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Research Article

THE EFFECT OF WATER DEFICIT STRESS ON GERMINATION COMPONENTS OF GRAIN SORGHUM CULTIVARS

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ABSTRACT
In order to investigate the effect of drought stress on germination characteristics of grain sorghum cultivars a laboratory research was conducted in 2013. The controlled experiment consisted of the first treatment including three grain sorghum cultivars (Sepideh, Kimia, and Payam) and the second treatment including drought stress using three levels of polyethylene glycol solution (0, -6, and -9 bar) as factorial in the form of randomized complete block design with four replications. The results of the experiment showed that at all levels of drought stress of -6 and -9 bar the growth traits including germination percentage, mean daily germination, coefficient of velocity of germination, rootlet length, stemlet length, and seed vigor decreased and a descending trend was observed in them. The highest reduction was related to the drought level of -9 bars and among the sorghum cultivars the best cultivars in terms of germination traits were Sepideh, Kimia, and Payam, respectively. In general, the effect of drought stress on the majority of germination traits of grain sorghum cultivars was significant at 1% level. It can be concluded that drought stress had an adverse effect on most evaluated parameters.

Keywords: *Germination, Polyethylene Glycol, Drought Stress, Grain Sorghum Cultivars*

INTERDUCTION
Water is one of the major limiting factors for the producers of agricultural products in arid and semiarid areas. This material is economically one of the most important resources all around the world particularly in arid and semiarid areas that nations are always dealing with (Selote *et al.*, 2004). Iran with the average annual precipitation of 250mm is classified as one of the arid regions of the world (Koochaki *et al.*, 1997). Considering the dominance of arid areas in Iran, practicing some procedures such as the proper utilization of available water, sowing drought resistant plants as well as examining morpho-physiological and metabolic responses of plants to water deficit is highly important (Mansoori *et al.*, 2011). Evaluating crops tolerance of environmental stresses particularly during the germination and emergence stages is an important factor in selecting them to be cultivated at different situations.
Since the common assessments in fields are time consuming and are also influenced by many other uncontrollable factors such as climate and soil factors, application of a laboratory approach under controlled conditions makes it possible to evaluate the plants response to stress quickly and accurately.
Grain sorghum is the main food for millions of people in China, India, and Africa and is also consumed for the poultry in other parts of the world.
Sorghum cultivation area in the world is about 43.7 million hectares and 90% of this area is cultivated by grain sorghum varieties (FAO, 2007).
The global production of grain sorghum (2009) has been about 80 million tons and after wheat, rice, and maize it is in the fourth place among the world grain (FAO, 2009). Water stress can reduce both germination rate and percentage and the plants seeds responses even the response of different species of one plant to one type of stress can be very wide.
The seeds access to water decreases as the osmotic and matric forces increase. Stresses greater than 0.38 MPa reduce water absorption in the seeds of mung bean and pea (Koochaki *et al.*, 1997). De and Kar (1995) did an experiment on the mung bean and concluded that all germination indices decreased due to drought stress because the initial rate of water absorption by water decreased. Shekari *et al.*, (1998) investigated the response of three bean cultivars to drought stress at germination stage and concluded that as the osmotic potential increased all the studied traits decreased.

Salehi (2010) reported the reduction of germination percentage and the decrease of osmotic potential by the produced polyethylene glycol. Jamshidi (2006) investigated safflower genotypes under water stress and reported that at lower potential levels the seedlings had had thinner and longer roots than the control treatment and as the stress increased up to about 1.2 MPa, the rootlet length reduced more. Oskooei (2010) reported that as the drought stress increased, the stem growth decreased. Kafi (2005) stated that as the water potential decreased, germination percentage, germination rate, rootlet length, stemlet length, root dry weight, and stem dry weight decreased. The results of the research conducted by Sarmadnia *et al.,* (1988) indicated that the seeds with better germination at stress conditions would produce seedlings with stronger roots at the next growth stages.
The results of the research carried out by Rahimian Mashhadi (1999) indicated that as the osmotic potential increases, germination components decreased in wheat.

