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Full Length Research Paper

Physiological and morphological responses of three *Bromus* species to drought stress at seedling stage and grown under germinator and greenhouse conditions

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In order to determine the reaction of three *Bromus* species to drought stress, two separate experiment were conducted in both germinator and greenhouse conditions using factorial experiment based of completely randomized design with three replications in 2010 in Tehran, Iran. The drought treatments were four levels of osmotic potential (0, -0.3, -0.6 and -0.9 MPa) in germinator and four levels of osmotic potential (FC, 25% FC, 50% FC and 75% FC) in greenhouse that were made by poly ethylene glycol (PEG 6000) solution and field capacity method, respectively. Data were collected and analyzed for germination percent, root length, shoot length, seedling length, root/shoot length ratio (RSR), seedling weight, seedling dry/fresh weight ratio (DFR) and seed vigor index. In greenhouse, chlorophyll, carbohydrates and proline contents were also measured. The results showed significant differences among species, droughts levels and species by drought interaction effects for the most of traits in both conditions. However, the relationship between germinator and greenhouse, quantified using correlation was high. It was concluded that evaluation under germinator conditions is desirable for selection purposes. In both conditions all of seedling traits except RSR, DFR were increased and proline and carbohydrate content were increased by increasing osmotic potential. The results showed that the *Bromus tomentellus* species had higher values for the most of seedling attributes than other species. Results of probit analysis of LD_{50} and LD_{90} showed the same trend.

Key words: Drought, PEG6000.germination, seed vigor, *Bromus.*

INTRODUCTION

Bromus is one of important perennial grass species which belong to genus of *Bromus*, subgenus of *Festucoides* and family of *Poaceae*. It naturally grows in Zagros and Alborz mountains rangelands in the west and north of Iran. It is being used for grazing and hay production and consumed by livestock. *Bromus tomentellus* grows in areas with 750 m to 2900 m altitude (Ebrahimzadeh, 2010). It has early growth in spring and good quality for animal productivity and good adaptability in vast range of sever conditions in all over the country. In recent years, higher grazing pressure and unpalatable weed invasion had led to increasing soil erosion and consequently decreasing population of this species. Therefore, re-vegetating of those areas by new improved grass varieties is the most economical and possible means of recovery.

Bromus genus has an important role in grassland productivity in Iran. Little breeding work has been done on this species especially under Iran climatic conditions (Moghaddam 1998).

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Under water deficiency conditions, the rate of water loss from transpiration exceeds the rate of water absorption by the roots, and plants undergo water stress. Water stress can vary from a small decrease in water potential to the lethal limit of desiccation (Liberato et al., 2007). Among the different abiotic stresses, drought is by far the most complex and devastating on a global scale (Pennisi, 2008). Although range plants have mechanisms that help reduce damage from water stress, water deficiency conditions lasting a month cause plants to experience water stress severe enough to reduce herbage production. (Larcher, 2003; Nevo et al., 2002). We anticipate a growing interest in wild relatives of crops and landraces in an attempt to identify superior alleles among these that the domestication bottleneck and modern agriculture have left behind (Tanksley and McCouch, 1997; Grandillo et al., 2007, Lippman et al., 2007; Feuillet et al., 2008).

Drought is one of the major causes for crop loss worldwide, reducing average yields with 50% and over. In addition, water stressed plants could be more sensitive to other biotic or abiotic stresses such as pathogen attack, chilling or air pollution, which limits plant productivity. Plant stress resistance can be studied at molecular, cellular or physiological levels (Bohnert et al., 1995; McCue and Hanson, 1990; Wang et al., 2003). In water stress, plant height and herbage biomass accumulation are reduced. Leaf senescence increases and as a result, nutritional quality of forage decreases. The rate of sexual reproduction is diminished as a result of a decrease in seed stalk numbers and height and a reduction in numbers of seeds in the seed heads. Rate of vegetative reproduction is reduced because the number of axillary buds and the number of secondary tillers decrease. (Zareh, 2009; Tavili, 2007). In order to respond to drought, plants have developed the capability to rapidly perceive stressful factors and trigger the accumulation of a large number of newly synthesized mRNAs and polypeptides (Ingram and Bartels, 1996; Urao et al., 1999; Urao et al., 2000). Responses to drought are multiple and interconnected. It leads to growth reduction, reduction in the content of chlorophyll pigments and water, and changes in fluorescence parameters (Lu and Zhang, 1999; Lima et al., 2002; Colom and Vazzana, 2003; Souza et al., 2004; Zlatev and Yordanov, 2004; Ekmekci et al., 2005; Mohsenzadeh et al., 2006; Rong-hua et al., 2006; Nayyar and Gupta, 2006; Yang et al., 2006). Rangelands are areas unsuitable for cultivation, but provide forage for animals (Miller, 1997).

