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Determination of Seed Size Properties of Soybean Cultivars and Their Response under Salinity during Early Growth

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ABSTRACT

Background: Seed sorting by seed size has been increasingly given importance in Türkiye but little is known about the impacts of seed size of soybean on germination and seedling growth, in regions suffering from salinity problems.

Methods: The seeds classified as small (6-7 mm for Ataem, 4-6 mm for Kocatürk, 4-7 mm for Batem Erensoy and 4-5 mm for Göksoy) and large (>8 mm for Ataem and Batem Erensoy, >7 mm for Kocatürk and >6 mm for Göksoy. Seeds were exposed to 0, 10 and 20 dS m^{-1} of NaCl. Germination percentage, mean germination time and seedling growth parameters were investigated and compared.

Result: Investigations revealed that, regardless of variety small seeds had a high content of chlorophyll pigments and slow and late mean germination time under NaCl stress. Emergence percentage differentiated in relation to seed size large seeds with 90.67% and small seeds with 73.67%. In conclusion, the large seeds produced significantly vigorous germination and seedling growth related to their high nutrient reserves and containing less chlorophyll pigmentation in their seeds. Therefore, care should be taken to select larger seeds, under saline conditions (10 dS m^{-1}).

Key words: *Glycine max,* Mechanoperception, MGT, NaCl, Seed pigmentation, Seed size.

INTRODUCTION

Soybean (*Glycine max*) has high importance as an oil seed and protein source worldwide (Mishra *et al*., 2022; Jaybhay *et al*., 2021). Soybean is a multipurpose crop, popular among rural and urban folks its cultivation area is continuously increasing across the world. However, soybean cultivation in Turkiye is restricted to defined areas approximately 38, 000 ha (TUIK, 2022) due to major constraints like lack of development of sowing technology for the crop. Therefore large part of the demand in the country is supported by import. This increasing demand has given rise to interest in development of soybean seed and cultivation technologies in search of high-quality seed production to improve crop yield. It is well known that the optimum soybean seed size could vary from genotype to genotype. Attainable seed size, seed weight or increase in seed weight per day, the duration of the seed filling and the number of seeds per pod are affected by the climatic conditions during seed filling (Bianchi *et al.*, 2022). The seed development in soybean crop occurs in many different environmental conditions which give rise to diversity in seed size and quality. Seed germination seedling emergence and these phases successfully turn into another phase under abiotic stresses mainly depend on seed vigor.

There are studies reporting that large size soybean seeds are superior compared to small sized ones (Vinhal-Freitas *et al*., 2011). Despite the studies on the significance of water absorption for seedling emergence, there is still insufficient information regarding its impact on each seed size.

The synthesis and degradation of chlorophyll occurs in matured seeds similar to leaves. The main function of photosynthetic activity in developing seeds is to increase oxygen concentration in developing seeds to sustain ATP synthesis in mitochondria (Nakajima *et al*., 2012). Oil seeds require high energy for lipid biosynthesis and seed photosynthesis plays a role in seed development. Chlorophyll degradation in late seed maturation is important because when the seeds contain low amount of chlorophyll, a significant increase in seed germination is reported (Smolikova *et al*., 2017).

Salinity is one of the major restriction in crop cultivation (Day and Koçak-Şahin, 2023a) also have an impact on soybean germination and seedling emergence. Plants show different responses against salinity, if the seeds are not uniform. Seed germination and seedling growth stages are vulnerable to the osmotic impact of salinity, nutrient shortage and oxidative stress. Currently, there are only a few reports available on seed size affects on reduction of salinity impacts during the early growth stages of the crop.

This study aimed to determine the differences of the seed size in terms of germination, seedling growth and seed

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vigor, as well as the electrical conductivity of the seeds and their seed pigment contents of different sized graded seeds of four soybean cultivars under saline conditions.

