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# The Effect of Seed Aging on the Seedling Growth as Affected by Environmental Factors in Wheat

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**Abstract:** The present study was conducted to evaluate the effect of seed aging (seed quality) on germination, emergence and seedling growth of wheat under optimum (control) and stressful conditions including salinity (2 levels), drought (2 levels) and deep sowing depth (physical stress). Seeds (cv. Zagros) were kept at a high temperature (43°C) and high relative humidity (90-95%) to create different classes of seed aging. Factorial combinations of 5 seed aging treatments (0, 48, 72, 96 and 144 h accelerated aging periods) and 6 levels of environmental factor were treatments of the experiment. Maximum and rate of emergence reduced significantly with increase in the duration of accelerated aging. The ranking of the stress factors from most to least harmful for maximum emergence were: severe drought, severe salinity and sowing depth of 7 cm, medium drought and medium salinity. Seed aging significantly decreased leaf area and seedling dry weight at the first harvest, but reduction in these characteristics was not significant at the second harvest. The ranking of the importance of stress conditions in terms of harmful effects on the leaf area and seedling dry weight were severe drought, medium drought, severe salinity and sowing depth of 7 cm and medium salinity. Seed aging had no a pronounced effect on the number of leaf at the first or second harvests.

**Key words:** Seed aging, early growth, salinity, drought, deep sowing

## INTRODUCTION

Emergence and seedling growth of crops are affected by environmental factors such as soil water, salinity and sowing depth (Anda and Pinter, 1994; Jacobson and Bach, 1998; Soltani *et al*., 2006) and seed quality (De Figueiredo *et al*., 2003; Soltani *et al*., 2001). De Figueiredo *et al*. (2003) reported that the effect of seed vigor on early seedling vigor depends on environmental conditions during early growth stages. Low seed quality may be followed by undesirable germination and lead to low vigor seedlings, especially under stressful conditions (Tillmann *et al*., 1994; Rehman *et al*., 1999; De Figueiredo *et al*., 2003).

Reports indicate that seed aging reduces germination (Soltani *et al*., 2008; Rehman *et al*., 1999; Khajeh-Hosseini *et al*., 2003), emergence (De Figueiredo *et al*., 2003; Verma *et al*., 2003; Basra *et al*., 2003), shoot and root dry weight (Rice and Dyer, 2001; Verma *et al*., 2003), seedling length (Joaoabba and Lovato, 1999; Verma *et al*., 2003), normal seedling percentage (Dell' Aquila and Di Turi, 1996) and leaf appearance rate (Grieve and Francois, 1992). This might led to reduced yield potential by lengthening the days from sowing to complete ground cover and a delay in the establishment of an optimum canopy (Soltani *et al*., 2001). Optimum canopy establishment is required to minimize interplant competition and to maximize crop yield.

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Khajeh-Hosseini *et al*. (2003) reported that crop establishment depends on an interaction between seedbed environment and seed quality. Soltani *et al*. (2002) showed that the interaction effect of salinity and seed size was not significant on germination percentage, rate and uniformity of chickpea, but salinity and seed size affected all germination characteristics. Seed size (weight) can be considered as an indicator of seed quality (Ellis, 1992). De Figueiredo *et al*. (2003) studied the effect of environmental stress on sunflower, soybean and maize seeds emergence in different levels of seed quality. They indicated that the interaction effect of environmental stress and seed quality on sunflower and soybean was significant, but it was not significant in maize. Grieve and Francois (1992) showed that seed size and salinity had a pronounced effect on the vegetative characteristics and they results showed some significant seed size×salinity interactions on vegetative characteristics such as leaf appearance rate, but blade area, leaf number and yield component showed no significant seed size×salinity interaction.

Therefore, the present study was conducted to evaluate the effect of seed aging (seed quality) on germination, emergence and seedling growth of wheat under optimum (control) and stressful conditions including salinity, drought and deep sowing depth (physical stress).

## MATERIALS AND METHODS

### Accelerated Aging Treatments

Seeds of wheat (*Triticum aestivum* L.) cv. Zagros were obtained from Gorgan Agricultural Research Center, Gorgan, Iran. Accelerated aging treatments were created by aging the seeds (with initial moisture content of 11.8%) at 43°C and relative humidity of 90-95% for 0, 48, 72, 96 and 144 h periods (Modarresi *et al*., 2002; Basra *et al*., 2003). For each aging treatment, about 100 g of seeds were scattered within a vacuum container on wire screens; the floor of the container was covered by distilled water (10% of total container volume). The containers were placed in an incubator at a fixed temperature of 43°C. After aging, seed moisture content was determined and ranged between 29.1 and 33.2%.