MATERIALS AND METHODS
The research was conducted in the specialized laboratory of the Faculty of Agriculture in Ahvaz Islamic Azad University in 2013.
The experiment was carried out as factorial in the form of randomized complete block design with four replications.
The fist factor contained three varieties of grain sorghum including (Kimia, Payam, and Sepideh).
The second factor included three levels of drought stress as 0, -6, and -9 bars using polyethylene glycol.
Polyethylene glycol 600 was used to evaluate resistance to drought at germination stage and to create different levels of water potential. According to Mitchell and Kaufman recipe different water potentials were created including 0, -6, and -9 bars. Distilled water was used to establish the potential of zero bars. At first, the seeds were immersed in the solution of sodium hypochlorite 1% for 5 minutes and were disinfected; then, they were washed by distilled water three times. Petri dishes and the seeds bed (Whatman paper) were all sterilized in autoclave. 20 seeds were transferred into each sterilized glass Petri dish with a diameter of 9 cm in which the filter papers were placed. 10 ml of distilled water was added to each Petri dish. On the whole, the experiment was carried out with 36 Petri dishes in the laboratory with four replications. Then, after 48 hours 7 ml of the solution related to each treatment was added to the Petri dishes. After 48 hours the germinated seeds were counted for 14 days, every 24 hours the germinated seeds were counted until the 14^{th} day. The seeds whose rootlet length is 2 mm or more are considered as the germinated ones. In the 9^{th} day, 5 germinated seeds were taken out of the Petri dishes and the stemlet and rootlet of each seedling were separated to assess the morphological parameters. At this stage, germination percentage, germination rate, mean daily germination, coefficient of velocity of germination, stemlet length, rootlet length, and the seed viability were measured and calculated using the mentioned mathematical equations.
Seed Viability (Germination Percentage)
Viability refers to the seed germination and its percentage is calculated by the number of grains which emerge in a certain period of time. In order to determine the seed viability, certain temperature and time period are required. Since the field conditions might not be appropriate in terms of temperature and time period for determining the seed viability, the seed should be examined under proper conditions in standard laboratories (Sarmadnia *et al.,* 1988). Germination percentage was calculated though the following Formula:
Seed germination = (the number of germinated seeds until the i day / total number of seeds) $\times 100$
Mean Daily Germination
Mean daily germination which is an index of daily germination speed was determined by the following equation (Ellis *et al.,* 1981):

Mean Daily Germination $(MDG) = \dfrac{FGP}{d}$

Where: FGP: final germination percentage (Viability)
d: day(s) to get mature in total

Coefficient of Velocity of Germination

This index is the velocity and acceleration of seed germination that was calculated via the following equation (Maguire, 1962):

$$CVG = \frac{G_1 + G_2 + G_3 + \ldots + G_n}{(1 \times G_1) + (2 \times G_2) + (3 \times G_3) + \ldots + (n \times G_n)}$$

G_1 to $G_{n:}$ the number of germinated seeds since the first to the last day

Measuring the Length of Rootlet and Stemlet

The lengths of rootlet and stemlet were measured with a ruler.

Measuring the Seed vigor Index or Vegetative Energy

In this approach, the germination percentage and the measurement of plant elongation were applied (Abdulbaki and Anderson, 1973), so that after the sufficient growth of seedlings, the lengths of seedling stems and roots were measured and then having the germination percentage and total seedling length the seed vigor index was measured.

Seed Vigor Index = Germination Percentage ×Mean Seedling length (rootlet and stemlet) /100

The data were analyzed by minitab and SAS statistical software and the means of the data were compared via Duncan's test and the EXCEL software was used to draw the diagrams and curves.

RESULTS AND DISCUSSION

Germination Percentage

Drought stress had a significant effect on germination percentage at 1% level. Cultivars were also significantly different at 1% level in terms of germination. Salehi (2010) and Sadat Asilan (2009) reported that as the levels of drought stress increased, the germination percentage decreased in the studied plants. Water absorption and the seed imbibitions are necessary as the first steps for germination.

