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Study of germination and emergence of monogerm seed of sugar beet cultivars under moisture stress

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ABSTRACT

In order to further understand the emergence and germination of sugar beet monogerm cultivars under moisture stress, the current study was carried out at three stages. At the first stage, the quality of germination of three monogerm cultivars (Rizofort, Rasoul and Zarghan) were studied under five moisture stress levels (0, -2, -4, -6 and -8 bars) in germinator at 15°C by between-paper method. At this stage, after the onset of the germination, the number of germinated seeds was daily counted and at the end, germination percentage and rate was determined. The second stage was similar to the first one with the difference that at this stage, the percentage of normal and abnormal seedlings was determined 14 days after sowing and then, radicle length, coleoptile length and their ratio as well as radicle and coleoptile dry weight and their ratio were measured for each treatment. At the third stage, the studied cultivars were evaluated in clay soil in growth chamber under moisture stress of 17.5, 20, 22.5 and 25% (control) of soil volumetric moisture. At this stage, when emergence started, the number of emerged seeds was daily counted and then, emergence rate, days to 50% emergence and final emergence percentage were determined for each cultivar and treatment. The statistical design of all stages was a two-factor factorial (the levels of the factors were different at each stage depending on the number of treatments) based on a Randomized Complete Block Design with four replications. The studies were carried out in the laboratories of Agricultural and Natural Resources Research Center of Kermanshah, Iran. Results of the first study showed that moisture stress significantly impacted germination percentage and days to 50% germination, so that as moisture stress was intensified, germination percentage decreased. Also, results revealed that germination percentage of cv. Rizofort was higher than that of Rasoul and Zarghan. Results of the second study indicated that moisture stress significantly affected normal seedlings and ungerminated seeds at 1% probability level. According to the results of the third study too, moisture stress significantly influenced emergence percentage, emergence rate and days to 50% emergence. Results showed that the emergence of sugar beet seeds dramatically decreased at soil volumetric moisture level of lower than 17.5% (-6 bars soil tension) and the emergence percentage of sugar beet seeds did not significantly change with the increase in clay soil volumetric moisture level from 20 to 25% (soil tension of -3 to -0.3 bars).

Keywords: Germination, Germinator, Moisture stress, Monogerm seed, Sugar beet

INTRODUCTION

The interest to sugar beet monogerm seeds has been extensively grown in recent years and its cultivation area has been increased compared to polygerm seeds. At present, 80% of total sugar beet cultivation area belongs to monogerm seeds. Soil moisture at sowing time is one of the factors affecting germination and emergence of sugar beet seeds, while sugar beet seeds are rarely irrigated immediately after sowing in most parts of Iran, particularly in Kermanshah where farmers wait for the seeds to emerge by rainfall and then, they start irrigation, whereas precipitation is usually inadequate and disperse during this time. Consequently, optimum plant density is not obtained in sugar beet fields which in addition to yield loss, results in loss of some of inputs, water and energy and finally, leads to considerable eco-

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nomical loss. Soil moisture is one of the important factors limiting germination and emergence of sugar beet seeds under field conditions (Akson *et al*., 1980). Moisture deficiency or so-called moisture stress results in the loss of germination percentage and rate. Delayed emergence of sugar beets intensifies the damages of pests and diseases and decreases the capability of the plants in competing with weeds (Campbell and Enz, 1991) and finally, optimum density is not obtained.

Sugar beet seeds are sown at the depth of 2.5-3 cm. Soil can be rapidly dried at this depth and pose a problem for the germination of seeds (Akson *et al*., 1980), whereas most other plants are able to emerge even from deeper depths of soil. Furthermore, sugar beet seeds need more moisture than other corps. Hunter and Erickson (1952) reported that soil suction must be less than 12.5, 7.9, 6.6 and 3.5 atmospheres at 25°C in order for the seeds of maize, rice, soybean and sugar beet to be able to germinate, respectively. Therefore, for example maize can germinate in drier soils compared to sugar beet.

Yavari *et al*. (2002) studied the effect of mannitol-induced drought stress at germination and initial seedling growth stages of sugar beet on drought-tolerant and drought-susceptible sugar beet lines *in vitro*. Their results revealed that drought stress decreased germination and seedling growth and that there were significant differences among lines in germination percentage, cotyledon and root fresh weight, and root length.

Akson *et al*. (1980) showed that moisture stress adversely affected both germination rate and germination percentage and that moisture stress down to -4 bars decreased germination rate but it did not impact final germination percentage. However, lower potentials of moisture decreased both germination rate and germination percentage, and almost no germination occurred at <-7 bars potentials.