### Germination

Four replicates were conducted, each consisting of 30 seeds for each seed aging treatment in which seeds were germinated at 20°C. Seeds were placed on two moistened paper towels. After covering the seeds with a third sheet of paper, the three towels were loosely rolled to form a tube and placed in plastic bags (23×33 cm) to prevent evaporation. Seeds were observed twice daily and considered germinated when the radicle was approximately ≥2 mm long. Estimates of time taken for cumulative germination to reach 50% of its maximum at each replicate ($D_{50}$) were interpolated from the germination progress curve versus time. Germination rate ($R_{50}$ 1/h) was then calculated according to Soltani *et al*. (2001, 2002):

$$R_{50} = 1/D_{50} \tag{1}$$

### Greenhouse Experiment

The pot experiment was conducted at Gorgan University of Agriculture Sciences and Natural Resources, Gorgan, Iran. During the experiment minimum and maximum air temperatures were 12.4 and 21.2°C. Factorial combinations of 5 seed aging treatments (0, 48, 72, 96 and 144 h accelerated aging periods) and 6 levels of environmental factor were treatments of the experiment. Environmental conditions were optimum, no-stress conditions (control), medium salinity ($EC_e$ = 7 dS $m^{-1}$), severe salinity ($EC_e$ = 14 dS $m^{-1}$), medium drought (-5 bar), severe drought (-10 bar) and deep sowing (depth of 7 cm). Untreated soil ($EC_e$ = 0.7 dS $m^{-1}$; soil water potential = -1 bar) was considered as the control. In all conditions except for deep sowing, seeds were planted in 3 cm deep.

Salinity treatments were created as described by Soltani *et al*. (2004). The amount of salt required to achieve salinity levels of 7 and 14 dS $m^{-1}$ was calculated using method of staff (US Salinity Laboratory, 1954; Richter *et al*., 1995). NaCl and $CaCl_2$ salts with a weight ratio of 50:50 were used for soil salinization.

Soil water potentials (-5 and -10 bar) were created based on soil moisture release curve, which indicate the relationship between soil water potential and soil moisture (Saxton *et al*., 1986).

Leaf number, leaf area and seedling dry weight were measured at two harvests, one at 3-leaf stage and another at stem elongation.

**Data Analysis**

Because seed aging levels were quantitative, we applied regression analysis (Soltani, 2007) to quantify effect of seed aging on seed germination, emergence and vegetative characteristics. Simple linear regression (y = a+bx) was adequate for all the traits. The slope of regression line (b) shows direction and magnitude of the effect of seed aging on germination, emergence and vegetative characteristics.

Analysis of variance and mean comparison used to compare the effect of environmental factors on seed emergence, leaf number, leaf area and seedling dry weight (Soltani, 2007).

## RESULTS

The time course of germination as influenced by seed aging is shown in Fig. 1. There were clear differences between aging treatments with respect to cumulative germination. Germination rate and the maximum germination decreased as the seeds experienced longer durations of accelerated aging. The highest and the lowest maximum germination were observed in control seeds (98.3%) and in seeds that were aged for 144 h (63.3%), respectively (Fig. 1). Maximum and rate of germination reduced significantly with increase in the duration of accelerated aging; 0.243% $h^{-1}$ for maximum germination and 0.00001 1/h for germination rate (Fig. 2).

Environment factor and seed aging significantly affected maximum emergence and emergence rate, but the environment factor×aging interaction was not significant for maximum emergence and emergence rate, indicating that low and high vigor seed responded in the same way to environmental conditions (Table 1).

