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*Full Length Research Paper*

# Effects of seed size and drought stress on germination and seedling growth of some oat genotypes (*Avena sativa* L.)

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**Effects of seed size and osmotic stress on germination and seedling growth of fifty-five oat genotypes obtained from Europe, North and South America, Asia and Oceania were investigated. Small, medium and large seeds of fifty-five oat genotypes were germinated in polyethylene glycol (PEG 6000) solutions with initial osmotic potentials ranging from 0 to -0.75 MPa at 8°C. In this study, final germination percentage (FGP), median germination time (MGT), root length, and shoot length were measured and calculated. In all genotypes examined, decreasing seed size and osmotic potential increased median germination time and decreased final germination percentage, root and shoot length. Among genotypes, the highest final germination percentage was obtained with 88.6% from the cv. Evita. The cv. Flämingsplus, Pajaz, Iltis, Lvovskii Rannii, Marta, Auteuil and Samsun (local population) followed with final germination rates of 83.5, 83.4, 83.3, 82.7, 82.1, 82.0, and 80.8%, respectively. Among these genotypes, Pajaz and Lvovskii Rannii also had the fastest median germination time, however, the highest root and shoot length was measured the cv. Centennial. In addition, this genotype also had higher final germination percentage and lower median germination time.**

**Key words:** Oat, seed size, drought stress, genotype, germination

## INTRODUCTION

As generally known, the most important stage in seedling development is the germination phenomenon, which leads at normal conditions in the further development of plants to high yield and quality. This process starts with the absorption of water, continues with radicle emergence and terminates with successful crop production (Almansouri et al., 2001; Willenborg et al., 2005). The effect of seed size on germination and following seedling emergence have been investigated by many researchers in various crop species/ cultivar (Mathur et al., 1982; Lafond and Baker, 1986; Kawade et al., 1987; Roy et al., 1996; Guberac et al., 1998; Larsen and Andreasen, 2004; Willenborg et al., 2005; Kaydan and Ya-mur, 2008). However, these results varied widely between species. With increased seed size higher germination and emergence were determined in pearl millet (Kawade et al., 1987) and in triticale (Kaydan and Yamur, 2008), but besides higher germination percentage declined median germination time were determined in some forage plants (Larsen and Andreasen, 2004). On the contrary, Lafond and Baker (1986) obtained faster germination from small bread wheat kernels under different temperature and moisture stress combinations. Doehlert et al. (2002, 2004) are describing that the oat plant produces seeds with varying sizes. This arises from the multi-floret habit characteristic of the oat spikelet. The primary seed on the spikelet, called the innermost seed, is the largest seed. The seed size and weight of the seeds on the spikelet decrease with increasing seed order. This shows that seed size in oat is inherently non-uniform because seed number per spikelet changes - one, two or three seeds. In different studies (Guberac et al., 1988; Marthur et al.,

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1982; Willenborg et al., 2005) increased germination was observed with increasing seed size in oat. But either only a limited number of cultivars were investigated or used seed was not subjected to moisture stress in these studies.

The effect of seed size on the germination of oat genotypes, particularly under moisture-limited conditions is not well investigated (Willenborg et al., 2005). Posponed and decreased seed germination, unequal seedling emergence, and changed number of plants per unit area and reduced seed yield are common in soils displaying water deficiency (Bliss et al., 1986; Hampson and Simpson, 1990). Between cereals on the other hand oat is the most sensitive species regarding drought stress at stages of germination and seedling emergence (Mos et al., 2007). It is well known that rapid and complete germination are critical issues during the establishment of a competitive crop. In cultivated oat early planting, rapid germination and early emergence results in a competitive advantage over wild oat (Willenborg et al., 2005).

In Turkey, especially in interior regions, oat is generally sown in spring. In these regions, where rainfall is irregular and inadequate, homogenous and uniform emergence is very important regarding high yield and quality. Therefore, the objective of this study was to determine the effects of genotype and seed size on the germination of oat seed subjected to moisture stress.