MATERIALS AND METHODS

Four soybean cultivars (Kocatürk, Batem Erensoy, Göksoy and Ataem) were obtained from the Batem, Antalya, Türkiye. The experiment was conducted in the seed technology laboratory of Field Crop Department of Ankara University Faculty of Agriculture in 2023. The seeds were graded individually into two categories depending on their genotypes as small (6-7 mm for Ataem, 4-6 mm for Kocatürk, 4-7 mm for Batem Erensoy and 4-5 mm for Göksoy) and large (>8 mm for Ataem and Batem Erensoy, >7 mm for Kocatürk and >6 mm for Göksoy. The one thousand seed weight and water uptake of four cultivars is shown in Table 1.

Germination test

The electrical conductivity of NaCl concentrations was adjusted to 10 and 20 dS m^{-1} before the start of the experiment by using YSI 3200 conductivity meter (Day and Aasim, 2017). Distilled water was used as control (0 dS m^{-1}).

The experiment made use of 200 seeds per treatment for each category of seeds. These were equally divided into four replications containing 50 seeds in each replication. The seeds were germinated in between 3 rolled filter papers with 10 ml of respective test solutions and put into sealed plastic bags. The seeds were incubated at 25±1°C in the dark for 10 days. The papers were replaced to prevent the accumulation of salts after every two days. When the emerging radicles elongated to 2 mm, the seeds were considered germinated. Mean germination time (MGT) was calculated using the formula given below to evaluate germination speed (ISTA, 2017).

$$MGT = \frac{\Sigma\ (n \times t)}{\Sigma n}$$

n= Number of germinated seeds on day t.

t= Number of days from the beginning of the germination test.

Σn= Total number of germinated seeds.

The germination percentage calculation was conducted following Day and Koçak-Şahin, (2023a).

$$GP = \frac{NG}{NT} \times 100$$

Where:

GP= Germination percentage.

NG= Number of germinated seeds.

NT= Total number of seeds.

Root length (RL), shoot length (SL), seedling fresh weight (FW) and dry weight (DW) of 10 seedlings randomly selected from each replicate were measured on the 15th day.

Dry weight was measured after drying samples at 70°C for 48 hours in an oven (Kaya *et al.,* 2013). Dry matter was calculated with the given formula:

$$\text{Dry matter} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

(ISTA, 2017)

One thousand seed weight of each genotype was determined with the formula given below:

$$x = \frac{8 \times 100}{8} \times 10$$

(Day *et al.,* 2023)

Water uptake

Ten grams of seeds from each of both seed sizes of soybean cultivars were placed in petri dishes containing distilled water to observe the water uptake of respective genotype to germinate. The percentage increase of moisture contents was calculated individually for each size of each genotype. The seeds in each replicate were weighed before and after germination and water uptake was calculated as given below.

$$\text{Water uptake (\%)} = \frac{\text{Weight after priming (mg) - Intial weight (mg)}}{\text{Initial weight (mg)}} \times 100$$

Electrical conductivity (EC) test

The electrical conductivity (EC) of three replicates of 25 seeds each of soaked soybean seeds with distilled water was measured using a YSI 3200 Conductivity Instrument (Day and Koçak-Şahin, 2023b). The results were expressed in µS cm^{-1} to take account of variability in different seed cultivars and sizes.

Seed pigment content

The seed samples of cultivars (500 mg) for each seed size of each variety were ground to powder with a mortar. The grounded seeds were mixed with 2 ml of petroleum ether (PE 60-80°C, pure) and tetrahydrofuran (THF) in a ratio of 1:1 with continuous grinding in a mortar with 3 ml of PE added. The samples were rinsed twice with 3 ml of PE: THF (4:1) mixture. The homogenate was then filtered through micro filters with a pore size of 0.45 µm. The filtrate of each sample was used to measure chlorophyll a (Chl a) and chlorophyll b (Chl b) using a spectrophotometer at wavelengths of 645 and 655 nm. The pigment contents were calculated with the equation reported by Bulda *et al.* (2008).