Although the amount of absorbed water is not absolutely high and does not exceed twice or three times as much as the seed dry weight, the continuous supply of water for the stage after inflammation is highly important for germination.

Water potential in the environment is the most important or the most effective parameter in water uptake and seed inflammation and the seed of each plant requires a minimum hydration and inflammation and in order to achieve that minimum, the water potential of the environment should not lower a certain extent which is called the critical potential. Different studies have shown that as the potential decreases the water absorption by the seed reduces and germination capability decreases.

Drought stress tolerant cultivars are the ones that, in spite of their high means of germination percentage, when the drought level increases, their germination percentage does not reduce significantly even though one of the factors limiting the plants establishment is the lack of moisture during the seed germination (Khan, 1980).

Various responses of different cultivars to drought stress can result from different factors such as less absorption of water in sensitive cultivars, size of the seeds, and probably the features of surface coating of the studied seeds.

The decrease of water penetration into the seed due to the increase of drought stress leads to the reduction of hydraulic conductivity and consequently metabolic and physiological processes of germination are affected and their rate or amount will decrease (Kiani *et al.*, 1998).

Table 1: The ANOVA results of the measured traits including germination percentage mean daily germination, coefficient of velocity of germination, rootlet length, stemlet length, seed vigor index based on the mean of squares

Seed vigor	Stemlet length	Rootlet length	Coefficient of velocity of germination	Mean daily germination	Germination percentage	Degree of freedom	Sources of variations
69/77**	14/4**	17/68**	0/399**	1067/13**	192/36**	2	**Irrigation (I)**
42/02**	6/512**	10/47**	0/32238**	446/91**	252/78**	2	**Variety (V)**
0/522 $^{n.s}$	0/104 $^{n.s}$	0/1141 $^{n.s}$	0/00344$^{n.s}$	117/23 $^{n.s}$	11/11 $^{n.s}$	4	**Irrigation x Variety (V x I)**
0/811	0/0575	0/3853	0/005	2/95	7/64	27	**Error**
10/85	6/14	13/21	12/55	7/883	2/93		**C.V**

**and ** respectively mean significant at 5% and 1% level, ns means non-significant difference.*

Table (2): Mean comparison of the simple effect of irrigation and variation on germination traits including germination percentage, mean daily germination, coefficient of velocity of germination, rootlet length, stemlet length, seed vigor index in laboratory plan

Seed vigor	Stemlet length (cm)	Rootlet length (cm)	Coefficient of velocity of germination	Mean daily germination (day)	Germination percentage	Treatment
						Variety
9/86 ^{a}	4/64 ^{a}	5/52 ^{a}	0/69 ^{a}	24/53 ^{a}	97/08 ^{a}	**Sepideh = (V_1)**
8/73 ^{b}	3/89 ^{b}	4/89 ^{a}	0/62 ^{a}	26/03 ^{a}	96/25 ^{a}	**Kimia = (V_2)**
6/23 ^{c}	3/17 ^{b}	3/68 ^{b}	0/38 ^{b}	14/79 ^{b}	88/75 ^{b}	**Payam = (V_3)**
						Potential (bar)
10/85 ^{a}	5/06 ^{a}	5/94 ^{a}	0/76 ^{a}	32/48^{a}	98/33 ^{a}	**0**
7/93 ^{ab}	3/76 ^{b}	4/63 ^{b}	0/53 ^{b}	18/21 ^{b}	93/33 ^{b}	**-6 bars**
6/07 ^{ac}	2/89 ^{c}	3/51 ^{c}	0/4 ^{c}	14/67 ^{c}	90/42 ^{c}	**-9 bars**

**According to Duncan's test the means with similar letters in each column are not significantly different at 5% probability level.*

Mean Daily Germination (MDG)

The ANOVA results showed that the effect of polyethylene on the mean daily germination was significant at 1% level. As the drought stress increased, germination time increased, too and consequently the mean daily germination decreased. Different sorghum cultivars were significantly different at 1% level in response to drought stress in terms of mean daily germination. The highest mean daily germination belonged to Kimia cultivar. It seems like that as Zare' *et al.*, reported (2010), the increase of drought stress due to reduction of osmotic pressure and water absorption led to the decrease of seeds germination percentage and the increase of the time required for germination and ultimately the decrease of mean daily germination. The results were consistent with the findings of Jalilian and Tavakol (2004).