## MATERIALS AND METHODS

This study was carried out at the Department of Agronomy, Faculty of Agriculture, University of Ondokuz Mayis, Samsun, Turkey. The experiment was designed as a completely randomized factorial of fifty-five genotypes, three seed sizes, and four moisture stress treatments. Each treatment was replicated four times and Germination tests were performed from October 2008 to July 2009. The study was conducted in a YAMATO IN/802 incubator under total darkness at a temperature of 8°C (Wiilenborg et al., 2005). Fifty-five oat genotypes obtained from Europe, North and South America, Asia and Oceania were used as plant material in this study. Name, hull colour and thousand-kernel weight of fractionated seed samples of these genotypes were presented in Table 1. Seed of these genotypes was grown in Samsun, Turkey, under conditions of the 2007-2008 growing seasons in order to obtain newly harvested seed. Within each seed lot, seed of each of the fifty-five genotypes was fractionated into classes consisting of small, medium, and large seed. Small seeds were those that passed through a 1.95 X 8.33 mm slotted sieve, medium seeds were those retained on a 1.95 X 8.33 mm slotted sieve, and large seeds were those retained on a 2.35 X 8.33 mm slotted sieve. Subsequent to fractionation, all physically damaged seeds were manually removed. Thousand-kernel weight (TKW) was determined for each of the 15 seed fractions by counting and weighing two samples of 200 seeds (Table 1). Moisture stress treatments consisted of seed imbibed in solutions with initial osmotic potentials of 0, -0.25, -0.50 and -0.75 MPa. Seeds were initially treated with a 1.0% solution of sodium hypochlorite for 3 min for surface sterilization (McGee, 1988). Residual chlorine was eliminated by thorough washing of seeds with distilled water. For each treatment, 40 seeds were placed on two layers of Whatman No 2 filter paper in a 9 cm plastic Petri dish Moisture stress treatments were established by irrigating each Petri dish with 8 mL of the appropriate osmotic solution.

Osmotic potentials were created using polyethylene glycol (PEG 6000, Sigma Chemical Company, USA) and were adjusted for temperature (8°C) according to Michel and Kaufmann (1973). Petri dishes were placed in trays and covered with light-excluding plastic to prevent light penetration and moisture loss. Seeds were incubated in a germination cabinet at 8°C. Germination was recorded every 24 h for 15 d. Seeds were regarded as germinated when the radicle appeared normal and had protruded at least 2 mm. The response of oat germination characteristics to genotype, seed size, and moisture stress was examined by calculating final germination percentage (FGP) and median germination time (MGT), or the time to 50% germination. Final germination percent-tage was calculated as the cumulative number of germinated seeds with normal radicles in each experimental unit at termination of the experiment as follows:

$$FGP = (\sum_n / N_t).100$$

Where $n$ is the number of germinated seed at each enumeration interval, and $N_t$ is the number of seeds in each experimental unit. Median germination time (MGT) was calculated to assess the rate of germination (Lafond and Baker, 1986) as follows: MGT = $\sum (nx)/n$, Where n is the number of newly germinated seeds on each day and x is the day of counting. Root and shoot length (mm) were measured on the 15$^{th}$ day. Data given in percentages were subjected to arcsine transformation before statistical analysis. For all investigated parameters, analysis of variance was performed using the MSTAT-C software package. Significant differences among the mean values were compared by LSD test ($P < 0.01$).

## RESULTS AND DISCUSSION

Oat TKWs varied considerably between genotypes and seed size classes (Table 1). Charlton exhibited the greatest seed size variation (12.0 - 46.3 g), while Lvovskii Rannii exhibited the least (17.6 - 31.5 g). The relatively low TKW of small seed of Charlton, Centennial, GK Pillango, Aberglen, Urano, Mantaro 15, Akiyutaka, Auteuil, Dal, and Dane are likely due to the high proportion of tertiary kernels in these genotypes. The largest range of TKW existed in the large seed size class (31.5 - 52.4 g) whereas the smallest occurred in the small class (14.6 - 26.6 g). These differences likely result from differences in hull content between genotypes and seed size classes.

A significant three-way interaction (cultivar, seed size and osmotic stress) was found ($P < 0.01$) for all investigated characters. Significant differences were found amongst genotypes, seed size and osmotic stress regarding final germination percentage, median germination time, shoot length and root length (Table 2 and 3). Willenborg et al. (2005) also reported that germination characteristics were affected by cultivar, seed size and moisture stress in six western Canadian oat genotypes.