Rangeland degradation is often manifested by decreases in plant yields. The dispersal of seeds through over sowing is an important strategy to actively restore vegetation in degraded areas as their seed banks are usually depleted of viable seed. One of the greatest challenges in restoration ecology is to sow a seed type or cultivar that has the capacity to produce abundant biomass and cover in a short period of time (Van den Berg, 2002). In addition to grazing by domestic livestock, rainfall patterns are the most important factors influencing rangeland condition (Hoffman and Ashwell, 2001). Drought, extreme temperatures, increased soil salinity, soil crusting or sand covering, as well as pathogens and herbivores all adversely affect the germination and growth of seedling. Grasses, with strong development of underground organs, tend to have efficient adaptive mechanisms to cope with drought, fire and herbivory and provide superior protection against soil erosion than most woody shrub and tree species (Imevbore, 2003). Iran is one of the countries that majority of its extent is located in arid and semi arid regions. 64% of Iran (100 million hectares) is covered by dry lands, and their area is increasing (Jafari and Firouzabadi, 2001). Only 35% of the whole area of Iran has more than 250 mm of annual rainfall (Kuchaki, 2008). Therefore, in Iranian rangelands, water is one of the most important factors that limits plant growth and causes the failure of range improvement plans. The objective of this study was to identify Physiological and morphological responses of three *Bromus* species to drought stress in germinator and greenhouse.

MATERIALS AND METHODS

The study was conducted in the germinator and greenhouse. For each trail a factorial experiment based on completely randomized design was conducted in Gene Bank division in Research Institute of Forests and Rangelands, Tehran, Iran, in November 2009. Four *Bromus* species: B. tomentellus, B. inermis and B .persicus were used in this study.

Germinator experiment

Water stress treatment was applied during 15 days by adding PEG 6000 (50 gL^{-1}) (Fluka, Buchs, France) to the watering solution in germinator condition, In germinator, for each accession 100 pure seeds were sterilized with 70% ethyl alcohol for five minutes and washed with distilled water. Four replicates (25 seeds per replicate) of sterilized seed were placed in Petri dishes on double Whatman papers (TP). For protection against molds, the water used to moisten the seed samples and substrata contained 0.002% Benomil fungicide. The samples were immediately transferred into a germinator at (20± 4°C) with 1000 Lux light for 15 days.

After growth of seedlings for 15 days, the length of roots and shoots of 10 randomly-selected seedlings from each replicate were measured. The vigor index measures seedling performance, relating together the germination percentage and growth of seedlings produced after a given time (Abdul-Baki and Anderson, 1973). It was calculated by following equation:

$$Vi = \frac{\%Gr \times MSH}{100}$$

Where:
VI = vigour index,
% Gr. = final germination percentage,
MSH = mean seedling height.

Greenhouse experiment

The seeds of the same ecotypes were sown on pots with fluctuation temperatures 20± 5°C during day and (5 to 12)°C during night of greenhouse. In order for vegetative growth development, the pots were irrigated normally for three weeks. Water stress treatment was applied using four levels of osmotic potential (FC, 25% FC, 50% FC and 75% FC) for three weeks by using the field capacity (FC) method (Panda et al., 2004). At the end of each treatment, the seedlings were counted to estimate germination percent. The root length and shoot length (the distance from soil surface to upper end of the longest leaves) was measured (mm/plant). The fresh (g/FW) and dry (g/DW) biomass of the seedling and vigor index was also determined.