Yonts *et al*. (1983) revealed that the increase in drought stress and the decrease in soil moisture resulted in the loss of germination rate and sugar beet seeds emergence and that the loss of germination percentage was greater at temperatures lower than 10°C. Also, they found a positive relationship between soil temperature at sowing time and final establishment of sugar beets. The effect of moisture stress at germination and emergence stages can be evaluated more precisely in controlled laboratory conditions than in the field conditions. Osmotic solutions like polyethylene glycole, Mannitol and NaCl are used to simulate moisture stress in different crops e.g. sugar beet in laboratory (Hadas, 1997; Gumerson, 1986; Akson *et al*., 1980; Habibi, 1994; Yavari *et al*., 2002; Wright *et al*., 1978; Khajeh Hossini *et al*., 2000). One of the indices used to further study the causes of seed germination loss under moistures stress is germination rate which is determined by days to 50% germination and coefficient of germination rate (Campbell and Enz, 1991; Foti *et al*., 2002).

Given the growing cultivation area of sugar beet monogerm seeds and their special susceptibility to moisture stress, understanding the germination and emergence pattern of monogerm seeds under moisture stress and determining the minimum moisture required for the production of normal seedlings have always been particularly important. The current study tried to further examine the effect of moisture stress on germination and emergence of sugar beet monogerm seeds.

MATERIALS AND METHODS

The current study was carried out at three stages as follows:

Stage 1: Study of germination pattern at different levels of moisture stress

The seeds of three monogerm cultivars of sugar beet (Rizofort, Rasoul and Zarghan) were used in the present study. The seeds of these commercial cultivars were produced in Sugar Beet Seed Institute of Karaj, Iran in 2006. Before the study, all seeds were washed for 2 hours (ISTA, 1996). In this study, the cultivars were evaluated under different levels of moisture stress including control (0 bar) and -2, -4, -6 and -8 bars. Moisture stress was created by polyethylene glycol (PEG) solution. The following equation was used for obtaining different osmotic potentials out of PEJ solution (Michel, 1983):

$$\psi(\text{bar}) = 1.29[\text{PEG}]^2\text{t} - 140[\text{PEG}]^2 - 4[\text{PEG}]$$

where, *PEG*, *t* and *Ψ* were in terms of $g.g^{-1}$ water, °C and bar, respectively. The study was carried out as a factorial experiment based on a Randomized Complete Block Design with four replications. In each replication, 50 seeds were sown inside germination paper and were put inside special containers. The replications were uniformly treated with 20 ml solutions with a predetermined osmotic potential depending on the treatment, and the control was treated with 20 ml distilled water. The seeds in containers were put into germinator at

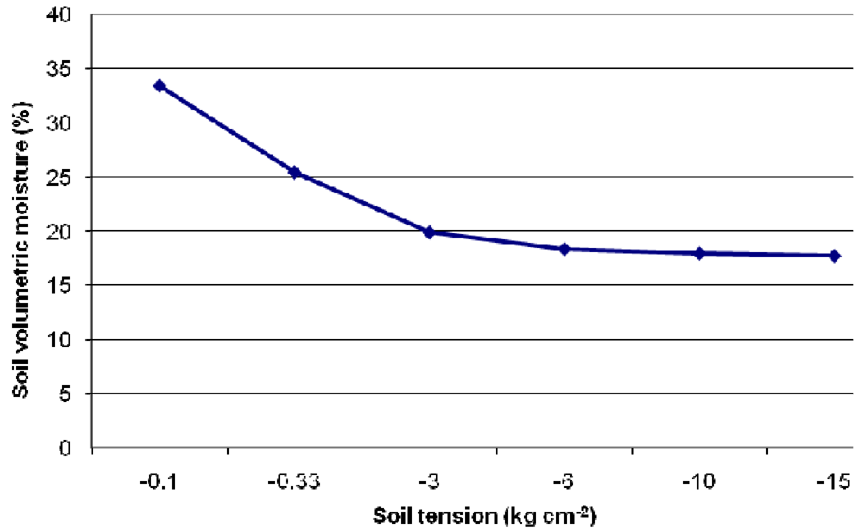

Fig. 1. PF-curve of the soil used at the third stage of the study

15℃. The temperature was selected according to mean temperature during sugar beet sowing in spring. With the onset of germination, the germinated seeds with 1 mm radicle length were daily counted and removed. At the end of this stage of the study, the number of germinated seeds, germination rate and days to 50% germination of the treatments were determined by the following equations. Days to 50% germination was determined by Eq. 1 (Foti *et al.*, 2002):

$$MGT = \sum \frac{T_i N_i}{S} \quad (1)$$

where, T_i was the time after study onset (day), N_i was the number of germinated seeds at *n*th day and *S* was the total number of germinated seeds at the end of the study. Coefficient of germination rate (CV) was obtained by Eq. (2) (Campbell and Enz, 1991; Phartyal *et al.*, 2003):

$$CV = 100\left(\frac{\sum N_i}{\sum N_i T_i}\right) \quad (2)$$

The higher the CV was, the higher the germination rate would be.