The highest final germination percentage was obtained with 88.6% from the cv. Evita. The cv. Flämingsplus, Pajaz, Iltis, Lvovskii Rannii, Marta, Auteuil, and Samsun (local population) followed with final germination rates of 83.5, 83.4, 83.3, 82.7, 82.1, 82.0, and 80.8%, respectively (Table 2). On the contrary, the lowest final germination percentage (49.3%) was obtained from the cv. Urano (Table 2). The cv. Ogle followed with final

**Table 1.** Origin, hull colour and thousand-kernel weight (g) of fractionated seed samples for each genotype.

| Genotype | Origin[a] | Hull [b] | Seed size class (g) | | | Genotype | Origin[a] | Hull [b] | Seed size class (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Large | Medium | Small | | | | Large | Medium | Small |
| Blaze | US | W | 34.4 | 29.8 | 17.0 | TAM 301 | US | W | 40.9 | 30.0 | 19.0 |
| Expo | AT | Y | 46.2 | 33.5 | 21.2 | Bakonyalja | HU | W | 43.6 | 32.4 | 20.8 |
| Neklan | CZ | Y | 42.4 | 27.4 | 17.2 | Expander | AT | Y | 42.4 | 30.8 | 21.1 |
| H'daka | JP | W | 40.3 | 28.5 | 19.6 | Flämingsplus | DE | W | 39.7 | 34.3 | 20.8 |
| Avesta | FR | B | 46.4 | 27.2 | 18.5 | Sinelnikovski | UA | Y | 42.5 | 34.4 | 20.9 |
| Kwant | PL | W | 37.8 | 32.1 | 20.7 | Charlton | NZ | Y | 46.3 | 33.0 | 12.0 |
| Iltis | DE | Y | 39.0 | 25.2 | 17.5 | Revisor | DE | W | 37.3 | 34.1 | 17.6 |
| Alo | EE | W | 37.6 | 33.6 | 19.9 | Centennial | US | Y | 38.4 | 25.4 | 14.0 |
| Milton | US | Y | 41.4 | 24.3 | 17.2 | Lvovskii Rannii | UA | Y | 31.5 | 26.4 | 17.6 |
| Bajka | PL | Y | 45.1 | 29.8 | 19.6 | Kolpashevskii | RU | Y | 48.4 | 39.1 | 26.6 |
| Zvolen | SK | Y | 40.9 | 32.5 | 20.4 | Aberglen | GB | W | 41.4 | 23.6 | 15.6 |
| Urano | CL | W | 46.1 | 25.6 | 15.9 | Calibre B | CA | W | 46.2 | 30.4 | 19.3 |
| Puhti | FI | W | 44.0 | 33.1 | 17.5 | Chantilly | FR | W | 40.8 | 25.3 | 19.3 |
| Pajaz | YU | W | 38.6 | 33.6 | 21.3 | Akiyutaka | JP | W | 43.7 | 31.8 | 16.6 |
| Katri | FI | W | 43.5 | 33.9 | 20.2 | Mantaro 15 | PE | W | 41.8 | 29.1 | 16.4 |
| Litoral | BO | W | 41.1 | 34.4 | 19.6 | Flämingsstern | DE | Y | 45.9 | 34.3 | 20.9 |
| Dal | US | W | 36.1 | 24.4 | 16.8 | CDC Boyer | CA | W | 50.0 | 29.0 | 19.1 |
| Pony | CL | Y | 38.2 | 23.7 | 17.0 | Samsun[c] | TR | Y | 46.0 | 38.4 | 22.7 |
| Veli | FI | W | 44.4 | 33.5 | 20.6 | Rize[c] | TR | B | 50.1 | 31.7 | 20.8 |
| Dane | US | Y | 33.4 | 30.0 | 16.9 | Faikbey | TR | R | 52.4 | 37.1 | 26.8 |
| Sisko | FI | Y | 41.6 | 25.9 | 18.3 | Yeşilköy-330 | TR | R | 50.1 | 34.8 | 21.3 |
| Bara | SE | W | 37.3 | 31.6 | 18.6 | Yeşilköy-1779 | TR | R | 50.9 | 37.1 | 24.8 |
| Mara | LV | W | 38.4 | 25.6 | 17.2 | Auteuil | FR | B | 40.5 | 26.1 | 16.7 |
| Evita | DE | W | 34.0 | 27.2 | 17.4 | GK Pillango | HU | W | 35.5 | 22.1 | 14.6 |
| Ogle | US | Y | 43.1 | 29.7 | 17.7 | Sidabres | LT | W | 40.3 | 27.9 | 20.0 |
| Petra | SE | W | 45.8 | 35.8 | 22.9 | Monarch | AT | Y | 47.3 | 31.2 | 24.1 |
| Matra | NL | W | 39.6 | 30.9 | 18.7 | Skakun | RU | W | 40.9 | 23.6 | 17.5 |
| Boog | BY | Y | 39.8 | 26.8 | 18.3 | | | | | | |