Coefficient of Velocity of Germination (CVG)

Coefficient of velocity of germination (CVG) was significantly different at 1% level among different varieties. Moreover, the effect of different levels of drought stress on CVG was significant at 1% level. The highest coefficient of velocity of germination belonged to the control treatment and as the drought stress increased the CVG decreased and this trend was observed in all varieties, so that Sepideh cultivar by 0.69 had the highest CVG among the cultivars. As the levels of drought stress increased the rate of germination speed decreased and it seems that Sepideh and Kimia cultivars were more tolerant of drought stress conditions.

Comparison of sorghum with other crops which are planted in the semiarid areas of the province such as peas through the research conducted by Masoomi (1999) showed that all varieties of peas were able to germinate at drought stress level of -9 bars although drought stress had a significant effect on germination speed and the lowest germination speed was observed in the potential of -9 bars. Since there is an inverse relationship between the CVG and the germination time, the more different levels of drought stress reduce the CVG, the more the germination time will be postponed (Scott, 1984). Biological processes need more energy within the stress conditions so that biochemical routes and physiological activities could continue and growth could be achieved. The trend of biological activities within the optimal environmental conditions will be different from drought stress conditions and consequently the growth will be different as well in the mentioned conditions.

In general, it seems like that since there is a high correlation between germination speed and rate and the seed quality and water potential, as the drought stress increases the time required for germination increases and the coefficient of velocity of germination decreases. The results were consistent with the findings of Hamidi *et al.*, (2005).

Rootlet Length

The effect of water potentials on the rootlet length in different varieties of grain sorghum was significant at 1% level and there was a significant difference between different varieties at 1% level, as well. As the water potential decreased from 0 to -9 bars the rootlet length decreased significantly. The highest length of rootlet was related to the lack of stress and the lowest length was related to the potential of -9 bars. The varieties were also significantly different in terms of the rootlet length. The highest rootlet length belonged to Sepideh cultivar by the mean of 5.52 cm and then Kimia cultivar by 4.89 cm and the lowest rootlet length belonged to Payam cultivar by 3.68 cm. Akhondi (2010) reported that as the stress increased, morphological traits such as rootlet length decreased. Shahriari and Hassan (2005) reported that as the levels of stress increased the length of rootlet decreased. The decrease of elongation of stem and root (stemlet and rootlet) due to drought stress could be associated with the fact that meristem cells of the rootlet and stemlet are affected and the cell division and elongation process is disrupted. Water deficit conditions affect the water absorption by the cells and thus the necessary turgescence pressure for the cells enlargement decreases which accelerates the growth stopping or slowing. The results were consistent with the findings of Akhondi (2010).

Stemlet Length

The stemlet length responded to sever drought stress and decreased seriously compared to the control treatment and rootlet length. The effect of water potentials on the stemlet length was significant at 1% level in the studied varieties. As the drought stress increased, the length of stemlet decreased so that the highest stemlet length was observed at the potential of 0 and the lowest one at the potential of -9. Cultivars were also significantly different at 1% level in terms of the length of stemlet. The highest stemlet length belonged to Sepideh cultivar by 4.64 cm. As the drought stress increased, the length of stemlet decreased in all varieties and the lowest length of stemlet was related to Payam cultivar by 3.17 cm.

One of the reasons of the decrease of stemlet length in drought stress conditions could be the lack of transfer of nutrients from the storage tissues of the seeds into the embryo. Furthermore, the decrease of

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water absorption by the seeds under drought stress conditions leads to the decrease of secretion of hormones and enzymes and consequently the seedling (rootlet and stemlet) growth disorder. The similar results have been reported by Uniyal and Nautiyal, (1998).