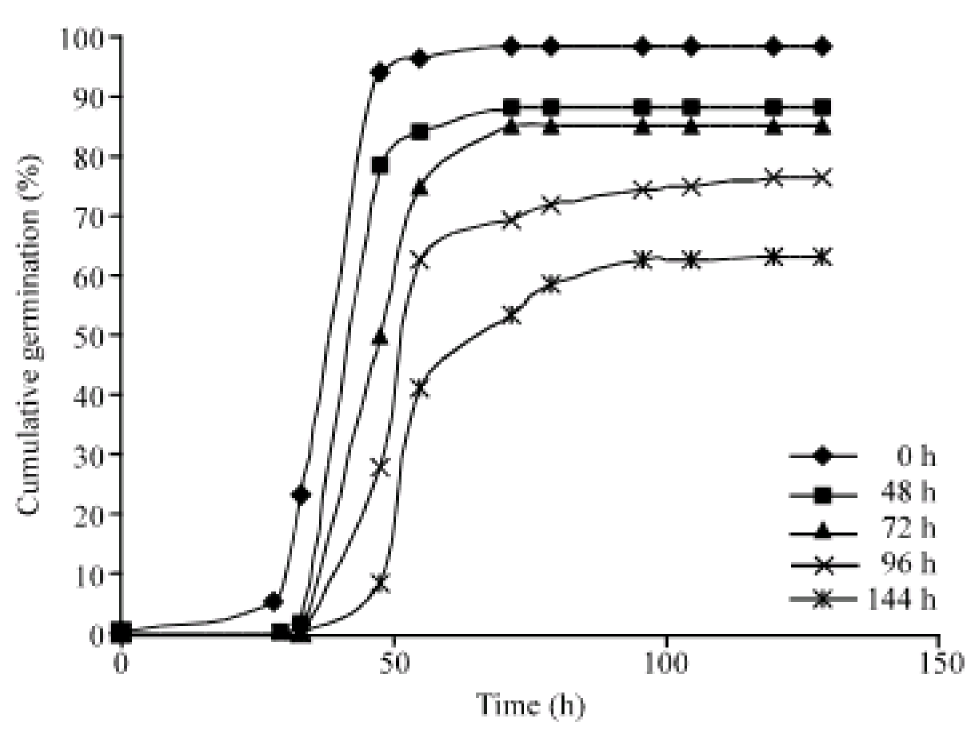


Fig. 1: Cumulative germination percentage versus time for the different aging duration

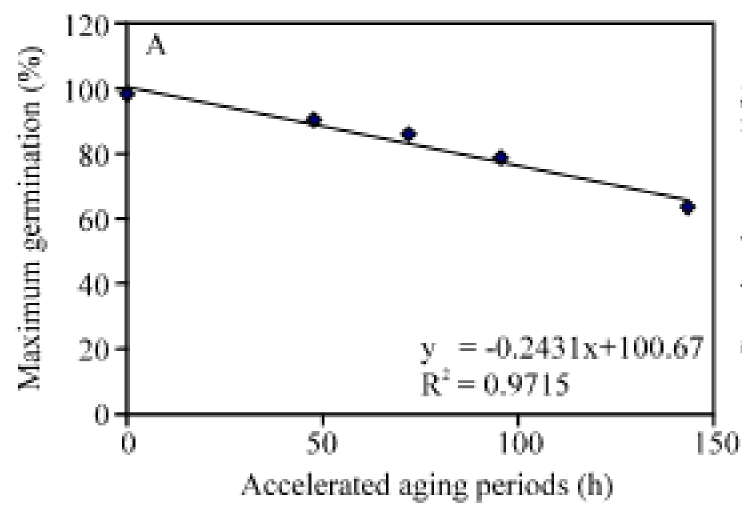


Fig. 2: Regression analysis to examine the effect of aging period on (A) maximum germination (%) and (B) germination rate (1/h). Both of the regressions are significant

Table 1: Results of analysis of variance (mean squares) for maximum and rate of emergence in emergence stage and leaf area, seedling dry weight and leaf number in the first and the second harvests

| Emergence | df | Max. emergence | | Emergence rate |
|---|---|---|---|---|
| Block | 3 | 277.02 | | 0.0002 |
| Environment Condition (EC) | 6 | 9025.74** | | 0.0065** |
| Seed Aging (SA) | 4 | 3423.01** | | 0.0039** |
| EC×SA | 24 | 91.24 | | 0.0001 |
| Residual | 102 | 156.75 | | 0.0004 |
| Parameters | df | Leaf No. | Leaf area | Seedling dry weight |
| **The first harvest** | | | | |
| Block | 3 | 0.13 | 9.39* | 0.00010** |
| Environment Condition (EC) | 5 | 2.59** | 134.96** | 0.00110** |
| Seed Aging (SA) | 4 | 0.63** | 31.87** | 0.00100** |
| EC×SA | 20 | 0.10 | 1.76 | 0.00003 |
| Residual | 87 | 0.09 | 1.84 | 0.00002 |
| **The second harvest** | | | | |
| Block | 3 | 0.38* | 42.02 | 0.0010* |
| Environment Condition (EC) | 4 | 19.80** | 1036.41** | 0.0260** |
| Seed Aging (SA) | 4 | 0.51** | 121.05** | 0.0040* |
| EC×SA | 16 | 0.13 | 11.69 | 0.0005 |
| Residual | 72 | 0.12 | 10.90 | 0.0004 |