[a] Country of origin abbreviated by the ISO 3166 country codes.
[b] Hull colour: W, white; Y, yellow; B, black; R, red oat. [c] Local population.

germination percentage of 53.8%. Oat germination characteristics varied considerably between seed size classes (Table 2). While the highest final germination percentage (77.7%) was obtained from large seed, the lowest final germination percentage (63.2%) was obtained small seed. In this present study, large seed exhibited 14.5% greater final germination than small seed, regardless of moisture stress. Final germination percentage differed significantly among moisture stress treatments (PEG) (Table 2). Overall, final germination percentage was 4.4%, 18.1%, and 69.4% lower at PEG -0.25, -0.50, and -0.75 MPa than oat final germination percentage with no moisture stress, respectively (Table 2). Similar results were reported by Guberac et al. (1998) and Willenborg et al. (2005) in oat (*Avena sativa* L.) and Kaydan and Yağmur (2008) in triticale (Triticale with mack). Furthermore, in barley (*Hordeum vulgare* L.), Turk and Tawaha (2002) and in pinto bean (*Phaseolus vulgaris* L.), Gholami et al. (2009) observed increased germination percentage as well as greater speed of germination in large seed compared with small, however, these results are inconsistent with those of Mian and Nafziger (1992) who reported that seed size had no effect on germination characteristics in wheat. Kaydan and Yağmur (2008) pointed out that large seed with higher germination percentage in normal and stress condition may be related to privileged water uptakes. Al-Karaki (1998) also reported that large lentil seed had higher water potential compared to small seed in low water potentials. Under extreme stress conditions, large seed in oat may have higher benefits in germination compared to small seed. Hence, higher germination percentage from large seed may be beneficial in establishing plants under dry soil conditions (Mian and Nafziger, 1994). Willenborg et al. (2005) also reported that large oat seed had greater final germination that resulted in better stand establishment, particularly where low spring soil moisture limits stand establishment than that of small seed.

**Table 2.** The mean effect of genotype, seed size and osmotic stress (MPa) on final germination percentage and median germination time.