Stage 2: Determination of normal and abnormal seedlings at different levels of moisture stress

At this stage, the seeds were first cultivated inside germination paper and then, they were transferred to PVC tubes with the diameter of 3.5 cm and the height of 18 cm. For this purpose, first four replications of each cultivar including 50 seeds were put inside the germination paper and then, half of PEG osmotic solutions with different concentrations (0, -2, -4, -6 and -8 bars) were uniformly poured on them. Afterwards, they were rolled and put into the PVC tubes. Then, all four PVC tubes were vertically put in containers and the remaining of the osmotic solution was added. The samples were situated inside germinator at 15℃. The number of normal, abnormal and ungerminated seedlings was counted 14 days later (ISTA, 1996). In addition, the length of radicle and coleoptile, the ratio of their lengths, their dry weight and the ratio of their dry weights were determined for the treatments of control, -2 and -4 bars. At stress levels of -6 and -8 bars, the lengths of radicle and coleoptile could not be measured due to the over-stunted growth of the seedlings and even at -8 bars level, the germination was so low that the whole treatment was eliminated.

Stage 3: Study of emergence pattern in soil at different levels of moisture stress

At this stage of the study, emergence pattern of the sugar beet cultivars (Rizofort, Rasoul and Zarghan) were studied in soil under different levels of moisture stress in growth chamber. Moisture stress levels included 17.5, 20, 22.5 and 25% (control) of volumetric moisture of loam soil taken from the field. Twenty-five percent moisture was approximately equal to field capacity (FC). Before the study, a sample of soil was used to determine soil tension at each level of volumetric moisture in order to determine its PF-curve. The results are presented in Fig. 1.

In this study, field soil was first screened by 2-mm mesh. Then, it was autoclaved at 120°C. To prepare soils with different moisture levels, 17.5, 20, 22.5 and 25 g water was added to 100 g dry

Table 1. Results of analysis of variance for the measured traits in the study of germination pattern at different moisture stress levels

S.O.V.	df	Means of squares		
		Germination percentage	Germination rate	Days to 50% germination
Replication	3	0.008	0.013	3.216
Moisture stress (S)	4	2.114**	0.175**	114.41**
Cultivar (C)	2	0.234**	0.043**	7.75**
S × C	8	0.019**	0.027**	1.80ns
Error	42	0.002	0.006	1.37
Coefficient of variation (%)		5.66	20.3	14

**, * and *ns* show significance at 1 and 5% levels and non-significance, respectively.

soil and then, they were kept in plastic bag for 24 hours during which they were frequently intermingled to uniformly disperse the moisture. Afterwards, the seeds of the cultivars were sown in these soils for which firstly, the soils were poured in 20×30 cm^2 plastic boxes up to the height of 10 cm. Then, two seeds were row-sown and covered with the same soil to put them in the depth of 2.5 cm. Next, they were compacted by exerting a power of 70 $g.cm^2$ (Yonts *et al*., 1983). After that, the boxes were capped to prevent moisture evaporation. No crust was formed in containers because they had been capped and no additional water was added to them. As a result, physical resistance of the crust was removed and only moisture stress played role in emergence. The containers were put in growth chamber at 15°C. This study was carried out as a factorial experiment (soil moisture at four levels and cultivar at three levels) based on a Randomized Complete Block Design with four replications. After the onset of emergence of each treatment, the emerged seeds were daily counted to determine the emerged seeds percentage, emergence rate and days to 50% emergence by Eqs. 1 and 2. The criterion of emergence was the exit of cotyledon from soil surface and their complete opening.

It should be noted that the data were transformed at all three stages for the traits for which data transformation was needed. Then, their variance was analyzed and their means were compared. But, only major figures are mentioned in the tables of means and the coefficients of variations are mentioned on the basis of major figures.

Results and Discussion

Germination trend at different levels of moisture stress

Results of analysis of variance revealed that the effect of moisture stress was significant on germination percent and days to 50% germination. Also, the difference among cultivars was significant (Table 1). The interaction between cultivar and moisture was significant on germination percentage and rate. According to the results of means comparison, germination percentage decreased with the increase in moisture stress level, so that mean germination percentage which was 90% in control (no-stress treatment) reached to as low as 12% at -8 bars stress level (Table 2). A study showed a positive relation between sugar beet seed emergence rate and emergence percentage in the field (Durrant, 1988). Moisture stress dramatically affected germination rate and days to 50% germination too, so that as moisture stress was intensified, days to 50% germination increased from 4 days in control to 11 days in -8 bars stress level and vice versa; i.e. germination rate was greatly decreased with the increase in moisture stress level (Table 2). Other studies have shown that moisture stress retards germination and reduces its percentage, so that germination is retarded 1 day per -2 bars increase in osmotic potential (Jalilian and Tavkol Afshar, 2005).

In another study, it was shown that moisture stress adversely influenced sugar beet seed germination rate and percentage and that the tensions of less than -7 bars almost halted seed germination (Akson *et al*., 1980). In total, seed germination rate is directly proportional to available water potential.