*,**Significant at $p<0.05$ and $p<0.01$, respectively

Aged seeds indicated different pattern of cumulative emergence versus time under each environmental factor (Fig. 3). Maximum and rate of emergence significantly reduced as affected by seed quality under different environment factors; 0.17% per h aging period for maximum emergence and 0.0002 1/day/h aging period for emergence rate (Fig. 4). Environment factors also affected emergence performance in seed vigor treatments. Control seeds had the highest maximum and rate of emergence and severe drought indicated the lowest emergence percentage and rate (Table 2). The ranking of the stress factors from most to least harmful for maximum emergence were: severe drought, severe salinity and sowing depth of 7 cm, medium drought and medium salinity.

Environmental conditions and seed aging affected vegetative characteristics in the first and the second harvests (Table 1). Seed aging significantly decreased leaf area and seedling dry weight at the first harvest (Fig. 5A; p = 0.0465), but reduction in these characteristics was not significant at the second harvest (Fig. 5B; p = 0.1130). Seed aging had no a pronounced effect on the number of leaf at the first or second harvests (Fig. 6A, B).

Severe and medium drought strongly decreased leaf area and seedling dry weight at the both harvests. However, there was no significant difference between medium salinity and control

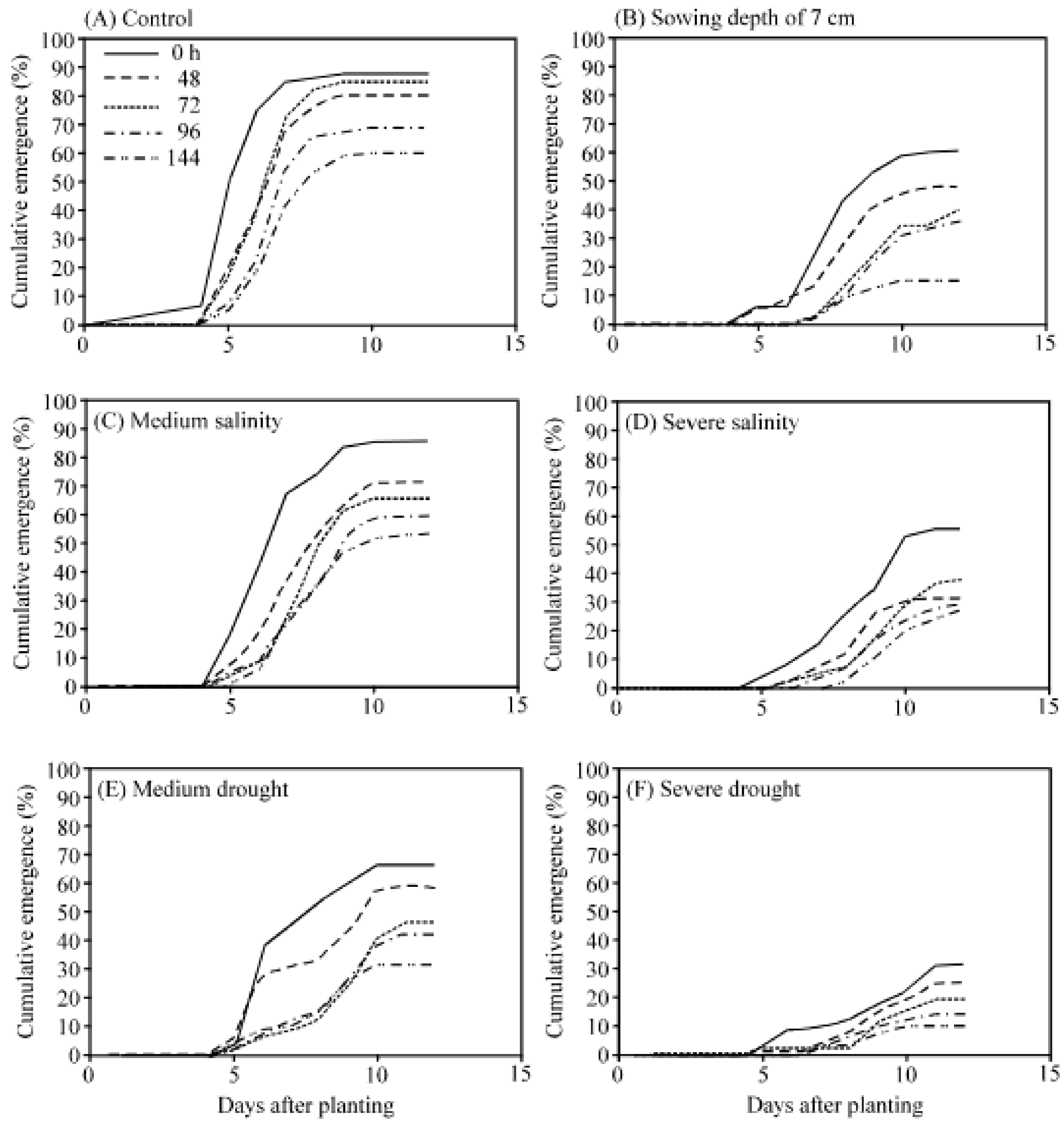


Fig. 3: Cumulative emergence percentage versus time for the different aging duration under different environmental conditions

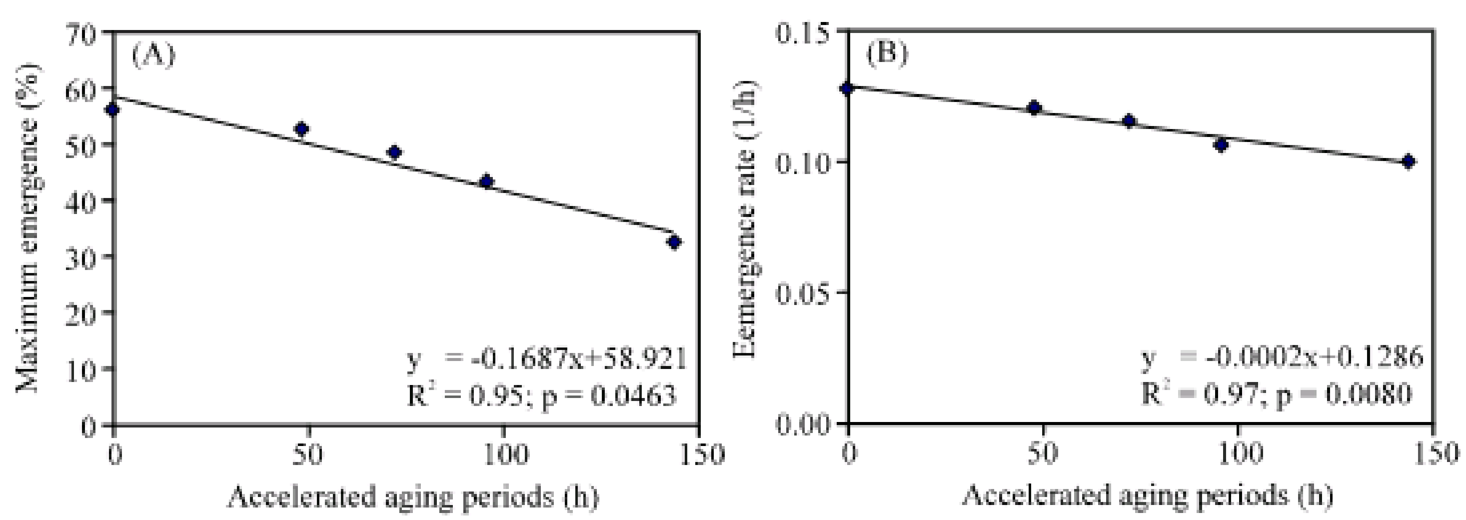


Fig. 4: Regression analysis to examine the effect of aging period on (A) maximum emergence (%) and (B) emergence rate (1/day), across the environment treatments. Both of the regressions are significant