Seed Vigor Index

The effect of water deficit stress on the seed vigor index was significant at 1% level in sorghum varieties. As the water potential decreased, the seed vigor decreased, too. There was a significant difference between sorghum cultivar in terms of the seed vigor at 1% level. As reported by Kaur *et al*., (2005) in the control treatment (water potential = 0), due to activating the necessary metabolic for germination and the increase of activity of alpha and beta amylase enzymes, the quality of seed germination improved through starting the initial stages of germination which consequently led to the increase of seed vigor. Falleri (1994) reported that the seedling dry weight indicated the seed vigor and the greater storage of nutrients in seeds would improve the seed quality. The highest seed vigor index belonged to the control treatment and Sepideh variety and the lowest one was related to the treatment with the potential of -9 bars and Payam cultivar. The results were consistent with the findings of Giri *et al.,* (2003).

Since it has been proved that germination time and the rate and speed of germination are highly correlated with the seed quality (Rumbaugh, 1990; Khan, 1980), the less the germination time is the higher the quality will be. Different experiments have also shown that the germination rate can be a good indicator of seed vigor (Falleri, 1994; Khan, 1980).

Conclusion

The results of the research showed that the drought stress treatment by using polyethylene glycol had a significant effect on germination traits including germination percentage, mean daily germination, coefficient of velocity of germination, rootlet length, stemlet length, and seed vigor and lead to their decrease and descending trend.

Generally, different levels of drought stress had a significant effect on all the measured traits at 1% level. In this experiment, germination speed was affected by drought stress more than germination percentage. Most cultivars had acceptable germination in drought stress of -6 bars which indicates the characteristics of sorghum in tolerating drought stress and its suitability for being cultivated in arid and semiarid areas. Considering the cultivars, it can be said that in drought stress of -9 bars, the highest germination percentage belonged to Sepideh cultivar and the lowest germination percentage belonged to Payam cultivar. In summary, due to its better growth responses to stress conditions, Sepideh cultivar was the superior one.

REFERENCES

Abdu – Baki AA and JD Anderson (1973). Vigour determination in soybean by multiple criteria .*Crop Science* **13** 630-633.

Akhondi M (2010). The effect of polyethylene glycol on alfalfa genotypes in hydroponic medium. The 11th Congress on Iranian Agronomy and Plant Breeding, Shahid Beheshti University.

De R & RK Kar (1995). Seed germination and seedling growth of mungbean (*Vigna radiata*) under water stress induced by PEG-6000. *Seed Science and Technology* **23** 301-308.

Ellis RH and EH Roberts (1981). The quantification of ageing and survival in orthodox seeds. *Seed Science and Technology* **9** 377-409.

Falleri E (1994). Effect of water stress on germination in six provenances of *pinus pinaster* Ait. *Seed Science and Technology* **22** 591-599.

FAO (2009). Food outlook, Global Market Analysis. Available: http://www.Fao. Food outlook.Com.Koocheki A 1985. Crop production in dry regien (Cereals, Leghums, Industerial Crops, Forage crops) Mashhad University.

Food and Agricultural Organization (FAO) (2007). *FAO Production Year Book* [online]. Available: http://faostat.fao.org.

Giri GS and WF Schilinger (2003). Seed priming winter wheat for germination emergence and yield, *Crop Science* **43** 2135-2141.