The sugar beet cultivars exhibited significant differences in the measured traits too, so that among the studied cultivars, treatment no. 3 significantly differed from two other treatments in terms of both germination rate and percentage, but treatments no. 1 and 2 were ranked in the same group (Table 2). Results of other studies have shown significant differences in germination percentage among sugar beet lines (Yavari *et al*., 2002). In a study on different sugar beet germplasms under salinity stress, significant differences were found among germplasms and it

Table 2. Grouping of means of the measured traits in the study of germination pattern at different moisture stress levels (Duncan Test)

Moisture stress levels	Cultivars	Germination percentage	Germination rate	Days to 50% germination (day)
Control		90.2 a	32.0 a	4.0 d
-2 bars stress		87.5 a	16.1 b	6.4 c
-4 bars stress		59.3 c	10.8 bc	9.4 b
-6 bars stress		22.7 b	9.6 c	10.6 ab
-8 bars stress		12.2 d	8.9 c	11.4 a
	Zarghan	47.2 c	12.6 b	9.0 a
	Rasoul	52.6 b	13.6 b	8.4 ab
	Rizofort	63.3 a	20.2 a	7.7 b
Control	Zarghan	86.0 b	20.1 bc	5.1 e
Control	Rasoul	90.3 ab	23.5 b	4.5 e
Control	Rizofort	94.3 a	52.3 a	2.5 f
-2 bars stress	Zarghan	85.0 b	15.1 bcde	6.7 cd
-2 bars stress	Rasoul	85.8 b	14.2 bcde	7.1 c
-2 bars stress	Rizofort	91.8 a	19.0 bcd	5.3 de
-4 bars stress	Zarghan	46.5 d	9.8 cde	10.3 ab
-4 bars stress	Rasoul	64.8 c	11.3 cde	8.9 b
-4 bars stress	Rizofort	66.5 c	11.2 cde	9.0 b
-6 bars stress	Zarghan	12.3 f	9.1 de	11.3 a
-6 bars stress	Rasoul	17.0 f	9.6 de	10.5 ab
-6 bars stress	Rizofort	38.8 d	10.0 cde	10.1 ab
-8 bars stress	Zarghan	6.0 g	8.9 e	11.5 a
-8 bars stress	Rasoul	5.3 g	9.3 de	10.9 a
-8 bars stress	Rizofort	25.3 e	8.6 e	11.7 a

Figures with similar letter(s) in each column did not show significant differences at 5% probability level.

was concluded that it was possible to select for stress tolerance at germination stage (McGrath *et al*., 2008).

Mean comparison of the combined treatments of drought stress and cultivars indicated that cultivar no. 3 treated with no stress had the highest germination percentage (94.3%) and cultivars no. 1 and 2 treated with -8 bars moisture stress had the lowest one (Table 2 and Fig. 2). It is worth noting that the germination percentage of cultivar no. 3 treated with -6 bars stress was 38.8%, but cultivars no. 1 and 2 had the germination percentages of 17 and 12% at the same stress level, respectively. The study of the interaction between stress and cultivar levels revealed that the responses of the cultivars varied as stress was intensified and that

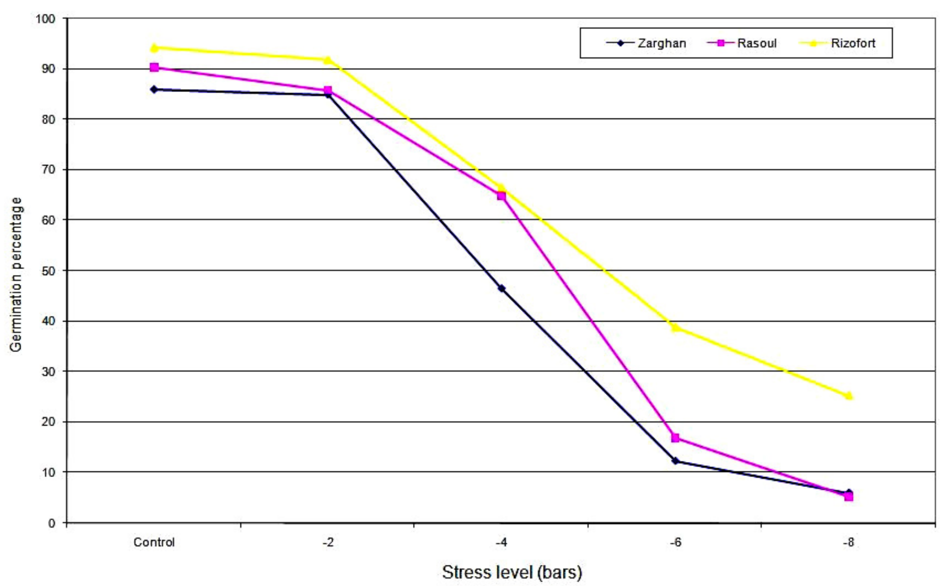

Fig. 2. Variations of interaction between cultivar and stress levels for germination percentage

