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Effects of seed size and aging on field performance of lentil (*Lens culinaris* Medik.) under different irrigation treatments

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ABSTRACT

A sub-sample of lentil (*Lens culinaris* 'Kimia') seeds was kept as bulk (S_1) and another sample was separated to large (S_2) and small (S_3) seeds. A sub-sample of each size was kept as control or high vigor seed lot (A_1) and the two other sub-samples were artificially aged for 2 and 4 days (A_2 and A_3, respectively). Field performance of these seeds was evaluated during 2011 and 2012. Yield components and grain yield of lentil decreased with decreasing water availability. The highest yield components (except 1000 grain weight) and grain yield per unit area were obtained by plants from large seeds. The superiority of plants from large seeds in grain yield was more evident under limited irrigations than under well watering. Seed aging resulted in poor stand establishment and consequently low grain yield per unit area. Plants from aged large seeds showed the lowest reduction in grain yield per unit area, compared with those from aged small and bulk seeds. It seems that cultivation of large seeds somehow can reduce the deleterious effects of drought stress and seed aging on grain yield per unit area of lentil.

Key words: grain yield, lentil, seed aging, seed size, drought stress

IZVLEČEK

VPLIV VELIKOSTI IN STARANJA SEMENA NAVADNE LEČE (*Lens culinaris* Medik.) NA NJENO USPEVANJE V POLJSKEM POSKUSU PRI RAZLIČNIH REŽIMIH NAMAKANJA

Semena navadne leče (*Lens culinaris* 'Kimia') so bila pred setvijo razdeljena na večji podvzorec (S_1) in manjšega, ki je bil razdeljen na velika (S_2) in mala (S_3) semena. Podvzorec semen vseh velikost je bil vzet kot kontrola, oziroma kot vitalna semena (A_1), ostala dva podvzorca semen sta bila umetno starana 2 in 4 dni (A_2 in A_3, vzorca). Uspevanje semen je bilo v poljskem poskusu ovrednoteno v sezonah 2011 in 2012. Komponente pridelka in pridelka zrnja leče so upadale z zmanjševanjem dostopnosti vode. Največje vrednosti komponent pridelka (razen mase 1000 zrn) in pridelka zrnja na enoto površine so bile dosežene z rastlinami iz velikih semen. Superiornost rastlin iz velikih semen v pridelku zrnja je bila še bolj očitna v razmereh omejenega namakanja v primerjavi z dobro zalitimi rastlinami. Staranje semen je povzročilo slabšo vzpostavitev sestoja posevka in posledično manjši pridelek zrnja na enoto površine. Rastline iz velikih semen so imele manjše zmanjšanje pridelka na enoto površine v primerjavi s tistimi iz staranih manjših semen in semen enotnega vzorca. Izgleda, da setev velikih semen pri navadni leči nekako zmanjša škodljive učinke sušnega stresa in staranja semen na pridelku zrnja na enoto površine.

Ključne besede: pridelek zrnja, navadna leča, staranje semen, velikost semen, sušni stres

1 INTRODUCTION

Drought stress is known to limit plant productivity in many regions of the world. The onset of stress may initially cause a loss of cell turgor which in turn reduces gas exchange and leaf elongation since both are turgor-dependent processes. The result is a decrease in growth rate since this is a function of transpiration rate and leaf area (Chartzoulakis *et al*., 1993). Some studies have

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shown that growth rates of several plants are directly proportional to the availability of water in the soil (Kamel and Loser, 1995; Ghassemi-Golezani *et al*., 2009). The reduction in growth, yield and quality by water stress has been well documented (Kriedemann and Barrs, 1981; Ghassemi-Golezani *et al*., 2009). Water deficit is also known to alter a variety of biochemical and physiological processes ranging from photosynthesis to protein synthesis and solute accumulation (Hu and Schmidhalter, 1998). Water stress may range from moderate and of short duration to extremely severe and prolonged summer drought that has strongly influenced evolution and plant life (Pereira and Chaves, 1995). The physiological responses of plants to water stress and their relative importance for crop productivity vary with species, soil type, nutrients and climate.