Hamidi S (2005). Evaluation of late corn hybrids under drought stress conditions in the grain filling stage, using indicators of drought tolerance and path analysis. MS thesis, Faculty of Agriculture, Mazandaran University.
Jalilian V and Tavakol Afshari R (2004). The effect of osmopriming on seed germination in sugar beet under drought stress conditions, *Journal of Agriculture* **27**(2) 23 – 35.
Jamshidi M (2006). The effect of environmental stress on safflower genotypes. The 9th Congress on Iranian Agronomy and Plant Breeding, Shahid Beheshti University.
Kafi M *et al.*, (2005). The Physiological effects of drought stress resulting from polyethylene glycol on germination of lentil genotypes. *Iranian Agronomy Research*.
Kaur S, Gupta AK and Kaur N (2005). seed priming increase crop yield possibly by modulating m enzyme of sucrose metabolism in chickpea. *Journal of Agronomy and Crop Science* **191** 81-87.
Khan AA (1980). *The Physiology and Biochemistry of Dormancy and Germination* (North- Holland Publishing company) Oxford.
Kiani M, Bagheri A and Nezami A (1998). The response of lentil genotypes to drought stress resulting from polyethylene glycol 6000 at germination stage. *Journal of Agricultural Science and Industry* **12** 42 – 55.
Koochaki A, Soltani A and Azizi M (1997). *Plant Ecophysiology*, 2nd edition, Ferdowsi University of Mashhad **2** 271.
Maguire JD (1962). Seed of germination – aid in selection and evaluation for seedling emergence and vigour. *Crop Science* **2** 176-177.
Mansouri M, Hakimzadeh MA, Zare Ernani M and Mosleh Arany A (2011**).** Effect of drought and salinity stress on germination of Arbusculiso salsola and Anabasis karea. MSc. Thesis. Faculty of Natural Resources, Yazd University .
Oskooei B (2010). The effect of drought stress on some lines and cultivars of wheat at vegetative growth stage. The 11th Congress on Iranian Agronomy and Plant Breeding, Shahid Beheshti University.
Rahimian Mashhadi H (1999). The effect of different potentials resulting from glycol and sodium chloride and temperature on germination of rainfed wheat masses. Agricultural Science and Industry, Ferdowsi University, Mashhad.
Rumbaugh MD and Pendry BM (1990). Germination salt resistance of alfalfa (M*edicago sativa* L.) germplasm in relation to subspecies and centers of diversity. *Plant Soil*.
Sadat Asilan K (2009). The effect of water deficit stress on germination traits of the seeds of ten ecotypes of perennial alfalfa. *Iranian Journal of Agriculture* **1**.
Salehi Far M (2010). The effect of drought stress on seedling germination and growth in 8 genotypes of bean. The 11th Congress on Iranian Agronomy and Plant Breeding, Shahid Beheshti University.
Sarmadnia G, Tavakoli H and Ghorbani A (1988). Investigating the resistance of different masses of rainfed wheat at germination stage. *The Proceedings and the Results of the First Conference on Investigating Rainfed Issues in Iran*, Ferdowsi University, Mashhad.
Scott SJ, Jones RA and Williams WA (1984). Review of data analysis method for seed germination. *Crop Science* **24** 1192-1199.
Selote DS and Khanna-Chopra R (2004). Drought-induced spiked sterility is associated with and inefficient antioxidant defense in rice panicles. *Physiologia Plantarum* **121**(3) 462-471.
Shahriari R and Hassan Panah D (2005). Measuring the length of coleoptiles in native and promising genotypes of wheat in vitro using mannitol as the osmotic stress factor. The Fourth Congress on Iran Biotechnology.
Shekari F, Banay Khosraghi A and Rahimi M (1998). The response of three cultivars of bean to drought stress at germination stage. The Proceedings of the Fifth Congress on Agronomy and Plant Breeding, Iran, Karaj.
Shekari F, Rahim Zadeh Khoei F, Valizadeh M, Alyari H and Shakiba MR (1998). The effect of salinity stress on germination of 18 varieties of canola. The Proceedings of the Fifth Congress on Agronomy and Plant Breeding, Iran, Karaj.

Uniyal AR and Nautiyal AR (1998). Seed germination and seedling extension growth in *ougeinia dalbergioides* Benth. Under water and salinity stress. *New Forests* **16** 265-272.
Zare' S, Tavili A and Shahbazi R (2010). The effect of different levels of salicylic acid on the improvement of germination components in berry plant under salinity and drought stress. Journal of Range and Watershed, *Iranian Journal of Natural Resources* **3**(1) 29 – 39.