The carbohydrates content of drought stressed and irrigated (control) plants were determined using the method of Irigoyen et al., (1992). Carbohydrates were extracted from leaf samples (20 mg DW) according to Weimberg (1987) with minor modifications. The absorbance of the sample extract was Spectrophotometrically determined at 535 nm. The proline concentration was determined as (µmol g/DW) using a standard curve.

For proline content, the method of Bates et al., (1973) was used to determine praline content. Proline was extract from leaf samples (20 mg DW) according to Weimberg (1987) with minor modifications. The absorbance of the sample extract was Spectrophotometrically determined at 520 nm. The praline concentration was determined as (µmol g/DW) using a standard curve.

The factorial experiments based on completely randomized design were analysed using ANOVA a. Differences among the treatments as well as the cultivars and their intraction effects were tested using the DMRT method. The relationship between germinator and greenhouse, quantified using phenotypic correlations. Probit analysis were used to determination of lethal dose concentration of PEG6000 for stopping 50% (LD50) and 90% (LD90) of seed germination in three *Bromus* species. All statistical analyses were conducted by SAS (SAS Inst. 2004).

RESULTS

Germinator experiment

The results of analysis of variance in germinator, showed significant differences among species, droughts stress and species by drought interaction effects for the all of traits (Table 1). All of traits except RSR and DFR, were decreased by increasing osmotic potential (Table 2). The maximum values of traits were obtained for the control treatment and its minimum level was in the drought treatment -0.9 MPa in the germinator. For germination percent there was no difference between control and -0.3 MPa and for other traits this treatment were ranked as the second. The traits tend to drop sharply by increasing osmotic potential to 0.6 MPa and 0.9 MPa (Table 2). The average values of both RSR and DFR were significantly decreased by increasing osmotic potential and the highest values were obtained for 0.9 MPa (Table 2).

The comparisons among three species in germinator are show in Table 3. Results showed that, *B. tomentellus* species with average value of 79.25 had higher germination percent than the of two other ones.

The species × drought interaction effects for all traits are shown in Figure 1. The comparison among species for every levels of drought stress indicated that *B. tomentellus* species were stable by increasing osmotic potential. Suggesting that it was more resistance to drought than other species. Using probit analyses LD50 was estimated as -0.99 MPa osmotic potential for *B. tomentellus* species. The results indicated that *B. tomentellus* was more resistance than other species for drought stress and it could be used for cultivation in moderate rainy rangelands with 300 mm annual precipitation (Table 4).

Greenhouse experiment

The results of analysis of variance in greenhouse, showed significant differences among droughts stress and species by drought interaction effects for germination percent, root length, shoot length, seedling length, vigor index, RSR, seedling fresh weight, seedling dry weight DFR, chlorophyll index, proline and non structural carbohydrates (Table 5). By increasing osmotic potential, all germination traits except RSR, DFR were decreased, in contrast proline and carbohydrates content were increased by drought stress (Table 6).

For germination traits, the higher values were obtained for the control treatment and their minimum level were obtained in the drought treatment of 75% FC. For germination% there was no difference between control and 25% FC and for other traits the 25% FC treatment were ranked as the second. The traits tend to drop sharply by increasing osmotic potential to 50% FC and 75% FC (Table 5). The average values of RSR and DFR, proline and carbohydrates content were significantly increased by increasing osmotic potential and the highest values were obtained for 75% FC (Table 5).

In comparisons among three species in greenhouse (Table 7), results showed that, *B. tomentellus* species had higher value for germination%, seedling length and vigor index. In comparison among species for every levels of drought stress indicated that *B. tomentellus* species were stable for germination percent by increasing osmotic potential. The declines of seedling length and vigor index in *B. tomentellus* species was less as compared to other species by the results indicated that both species of *B. tomentellus* and *B. persicus* were more resistance than for drought stress and they could be used for cultivation in moderate rainy rangelands.