High and rapid field emergence and early establishment are essential to obtain an adequate stand and to gain an advantage of the growing season before the onset of the severe drought stress late in the season (TeKrony and Egli, 1991). This can be achieved by cultivating high vigor seeds (Ghassemi-Golezani *et al*., 2010). Seed vigor comprises those properties that determine the potential for rapid and uniform emergence under a wide range of field conditions (ASPB, 2003). Seed vigor could be reduced by aging. Reducing seed vigor following aging has been attributed to a series of metabolic defects that accumulate in embryonic and non-embryonic structures (Osborne, 1983). A large number of reactive oxygen species are generated in the seed during aging which causes lipid peroxidation (McDonald, 1999). This free radical induced non-enzymatic peroxidation, which has the potential to damage membrane, is the major cause of seed deterioration. The deleterious effects of aging on seed vigor and viability are associated with the damage occurring at the membrane, nucleic acid and protein levels (Fujikura and Karssen, 1995). Natural and artificial aging have been reported to reduce seed vigor of many species (Vieira *et al*., 1999; Ghassemi-Golezani *et al*., 2010, 2011, 2012) and were associated with field emergence, growth and yield of barley (Kim *et al*., 1989), winter oilseed rape (Ghassemi-Golezani *et al*., 2010), maize (Ghassemi-Golezani *et al*., 2011) and chickpea (Ghassemi-Golezani *et al*., 2012).

Another factor which may influence seed vigor is seed size, since it is generally proportional to the amount of food reserves that will be destined to the embryo (Lloret *et al*., 1999). Seed size reflects maternal environment, since it is influenced by resource availability (Krannitz *et al*., 1999; Wulff *et al*., 1999) and the environmental conditions to which the mother plant was exposed during seed formation (Vaughton and Ramsey, 1998). Large seeds have a better performance than small seeds, especially under competitive conditions (Eriksson, 1999; Moles and Westoby, 2004). Better performance can be seen in higher emergence (Seiwa, 2000), increased seedling growth (Osunkoja *et al*., 1994), reduced mortality (Seiwa, 2000), increased root/shoot ratio (Lloret *et al*., 1999) and higher grain yields (Rao, 1981).

Larger seeds with well-developed root systems of seedlings may gain an advantage by reaching soil moisture at deeper levels (Leishman and Westoby, 1994). Schimpf (1977) argued that moisture availability was more important than length of the growing season, due to the increased capacity of seedlings from large seeds to establish roots in deeper soil horizons. Royo *et al*. (2006) found that larger seeds resulted in high biomass, green area index, number of spikes per m^2 and heavier kernels. Seed size was also found to be significantly influencing early vigor, tiller number, plant height and dry-matter production in pearl millet (Manga and Yadav, 1995). However, the interaction of seed size and aging on field performance of crops is not clear. Thus, this research was carried out to investigate the effects of seed size and aging on seedling establishment and yield of lentil under different irrigation treatments in two years.

2 MATERIALS AND METHODS

Seeds of lentil (*Lens culinaris* 'Kimia') were obtained from Research Center of Dry-land, Kermanshah, Iran. A sub-sample of the seeds was kept as bulk (S_1) with 1000 grain weight of 42 g. The other seeds were separated by a sieve with four millimeters diameter. The seeds that remained on the sieve were considered as large (S_2) with 1000 grain weight of 50 g and those passed the sieve were considered as small (S_3) seeds with 1000 grain weight of 35 g. Seeds of each size were divided into three sub-samples. A sub-sample was kept as control or high vigor seed lot with 97.2% normal germination (A_1). The two other sub-samples with about 20% moisture content were artificially aged, using controlled deterioration test (ISTA, 2010) at 40°C for 2 and 4 days reducing germination to 90.8% and 82.3% (A_2 and A_3, respectively). So, three seed lots from each size with different levels of aging were provided for field experiment.

The field experiment was conducted at the Research Farm of the University of Tabriz (Latitude 38˚05' N, Longitude 46˚17' E, Altitude 1360 m above sea level) in 2011 and 2012. All the seeds were treated with Benomyl at a rate of 2 g kg^{-1} before sowing. Seeds were hand sown in about 5 cm depth with a density of 100 seeds m^{-2} on 5th May 2011 and 14th May 2012. Each plot consisted of 6 rows with 4 m length in 2011 and with 3 m length in 2012, spaced 25 cm apart. The experiments were arranged as split plot factorial, based on RCB design with three replications. All plots were irrigated immediately after sowing and subsequent irrigations were carried out after 70 (I_1), 120 (I_2) and 170 (I_3) mm evaporation from class A pan. Weeds were controlled by hand during crop growth and development.