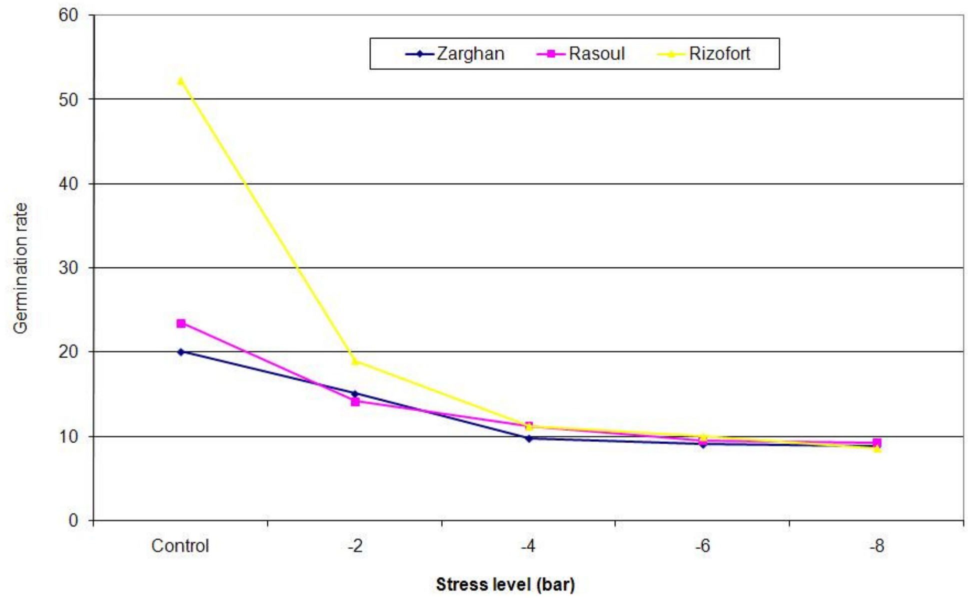

Fig. 3. Variations of interaction between cultivar and stress levels for germination rate

the loss of germination percentage of cvs. Rasoul and Zarghan was greater with the increase in stress, while cultivar no. 3 had a considerable germination percentage even at severe stress level (Fig. 2). The interaction of stress levels and cultivars on germination rate showed that the germination rate of cultivar no. 3 treated with no stress was higher than that of two other cultivars, but the germination rate of all three cultivars tended to equate with the increase in stress intensity (Fig. 3).

Despite the interactions between stress levels with cultivars on days to 50% germination were not significant according to the analysis of variance (Table 1), they were ranked in different groups, so that Rizofort had the lowest days to 50% germination (2.5 days) under no-stress conditions (control). But, it should be noted that the cultivars were not significantly different at stress levels of -4 to -8 bars (Table 2).

Overall, moisture stress plays a very important role in germination and emergence of sugar beet seeds. The results of the study showed that over -4 bars moisture stress sharply decreased germination percentage and resulted in the loss of plant density. Therefore, soil moisture is recommended to be so managed during germination and emergence that tension does not fall below -4 bars.

Normal and abnormal seedlings and the length of radicle and coleoptile at different moisture stress levels

Given that the length of radicle and coleoptile and their dry weights were impossible to be measured at -6 bars stress level, they were measured at three other levels (0, -2 and -4 bars). But, other traits were separately measured at all four stress levels and their variances were analyzed.

Results revealed that the effect of moisture stress was significant on normal seedlings and ungerminated seeds at 1% probability level. Cultivars exhibited significant differences in normal seedlings and ungerminated seeds percentage, too (Table 3). Also, the interaction was significant on abnormal seedlings and ungerminated seeds percentage at 1% level. As stress level was increased, germination percentage decreased and the num-

Table 3. Results of analysis of variance for the measured traits at different moisture stress levels

S.O.V.	df	Means of squares		
		Normal seedlings percentage	Abnormal seedlings percentage	Ungerminated seeds percentage
Replication	3	0.006	0.004	0.007
Moisture stress (S)	3	1.115**	0.005ns	0.906**
Cultivar (C)	2	0.108**	0.009ns	0.134**
S × C	6	0.011ns	0.027**	0.030**
Error	33	0.005	0.003	0.005
Coefficient of variation (%)		12.2	24.3	16.3

**, * and *ns* show significance at 1 and 5% levels and non-significance, respectively.

Table 4. Grouping of means of the measured traits at different moisture stress levels

