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Research Article

The Effects of Light, Temperature and Salinity on Seed Germination of Three Maize Forms

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ABSTRACT

This study was carried out to determine the effect of different light, temperature and salt concentration levels on dent (P 3394), sweet corn (Sunshine) hybrids and popcorn (local variety of Çanakkale) seeds which have different endosperm. In this study, research was conducted to evaluate the effect of two different light periods (continuous light and 12 h light : 12 h dark), two different temperatures (17 and 30 ºC) and four different salt concentrations (0, 25, 50 and 100 mM) on germination speed, germination rate, radicle length, coleoptile length, plumula length and vigor index of maize grain. The light periods had a significant effect on germination speed, germination rate and radicula length at 12 hours light and 12 hours dark (26.83%, 31.26% and 1.71cm respectively), and continuous light (32.77% 41.12% and 2.29cm respectively). The germination rate and coleoptile length were affected at 17 ºC temperature (40.47% and 1.57cm) and at 30 ºC temperatures (31.91% and 2.29 cm). Salt concentration had a significant effect on radicula length, coleoptile length and plumula length. They decreased with increasing of salt concentration level. There were significant differences among maize seeds that have different endosperm in terms of all investigated traits in this study. The popcorn seed had significantly higher values than the other maize hybrids in respect to all investigated traits. The seed of popcorn has superiority 50% than dent and sweet corn hybrids.

INTRODUCTION

Human beings have maintained their lives by consuming the plants growing on earth and the animals feeding on these plants throughout human history. They developed some methods to use these crops at several stages and use them in different ways. One of the crops that men have been utilizing and multi-dimensionally using at several growing stages since ancient times is corn. So, a lot of researches have been conducted on the maize plants and as its importance increases, up to date researches are necessary to facilitate innovative techniques.

Some plant seeds can germinate at a wide range of temperature but others can only be germinated at a certain narrow range of temperature. Temperature has an effect on plant development after germination. Temperature is examined as minimum, optimum and maximum temperatures in terms of germination. It is quite difficult to determine these temperatures for any plant. Because, temperature has effects both germination power and germination speed (Yılmaz, 2008). Corn maintains its growing at high temperatures. Ideally, corn plant needs 10-11 ºC temperature to start germination. It needs a temperature parameter above 15 ºC (17-18 ºC) and 30 ºC for optimum and maximum temperature respectively. If it reaches to 32 ºC, there would be a sudden decrease in stem and root growth and when it reaches to 40 ºC sprouts would die. If temperature is lower than 9 ºC root growth stops, too. (Kırtok,1998).

Though corn is resistant to salt in germination period, it is in the list of the plants which are sensitive to salinity and salty irrigation water. When electrical permeability parameter of the soil is above 5.9 dS/m (EC total resoluble salt concentration in soil) decrease in yield might be as high as 50% (Orcutt and Nielsen, 1996). The causes of decrease in yield are shown as the inability of the plant to use water effectively due to increased osmotic potential, toxic effect resulting from Na and Cl ions found in soil in excessive amount and disturbance in ionic equilibrium (Taban et al., 1999; Ebrahimzadeh et al., 2000; Essa, 2002). Corn plant under salt stress suffers from development disorders and other parameters are also affected from this situation (Cicek and Cakirlar, 2002; Yakıt and Tuna, 2006).

Although phytochrome is the basic cycle for the germination of seeds needing light, embryo can also germinate without light (Ravan et al, 2003). For a desired effect of light, a suitable temperature level is necessary because the impulse effect of light stops at unsuitable temperatures. Response to light increases greatly in the event of changes in temperature and treatment of seed with potassium nitrate solution. Light affects the young plant emerging from the seed. When the light is limited, plants fade; hypocotyl grows and the leave growth stops.

When plants are exposed to light, hypocotyl growth stops and a normal growth starts in epicotyl. At earlier stages, young plants use cotyledon in seed and reserve nutrients in endosperm (Yılmaz, 2008).

Taking into consideration that corn is a C4 plant, its light equilibrium point is high, it needs a certain temperature level for germination and salinity increases due to irrigation in summer, we aimed to study the effects of light, temperature and salt concentration on the germination of the three types of corn seeds which vary from each other according to endosperm shape.