Seedling emergence was recorded after final establishment in each plot and percentage of emergence was calculated. At maturity, 10 plants were harvested from each plot and grains per plant and grains per unit area and 1000 grain weight were recorded. Finally, plants of 1 m^2 in the middle part of each plot were harvested and grain yields per plant and per unit area were determined. Analyses of variance of the data based on the experimental design and comparison of means at $p \leq 0.05$ were carried out, using MSTATC software. Excel software was used to draw figures.

3 RESULTS

Seed aging had significant effect on mean emergence percentage ($P \leq 0.01$), but this trait was not significantly affected by seed size ($P > 0.05$). The interaction of year × seed aging for seedling emergence percentage was also significant ($P \leq 0.01$). Seedling emergence percentage was significantly decreased with increasing seed aging (Fig. 1). Seedling emergence percentage for non-aged seed lot (A_1) was similar in both years, but for aged seed lots (A_2 and A_3), it was significantly lower in the second year (Fig. 2).

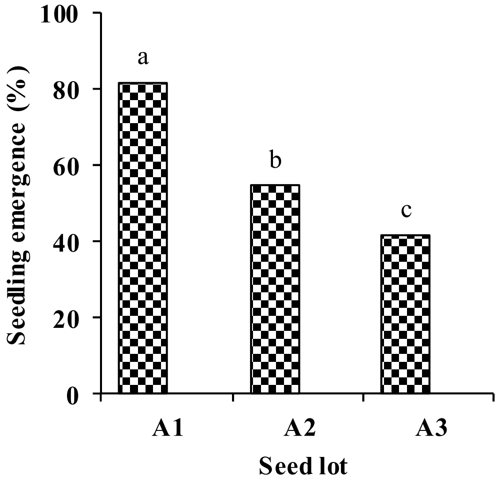

Figure 1: Mean seedling emergence percentage of lentil affected by seed aging
Different letters at each column indicate significant difference at $p \leq 0.05$
A_1, A_2 and A_3: Control and aged seed lots of lentil for 2 and 4 days at 40°C, respectively

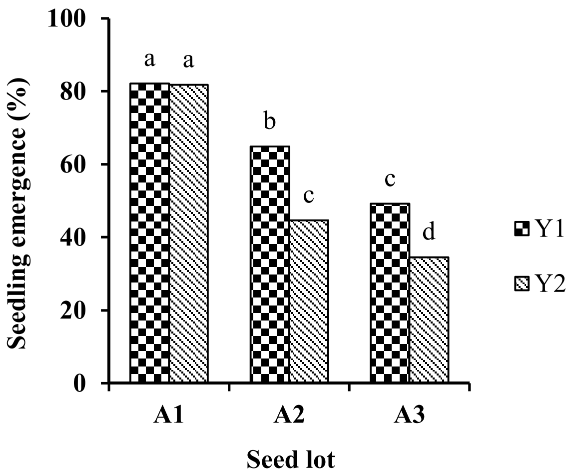

Figure 2: Mean seedling emergence percentage affected by seed aging in two years
Different letters indicate significant difference at $p \leq 0.05$
A_1, A_2 and A_3: Control and aged seed lots of lentil for 2 and 4 days at 40°C, respectively
Y_1 and Y_2: First and second years, respectively

Combined analyses of variance showed that the effects of irrigation and seed aging on grains per plant, grains per unit area, 1000 grain weight, grain yield per plant and grain yield per unit area were significant. All these traits, except 1000 grain weight, were also significantly affected by seed size. Interaction of irrigation × seed size for grains per plant, grain yield per plant and grain yield per unit area, interaction of irrigation × seed aging for grains per plant, grains per unit area and grain yield per unit area and interaction of seed size × seed aging for grains per plant, 1000 grain weight and grain yield per unit area were significant (Table 1).

Grains per plant, grains per unit area, 1000 grain weight, grain yield per plant and grain yield per unit area significantly decreased with decreasing water availability. Yield components, except 1000 grain weight, and grain yield per unit area were considerably higher for plants from large seeds (S_2), compared with those from bulk (S_1) and small seeds (S_3) (Table 2). The superiority of plants from large seeds in grain yield per unit area was more evident under limited irrigations than under well watering (Table 3).