Table 2: The results of comparisons means for maximum and rate of emergence, leaf number (LN), leaf area (LA, $cm^2$/plant) and seedling dry weight (TDM, mg/plant) and at the first and the second harvests

| | | | The first harvest | | | The second harvest | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | Max. emergence (%) | Emergence rate (1/day) | LN | PLA ($cm^2$/plant) | TDM (mg/plant) | LN | PLA ($cm^2$/plant) | TDM (mg/plant) |
| Control | 76.20$^a$ | 0.1439$^a$ | 2.59$^a$ | 9.12$^a$ | 0.032$^a$ | 4.23$^b$ | 22.12$^a$ | 0.112$^a$ |
| Medium drought | 47.09$^c$ | 0.1219$^b$ | 1.90$^c$ | 2.97$^d$ | 0.015$^d$ | 2.27$^c$ | 3.01$^d$ | 0.024$^c$ |
| Sever drought | 20.60$^e$ | 0.0951$^c$ | 1.60$^d$ | 1.73$^e$ | 0.012$^d$ | - | - | - |
| Medium salinity | 67.80$^b$ | 0.1242$^b$ | 2.70$^a$ | 8.46$^a$ | 0.030$^a$ | 5.05$^a$ | 23.73$^a$ | 0.121$^a$ |
| Sever salinity | 38.10$^d$ | 0.1048$^c$ | 2.30$^b$ | 4.79$^c$ | 0.018$^c$ | 4.31$^b$ | 15.99$^b$ | 0.080$^b$ |
| Sowing depth of 7 cm | 40.60$^{cd}$ | 0.1019$^c$ | 2.52$^a$ | 5.75$^b$ | 0.027$^b$ | 4.45$^b$ | 13.68$^c$ | 0.081$^b$ |

Values with differences letter(s) are significant different at p<0.05 level

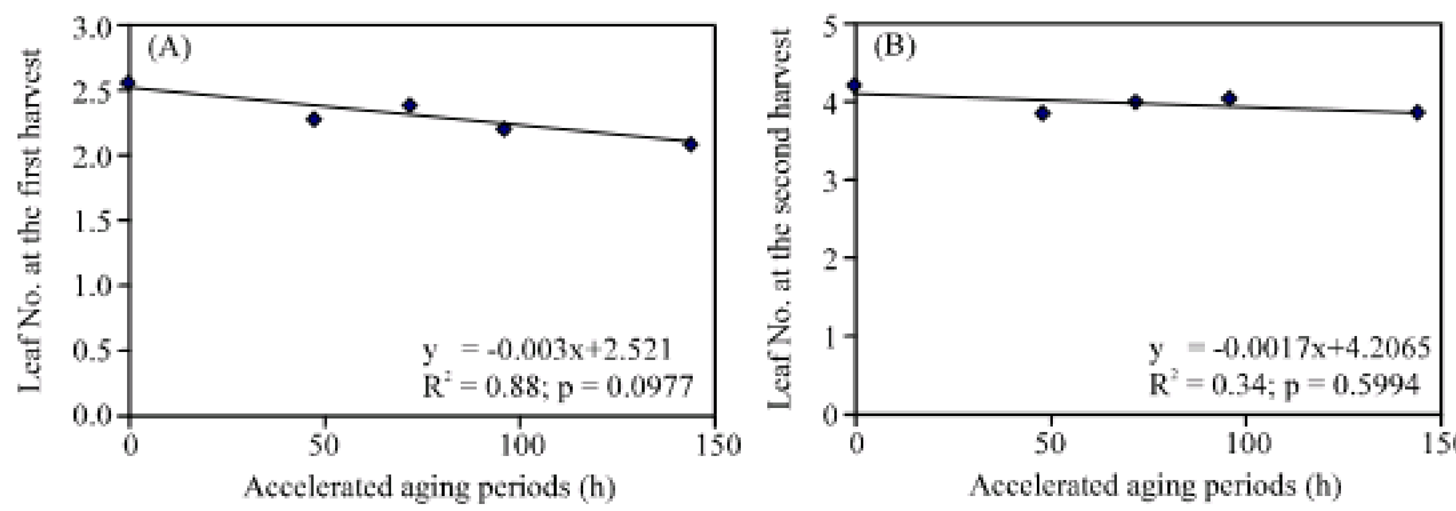


Fig. 5: Regression analysis to examine the effect of aging period on the leaf number at (A) the first (3-leaf stage) and (B) the second (stem elongation) harvests, across the environment treatments. Both of the regressions are not significant