| Genotype | Final germination (%) | Median germination time (h) | Genotype | Final germination (%) | Median germination time (h) |
|---|---|---|---|---|---|
| Blaze | 71.8 lmn | 1851.8 i-l | TAM 301 | 76.9 f-i | 1600.7 wxy |
| Expo | 68.1 opq | 1797.2 mn | Bakonyalja | 67.6 opq | 1920.8 ef |
| Neklan | 77.5 e-h | 1707.0 q-r | Expander | 68.9 n-q | 1875.3 ghi |
| H'daka | 60.7 t | 2013.7 ab | Flämingsplus | 83.5 b | 1729.1 pq |
| Avesta | 67.5 opq | 1894.1 fgh | Sinelnikovski | 78.1 d-g | 1935.9 de |
| Kwant | 72.8 klm | 1719.3 pq | Charlton | 73.5 kl | 1977.1 c |
| Iltis | 83.3 b | 1660.1 q-u | Revisor | 69.5 nop | 1850.3 i-l |
| Alo | 78.2 d-g | 1831.3 j-m | Centennial | 79.1 def | 1597.5 wxy |
| Milton | 61.0 t | 1864.6 hij | Lvovskii Ranni | 82.7 bc | 1515.6 z |
| Bajka | 61.5 t | 1936.0 de | Kolpashevskii | 69.2 nop | 1812.8 lm |
| Zvolen | 80.3 cde | 1657.6 stv | Aberglen | 77.0 f-i | 1648.1 r-u |
| Urano | 49.3 v | 2024.8 a | Calibre B | 64.2 rs | 1935.6 de |
| Puhti | 67.2 qp | 1975.3 c | Chantilly | 78.5 def | 1821.8 klm |
| Pajaz | 83.4 b | 1504.0 z | Akiyutaka | 73.4 kl | 1820.3 klm |
| Katri | 60.7 t | 1854.5 i-l | Mantaro 15 | 66.7 pqr | 1689.6 q-t |
| Litoral | 73.6 kl | 1623.6 tuv | Flämingsstern | 74.9 h-k | 1664.6 q-u |
| Dal | 61.1 t | 1835.3 j-m | CDC Boyer | 71.7 lmn | 1778.4 mno |
| Pony | 69.7 nop | 1806.2 lm | Samsun[c] | 80.8 bcd | 1924.1 def |
| Veli | 74.7 h-k | 1702.9 qr | Rize[c] | 73.8 jkl | 1747.0 no |
| Dane | 70.3 mno | 1744.3 no | Faikbey | 74.9 h-k | 1736.8 op |
| Sisko | 78.5 def | 1693.9 qrs | Yeşilköy-330 | 75.0 h-k | 1958 cd |
| Barra | 62.3 st | 1802.7 lm | Yeşilköy-1779 | 68.5 opq | 1986.5 bc |
| Mara | 75.2 h-k | 1668.0 q-u | Auteuil | 82.0 bc | 1604.3 wxy |
| Evita | 88.6 a | 1603.9 wxy | GK Pillango | 76.8 g-j | 1700 qr |
| Ogle | 53.8 u | 1798.3 mn | Sidabres | 74.1 i-l | 1739.0 nop |
| Petra | 68.3 opq | 1906.5 efg | Monarch | 66.0 qr | 1797.3 mn |
| Matra | 82.1 bc | 1643.7 r-u | Skakun | 75.4 g-k | 1857.4 ijk |
| Boog | 68.2 opq | 1655.8 stv | | | |
| **Seed size** | | | | | |
| Large | 77.7 a | 1751.4 b | | | |
| Medium | 75.9 b | 1737.3 c | | | |
| Small | 63.2 c | 1857.0 a | | | |
| **Osmotic moisture stress** | | | | | |
| 0.00 MPa | 95.2 a | 1350.4 d | | | |
| -0.25 MPa | 90.8 b | 1494.3 c | | | |
| -0.50 MPa | 77.1 c | 1834.3 b | | | |
| -0.75 MPa | 25.8 d | 2448.4 a | | | |

Means within a column followed by the same lowercase letter are not significantly different ($P < 0.01$) by LSD.

Oat MGT was greatly affected by oat genotype. The MGT of investigated oat genotypes varied considerably between 1504.0 to 2024.8 h. The cv. H'daka and Urano took significantly longer to achieve 50% germination than all other genotypes, while the cv. Lvovskii Rannii and Pajaz achieved 50% germination more quickly than all others (Table 2). Median germination time of the fastest germinating genotype (Pajaz) was 520.0 h lower than the slowest germinating genotype (Urano). Large, medium, and small oat seed took 1751.4, 1737.3, and 1857.0 h to reach 50% germination, respectively, irrespective of genotype or moisture stress. Medium oat seed took 0.81% (14.1 h) and 6.45% (119.7 h) less time to reach 50% germination than large and small seed, respectively. Large seed also had significantly lower MGT than small seed. Large oat seed took 5.69% (105.6 h) less time to