Moisture stress levels	Cultivars	Normal seedlings percentage	Abnormal seedlings percentage	Ungerminated seeds percentage
Control		6.67 a	13.58 a	19.75 c
-2 bars stress		65.00 a	15.83 a	19.17 c
-4 bars stress		50.43 b	16.50 a	33.08 b
-6 bars stress		9.83 c	17.67 a	72.50 a
	Zarghan	49.00 a	13.75 a	37.25 b
	Rasoul	40.63 b	16.19 a	43.19 a
	Rizofort	54.31 a	17.75 a	27.94 c
Control	Zarghan	72.00 ab	14.00 bc	14.00 fg
Control	Rasoul	50.50 de	14.25 bc	35.25 c
Control	Rizofort	77.50 a	12.50 bc	10.00 g
-2 bars stress	Zarghan	65.00 bc	15.00 bc	20.00 efg
-2 bars stress	Rasoul	60.50 bcd	17.00 b	22.50 dfg
-2 bars stress	Rizofort	69.50 ab	15.50 bc	15.00 fg
-4 bars stress	Zarghan	48.50 de	16.50 bc	35.00 c
-4 bars stress	Rasoul	46.50 e	20.00 b	33.50 cd
-4 bars stress	Rizofort	56.25 cde	13.00 bc	30.75 cde
-6 bars stress	Zarghan	10.50 fg	9.50 c	80.00 a
-6 bars stress	Rasoul	5.00 g	13.50 bc	81.50 a
-6 bars stress	Rizofort	14.00 f	30.00 a	56.00 b

Figures with similar letter(s) in each column did not show significant differences at 5% probability level.

Table 5. Results of analysis of variance for radicle and coleoptile length and their ratios at different moisture stress levels

S.O.V.	df	Means of squares					
		Radicle length	Coleoptile length	Radicle:coleoptile length ratio	Radicle weight	Coleoptile weight	Radicle:coleoptile weight ratio
Replication	3	0.273	0.389	0.060	0.001	0.002	0.001
Moisture stress (S)	2	16.32**	11.89**	0.819**	0.006ns	0.010ns	0.034*
Cultivar (C)	2	11.18**	0.492ns	0.135ns	0.009ns	0.019**	0.054**
S × C	4	1.11ns	0.173ns	0.098ns	0.007ns	0.013**	0.015ns
Error	24	0.967	0.211	0.128	0.003	0.002	0.007
Coefficient of variation (%)		10.7	9.4	18.50	10.5	7.3	11.0

**, * and *ns* show significance at 1 and 5% levels and non-significance, respectively.

ber of abnormal seedlings and ungerminated seeds increased, so that the abnormal seedlings percentage rose up to 17.67% and ungerminated seeds percentage went up to 72.5% at -6 bars moisture stress (Table 4). Among cultivars, cv. Rasoul showed the lowest germination percentage and the highest ungerminated seeds percentage. The studied cultivars did not show significant differences in abnormal seedlings percentage, but cv. Rasoul had the highest ungerminated seeds percentage (43%). The germinating ability of seeds depends not only on genetics but also on environmental conditions of their maternal seeds and particularly the time of seed maturity. Some studies have revealed that seeds matured completely on their maternal parent were more able to translocate reserves during germination and enjoyed higher seed vigor (Catusse *et al.*, 2008). The study of the interaction of stress and cultivar levels on abnormal seedlings percentage and ungerminated seeds percentage showed that cultivar no. 3 had high germination percentage under severe stress, but stress in turn brought about the formation of abnormal seedlings; however, the seeds of cultivars Rasoul and Zarghan were not able to germinate with the increase in stress and consequently, they produced fewer number of abnormal seedlings (Figs. 4 and 5).

Analysis of variance indicated that moisture stress significantly affected the length of radicle and coleoptile and their ratios (Table 5), but its impact on the weight of radicle and coleoptile was not significant (Table 5). The difference in the length of radicle and the weight of coleoptile was significant among the cultivars, too (Table 5).

Means of the measured traits are compared in Table 6 according which the length of radicle and coleoptile decreased with the increase in moisture stress level and the highest radicle:coleoptile length ratio was obtained at -4 bars stress level. These results stated that as moisture stress level was intensified, the increase in radicle length was greater than the increase in coleoptile length making it possible for the plants to access more soil

