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EFFECT OF SEED SIZE AND DROUGHT STRESS ON GERMINATION AND SEEDLING GROWTH OF NAKED OAT (*AVENA SATIVA* L.)

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Abstract

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Effects of seed size and osmotic stress on germination and seedling growth of five naked oat genotypes were investigated in this study. Oat genotypes were Mozart, CROA 60, Detvan, Eva 1 and AC Belmont. Small, medium and large seeds of five naked oat genotypes were germinated in polyethylene glycol (PEG 6000) solutions with initial osmotic potentials ranging from 0 to -0.75 MPa at 8°C. Final germination percentage, median germination time, root length and shoot length were measured in this study. In all genotypes examined, decreasing seed size and osmotic potential increased median germination time (MGT) and decreased final germination percentage (FGP), root and shoot length. Among genotypes, CROA 60, Eva 1 and AC Belmont had the highest final germination percentage while AC Belmont had the fastest median germination time and the highest root and shoot length. The study results also show that large seed of genotype such as AC Belmont seems better fitted to germinate under the range of osmotic potential in this study.

Key words: oat, seed size, drought stress, genotype, germination
Abbreviations: FGP- final germination percentage; MGT: median germination time; PEG: polyethylene glycol; TKW: thoussand-kernel weight

Introduction

Seed germination is one of the most important phase effecting yield and quality in crop production (Almansouri et al., 2001). Further, the interaction between seedbed environment and seed quality plays an important role in crop establishment (Brown et al., 1989; Khajeh-Hosseini et al., 2003). Water shortage in soil cause postponed and reduced seed germination, unequal seedling emergence, and varied number of plants per unit area and decreased seed yield and quality (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).

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

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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.

The effect of seed size on germination and following seedling emergence have been investigated by many researchers in various crop species/cultivar (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 Yagmur, 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 Yagmur, 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.

Results of some researchers clarified that seed size notably affected grain yield and grain yield components such as plant stand, plant height, seed weight, and number of seeds per spike (Stougaard and Xue, 2004; Royo et al., 2006). Manga and Yadav (1995) and Lopez et al. (1996) showed out that larger seeds achieved vigorous seedlings, taller plants with more tillering and higher levels of dry matter under water deficient condition. Moreover, 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). Also, larger seeds with well-developed root systems of seedlings may gain an advantage by allowing reach to soil moisture at deeper levels (Leishman and Westoby, 1994).

Willenborg et al. (2005) stated that little is known about the effect of seed size on the germination of various naked oat genotypes, particularly under moisture-limited conditions. 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. The objective of this study was to determine the effects of cultivar and seed size on the germination and seedling growth of naked oat seed subjected to moisture stress.

Materials and Methods

This study was carried out at the Department of Field Crops, Faculty of Agriculture, University of Ondokuz Mayis, Turkey. The experiment was designed as a completely randomized factorial of five genotypes, three seed sizes, and four moisture stress treatments. Each treatment was replicated four times and the study was performed in January and March of 2009. The study was conducted in a YAMATO IN/802 incubator under total darkness at a temperature of 8°C. Genotypes examined included Mozart, CROA 60, Detvan, Eva 1 and AC Belmont obtained from the Czech Republic, New Zealand, Slovakia, Republic of Chile and Canada, respectively. Seed of these genotypes was grown in Samsun condition in 20072008 growing seasons to obtain newly harvested seed. Within each seed lot, seed of each of the 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 count-

Table 1
Thousand-kernel weights (g) of fractionated seed samples for each genotype

Genotype	Seed size class, g		
	Small	Medium	Large
Mozart	13.2	30.3	34.3
CROA 60	19.6	25.5	33.3
Detvan	13.3	21.4	32.0
Eva 1	16.1	26.3	34.0
AC Belmont	21.5	27.0	32.5

ing 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 percentage was calculated as the cumulative number of germinated seeds with normal radicles in each experimental unit at termination of the experiment as follows:

$$FGP = (\Sigma_{n} / N_{t}).100,$$

where n is the number of germinated seed at each enumeration interval, and N_t is the number of seeds in each experimental unit.