**Table 3.** The mean effect of genotype, seed size and osmotic stress (MPa) on root length (mm) and shoot length (mm).

| Genotype | Root length (mm) | Shoot length (mm) | Genotype | Root length (mm) | Shoot length (mm) |
|---|---|---|---|---|---|
| Blaze | 35.2 o-t | 18.8 c | TAM 301 | 38.6 i-l | 15.1 h-k |
| Expo | 42.6 e | 17.6 e | Bakonyalja | 32.9 vwx | 14.3 lmn |
| Neklan | 30.1 y | 10.4 st | Expander | 33.8 tuv | 13.7 no |
| H'daka | 38.5 jkl | 14.5 klm | Flämingsplus | 32.0 xw | 11.5 qr |
| Avesta | 31.9 x | 14.7 j-m | Sinelnikovski | 31.8 x | 12.4 p |
| Kwant | 38.6 i-l | 21.4 b | Charlton | 32.1 xw | 14.3 lmn |
| Iltis | 38.2 jkl | 12.3 p | Revisor | 25.9 z | 9.6 u |
| Alo | 34.1 s-v | 12.1 pq | Centennial | 55.8 a | 24.0 a |
| Milton | 39.4 h-k | 15.6 ghi | Lvovskii Rannii | 38.1 jkl | 18.0 de |
| Bajka | 35.0 o-u | 17.8 de | Kolpashevskii | 46.3 c | 18.4 cd |
| Zvolen | 40.1 ghi | 18.4 cd | Aberglen | 34.5 r-u | 15.0 i-l |
| Urano | 25.8 z | 9.8 tu | Calibre B | 41.9 ef | 18.9 c |
| Puhti | 35.9 n-r | 16.1 fg | Chantilly | 24.1 z | 7.9 v |
| Pajaz | 37.8 klm | 13.2 o | Akiyutaka | 44.1 d | 16.2 fg |
| Katri | 36.3 m-p | 15.1 h-k | Mantaro 15 | 38.9 i-l | 13.5 o |
| Litoral | 36.5 mno | 18.1 de | Flämingsstern | 41.3 efg | 15.3 hij |
| Dal | 34.5 r-u | 16.4 f | CDC Boyer | 40.5 fgh | 15.8 fgh |
| Pony | 47.1 bc | 17.8 de | Samsun[c] | 34.7 q-u | 12.3 p |
| Veli | 35.9 n-r | 11.0 rs | Rize[c] | 38.2 jkl | 11.3 r |
| Dane | 36.3 m-p | 16.4 f | Faikbey | 47.9 b | 16.4 f |
| Sisko | 37.6 lm | 15.6 ghi | Yeşilköy-330 | 44.7 d | 15.1 ijk |
| Barra | 31.5x | 13.1 o | Yeşilköy-1779 | 36.3 m-q | 11.2 r |
| Mara | 34.8 p-u | 13.4 o | Auteuil | 38.5 jkl | 17.6 e |
| Evita | 37.4 lmn | 16.3 fg | GK Pillango | 42.1 e | 16.2 fg |
| Ogle | 28.7 y | 11.7 pqr | Sidabres | 39.6 hij | 14.2 mn |
| Petra | 33.4 uvw | 13.3 o | Monarch | 26.4 z | 8.4 v |
| Matra | 29.9 y | 12.4 p | Skakun | 27.0 z | 9.8 tu |
| Boog | 35.4 o-s | 13.2 o | | | |
| **Seed size** | | | | | |
| Large | 39.2 a | 15.0 a | | | |
| Medium | 38.5 b | 14.1 b | | | |
| Small | 31.8 c | 13.5 c | | | |
| **Osmotic moisture stress** | | | | | |
| 0.00 MPa | 72.8 a | 31.7 a | | | |
| -0.25 MPa | 49.8 b | 22.2 b | | | |
| -0.50 MPa | 20.2 c | 2.82 c | | | |
| -0.75 MPa | 3.2 d | 0.0 d | | | |

Means within a column followed by the same lowercase letter are not significantly different (P < 0.01) by LSD.

reach 50% germination than small seed (Table 2). MGT differed significantly between all moisture stress treatments (Table 2). With no osmotic stress (0 MPa), MGT was 9.63% (143.9 h), 26.38% (483.9 h) and 44.85 % (1098 h) lower compared with germination at osmotic potentials of -0.25, -0.50 and -0.75 MPa, respectively (Table 3). These findings are similar to those obtained for wheat (Lafond and Baker, 1986), barley (Turk and Tawaha, 2002) and six western Canadian oats (Willenborg et al., 2005). Ashraf and Abu-Shakra, (1978) reported that among four common Middle East wheat varieties, speed of germination was lowest and final germination percentage highest in the variety Najah, under both low temperatures and high moisture tensions. Similarly, Briggs and Dunn (2000) indicated that germination characteristics differed significantly among a diverse range of western Canadian six-row barley cultivars. Furthermore, Willenborg et al. (2005) pointed out that varieties AC Mustang and CDC Bell exhibited the fastest time to 50% germination while variety AC Mustang had the greatest final germination percentage of the six common western Canadian oat genotypes. Imbibition's time varies considerably in oat depending on seed size, hull and seed coat permeability, and soil moisture (Peterson, 1992).