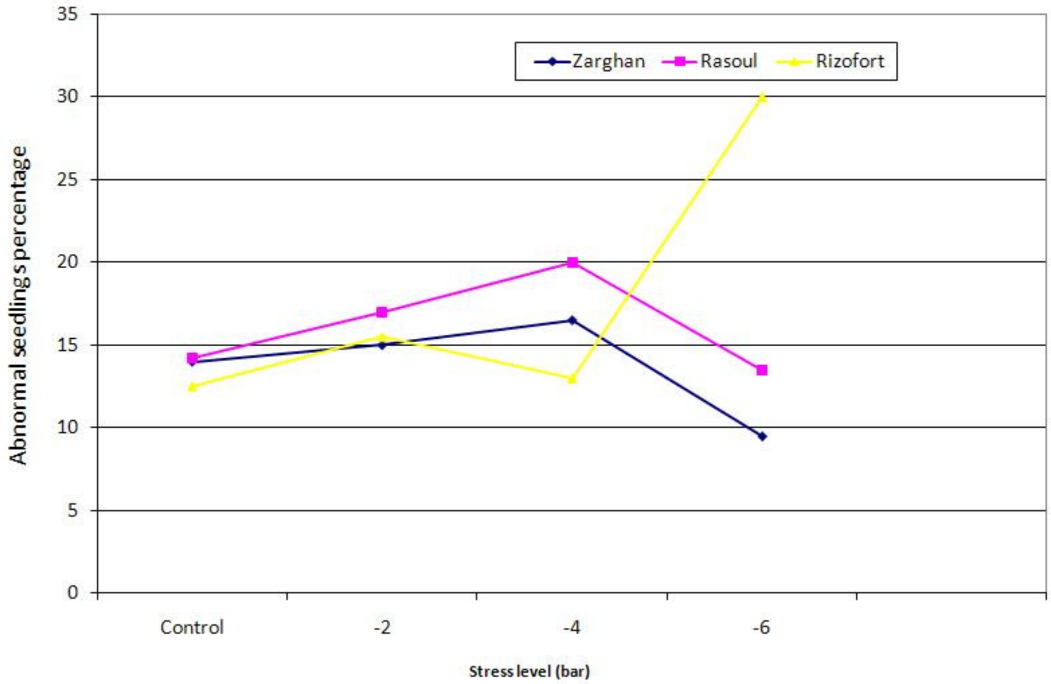

Fig. 4. Variations of interaction between cultivar and stress levels for abnormal seedlings percentage

moisture. Similar results have been found about wheat in other studies so that the increase in stress level resulted in the loss of the length of radicle and coleoptile in 16 genotypes, but the ratio of radicle:coleoptile ratio increased from 1.14 to 2.32 (Rauf *et al*., 2007). Okcu *et al*. (2005) studied the effect of PEG and NaCl-induced drought stress on the germination of peas and revealed that higher drought stress level decreased the length of root and shoot but it resulted in higher ratio of root:shoot length.

According to results, no significant difference was observed between different levels of drought stress levels in terms of radicle dry weight (Table 6). It means that the increase in stress level was followed by the decrease in radicle diameter and the increase in its length. The insignificant difference in radicle weight among the stress levels (Table 6) showed that as the germination of sugar beet seeds commenced, perispermic reserves

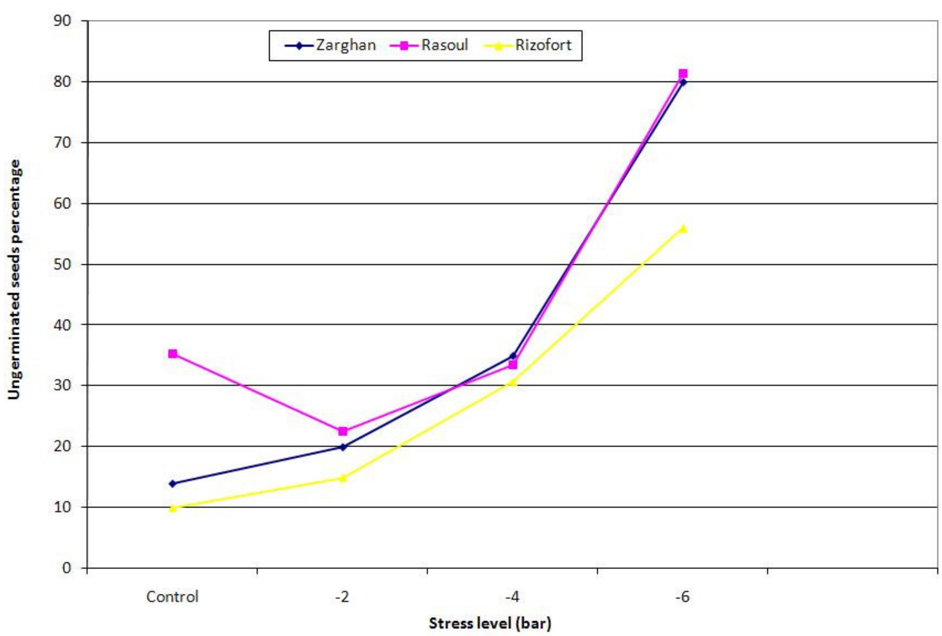

Fig. 5. Variations of interaction between cultivar and stress levels for ungerminated seeds percentage

Table 6. Grouping of means of the measured traits in the study of germination pattern at different moisture stress levels

Moisture stress levels	Cultivars	Radicle length (cm)	Coleoptile length (cm)	Radicle:coleoptile length ratio	Radicle weight (mg)	Coleoptile weight (mg)	Radicle:coleoptile weight ratio
Control		10.5 a	5.7 a	1.85 ab	0.5217 a	0.6583 ab	0.800 a
-2 bars stress		8.8 b	5.1 b	1.73 b	0.4817 a	0.6942 a	0.697 b
-4 bars stress		8.3 b	3.8 c	2.23 a	0.4842 a	0.6375 b	0.766 ab
	Zarghan	10.1 a	5.1 a	2.02 a	0.5183 a	0.6925 a	0.754 ab
	Rasoul	8.2 b	4.7 b	1.82 a	0.4658 a	0.6792 a	0.686 b
	Rizofort	9.4 a	4.9 ab	1.97 a	0.5033 ab	0.6183 b	0.820 a

Figures with similar letter(s) in each column did not show significant differences at 5% probability level.