MATERIAL AND METHOD

This study was conducted in a split block experimental design with three replications, in the laboratory of Department of Field Crops of Faculty of Agriculture in Kahramanmaraş Sütçü Imam University in 2009. In the experiment, two different light periods [(continuous and 12 h light: 12 h dark) (100 micromole m^{-2} s^{-1})], two different temperatures (17 and 30 ºC), four salt concentrations (0 mM NaCl, 25 mM NaCl = 2.86 dS/m, 50 mM NaCl = 5.38 dS/m, 100 mM NaCl = 9.97 dS/m) were used as factors. In addition, three types of corn seeds [dent (P3394), sweet corn (Sunshine) hybrids and popcorn (local variety of Çanakkale)] which varied from each other depending on endosperm shape were used as material in the study. Popcorn seeds used in the study was obtained from village of Çanakkale province and was named after it. The other seeds were obtained from commercial seed firms.

After filter papers were cut and placed into petri dishes, 25 seed from each corn type were placed in them and watered, depending on salt concentrations (0, 25, 50 and 100mM NaCl), 40 ml water was added to each petri dish and they were placed to growth chamber. (Munns and Termaat, 1986; Tord and Turkyilmaz, 2003). The fact that optimum and maximum temperature for germination of corn seeds were 17 ºC and 30 ºC respectively was taken into consideration during the study (Kırtok, 1998; Kün, 1985) and the temperature of germination environment was adjusted to these values. After fourth day of germination, 40 ml additional water was put only to the Petri dishes at 30 ºC. Germination speed was measured on the fourth day of the germination but germination rate, vigor index radicle length, coleoptile length and plumula length was measured on the eighth day. In this study, germination speed, germination rate, radicula length, coleoptile length and plumula length and vigor index properties were examined relying on the methods used Steiner et al., (1989), Kirtok et al. (1994), Dumlupınar et al. (2007). The results were analyzed using SAS statistical program and mean values were performed using least significant difference (LSD) test.

RESULTS

In this study, dent, sweet corn and popcorn genotypes were germinated by keeping them in two different light periods (continuous light and 12 h light : 12 h dark) and at different salt concentrations (0, 25, 50 and 100 mM NaCl) and the mean values for the investigated traits were indicated in Table 1.

The effect of different light levels on germination of corn seeds

In the study was indicated that light had a significant effect on germination speed, germination rate and radicula length but its effect on coleoptile length, plumula length and vigor index was not statistically significant. It was clearly reported that germination speed of the corn seeds at continuous light treatment was 32.77%, that of at 12 h light: 12 h dark treatment was 26.83% and continuous light treatment affected germination speed positively. It was observed that the germination rates of the corn seeds at continuous light and 12 h light: 12 h dark treatments were 41.12% and 31.26% respectively and continuous light treatment increased the germination rate. It was detected that the radicle lengths at continuous light and 12 h light: 12 h dark treatments were 2.29cm and 1.71cm respectively and there was a statistically significant difference between radicula lengths in different light treatments. Coleoptile length, plumula length and vigor index of the corn types germinated in 12 h light: 12 h dark environment were 1.90cm, 4.02cm and 108.24 respectively, these parameters were 1.97cm, 4.37cm and 162.28 respectively in continuous light treatment and there was no significant difference between them.

The effect of different temperature levels on germination of corn seeds

The germination rate and coleoptile length of the corn seeds that germinated at two different temperatures (17 ºC and 30 ºC) were different from each other but these temperature levels did not have significant effect on germination seeds, radicle length, plumula length and vigor index parameters. Germination rates were recorded as 40.47% and 31.97% at 17 ºC and 30 ºC respectively and germination rates were observed to decrease remarkably as temperature increased. The coleoptile lengths of the seeds germinated at 17 and 30°C were 1.57cm and 2.29cm respectively and as temperature increased, a statistically significant increase was observed in coleoptile length. Germination speed, radicula length, plumula length and vigor index parameters of the corn seeds germinated at 17 ºC and 30 ºC were 28.38%, 1.78cm, 3.89cm, 102.58 and 31.22%, 2.22cm, 4.50cm 167.94 respectively and it was detected that the difference between them was not statistically significant.