Table 1: Combined analyses of variance of the effects of seed size and aging on field performance of lentil under different irrigation treatments

		MS				
Source of variation	df	Grains per plant	Grains per unit area	1000 grain weight (g)	Grain yield (g/plant)	Grain yield (g/m^2)
Year (Y)	1	11.414	5384.914	0.233	0.001	0.001
Error	4	5.975	51568.451	0.924	0.008	159.803
Irrigation (I)	2	4505.796**	16684347.340**	12.364**	5.974**	20425.674**
Y × I	2	1.895	49002.858	0.028	0.006	0.006
Error	8	5.086	21942.423	0.286	0.005	25.996
Seed size (S)	2	338.389**	2571894.525**	0.876	0.863**	2088.630**
Y × S	2	7.895	1489.340	0.007	0.013	0.013
I × S	4	28.046*	128782.552	1.221	0.058*	543.764*
Y × I × S	4	7.960	48940.923	0.095	0.002	0.004
Seed aging (A)	2	307.907**	2972971.062**	225.326**	0.411**	1638.016**
Y × A	2	16.191	8613.432	0.017	0.005	0.007
I × A	4	32.481*	281454.867**	0.137	0.023	460.120*
Y × I × A	4	0.228	49061.627	0.116	0.004	0.018
S × A	4	42.769**	23172.219	9.642**	0.011	529.193*
Y × S × A	4	1.312	3019.664	0.187	0.002	0.006
I × S × A	8	0.968	4568.789	0.453	0.025	244.537
Y × I × S × A	8	0.224	3207.789	0.168	0.006	0.005
Error	96	11.855	72336.390	1.721	0.027	183.939
CV%	-	14.56	17.95	2.91	11.34	19.07

Table 2: Means of yield and yield components of lentil affected by irrigation, seed size and aging

Treatments	**Grains per plant**	**Grains per unit area**	**1000 grain weight (g)**	**Grain yield (g/plant)**	**Grain yield (g/m^2)**
Irrigation					
I_1	31.96 a	2017 a	45.64 a	1.739 a	90.00 a
I_2	25.11 b	1567 b	45.14 b	1.503 b	72.66 b
I_3	13.87 c	912 c	44.68 c	1.082 c	50.72 c
Seed size					
S_1	23.50 b	1489 b	45.63 a	1.433 b	71.50 b
S_2	26.22 a	1721 a	45.13 a	1.571 a	77.15 a
S_3	21.22 c	1285 c	44.67 a	1.319 c	64.73 c
Seed aging					
A_1	21.44 c	1739 a	43.22 c	1.363 b	76.42 a
A_2	23.31 b	1486 b	44.94 b	1.426 b	71.53 a
A_3	26.19 a	1271 c	47.29 a	1.535 a	65.43 b

Table 3: Means of yield and yield components of lentil for interactions of Irrigation × seed size, irrigation × aging and seed size × aging

Traits	Treatment	S_1	S_2	S_3
Grains per plant	I_1	32.94 a	34.72 a	28.22 b
	I_2	23.94 c	28.33 b	23.06 c
	I_3	13.61 de	15.61 d	12.39 e
Grain yield (g/plant)	I_1	1.791 a	1.859 a	1.565 b
	I_2	1.444 c	1.671 b	1.395 c
	I_3	1.064 e	1.184 d	0.997 e
Grain yield (g/m^2)	I_1	92.58 a	90.66 a	86.76 ab
	I_2	73.70 c	81.09 bc	63.19 d
	I_3	48.21 e	59.71 d	44.24 e
		A_1	A_2	A_3
Grains per plant	I_1	29.22 bc	31.28 b	35.39 a
	I_2	22.22 e	24.61 d	28.50 c
	I_3	12.89 f	14.06 f	14.67 f
Grains per unit area	I_1	2411 a	1949 b	1692 cd
	I_2	1786 bc	1556 d	1357 e
	I_3	1022 f	952 f	762 g
Grain yield (g/m^2)	I_1	97.51 a	89.38 ab	83.12 bc
	I_2	78.17 cd	72.34 de	67.46 e
	I_3	53.59 f	52.86 f	45.71 f
		A_1	A_2	A_3
Grains per plant	S_1	19.89 d	23.11 c	27.50 a
	S_2	25.56 ab	26.06 ab	27.06 a
	S_3	18.89 d	20.78 d	24.00 bc
1000 grain weight (g)	S_1	42.79 e	44.94 c	47.90 a
	S_2	43.94 d	44.70 cd	46.36 b
	S_3	42.92 e	45.19 c	47.60 a
Grain yield (g/m^2)	S_1	79.05 ab	71.01 bc	64.44 c
	S_2	79.65 a	77.36 ab	74.45 ab
	S_3	74.07 ab	64.22 c	55.90 d