Mean germination time (MGT) was calculated to assess the rate of germination (Lafond and Baker, 1986) as follows:

$$MGT = \Sigma \ (nx) / n,$$

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 15th 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

A significant three-way interaction (cultivar, seed size and osmotic stress) was found (P < 0.01) for all investigated characters (Table 2). Examination of the three way interaction indicated that CROA 60, Eva 1 and AC Belmont were relatively unaffected by increasing osmotic stress for final germination percentage (Figure 1). CROA 60, Eva 1 and AC Belmont exhibited the highest final germination percentage. On the contrary, the lowest final germination percentage (83.85%) was obtained from Detvan (Table 2, Figure 1). Oat germination characteristics varied considerably between seed size classes (Table 2). While the highest final germination percentage (95.16%) was obtained from large seed, the lowest final germination percentage (91.16%) was obtained small seed. Final germination percentage differed significantly among moisture stress treatments (PEG) (Table 2). Overall, final germination percentage was 2% and 22% lower at PEG -0.50 and -0.75 MPa than oat final germination percentage with no moisture stress, respectively (Table 2). Differences in FGP between 0 MPa and -0.25 MPa were not significant (*P* <0.01).

Oat MGT was greatly affected by oat genotype. Detvan took significantly longer to achieve 50% germination than all other genotypes, while AC Belmont achieved 50% germination more quickly than all others (Table 2, Figure 2). Median germination time of the fastest germinating genotype (AC Belmont) was 242.3°C h lower than the slowest germinating genotype (Detvan). Differences in MGT between CROA 60 and Eva 1 were not significant. Oat MGT also was most affected by moisture stress treatment (Tables 2). MGT differed significantly between all moisture

Table 2
The mean effect of genotype, seed size and osmotic stress (MPa) on percent germination of five naked oat genotypes

Treatment	Final germination, %	Median germination time, °C h	Root length, mm	Shoot length, mm
Genotype				
Mozart	89.58 b	1441.5 b	33.1 b	13.0 bc
CROA 60	97.81 a	1360.8 c	32.1 b	12.6 c
Detvan	83.85 c	1495.3 a	26.9 c	10.9 d
Eva 1	97.60 a	1368.3 c	32.8 b	13.6 b
AC Belmont	97.66 a	1253.0 d	34.5 a	15.0 a
Seed Size				
Large	95.16 a	1359.3 b	34.0 a	13.9 a
Medium	93.59 b	1390.9 a	33.8 a	14.2 a
Small	91.16 c	1401.1 a	27.8 b	10.9 b
Osmotic Moisture Stress				
0.0 MPa	99.54 a	1144.8 d	56.0 a	25.6 a
-0.25 MPa	99.08 a	1209.8 c	43.8 b	18.3 b
-0.50 MPa	97.29 b	1416.6 b	21.7 c	8.3 c
-0.75 MPa	77.29 c	1763.9 a	6.0 d	-