Table 1: The average data belong to investigated traits for dent, sweet corn and popcorn

Factors	germination speed (%)	germination rate (%)	Radicula length (cm)	coleoptile length (cm)	plumula length (cm)	Vigor index
Light (A)	**	**	*			
12 h light : 12 h dark	26.83b	31.26b	1.71b	1.90	4.02	108.24
24 h light	32.77a	41.12a	2.29a	1.97	4.37	162.28
LSD (%)	4.18	6.46	0.43	0.33	0.77	70.11
Temperatures °C (B)		**		**		
17 °C	28.38	40.47a	1.78	1.57b	3.89	102.58
30 °C	31.22	31.91b	2.22	2.29a	4.50	167.94
LSD (%)	4.18	6.46	0.43	0.33	0.77	70.11
Salt concentra. (mM) (C)			**	**	**	
0 mM NaCl	34.22	42.44	3.07a	2.57a	6.08a	193.91
25 mM NaCl	27.38	32.75	2.21b	2.22a	4.42b	125.92
50 mM NaCl	29.05	34.33	1.75b	1.70b	3.97b	155.80
100 mM NaCl	28.55	35.25	0.97c	1.24b	2.31c	65.42
LSD (%)	5.91	9.14	0.62	0.47	1.09	99.15
Varieties (D)	**	**	**	**	**	**
1 Dent corn	4.83b	13.75b	0.32c	0.53c	1.03c	7.56b
2 Popcorn	74.75a	76.54a	4.16a	3.09a	7.60a	379.40a
3 Sweet corn	9.83b	18.29b	1.51b	2.18b	3.95b	18.82b
LSD (%)	5.12	7.91	0.53	0.41	0.94	85.86
AxB	*	*	ns	**	*	ns
AXC	Ns	Ns	ns	ns	ns	ns
AxD	**	Ns	**	ns	ns	ns
CxD	Ns	Ns	**	*	**	ns
BxD	**	**	**	**	**	ns
BXC	Ns	Ns	ns	ns	ns	ns
AXBXC	Ns	Ns	ns	ns	ns	ns
AXCXD	Ns	Ns	ns	ns	ns	ns
BXCXD	Ns	Ns	ns	ns	ns	ns
AxBxD	Ns	Ns	ns	*	ns	ns
AXBXCXD	Ns	Ns	ns	ns	ns	ns

A= light, B= temperature, C= salt, D= varty, ** significant at 1% level, * significant at 5% level, ns: not significant.

The effect of different salt concentrations on germination of corn seeds

The highest radicula, coleoptile and plumula lengths parameters (3.07, 2.57 and 6.8cm respectively) were recorded at 0mM NaCl treatment and the lowest ones (0.97, 1.24 and 2.31cm respectively) at 100mM NaCl treatment and there was a significant difference between them. 100mM NaCl treatment limited radicula, coleoptile and plumula lengths by about 70%, 50% and 60% respectively. The germination speeds of the corn seeds germinated at different salt concentrations (0, 25, 50 and 100mM NaCl) were recorded as 34.22%, 27.38%, 29.05% and 28.55% respectively and there was no statistically significant difference among the parameters. The germination rates were 42.44%, 32.75%, 34.33% and 35.25% respectively and the differences among the parameters were not statistically significant. There wasn't any significant difference in terms of vigor index, either.

The effect of different maize forms on germination.

The highest germination speed (74.75%), germination rate (76.54%), radicula length (4.16cm), coleoptile length (3.09cm), plumula length (7.60cm) and vigor index (379.40) parameters were recorded in popcorn (local variety of Çanakkale) and sweet corn (Sunshine) and dent (P 3394) followed it respectively.

The effect of interactions among light levels, salt concentrations and temperature levels on germination of corn seeds

In terms of germination, significant interactions are indicated in figure 1., 2., 3., 4., 5., 6., 7., 8., 9., 10., 11., 12., 13., 14. and 15.