Different letters indicate significant difference at $p \leq 0.05$
I_1, I_2 and I_3: Irrigation after 70,120 and 170 mm evaporation from class A pan, respectively
S_1, S_2 and S_3: Bulk, large and small seeds of lentil, respectively
A_1, A_2 and A_3: Control and aged seed lots of lentil for 2 and 4 days at 40°C, respectively

Grains per plant, 1000 grain weight and grain yield per plant for plants from the most aged seed lot (A_3) were significantly higher than those from other seed lots (A_1 and A_2), but the highest number of grains per unit area and grain yield per unit area were recorded for plants from non-aged seed lot (A_1) (Table 2). These differences were diminished with increasing water stress. Plants from aged large seeds showed the lowest reduction in grain yield per unit area, compared with those from aged small and bulk seeds (Table 3).

4 DISCUSSION

Seed vigor is declined with aging followed by a loss of germination capacity and viability (Trawatha *et al.*, 1995), leading to reductions in seedling emergence percentage (Fig. 1), particularly in the second year (Fig. 2). This could be associated with the physiological changes during seed aging such as increased lipid peroxidation, decreased levels of anti-oxidants and reduced activity of several enzymes involved in scavenging of free radicals and peroxides (Hsu and Sung, 1997; Bailly *et al*., 1998).

Because of poor stand establishment (Fig. 1), plants from aged seed lots had the opportunity to use the environmental resources more efficiently, which resulted in production of comparatively more and larger grains and grain yield per plant (Table 2). However, this enhancement in grain yield per plant was not enough to compensate for poor stand establishment of plants from aged seed lots. Therefore, reductions in grains per unit area and grain yield per unit area were mainly influenced by large reductions of plant density, due to seed aging (Fig. 1). Decreasing grain yield per unit area due to cultivation of aged seeds were also reported for soybean (Saha and Sultana, 2008), winter oil-seed rape (Ghassemi-Golezani *et al*., 2010), maize (Ghassemi-Golezani *et al*., 2011) and chickpea (Ghassemi-Golezani *et al*., 2012). It seems that cultivation of large seeds somehow can reduce the deleterious effects of seed aging on grain yield per unit area (Table 3) via increasing the number of grains per plant and per unit area (Table 2).

Decreasing grain yield per unit area due to water deficit was attributed to reductions in grains per plant and 1000 grain weight (Table 2). Drought stress can decrease photosynthetic rate and disrupt carbohydrate metabolism in leaves (Kim *et al*., 2000); both may reduce amount of assimilate available for export to the sink organs, thereby increasing flower and pod abortion (Fulai *et al*., 2004), leading to reductions in grains per plant. Reduction in mean grain weight under severe and moderate water stress could be related to decreasing grain filling duration as a consequence of water limitation (Ghassemi-Golezani *et al*., 2009). However, decreasing grain yield under drought stress was mainly influenced by reduction in number of grains per plant rather than 1000 grains weight (Table 2), similar to that reported by Szilagyi (2003) for common bean. High density of plants from non-aged vigorous seeds increased competition of individual plants for water and other resources under limited irrigation conditions. As a result, the superiority of plants from high vigor seeds decreased with decreasing water supply (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. This may be the reason for better performance of plants from large seeds in grain yield per unit area under limited irrigation conditions (Table 3). Therefore, large seeds may somewhat alleviate the negative effects of drought stress on field performance of lentil.

5 CONCLUSION

It can be concluded that the rate of aging in large seeds is lower than that of small seeds, leading to the production of vigorous plants with high yield in the field. This superiority of large seeds is more evident when plants are subjected to drought stress. Therefore, cultivation of large seeds can reduce deleterious effects of aging and water limitation on field performance of crops such as lentil.

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