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

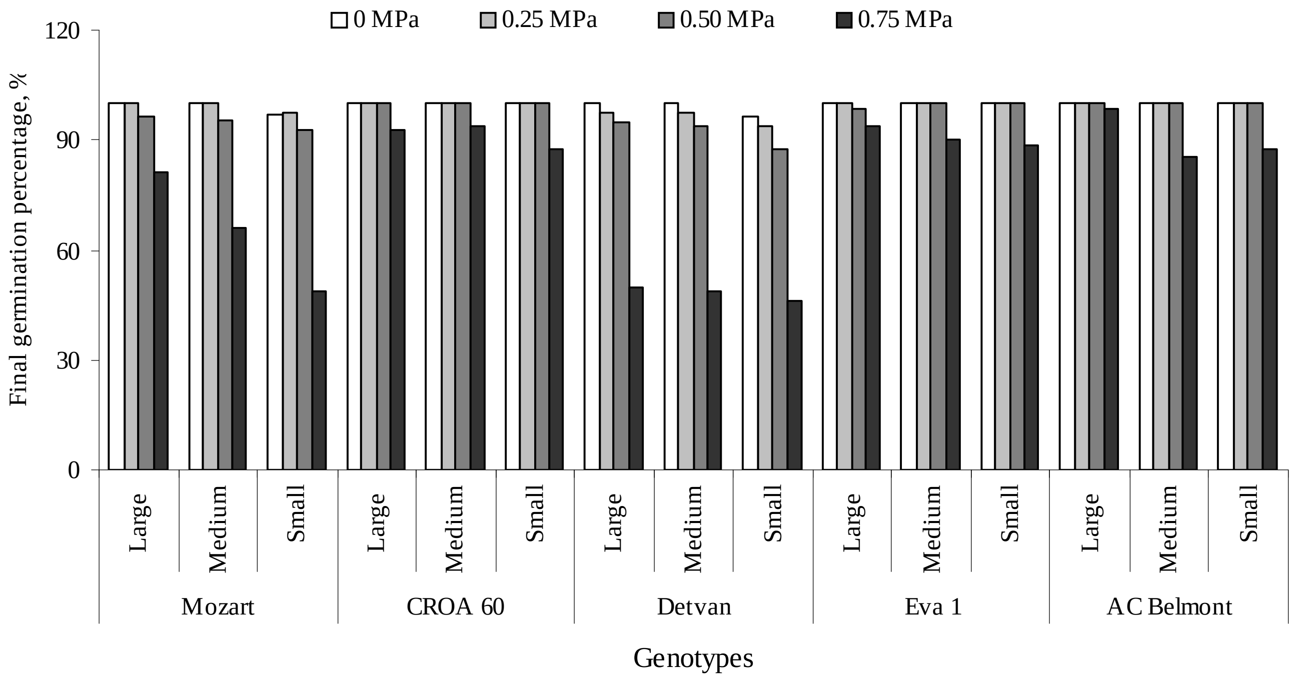

Fig. 1. Effect of seed size and osmotic stress on the median germination time of five naked oat genotypes

stress treatments (Table 2). With no osmotic stress (0 MPa), MGT was 5.4% (65°C h), 19.2% (271.8°C h) and 35.1% (619.1°C h) lower compared with germination at osmotic potentials of -0.25, -0.50 and -0.75 MPa, respectively (Table 2, Figure 2).

Large oat seed took 3% (41.8°C h) less time to reach 50% germination than small seed, irrespective of genotype or moisture stress. Large seed also had significantly lower MGT than medium seed. However, medium seed had not significantly than small seed (Table 2).

The root length of oat cultivars differed at the different osmotic potentials of PEG as shown in Table 2. While AC Belmont gave the highest root length as 34.5 mm, Detvan had the lowest root length as 26.9 mm. differences in root length between Mozart, CROA 60 and Eva 1 were not significant ($P<0.01$) (Table 2). The decreasing of osmotic potential of PEG decreased root length compared to control solutions for all oat cultivars (Table 3). 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).

Moreover, root length differed by seed size depends on various PEG concentrations. In normal condition, large and medium seeds had higher root length compared to small seeds regardless of genotype and osmotic potential. No significant differences in root length were observed between medium and large seed (Table 2).

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 cultivar AC Belmont showed the highest shoot length, the lowest shoot length was obtained from the cultivar Detvan 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).

The observed difference is minimal at 3.0 mm, while there was no difference observed in shoot length between the medium and large seed fractions (Table 2). Shoot length was severely influenced by osmotic potential. The highest shoot length was determined in no osmotic stress (0 MPa). No shoot length was recorded for all oat cultivars at -0.75 MPa of PEG.

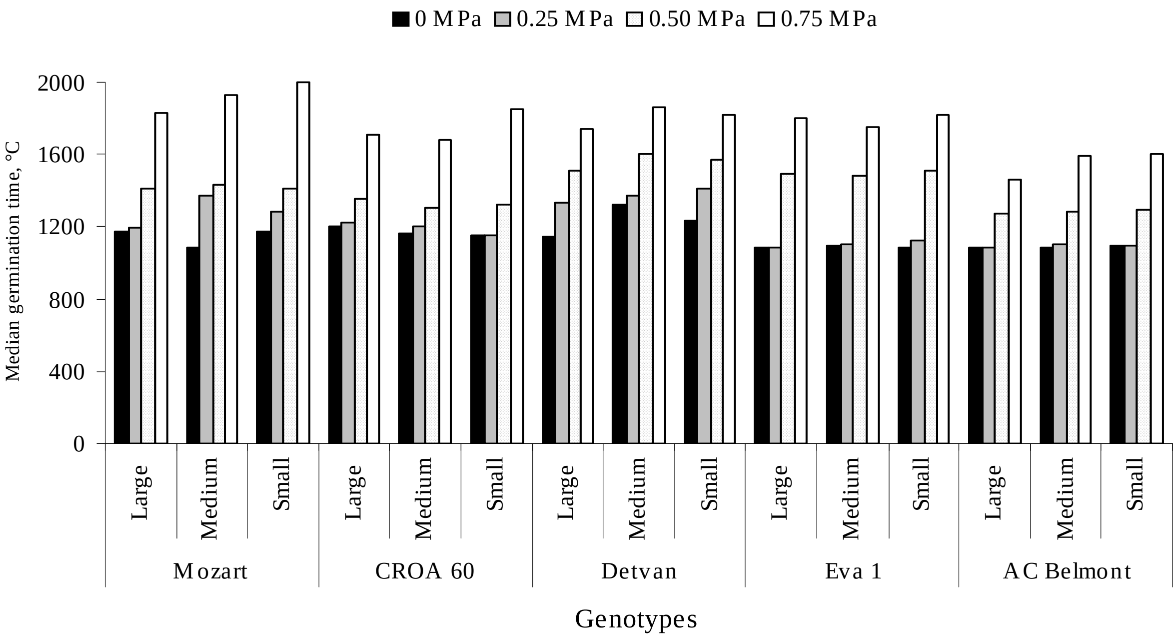

Fig. 2. Effect of seed size and osmotic stress on the median germination time of five naked oat genotypes