Relationship between germinator and greenhouse

The relationship between germinator and greenhouse for all traits is important. Since, selection in germinator could be more efficient than that based on germinator and field depending on the correlation between characters. The phenotypic correlations between two environments were estimated. The estimates were high and significant for germination percent (r = 0.99**), root length(r = 0.76**), shoot length (r = 0.98**), seedling length (r = 0.91**), vigor index (r = 0.97**), RSR (r = 0.75**) and seedling fresh weight (r = 0.75**) indicated that results based on germinator

Table 1. Analysis of variance of germination properties of *Bromus* species in germinator condition.

Source of variance	DF	Germination (%)	Shoot L. (mm)	Root L. (mm)	RSR (mm)	Seedling L. (mm)	Vigor index	FW (g)	DW (g)	DFR (g)
Drought (D)	3	16556**	26469**	27157**	0.7655*	106937**	127659**	0.077**	0.00004^{ns}	0.0979**
Species (S)	2	1868**	125*	5916**	5.3066**	4660**	2730**	0.0041*	0.0008**	0.0727**
E × D	6	260^{ns}	241^{ns}	399**	0.7122**	1147*	1275*	0.0005^{ns}	0.00005^{ns}	0.0062^{ns}
Error	132	334	142	129	0.215	417	603	0.0013	0.0001	0.0044
CV (%)		24.8	23.2	21.8	41.04	19.7	28.5	23.4	35.4	33.5

*, ** = Means of squares are significant at 5, 1%, respectively.

Table 2. Effect of drought stress on seed germination properties of *Bromus* species in germinator condition.

Drought Treatment	Germination (%)	Shoot L. (mm)	Root L. (mm)	RSR (mm)	Seedling L. (mm)	Vigor index	FW (g)	DW (g)	DFR (g)
Control	92.67^{a}	79.94^{a}	83.06^{a}	1.34^{a}	163^{a}	151.46^{a}	0.221^{a}	0.031^{a}	0.253^{a}
-0.3 MPa	88.78^{a}	66.64^{b}	65.78^{b}	1.12^{b}	132.42^{b}	118.29^{b}	0.157^{b}	0.030^{a}	0.229^{a}
-0.6 MPa	66.22^{b}	39.18^{c}	36.32^{c}	1.04^{b}	75.50^{c}	53.21^{c}	0.125^{c}	0.029^{a}	0.177^{b}
-0.9 MPa	46.55^{c}	19.62^{d}	22.63^{d}	1.03^{b}	42.25^{d}	20.92^{d}	0.118^{c}	0.028^{a}	0.135^{c}

Table 3. Means comparison of seed germination characteristics in three Bromus species.

Ecotypes name	Germination (%)	Shoot L. (mm)	Root L. (mm)	RSR (mm)	Seedling L. (mm)	Vigor index	FW (g)	DW (g)	DFR (g)
Br.inermis	68.94^{b}	52.36^{a}	50.82^{b}	1.04^{b}	103.18^{b}	79.33^{b}	0.16^{a}	0.02^{b}	0.17^{c}
Br.persicus	69.25^{b}	47.95^{a}	77.03^{a}	1.90^{a}	124.98^{a}	95.64^{a}	0.13^{b}	0.03^{a}	0.27^{a}
Br.tomentellus	79.25^{a}	51.18^{a}	46.81^{b}	1.03^{b}	97.99^{b}	90.19^{ab}	0.15^{a}	0.03^{a}	0.21^{b}

Means of the columns with the same letter had no significant differences based on DMRT ($P \leq 0.05$).

were strong indicators of greenhouse and probably field experiment (Table 8).

DISCUSSION

Drought stress tolerant cultivars are the varieties which have no meaningful decrease in germination indicators against increasing the water deficiency level. The *B. tomentellus* species in both germinator and greenhouse conditions is considered as more tolerant varieties. Generally, the results showed that the drought stress had negative effect on the germination percent and seedling growth characteristics. The dryness cause delay in germination characteristics. In the similar results Rice and Dyer (2001) working with *Bromus tectorum* showed that late emerging seeds has lower competitive ability than early emerging seeds.

The results showed that the drought stress had negative effect on the growth characteristics. The results obtained from other researches (Kaul and

Table 4. Probit analysis for determination of lethal dose concentration of PEG6000 for stopping 50% (LD_{50}) and 90% (LD_{90}) of seed germination in three *Bromus* species.