Emergence test

To determine the impact of seed size on different cultivars of soybean, four replications of 50 seeds were sown in pots filled with sterilized peat and perlite mixture to a depth of 3 cm. The trays were placed in greenhouse at 25±1°C 45 µM photons m^{-2} s^{-1} light for 16 h. The peat used for sowing had 40 mS m^{-1} EC and 6.5 pH. The trays were irrigated with tap water every two days. Emerged seedlings (unfolding cotyledons on the surface) were counted daily. The emergence percentage (EP) and the mean emergence time (MET) were calculated with the formula given in the germination test. After 25 days in greenhouse, shoot length, root length, seedling fresh weight and dry weight were measured from randomly selected ten plants. The seedling weights were recorded soon after the end of the experiment to avoid any loss in weight (Day, 2016 a; b). The seedling dry weight determined after sample drying in an oven at 105°C for 2 h (Yildiz *et al.*, 2010).

Pigment analysis

The fresh leaf samples (0.1 g) were extracted in 10 mL of 100% acetone to determine the content of chlorophyll (a+b) and total carotenoids (x+c). Thereafter, the absorbance of extracts was measured at 470, 644.8 and 661.6 nm using a Hettich universal 30 RF spectrophotometer. The contents of chlorophyll (a+b) and carotenoids (x+c) were determined using adjusted extinction coefficients (Lichtenthaler, 1987; Sharma *et al.*, 2021).

Electrolyte leakage (EL) test

Electrolyte leakage (EL) measurement was done as described by Lutts *et al.* (1996); Hnilièková *et al.* (2019). The leaves were divided into 1 cm diameter (0.2 g) and washed with deionized water, placed in tubes with 10 ml of deionized water and incubated for 24 h at 25°C. Later, the electrical conductivity of the solution (L1) was determined. The samples were autoclaved at 120°C for 20 min and the final conductivity (L2) was measured after equilibration at 25°C. The *EL* was calculated as follows:

$$EL\ (\%) = \frac{L1}{L2} \times 100$$

Experimental design and statistical analysis

The experiment was arranged in a completely randomized design with four replications. The data given in percentages were subjected to arcsine transformation before statistical analysis. The differences among the means were compared with Duncans multiple range test ($p<0.01$ or $p<0.05$). For all investigated parameters, analysis of variance was performed using the MSTAT-C computer software program (Michigan State University, version 2.10).

RESULTS AND DISCUSSION

Seed characteristics tests

Diversities in one thousand seed weight, water uptake and electrical conductivity of the investigated soybean cultivars are given in Table 1. One thousand seed weight of cultivars and seed sizes showed significant variation among them. Large and small-sized seeds of cv. Ataem gave heavier seeds compared to both sizes of other cultivars. Water uptake was higher in large seeds of all cultivars (Table 1). EC among cultivars and sizes did not show variety except for large seeds of cv. Batem Erensoy (Table 1). The maximum and the minimum EC of the seeds were noted for large seeds of Batem Erensoy with 701.10 µS cm^{-1} and for the small seeds of Göksoy with 114.50 µS cm^{-1}.

Seed Chl a and Chl b content of cultivars represented a statistical difference (Table 2). The maximum chl a and chl b content of 7.04 mg g dw^{-1} and 10.58 mg g dw^{-1} was noted in cv. Göksoy. The Seed size impact on seed chl a and chl b showed significant differences. The large seeds had less chl a and chl b with the values of 3.96 mg g dw^{-1} and 6.99 mg g dw^{-1} and the small seeds had the higher chl a and chl b with the values of 6.76 mg g dw^{-1} and 8. 94 mg g dw^{-1}.

Seed size impact on one thousand seed weight, water uptake and seed EC along with the seedling growth parameters of soybean cultivars was significantly clear. The EC test is a type of seed vigor test. Usually, high levels of leakage are considered a sign of low vigor (Araújo *et al.*, 2022). However, it was found that larger soybean seeds with higher germination rate and vigor tend to leak more (Table 1).