The root length of oat cultivars differed at the different seed size and osmotic potentials of PEG as shown in Table 3. While the cv. Centennial gave the highest root length as 55.8 mm, the cv. Chantilly, Urano, Revisor, Monarch, and Skakun had the lowest root length as 24.1, 25.8, 25.9, 26.4, and 27.0 mm, respectively. Differences in root length between Chantilly, Urano, Revisor, Monarch and Skakun were not significant (p<0.01) (Table 3). The decreasing of osmotic potential of PEG decreased root length as compared to control solutions for all oat cultivars (Table 3). Root length at 0.0, -0.25, -0.50, and -0.75 Mpa of osmotic stress solutions was measured 72.8, 49.8, 20.2, and 3.2 mm, respectively. Significant differences in root length were observed between small, medium, and large seeds. While the root length decreased in all seed sizes with the decrease of osmotic potential, the decrease in osmotic potential caused in small seed sizes more negative effects regarding root length (Table 3). Large seeds (39.2 mm) had higher root length as compared to small and medium seeds (31.8 and 38.5 mm, respectively) regardless of genotype and osmotic potential. The shoot length of the oat cultivars differed under the different osmotic potentials of PEG and also shoot length differed with seed size and cultivars depending on stress conditions (Table 3). While the cv. Centennial showed the highest shoot length, the lowest shoot length was obtained from the cv. Chantilly and Monarch irrespective of seed size and osmotic potential. The smallest seed fraction had a significantly lower shoot length than the medium and large seed fractions (Table 3). Shoot length was severely influenced by osmotic potential. The highest shoot length was determined in no osmotic stress (0.0 MPa). No shoot length was recorded for all oat cultivars at -0.75 MPa of PEG. Water stresses depressed the shoot growth of the cultivars rather than their root growth (Table 3). Root length is an important trait against drought stress in plant varieties; in general, variety with longer root growth has resistant ability for drought (Leishman and Westoby, 1994). In the present study, the increasing concentrations induced water stress leading to decrease in root and shoot length, this reduction in root and shoot length was lower in large and medium seeds than those of small seeds (Table 3). Al-Karaki (1998) showed that lentil seedlings from large seeds had higher root length than those from small seeds at intermediate soil water potential. Similarly, Kaydan and Yağmur (2008) indicated that reduction in root and shoot length of variety Presto in Triticale was lower in large seeds than those of small seed under control and water stress conditions. Hence, large seeds had an advantage of seedling establishment in low soil moisture condition due to larger root system (Leishman and Westoby, 1994). Roots play an important role in plant survival during periods of drought (Hoogenboom et al., 1987) and also drought resistance is characterized by an extensive root growth and small reduction of shoot growth under drought conditions (Chenet al., 2002).

## Conclusions

The results of this study confirmed that the selection of oat genotypes with larger seed suitable for sowing in areas displaying moisture stress will help to reduce the risk of poor stand establishment and will enable more homogenous growth under varying rainfall conditions. So, the elimination of smaller seeds inside the seed material is important for homogenous growth or seed/plant density could be increased. The reason of this practice is that small seeds exhibit lower seedling growth and emergence in normal or extreme growing conditions. Genotypes such as Pajaz, Lvovskii Rannii, and Centennial were better suited to germinate under the range of osmotic potentials included in this study. Moreover, under field conditions the emergence differences between genotypes may be greater compared with the germination at laboratory conditions. The basic reason for these differences may be the coleoptile elongation during germination, because coleoptile length and elongation may differ among genotypes.

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### REFERENCES

Al-Karaki GN (1998). Seed size and water potential effects on water uptake, germination and growth of lentil. J. Agron. Crop Sci., 181: 237-242.

Almansouri M, Kinet JM, Lutts S (2001). Effect of salt and osmotic stresses on germination in durum wheat (*Triticum durum* Desf.). Plant Soil., 231: 243-254.

Ashraf CM, Abu-Shakra S (1978). Wheat seed germination under low temperature and moisture stress. Agron., J. 70: 135-139.

Bliss RD, Plat-Alola KA, Thomson WW (1986). Osmotic sensitivity in relation to salt sensitivity in germinating barley seeds. Plant Cell Environ., 9: 721-725.