Specie	LD_{50}		LD_{90}	
	PEG lethal dose concentration	SE	PEG lethal dose concentration	SE
Br.inermis	7.57	0.10	14.27	0.21
Br.persicus	7.60	0.19	14.30	0.26
Br.tomentellus	9.75	0.13	16.45	0.24

Table 5. Analysis of variance of germination properties of *Bromus* species in greenhouse condition.

Source of variance	DF	Germ (%)	Root L. (mm)	Shoot L. (mm)	Seedling L. (mm)	Vigo Index	RSR (mm)	FW (g)	DW (g)	DFR (g)	Chlorophyll index	Proline µmol g/DW	Carbohydrates µmol g/DW
Drought (D)	3	16556**	99651**	727280**	1359843**	2103857**	0.89**	1315**	74.53**	0.07**	7982**	0.15**	0.03*
Species (S)	2	1868**	5002*	11081*	29054**	135557**	0.11^{ns}	78.8 **	9.11 **	0.01^{ns}	7.31^{ns}	0.01^{ns}	0.03^{ns}
D x E	6	260^{ns}	749^{ns}	2112^{ns}	3073^{ns}	14070*	0.1*	16.13^{ns}	3.24 **	0.01*	37.65^{ns}	0.003^{ns}	0.002^{ns}
Error	132	334	1429	3029	3673	6484	0.04	7.78	0.68	0.007	24.30	0.008	0.01
CV %		24.85	21.60	17.88	12.55	20.97	31.44	33.74	40.20	31.62	16.13	5.74	30.59

*, ** = Means of squares are significant at 5, 1%, respectively.

Table 6. Effect of drought stress on seed germination properties of *Bromus* species in greenhouse condition .

Drought	Germination (%)	Root L. (mm)	Shoot L. (mm)	Seedling L. (mm)	Vigo index	RSR (mm)	FW (g)	DW (g)	DFR (g)	Chlorophyll index	Proline µmol g/DW	Carbohydrates µmol g/DW
Control	92.6^{a}	239^{a}	465^{a}	704^{a}	654^{a}	0.53^{c}	15.4^{a}	3.82^{a}	0.25^{b}	42.3^{a}	1.45^{c}	0.32^{b}
25% FC	88.7^{a}	190^{b}	378^{b}	568^{b}	506^{b}	0.51^{c}	10.8^{b}	2.57^{b}	0.23^{b}	41.8^{a}	1.53^{b}	0.36^{ab}
50% FC	66.2^{b}	153^{c}	242^{c}	396^{c}	258^{c}	0.66^{b}	4.82^{c}	1.19^{c}	0.27^{b}	27.6^{b}	1.58^{b}	0.40^{ab}
75% FC	46.5^{c}	116^{d}	144^{d}	261^{d}	116^{d}	0.85^{a}	1.96^{d}	0.62^{d}	0.33^{a}	10.7^{c}	1.67^{a}	0.43^{a}

Means of the columns with the same letter had no significant differences based on DMRT ($P \leq 0.05$).

Shankar, 1988; Kim et al., 1994) confirm this issue that increasing the water stress decreases the seedling growth. Drought stress causes increasing salts viscosity in plant organs. So, by increasing the salts viscosity increase the osmosis stress of soil solution, so the amount of energy which the plant need to absorb the water from the soil will be increased, this action cause the increase of respiration and decrease the plant performance (Brason et al., 1967). Rice and Dyer (2001) working with *Bromus tectorum* showed that late emerging seeds have lower competitive ability

Table 7. Means comparison of seed germination characteristics in three *Bromus* species in greenhouse condition.

Ecotype name	Germination (%)	Root L. (mm)	Shoot L. (mm)	Seedling L. (mm)	Vigo index	RSR (mm)	FW (g)	DW (g)	DFR (g)	Chlorophyll index	Proline µmolg/DW	Carbohydrates µmol g/DW
B. inermis	68.9[b]	166[a]	300[ab]	467[b]	345[b]	0.60[b]	7.94[b]	2.05[b]	0.29[a]	3.01[a]	30.4[a]	1.57[a]
B. persicus	69.2[b]	170[a]	285[b]	455[b]	345[b]	0.73[a]	11.2[a]	3.01[a]	0.26[a]	3.06[a]	29.8[a]	1.50[a]
B. tomentellus	79.2[a]	184[a]	320[a]	504[a]	432[a]	0.65[ab]	7.85[b]	1.81[b]	0.26[a]	3.37[a]	30.8[a]	1.56[a]

Means of the columns with the same letter had no significant differences based on DMRT (P≤0.05).