It was found that small seeds contain higher Chl a and Chl b compared to large seeds (Table 2). A decrease in GP and EP in small seeds could be attributed to less degradation of chlorophyll of small seeds during seed maturation (Nakajima *et al.,* 2012). Similar reports related to the inhibiting effect of seed high chlorophyll content on seed germination have been particularly noted by Costa *et al.* (2014) in rice.

Table 1: One thousand seed weight, water uptake, electrical conductivity of soybean cultivars according to seed sizes.

Cultivars	Seed sizes	One thousand seed weight (g)	Water uptake (%)	Electrical conductivity (µS cm^{-1})
Ataem	Large	179.62^{a**}	56.79^{ab**}	$339.67^{b\ **}$
	Small	107.95^{e}	53.18^{b}	194.77^{b}
Kocatürk	Large	153.94^{c}	54.10^{ab}	247.70^{b}
	Small	88.30^{g}	34.10^{d}	124.40^{b}
Batem erensoy	Large	166.27^{b}	58.33^{a}	701.10^{a}
	Small	98.36^{f}	55.59^{ab}	184.10^{b}
Göksoy	Large	115.77^{d}	53.67^{ab}	233.10^{b}
	Small	67.59^{h}	40.81^{c}	114.50^{b}

Means with the same letter(s) are not statistically different at **: $p<0.01$ level.

Germination test

The impacts of seed size and NaCl levels on MGT, GP, RL, SL and DM are given in Table 3. MGT represented a statistical difference over seed size and cultivars. Large sized seeds of cultivars germinated earlier and a higher GP was obtained (3.11 days; 93.50%) compared to small sized seeds (3.34 days; 68.33%). NaCl level increase from 10 dS m^{-1} to 20 dS m^{-1} caused increased MGT. The minimum and the maximum time to germination were noted in control (2.50 days) and 20 dS m^{-1} (4.46 days). A decrease in GP was observed in 20 dS m^{-1} (79.12%) and was significantly less compared to the control (84.00%). However, the GP recorded was similar at 10 and 20 dS m^{-1}. The results recorded significant impact of NaCl levels on the shoot length and root length. A comparison of the mean root length values showed that the maximum root length (6.78 cm) was recorded in control. Minimum root length was noted (1.24 cm) on 20 dS m^{-1} NaCl. Increase in dry matter was observed with the increase in NaCl levels. The minimum dry matter of seedlings was observed in control treatment (14.10%) and the maximum dry matter was detected at 20 dS m^{-1} NaCl level (29.89%).

A three-way interaction was observed for the MGT, root length and shoot length, (Table 4). MGT showed variation for all the cultivars, both the sizes studied which delayed time to germination with increasing NaCl levels. GP varied between 46% to 100%.

At a NaCl level of 10 dS m^{-1}, there was a small increase in the root length, but at 20 dS m^{-1}, there was a significant decrease in the root length. However, at 20 dS m^{-1} NaCl level, large and small seeds recorded similar root length in all the cultivars studied.

Analysis of variance showed significant differences among treatments for shoot length. The maximum shoot length value of 14.51 cm was observed in the control treatment for small seeds of Kocatürk. The shoot length of small seeds was superior or gave statistically similar values for large seeds especially in control treatments and 10 dS m^{-1}.

The harmful impact of NaCl levels applied to soybean cultivars was especially observed in MGT and EP parameters of seedlings of small-sized seeds. The larger seeds have a higher germination rate (Table 3). The MGT of the soybean varied and NaCl applied small seeds recorded delay in germination compared to large seeds. The early germination of large seeds could elevate competing capacity with the surrounding weeds and efficient uptake of the resources. The detrimental impacts of high levels of NaCl are in line with earlier observations in soybean by Putri *et al*. (2017) and Yin *et al*. (2022).

