condition.

Germination Index (GI)

Results from this experiment showed (Table 4) that types of seed production differed significantly for GI at $P<0.01$; whereas cultivars and interaction of "levels of polyethylene glycol × types of seed production" differed for GI at $P<0.05$. Results of mean comparison by using Duncan method at 5% probability level showed (Table 2) that seeds produced under irrigation condition had higher germination index than those produced under rainfed condition. Furthermore, Sardari (Table 3) had the highest value for this trait among the cultivars, though not so different from cultivars such as Azar-2 and Sabalan; whereas cultivars such as Rasad and Zaare' had the lowest values for this trait. Furthermore, application of drought stress by using polyethylene glycol 6000 did not have any impact in the experiment, thus mean comparison was not accomplished.

Results of mean comparison on types of seed production and levels of drought stress applied by polyethylene glycol with respect to GI trait (Diag. 8) shows that cultivars such as Sardari, Sabalan, Rasad and Zaare', with their seeds produced under normal irrigation condition, are same in terms of GI trait for cropping under both normal irrigation and drought stress conditions; whereas in order for Azar-2 cultivar to have higher value for this trait when grown under normal condition, its seed must be produced under normal irrigation, whereas in order to have higher value for this trait when grown under drought stress condition, its seed must be produced under terminal drought stress condition.

Germination Stress Index (GSI)

Results from this experiment showed (Table 4) that types of seed production differed significantly for GSI at $P<0.01$. In addition, results of mean comparison by using Duncan method at 5% probability level showed (Table 2) that seeds produced under normal irrigation had higher GSI than those produced under rainfed condition. Cultivars and levels of drought stress applied by polyethylene glycol did not differ for this trait, thus mean comparison was not accomplished.

Results of mean comparison on types of seed production and levels of drought stress with respect to this trait (Diag. 9) showed that all the cultivars except for Azar-2, with their seeds produced under normal irrigation condition, gives better results for this trait; whereas Azar-2 gives better results for this trait if its seed was produced under terminal drought stress condition.

High GSI is a criterion for evaluation of resistance against drought (Bouslama *et al.*, 1984). According to Sapra *et al.* (1991) genotypes with high GSI are suitable for stressed conditions. In addition, based on the proposed method by Bouslama and Schapaugh (1984) on GSI potential to select genotypes tolerant against drought stress, it can be used to select superior genotypes. Zarei *et al.* (2007) introduced GSI as an efficient index for indirect selection of genotypes tolerant against drought stress.

Simple correlation between the morphological traits

Simple correlation between the morphological traits showed (Table 5) that polyethylene glycol 6000 had negatively significant correlation with GRI, FGP, coleoptile length, shoot length and shoot weight.

Similarly, types of seed production had negatively significant correlation with GI; and cultivars with GRI and coleoptile length. In contrast, coleoptile length had positively significant correlation with FGP, GRI, and shoot length and shoot weight; and shoot length also had positively significant correlation with GRI, FGP and shoot weight. Likewise, there was a positively significant correlation between shoot weight and FGP; whereas CVG had a positively significant correlation with GRI and negatively significant correlation with MGT. Finally, the correlation between MGT and GRI was negatively significant; and between FGP and GRI was positively significant.

Conclusion

Based on results of this experiment, effect of polyethylene glycol on the cultivars indicates that germination index (GI) was higher under normal irrigation than under drought stress conditions.

Comparison on types of seed production with respect to germination indices shows that terminal drought stress produce better results for germination percentage (GP) and germination rate index (GRI); whereas normal irrigation produce better results for germination index (GI) and germination stress index (GSI).

Cultivars differed in terms of germination indices.

There was a negatively significant correlation between types of seed production and GI.

Polyethylene glycol 6000 had a negatively significant correlation with GRI, FGP, coleoptile length, shoot length and shoot weight.

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