Table 8. Phenotypic correlation between germinator and glasshouse for seed germination traits.

Trait	Ger (%)	Shoot L.	Root L.	Seedling	Vigor	RSR	Fresh W.	Dry W.	DFR
Correlation	0.99**	0.98**	0.76**	0.91**	0.97**	0.75**	0.75**	0.63*	-0.08[ns]

than early emerging seeds. The studies of Sharifi (2010) and Plauz (2003) showed that the growing up of water stress causes the decrease in shoot dried weight and increase in root dried weight and root:shoot ratio. The capacity of the root system for rapid and early development is an important factor in drought resistance. It is well known that increased efficiency of moisture absorption is primarily due to the development of an extensive root system. Also, it is a common feature among the arid and semi arid environment perennials, that these plants develop root systems that are larger than their shoots. This is an important factor in survival. The moisture collected by the extensive root system is drawn upon for the consumption of a reduced shoot. The preponderance of the root system over the above-ground shoot system facilitates adjustment of the water balance of desert plants. One of the depressant factors photosynthesis in the severe drought stress is the reduction of chlorophyll content (Behero et al., 2002). Some researches stated that the increase of dryness level in the plant decreased the chlorophyll viscosity in the leaves and cause to decrease the photosynthesis in the plant (Flaxas et al., 1999, 2002, 2004). The proline and carbohydrate content increased in cultivars of *Bromus tomentellus* species during the drought stress.

This increase caused to establish the state of transparent phase (vitreous) in lost water protoplasm which can protect the membranes. Also increase of carbohydrate/ ion ratio prevents the establishment of toxicity state and chaotropic, this increase cause the persistency during drought stress and makes a chance in order that adaptation solutions to be able to provide the conditions of agitation effects decrease.

All of seedling traits except RSR, DFR were increased and proline and carbohydrate content were increased by increasing osmotic potential. The results showed that the *B. tomentellus* species had higher values for the most of seedling attributes than other species. The phenotypic correlation estimates between two environments was high and significant for the most of traits (Table 8) indicated that results based on germinator were strong indicators of greenhouse and probably field experiment. This result were in agreement with Pourhadian and Khajehpour (2010), that found percent of seeds emerging during the first 2 to 4 days of emergence is a valuable laboratory index for field emergence of wheat. In contrast Wang et al. (2004) were unable to predict field emergence using laboratory tests.

REFERENCES

Abdul-Baki AA, Anderson JD (1973). Vigor determination in soybean seed by multiplication. Crop Sci. 3: 630-633.

Bates LS, Waldren RP, Teare ID (1973). Rapid determination of free proline for water stress studies. Plant and Soil 39: 205-207.

Behero RK, Mishra PC, Choadhury NK (2002). High irradiance and water stress induce alteration in pigment composition and chloroplast activities of primary wheat leave. J. Plant Physiol., 159: 967-973.

Bohnert HJ, Nelson DE, Jensen RG (1995). Adaptations to environmental stresses. Plant Cell 7:1099-1111.

Brason FA, Miller RF, McQueen JS (1967). Geographic distribution and factors affection the distribution of salt desert shrubs in the United States. J. Range Manage., 20: 287-296.

Colom MR, Vazzana C (2003). Photosynthesis and PSII functionality of drought-resistant and drought sensitive weeping lovegrass plants. Environ. Exp. Bot. 49: 135-144.

Ebrahimzadeh H (2010). Plant physiology, Volume 1, Tehran university press. pp. 340.

Ekmekci Y, Bohms A, Thomson JA, Mundree SG (2005). Photo-chemical and antioxidant responses in the leaves of *Xerophyta viscose* Baker and *Digitaria sanguinalis* L. under water deficit. Z. Naturforsch C., 60: 435-443.