Under NaCl stress, dry matter increased significantly, indicating that increasing NaCl decreased tissue water contents (Table 3). De Oliveira *et al*. (2020) in sorghum determined lower tissue water content and higher dry matter contents under stress conditions. The big seeds' superiority particularly in MGT and GP along with dry matter could be attributed to larger embryos and more carbon-based reserves in seeds (Pandey *et al.,* 2017). The findings of the study are in line with Okonwu *et al*. (2022). The results of the salinity experiment revealed that 20 dS m^{-1} NaCl level showed its detrimental effect on germination and seedling

Table 2: Impact of cultivars and seed size on seed Chl a and Chl b content.

	Chl a mg g dw^{-1}	Chl b mg g dw^{-1}
Cultivars		
Ataem	4.84^{ab**}	6.97^{b**}
Kocatürk	6.30^{a}	8.31^{ab}
Batem erensoy	3.26^{b}	6.01^{b}
Göksoy	7.04^{a}	10.58^{a}
Seed size		
Large	3.96**	6.99**
Small	6.76	8.94

Means with the same letter(s) are not statistically different at **: p<0.01 level.

Table 3: Impacts of cultivars, seed sizes and NaCl levels on mean germination time (MGT), germination percentage (GP), root length (RL), shoot length (SL) and dry matter (DM) of soybean.

	MGT (day)	GP (%)	RL (cm)	SL (cm)	DM (%)
Cultivars					
Ataem	2.99^{b} **	89.33^{a**}	6.32^{a**}	5.46^{a**}	23.11^{a**}
Kocatürk	3.55^{a}	74.50^{b}	5.55^{a}	6.13^{a}	20.90^{bc}
Batem erensoy	3.32^{a}	80.33^{b}	3.95^{b}	4.21^{b}	21.63^{ab}
Göksoy	3.02^{b}	79.50^{b}	5.42^{a}	6.03^{a}	19.55^{c}
Seed size					
Large	3.11**	93.50**	5.21	4.88**	23.37**
Small	3.34	68.33	5.41	6.03	19.21
NaCl levels					
0	2.50^{c**}	84.00^{a*}	6.78^{b**}	9.31^{a**}	14.10^{c**}
10	2.71^{b}	79.62^{ab}	7.91^{a}	5.10^{b}	19.91^{b}
20	4.46^{a}	79.12^{b}	1.24^{c}	1.98^{c}	29.89^{a}

Means with the same letter(s) are not statistically different at *p<0.05, **p<0.01 level.

growth of all the cultivars studied in both the sizes and is in line with Day *et al.* (2008).

Emergence test

The seedling emergence performance of the cultivars in relation to seed size was tested by emergence test. The EP of the cultivars differed from GP (Table 5). The seed size of the cultivars under the study significantly affected the root length. Large seeds recorded longer root lengths with 9.47 cm compared to small seeds. In emergence test, shoot length of soybean seedlings showed significant differences between seed sizes. A comparison showed that the maximum (31.30 cm) shoot length was noted in large seeds. Fresh weight and dry weight of seedlings also showed significant differences and seedlings of large seeds had the maximum values with 2.01 g in fresh weight and 0.216 g in dry weight.

Results about chlorophyll contents measurements clearly showed the impact of seed size on chl a and carotenoid pigments (Table 6). The maximum chl a and carotenoids were observed in seedlings from large seeds with 30.28 and 5.65 mg g fw^{-1}.

Based on the emergence test, it was found that seedlings from larger seeds had longer roots and shoots, leading to higher fresh and dry matter compared to seedlings from smaller seeds (Table 5). Earlier research by Bianchi *et al.* (2022) also supports the idea that larger seed growth parameters lead to better performance.