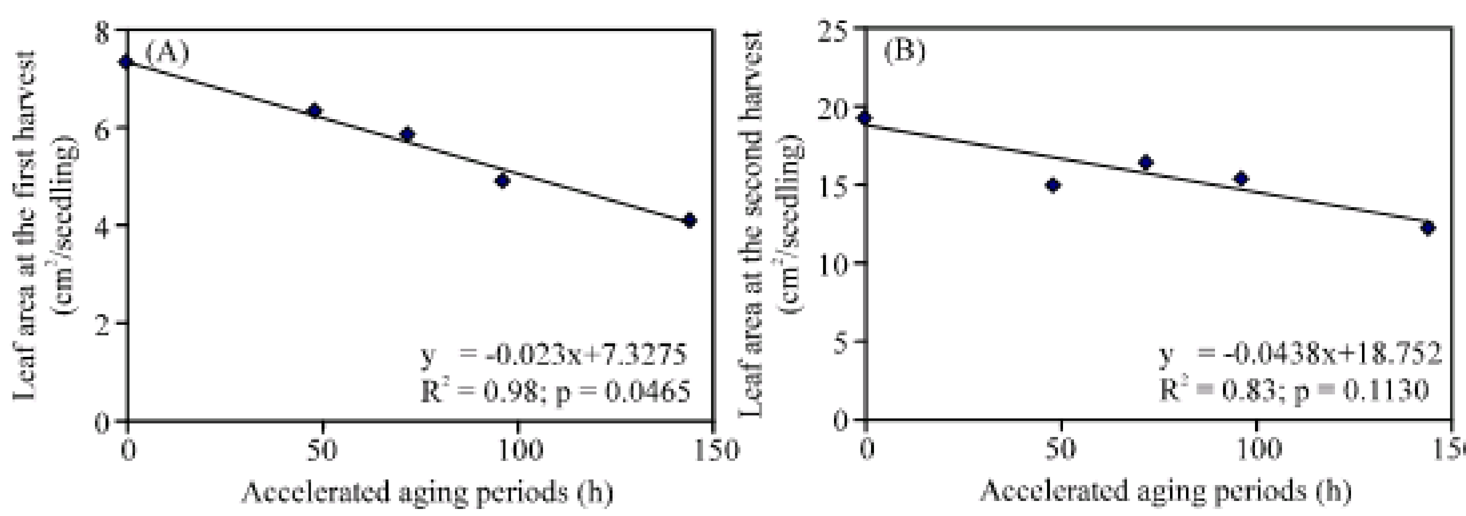


Fig. 6: Regression analysis to examine the effect of aging period on the leaf area at (A) the first (3-leaf stage) and (B) the second (stem elongation) harvests, across the environment treatments. The regression for the first harvest is only significant

(Fig. 7A, B). The ranking of the importance of stress conditions in terms of harmful effects on the leaf area and seedling dry weight were severe drought, medium drought, severe salinity and sowing depth of 7 cm and medium salinity.

It was concluded that seeds with different vigor rates were emerged better in medium drought than sowing depth of 7 cm and severe salinity, but the seeds could not sustain medium drought and severe salinity as sowing depth of 7 cm in vegetative growth stage (Table 2). Seeds with different vigor tolerated medium salinity in vegetative growth stage, but medium salinity adversely affected on seeds emergence.