Feuillet C, Langridge P, Waugh R (2008). Cereal breeding takes a walk on the wild side. Trends Genet., 24: 24-32.

Flexas J, Bota J. Cifre J, Escalona JM, Galmes J, Medrano H (2004) Understanding down-regulation of photosynthesis under water stress: future prospects and searching for physiological tools for irrigation management. Ann. App. Biol., 144: 273-283.

Flexas J, Escalona JM, Medrano H (1999). Water stress induces different levels of photosynthesis and electron transport rate regulation in grapevines. Plant, cell and environment. 22: 39-48.

Flexas J, Medrano H (2002). Drought-inhibition of photosynthesis in C3 plants: Stomatal and non-stomatal limitation revisited. Ann. Bot., 89: 183-189.

Grandillo S, Tanksley SD, Zamir D (2007) Exploitation of Natural Biodiversity through Genomics. In: Genomics-Assisted Crop Improvement-Vol. 1:Genomics Approaches and Platforms, Varshney, R.K. and R. Tuberosa (Eds.). Springer, Dordrecht, pp: 121-150.

Hoffman T, Ashwell A (2001). Nature Divided: Land Degradation in South Africa. University of Cape Town Press, Cape Town, pp: 168.

Imevbore AM (2003). Desertification and desiccation as a threat to the conservation and utilization of biodiversity. United Nations Convention to Combat Desertification. pp.314.

basis of dehydration tolerance in plants. Ann. Rev. Plant. Physiol. Plant Mol. Biol., 47: 377-403.

Irigoyen JJ, Einerich DW, Sanchez-Di-az M (1992). Water stress induced changes in concentrations of proline and total soluble sugars in nodulated alfalfa (*Medicago sativa*) plants. Physiologia Plantarum. 84: 55-60.

Jafari M, Firouzabadi AG (2001). Resistance to drought in Shore elurope (*Aeluropus littotalis*) and weeping alkaligrass *(Puccinelia distance*), Proceedings of the XIX International Grassland Congress. 83: 14-19.

Kaul A, Shankar V (1988). Ecology of seed germination of the chenopod shrub *Haloxylon salicornicum.* J. Trop. Ecol., 29: 110-115.

Kim KS, Yoo YK, Lee GY (1994). Comparative salt tolerance study in Korean grasses. J. Korean Soc. Hort. Sci., 32: 17-133.

Kuchaki E, Soltani A, Azizi M (2008). Plant physiology, Mashhad university press. p267.

Larcher W (2003). Physiological plant ecology, 3rd ed, Springer press, London. pp. 322.

Liberato MA, Gonçalves J, Chevreuil LR, Junior AR (2007). Leaf water potential, gas exchange and chlorophyll a fluorescence in acariquara seedlings (*Minquartia guianensis* Aubl.) under water stress and recovery, Braz. J. Plant Physiol., 29: 17-22.

Lima ALS, DaMatta FM, Pinheiro HA, Totola MR, Loureiro ME (2002). Photochemical responses and oxidative stress in two clones of *Coffea canephora* under water deficit conditions. Environ. Exp. Bot. 47: 239-247.

Lippman ZB, Semel Y, Zamir D (2007). An integrated view of quantitative trait variation using tomato interspecific introgression lines. Curr. Opin. Genet. Dev., 17: 545-552.

Lu C, Zhang J (1999). Effects of water stress on photosystem II photochemistry and its thermostability in wheat plants. J. Exp. Bot., 50: 1199-1206.

McCue KF, Hanson AD (1990). Drought and salt tolerance: towards understanding and application. Trends Biotechnol., 8: 358-362.

Miller D (1997). Rangelands and range management. Int. Center Integr. Mountain Dev. Newslett., 27: 1-3.

Moghaddam M (1998). Range and range management, Tehran university press, p. 470.

Mohsenzadeh S, Malboobi MA, Razavi K, Farrahi-Aschtiani S (2006). Physiological and molecular responses of *Aeluropus lagopoides* (Poaceae) to water deficit. Environ. Exp. Bot. 56: 314-322.