Chl a and carotenoids in seedlings of large seeds were more compared to small seeds (Table 6). Carotenoids are essential in absorbing light energy and transferring to chlorophylls in the spectrum 450-550 nm, a range that chlorophylls do not absorb (Hashimoto *et al.,* 2016). The vital role of carotenoids in photoprotection is to sustain adaptation to changing light (Simkin *et al.,* 2022). Emphasizing the significance of chlorophyll a and carotenoids also brings attention to the significance of seed size and its vitality in soybean. The large seeds contain a significant amount of Mg and N reserves, which can aid in the rapid synthesis of chlorophyll pigments.

Leaf electrolite leakage is a test used under stress (Demidchik *et al.,* 2014). However, developing cells and organs in plants are under the stress of mechanical internally apart from the stress caused by the environment. During germination and initial growth of seedlings, seeds experience mechanical stress because of fluctuations in osmotic and turgor pressure and this stress could lead to diversity in leaf electrolyte leakage. The principal mechanical stress that is experienced by all living plant cells is turgor pressure. Turgor is important for the structural stability of the plant cell.

Table 4: Interactive effects of NaCl levels and seed sizes on mean germination time (MGT), root length (RL) and shoot length of soybean cultivars after 15 days incubation.

Cultivar	Seed size	Mean germination time (day)			Root length (cm)			Shoot length (cm)		
		NaCl levels (dS m^{-1})			NaCl levels (dS m^{-1})			NaCl levels (dS m^{-1})		
		0	10	20	0	10	20	0	10	20
Ataem	Big	2.13^{fg}	2.40^{e-g}	4.52^{b}	8.33^{ab}	9.46^{a}	1.33^{de}	8.76^{bc}	4.58^{f-i}	2.34^{h-j}
	Small	1.89^{g}	2.75^{c-f}	4.28^{b}	8.33^{ab}	8.96^{ab}	1.52^{de}	8.76^{bc}	6.10^{c-f}	2.21^{h-j}
Kocatürk	Big	2.29^{e-g}	2.82^{c-e}	5.21^{a}	6.45^{b}	8.31^{ab}	1.33^{de}	8.10^{b-e}	4.86^{f-h}	2.23^{h-j}
	Small	3.04^{cd}	3.19^{c}	4.74^{ab}	7.87^{ab}	8.32^{ab}	1.03^{e}	14.51^{a}	5.22^{e-g}	1.85^{ij}
Batem erensoy	Big	2.86^{c-e}	2.51^{d-g}	4.80^{ab}	3.78^{cd}	3.79^{cd}	1.00^{e}	5.60^{d-g}	2.78^{g-j}	1.54^{j}
	Small	2.32^{e-g}	3.05^{cd}	4.38^{b}	6.80^{ab}	7.34^{ab}	1.00^{e}	8.22^{b-d}	5.58^{d-g}	1.53^{j}
Göksoy	Big	2.23^{e-g}	2.28^{e-g}	3.24^{c}	8.59^{ab}	8.81^{ab}	1.34^{de}	9.72^{b}	5.71^{d-f}	2.31^{h-j}
	Small	3.27^{c}	2.65^{c-f}	4.47^{b}	4.10^{c}	8.29^{ab}	1.42^{de}	10.83^{b}	5.82^{d-f}	1.79^{ij}

Means with the same letter(s) are not statistically different at **: p<0.01 level.

Table 5: Emergence percentage, mean emergence time, shoot length, root length, fresh weight and dry weight of the cultivars affected by seed size during emergence.

	Mean emergence time (day)	Emergence percentage (%)	Root length (cm)	Shoot length (cm)	Fresh weight (g)	Dry weight (g)
Cultivars						
Ataem	7.65^{a}**	92.50^{a}**	9.10	31.04^{a} **	1.94^{a}**	0.20^{a}**
Kocatürk	8.01^{a}	78.00^{c}	9.26	30.39^{a}	1.71^{b}	0.18^{b}
Batem Erensoy	6.66^{b}	83.83^{b}	8.27	27.85^{b}	1.68^{b}	0.19^{ab}
Göksoy	7.63^{a}	74.33^{c}	9.05	27.83^{b}	1.31^{c}	0.13^{c}
Seed size						
Large	6.92**	90.67**	9.47*	31.30**	2.01**	0.216**
Small	8.06	73.67	8.37	27.26	1.31	0.136

Means with the same letter(s) are not statistically different at *p<0.05, **p<0.01 level.