Briggs KG, Dunn GJ (2000). The effects of seeding rate, seeding date, and location on grain yield, maturity, protein percentage and protein yield of some spring wheats in central Alberta Can. J. Plant Sci., 59: 1129-1146.

Chen G, Krugman T, Fahima T, Korol AB, Nevo E (2002). Comparative study on morphological and physiological traits related to drought resistance between xeric and mesic *Hordeum spontaneum* lines in Israel. Barley Gent. News Lett., 32: 22-33.

Doehlert DC, McMullen MS, Jannink JL, Panigrahi GSH, Riveland NR (2004). Evaluation of oat kernel size uniformity. Crop Sci., 44: 1178-1186.

Doehlert DC, McMullen MS, Riveland NR (2002). Sources of variation in oat kernel size. Cereal Chem., 79: 528-534.

Gholami A, Sharafi S, Sharafi A, Gahemi S (2009). Germination of different seed size of pinto bean cultivars as affected by salinity and drought stres. J. Food, Agri. Environ., 7(2): 555-558.

Guberac V, Martincic J, Maric S (1998). Influence of seed size on germinability, germ length, rootlet length and grain yield in spring oat. Bodenkultur, 49: 13-18

Hampson CR, Simpson GM (1990). Effect of temperature, salt and osmotic potential on early growth of wheat (*Triticum aestivum* L.). I. Germination. Can. J. Bot., 68: 524-528.

Hoogenboom G, Huck MG, Peterson CM (1987). Root growth rate of soybean as affected by drought stress. Agron J. 79: 607-614.

Kawade RM, Ugale SD, Patil RB (1987). Effect of seed size on germination, seedling vigor, and test weight of pearl millet. Seed Res., 15: 210-213.

Kaydan D, Yağmur M (2008). Germination, seedling growth and relative water content of shoot in different seed sizes of triticale under osmotic stress of water and NaCl. Afri. J. Biot. 7: 2862-2868.

Lafond GP, Baker RJ (1986). Effects of temperature, moisture stress, and seed size on germination of nine spring wheat cultivars. Crop Sci., 26: 563-567.

Larsen SU, Andreasen C (2004). Light and heavy seeds differ in germination percentage and mean germination thermal time. Crop Sci., 44: 1710-1720.

Leishman MR, Westoby M (1994). The role of seed size in seedling establishment in dry soil conditions-experimental evidence from semi-arid species. J. Ecol., 82: 249-258.

Mathur PN, Sinha NC, Singh RP (1982). Effect of seed size on germination and seed vigour in oat (*Avena sativa* L.). Seed Res., 10: 109-113.

McGee DC (1988). Maize Diseases: A Reference Source for Seed Technologists. APS Press St. Paul, MN, p. 150.

Mian AR, Nafziger ED (1992). Seed size effects on emergence head number, and grain yield of winter wheat. J. Prod. Agric. 5: 265–268.

Michel BE, Kaufmann MR (1973). The osmotic potential of polyethylene glycol 6000. Plant Phsiol., 51: 914-916.

Mos M, Binek A, Zielinski A, Wojtowicz T (2007). Effect of Osmotic stress on vigor in naked and husked oat cultivars subjected to accelerated ageing. American-Eurasian J. Agric. Environ. Sci., 5: 465-469.

Palagyi A (1983). Tertiary seed proportions in the grain yield of several oat varieties. Cereal Res. Commun., 11: 269-274.

Peterson DM (1992). Physiology and development of the oat plant. p. 77–114. *In* H.G. Marshall and M.E. Sorrells (ed.) Oat science and technology. Agron. Monogr. 33. ASA and CSSA, Madison, WI.

Roy SK, Hamid AS, Giashuddin Miah M, Hashem A (1996). Seed size variation and its effects on germination and seedling vigour in rice. J. Agron. Crop Sci., 176: 79-82.

Turk MA, Tawaha AM (2002). Seed germination and seedling growth of two barley cultivars under moisture stress. Res. on Crops, 3: 467-472.

Willenborg CJ, Wildeman JC, Miller AK, Rossnaged BG, Shirtliffe SJ (2005). Oat Germination Characteristics Differ among Genotypes, Seed Sizes, and Osmotic Potentials. Crop Sci., 45: 2023-2029.