Table 7. Results of analysis of variance for the traits of seed germination quality inside soil at different moisture stress levels

S.O.V.	df	Means of squares		
		Emergence percentage	Emergence rate	Days to 50% emergence
Replication	2	0.003	1.03	0.68
Moisture stress (S)	3	0.950^{**}	106.2^{**}	104.5^{**}
Cultivar (C)	2	0.110^{**}	1.2^{ns}	0.56^{ns}
S × C	6	0.007^{ns}	0.39^{ns}	0.19^{ns}
Error	22	0.012	0.64	0.45
Coefficient of variation (%)		9.1	6.8	7.2

**, * and *ns* show significance at 1 and 5% levels and non-significance, respectively.

were equally transferred to radicle and coleoptile even under stress conditions (Durr and Boiffin, 1995). Among the studied cultivars, cv. no. 2 had the lowest radicle and coleoptile length (Table 6). Grouping of mean dry weight of radicle and coleoptile by Duncan method revealed significant differences among cultivars, so that the lowest one was obtained from cv. no. 3, but this cultivar had the highest radicle:coleoptile length ratio (Table 6).

Results of means comparison of the interaction between stress level and cultivar on radicle dry weight indicated that cv. Rasoul had the highest radicle dry weight (0.7275 mg) and cv. Rizofort had the lowest one (0.5750 mg) under no-stress conditions.

Germination quality in soil under various levels of moisture stress

Analysis of variance revealed significant effect of moisture stress on emergence percentage, emergence rate and days to 50% emergence (Table 7), but cultivars exhibited significant differences only in emergence percentage.

According to means comparison, the lowest emergence percentage (43%) was obtained at 17.5% volumetric moisture level and germination percentage increased with soil moisture. However, there was no statistically significant difference between soil volumetric moisture levels of 20 and 25%. Also, the lowest emergence rate was obtained at 17.5% volumetric moisture level (Table 8). Given that the emergence percentage was only 43% at 17.5% volumetric moisture level of soil, it can be inferred that appropriate moisture level for the emergence of sugar beet seeds in similar soils is over 17.5% volumetric moisture of soil and that lower levels would not result in optimum emergence under the field conditions. Among the cultivars, cv. no. 3 had the highest emergence percentage, but cultivars did not show significant differences in emergence rate and days to 50%

Table 8. Grouping of means of the measured traits in the study of germination pattern at different moisture stress levels

Moisture stress levels	Cultivars	Emergence percentage	Emergence rate	Days to 50% emergence (day)
25% moisture		94 a	14.4 a	6.97 c
22.5% moisture		96 a	14.2 a	7.07 c
20% moisture		93 a	11.2 b	9.03 b
17.5% moisture		43 b	7.0 c	14.23 a
	Zarghan	79 b	11.5 a	9.45 a
	Rasoul	78 b	11.5 a	9.45 a
	Rizofort	87 a	12.1 a	9.07 a

Figures with similar letter(s) in each column did not show significant differences at 5% probability level.

emergence (Table 8).

The increase in moisture stress level will decrease emergence rate which in turn, will increase days to 50% emergence. Under these conditions, the seedlings will rely on their perispermic reserves for emergence since they will not intercept light and they will have heterotrophic growth. As a result, they will be weakened. Durr and Boiffin (1995) showed that at 20°C in the dark, various organs of sugar beet seedlings used perispermic reserves up to 4 days after planting and elongated and grew in weight, but afterwards, the reserves transferred from cotyledon to hypocotyls and 6 days later, all organs of the seedlings started to lose their weights. Therefore, optimum establishment of the seedlings under the field conditions depends not only on initial weight of the seeds, but also on environmental conditions.The seedlings lose their initial reserves due to delayed emergence and so, when they germinate, they produce weak seedlings which will impact their subsequent growth. Hence, in order to have better establishment of sugar beet seedlings and to have stronger, healthy and uniform plants with optimum yield, proper conditions must be provided for the seedlings.

Conclusion

In total, results showed that higher moisture stress levels resulted in lower germination and emergence percentage of sugar beet seeds and that the highest germination percentage occurred under no-stress conditions. Similar results were obtained in the study of emergence pattern in soil, so that there was no significant difference in seed emergence percentage from 25% moisture level (FC) to 20% moisture level. However, at moisture levels of less than 20% at which the tension of the soil was -3 bars (Fig. 1), emergence percentage decreased and reached to 43% under 17.5% moisture level which would not result in economically appropriate plant density under field conditions. Therefore, given the sensitivity of sugar beet seeds to moisture stress at germination and emergence stages, it is required to provide enough moisture under field conditions. Any sort of moisture stress would drastically decrease plants establishment in the field.

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