Nayyar H, Gupta D (2006). Differential sensitivity of C3 and C4 plants to water deficit stress: Association with oxidative stress and antioxidants. Environ. Exp. Bot., 58: 106-113.

Nevo E, Korol AB, Beiles A, Fahima T (2002). Evolution of wild emmer and wheat improvement. Population genetics, genetic resources and genome organization of wheats progenitor, *Triticum dicoccoides*. Springer, Heidelberg, New York, p364.

Panda RK, Behera SK, Kashyap PS (2004). Effective management of irrigation water for maize under stressed conditions. Agric. Food Eng., 66: 181-203.

Pennisi E (2008). Plant genetics: The blue revolution, drop-by-drop, gene by gene. Sci., 320: 171-173.

Plauz Z (2003). Photosynthesis in plant crops under water and salt stress. In: Pessarakli M (ed), Handbook of plant and crop stress, Marcel Dekker, New York, pp 587-603.

Pourhadian H, Khajehpour MR (2010). Relationship between germination tests and field emergence of wheat. Asian J. App. Sci., 3: 160-165.

Rice KJ, Dyer AR (2001). Seed aging, delayed germination and reduced competitive ability of *Bromus tectorum*. Plant Ecol., 155: 237-243.

Rong-hua LI, Pei-guo GUO, Michael B, Stefania G, Salvatore C (2006). Evaluation of chlorophyll content and fluorescence parameters as indicators of drought tolerance in barley. Agriculture in Sciences in China 5: 751-757.

SAS Institute (2004). SAS/STAT users guide. 9.2. Version. SAS Institute Inc. Cary. NC. pp.404.

Sharifi KM (2010) Investigation of drought and salinity stress on *Agropyron intermedium, Avena barbata* and *Panicum antidotale*, M.Sc. thesis, Natural Resources College of Tehran University.

Souza RP, Machado EC, Silva JAB, Lagoa AMMA, Silveira JAG (2004). Photosynthetic gas exchange, chlorophyll fluorescence and some associated metabolic changes in cowpea (*Vigna unguiculata*) during water stress and recovery. Environ. Exp. Bot., 51: 45-56.

Tanksley SD, McCouch SR (1997). Seed banks and molecular maps: unlocking genetic potential from the wild. Sci., 277: 1063-1066.

Tavili A (2007). Effects of water deficiency on *Agropyron desertorum* and *Agropyron cristatum*, M.Sc. thesis, Natural Resources College of Tehran University.

Urao T, Yakubov B, Satoh R, Yamaguchi-Shinozaki K, Seki M, Hirayama T, Shinozaki K (1999). A transmembrane hybrid-type histidine kinase in Arabidopsis functions as an osmosensor. Plant Cell 11:1743-1754.

Urao T, Yamaguchi-Shinozaki K, Shinozaki K (2000). Two-component systems in plant signal transduction. Trends Plant Sci., 5: 67–74.

Van den Berg L (2002). The evaluation of a number of technologies for the restoration of degraded rangelands in selected arid and semi-arid regions of South Africa. M.Sc. Thesis, Potchefstroom University for Christian Higher Education, Potchefstroom, South Africa.

Wang W, Vinocur B, Altman A (2003). Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. Planta 218: 1-14.

Wang YR, Yu L, Nan ZB, Liu YL (2004). Vigor tests used to rank seed lot quality and predict field emergence in four forage species. Crop Sci., 44: 535-541.

Weimberg R (1987). Solute adjustments in leaves of two species of wheat at two different stages of growth in response to salinity. Physiol. Plant., 70: 381-388.

Yang X, Chen X, Ge Q, Li B,Tong Y, Altman A, Bohms A (2006). Tolerance of photosynthesis to photoinhibition, high temperature and drought stress in flag leaves of wheat: a comparison between a hybridization line and its parents grown under field conditions. Plant Sci., 171:389-397.

Zareh CMA (2009). Drought stress in plants. NSC seminar of range management, Tehran university. pp.204.

Zlatev ZS, Yordanov IT (2004). Effects of soil drought on photosynthesis and chlorophyll fluorescence in bean plants. Bulg. J. Plant Physiol., 30: 3-18.