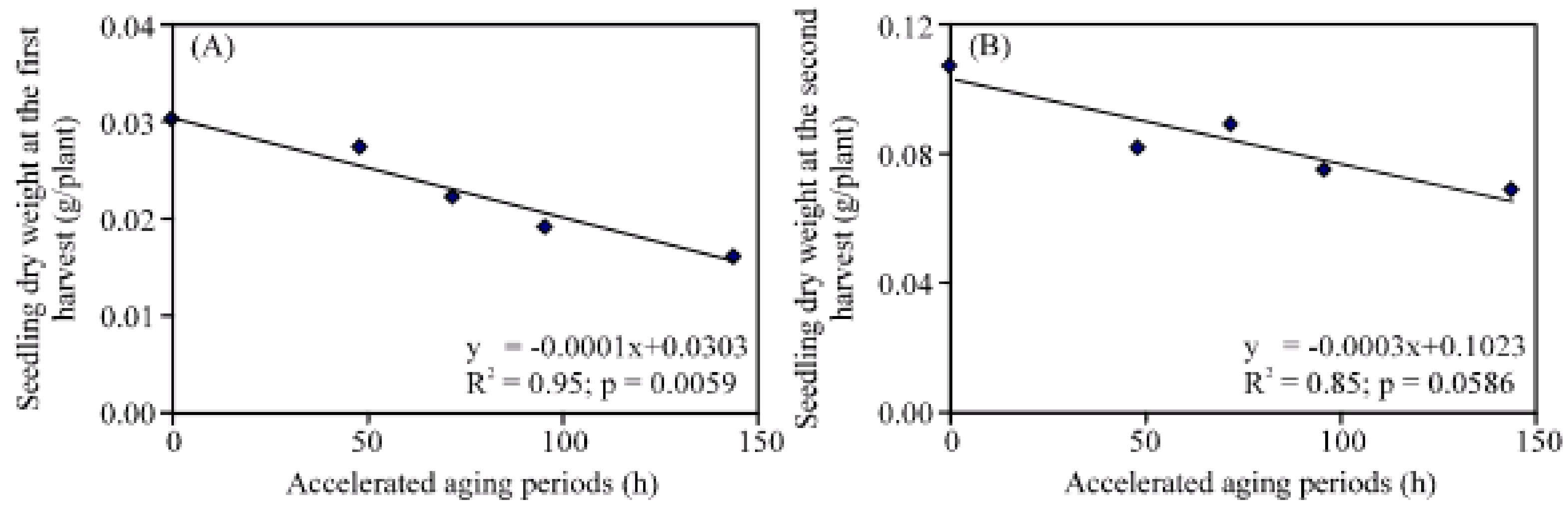


Fig. 7: Regression analysis to examine the effect of aging period on the seedling dry weight at (A) the first (3-leaf stage) and (B) the second (stem elongation) harvests, across the environment treatments. The regression for the first harvest is only significant

Table 3: Stress conditions in decreasing order of importance for the maximum emergence, leaf area and seedling dry weight for all seed aging treatments

| Max. emergence | Leaf area | Seedling dry weight |
|---|---|---|
| Severe drought | Severe drought | Severe drought |
| Severe salinity | Medium drought | Medium drought |
| Sowing depth of 7 cm | Severe salinity | Severe salinity |
| Medium drought | Sowing depth of 7 cm | Sowing depth of 7 cm |
| Medium salinity | Medium salinity | Medium salinity |

## DISCUSSION

Seed vigor may influence on early growth of the plant both directly through physiological injury or necrotic lesions and indirectly through percentage emergence and time from sowing to emergence or emergence rate (Ellis, 1992; TeKrony and Egli, 1991). The effects of seed vigor on emergence performance are well documented (Basra *et al*., 2003; Chitra Devi *et al*., 2003; Verma *et al*., 2003). Basra *et al*. (2003) stated that percentage emergence decreased with accelerated aging periods in cotton. Also, they reported that the decline in seed germination during accelerated aging was accompanied with the increase in mean emergence time. ChitraDevi *et al*. (2003) showed that in mustard large seeds and seeds from short duration of storage had more percentage of emergence compared to small seeds and seeds from long duration of storage. Verma *et al*. (2003) indicated that seedling establishment and emergence rate are reduced with increase in seed storage duration. All of these factors can influence dry mater accumulation (indirect effects). Khah *et al*. (1989) indicated that the most of the deleterious effect of poor seed vigor is on rate of germination and early seedling growth in wheat. Therefore, it was concluded that reduced leaf area and seedling dry weight may be due to the indirect and direct effects of seed aging, at the first harvest. The indirect effect influenced on seedling growth by delayed emergence. The effects of seed aging can gradually improve after early seedling growth.

Table 3 shows the environmental factors which, in decreasing order, were the most harmful to the maximum emergence, the leaf area and the seedling dry weight of all the seed aging treatments. It can be seen that the severe drought was the most harmful to the all studying development stages. Drought, Salinity and sowing depth stresses imposes serious environmental problems that affect on wheat rainfed agricultural systems in Iran. Farmers usually choice more sowing depth to minimize adverse effects of the drought on wheat emergence in the beginning planting season, so using of high vigor seeds suggest to confront adverse effects of the deeper sowing depth. Seeds of high vigor, also, are requisitioned to pass severe and specially medium salinity at the early crop growth stage (emergence), because the adverse effect of salinity in the emergence was more than the vegetative growth stage

(Table 3). Nevertheless, optimum environment condition and good quality of seeds were so important to perform faster and higher emergence and to pass vegetative growth stage well.

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