Table 3
The effects of seed size on shoot length (mm) and root length (mm) of five naked oat under osmotic stress of PEG

Genotype	Seed size	Root length, mm				Shoot length, mm			
		Osmotic stress, MPa							
		Control	0.25	0.5	0.75	Control	0.25	0.5	0.75
Mozart	large	68.1	44.5	18.9	3.6	29	19.1	10.5	-
	medium	70.1	41.5	21.7	4.6	26.1	21.4	10	-
	small	55.6	45.7	20.2	2.4	20.6	13.1	6.3	-
CROA 60	large	57.3	46.1	29.8	7.6	27.5	19	10.3	-
	medium	51.6	45.3	29.5	7.4	24.9	20.7	9.2	-
	small	48.3	36	19.4	6.6	20.5	12.9	6.2	-
Detvan	large	47.4	46.9	18	4.6	17.9	17.3	8.1	-
	medium	58.4	51	15.1	3.8	27.2	21.1	6.9	-
	small	31.5	29.9	11.9	3.9	16.6	12.9	3.2	-
Eva 1	large	68	44	18.9	8.1	31.5	19.1	8.7	-
	medium	62	45.9	20.5	7.1	27.6	19.4	8.5	-
	small	55	42.2	15.4	6.3	23.8	17.9	6.7	-
AC Belmont	large	58.9	48.5	32.3	8.2	31.7	18.7	9.8	-
	medium	53.2	48.7	31.2	7.8	32.1	19.1	10.4	-
	small	54.7	41.3	22.2	7.3	27.6	21.9	9.1	-
LSD (P<0.01) Int.		11.25				2.3			

Water stresses depressed the shoot growth of the cultivars rather than their root growth (Table 3).

Discussion

Our results show that oat germination characteristics and seedling growth may be affected by cultivar; seed size and moisture stress (Table 2). There were differences in final germination percentage of seed size depending on stress intensity. Willenborg et al. (2005) also reported that germination characteristics were affected by cultivar, seed size and moisture stress in six western Canadian oat genotypes. In present study, large seed exhibited 4 % greater final germination than small seed, regardless of moisture stress. Similar results were reported by Guberac et al. (1998) and Willenborg et al. (2005) and Mut et al. (2010) in oat (*Avena sativa* L.) and Kaydan and Yaðmur (2008) in triticale (Triticale With mack). Furthermore, in barley (Hordeum vulgare L.), Turk and Tawaha (2002) 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 Yagmur (2008) pointed out that large seed with higher germination percentage in normal and stress condition may be related to privileged water uptakes. Al-Karaki (1988) 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.

In present study, averaged over all genotypes and seed sizes, increased moisture stress induced by decreasing osmotic potentials increased median germination time and decreased final germination percentage (Table 2, Figures 1 and 2). Final germination percentage was reduced by 22.25%, while median germination time was delayed by 619.1°C h as a result of increasing moisture stress from 0 to -0.75 MPa. These findings are similar to those obtained for wheat (Lafond and Baker, 1986), barley (Turk and Tawaha, 2002), triticale (Kaydan and Yagmur, 2008), six western Canadian oats (Willenborg et al., 2005) and fifty-five different oat genotypes (Mut et al., 2010).

This study also shows differential final germination percentage and median germination time among five different naked oat genotypes (Table 2). In this study, CROA 60, AC Belmont and Eva 1 had the greatest final germination percentage at the highest water stress conditions (-0.75 MPa), and AC Belmont exhibited the fastest time to 50 % germination (Table 2, Figures 1 and 2). 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. Absorption time varies significantly in oat depending on seed size, hull and seed coat permeability, and soil moisture (Peterson, 1992).

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 this 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 lengths than those from small seeds at intermediate soil water potential. Similarly, Kaydan and Yagmur (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 in drought stressed conditions (Guoxiong et al., 2002).

Furthermore, in this study, root and shoot length of AC Belmont was higher than those of other genotypes.

Conclusions

The results of this study revealed 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. Therefore, the use of the material was removed from the small seeds could be suggested to growers to obtain higher germination and uniform emergence under field conditions. Large seed of genotype such as AC Belmont was better suited to germinate under the range of osmotic potentials included in this study.

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