Table 6: Leaf pigment content and electrolyte leakage of different soybean cultivars and different seed size of cultivars.

	Chl a mg g fw^{-1}	Chl b mg g fw^{-1}	Chl a+b mg g fw^{-1}	Carotenoids mg g fw^{-1}	Elektrolyte leakage (%)
Cultivars					
Ataem	24.09^{b*}	12.27	36.36^{b*}	3.98^{b**}	23.29^{a*}
Kocatürk	28.15^{ab}	12.15	40.31^{ab}	5.74^{ab}	15.61^{b}
Batem erensoy	23.59^{b}	10.67	34.26^{b}	6.23^{a}	18.62^{a}
Göksoy	33.49^{a}	15.81	49.31^{a}	4.36^{b}	13.39^{b}
Seed size					
Large	30.28^{a} *	12.70	42.99	5.65*	15.31^{b*}
Small	24.37^{b}	12.75	37.13	4.51	20.15^{a}

Means with the same letter(s) are not statistically different at *p<0.05, **p<0.01 level.

Table 7: Emergence percentage, chl a, carotenoids and elektrolyte leakage of cultivars according to seed size.

Cultivars	Seed size	EP %	Chl a mg g fw^{-1}	Carotenoids mg g fw^{-1}	Elektrolyte leakage (%)
Ataem	Large	96.00^{a**}	34.63^{a*}	5.27^{bc**}	14.52^{bc**}
	Small	89.00^{bc}	13.54^{b}	2.70^{cd}	32.10^{a}
Kocatürk	Large	88.00^{c}	28.14^{a}	6.65^{ab}	14.85^{bc}
	Small	68.00^{e}	28.16^{a}	4.83^{bcd}	16.38^{bc}
Batem Erensoy	Large	92.67^{b}	23.77^{ab}	4.30^{bcd}	20.66^{b}
	Small	75.00^{d}	23.42^{ab}	8.17^{a}	16.58^{b}
Göksoy	Large	86.00^{c}	34.61^{a}	6.40^{ab}	11.20^{c}
	Small	62.67^{e}	32.38^{a}	2.33^{d}	15.59^{bc}

Means with the same letter(s) are not statistically different at *p<0.05, **p<0.01 level.

Moreover, turgor pressure is the driving force behind cell expansion and it works together with tightly regulated cell-wall extensibility to determine the size and shape of a plant cell. In the context of seed mechano-responses due to expanding cells, this creates stresses which could change depending on the species, cultivars and seed size (Monshausen and Haswell, 2013). In this study, it is found that leaves obtained from small-sized seeds leaked more or equal over large seeds. Leaf electrolyte leakage diversity among cultivars and different sizes showed that in mechanostress perception their intrinsic mechanical stresses are changing depending on cultivars and seed size (Table 7).

CONCLUSION

Four soybean cultivars Ataem, Kocatürk, Batem Erensoy and Göksoy were used in the study to investigate level of salt stress during seed germination based on their size. There is need to use high-vigor soybean seeds to obtain maximum seeds yield, from these varieties with maximum germination emergence and yield with improved seed quality as an essential selection parameter including seed size and seed chlorophyll contents during growth and development stages of plants. From the present study the criterion of seed size is enough for use against abiotic stress of salinity. The conclusions based on the results of small and large size of the seeds showed that the varieties are more suitable when selected against salt stress in the order of Ataem>Batem Erensoy>Kocatürk>Göksoy.

Conflict of interest

All authors declare no competing interests.

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