Germination speed was increased from 23.22% to 33.45% with exposing 24 hours light instead of 12 hours at 17 ºC temperature, while germination speed of seeds at 30 ºC germination test was 30.44% for 12 hours light, while it was 30.00% for 24 hour. The effect of different light level on germination speed at higher-temperature was low, but it was higher at lower temperature (Fig. 1). Popcorn showed the best response among different grain shape corns at light period of 12 and 24 hours on germination speed. Germination speed of popcorn was 65.33% at 12 hours light, while it was 84.16% at 24 hours light. The germination speed of dent and sweet corn was 4.5% and 10.66% at 12 hour light, 5.16% and 9.00% at 24 hours light respectively (Fig. 2). Popcorn showed the best response among different grain shape corns at 17 ºC and 30 ºC on germination speed. Germination speed of popcorn was 72.33% at 17 ºC and 77.16 at 30 ºC. The germination speed of dent and sweet corn were 9.6% and 3.66 at 17 ºC and 0.5% and 16.00% at 30 ºC respectively. The high temperature had negative effect on germination speed of dent corn (Fig. 3). Germination rate was increased from 31.36% to 4958% with exposing 24 hours light instead of 12 hours at 17 ºC temperature. While germination rate of seeds at 30 ºC germination test was 31.16% at 12 hours light, while it was 32.66% at 24 hour light. The effect of light at high-temperature on germination rate was lower, while it was higher at low-temperature (Fig. 4). Popcorn showed the best response among different grain shape corns at 17 ºC and 30 ºC for germination rate. Germination rate of popcorn was 74.66% at 17 ºC and 78.41% at 30 ºC. The germination rate of dent and sweet corn were 27.00% and 19.75 at 17 ºC and 0.5% and 16.83% at 30 ºC respectively. The high temperature had negative effect on dent corn (Fig. 5). Popcorn showed the best response among different grain shape corns at light period of 12 and 24 hours for radicula length. Radicula length of popcorn was 3.34cm for 12 hours light, while it was 4.96cm for 24 hours light. The radicula length of dent and sweet corn were 0.38cm and 1.41cm at 12 hours light, 0.26cm and 1.62 at 24 hours light respectively. The radicula length of dent corn adversely was affected by prolonged light (Fig. 6). The radicula length of different grain form corn decreased in significant level at all salt concentrations. When radicula length of popcorn in 0mM NaCl compared to others salt concentrations, it was showed that a rapid decrease depending on increased salt concentrations. However, radicula length of popcorn was higher than performance of others. The radicula length of dent and sweet corn more slowly decreased by increased salt concentrations (Fig. 7). Popcorn showed the best response among different grain shape corns at 17 ºC and 30 ºC for radicula length. Radicula length of popcorn was 3.83cm for 17 ºC and 4.49cm for 30 ºC. The radicula length of dent and sweet corn were 0.62cm and 0.90cm at 17 ºC and 0.02cm and 2.13cm at 30 ºC respectively. The high temperature had negative effect on dent corn (Fig. 8). The coleoptile length was increased from 1.27cm to 1.86cm with exposing 24 hours light instead of 12 hours at 17 ºC temperature, while coleoptile length at 30 ºC was 2.52cm at 12 hours light, it was 2.07cm at 24 hour. The effect of light at high-temperature on coleoptile length was lower, but it was higher at low-temperature (Fig. 9). Coleoptile lengths of different grain-shape corns were varied according to increased salt concentrations. The coleoptile length of popcorn showed a regular decrease by increased salt concentrations. Dent corn had higher coleoptile length in 25 mM NaCl than 0mM NaCl. The negative effect of the concentration of 50 mM NaCl on coleoptile length of sweet corn was lower than 25 and 100mM NaCl concentrations (Fig. 10.).

Popcorn showed the best response among different grain shape corns at 17 ºC and 30 ºC for coleoptile length. Coleoptile length of popcorn was 2.72cm at 17 ºC and 3.46cm at 30 ºC. The coleoptile length of dent and sweet corn were 0.84cm and 1.14cm at 17 ºC and 0.21cm and 3.21cm at 30 ºC respectively. The high temperature had negative effect on coleoptile length of dent corn (Fig. 11). Coleoptile lengths of different grain shape corns showed variation depending on duration of light and degree of temperature. While the highest (8.77cm) coleoptile length of popcorn took place under (24 hours) continuous light at 17 ºC temperature, also, the highest (8.32cm) coleoptile length at 30 ºC of popcorn took place under 12 hours light. When sweet corn had 2.86cm of coleoptile length in continuous light at 17 ºC, coleoptile length was 2.00cm at 12 hours light. The coleoptile length of sweet corn was higher at 12 hours light (5.58cm) than at 24 hours light (5.37 cm) at 30 ºC. Dent corn had the lowest coleoptile length under both light and temperature conditions (Fig. 12). The plumula length was increased from 3.32 cm to 4.46 cm with exposing 24 hours light instead of 12 hours at 17 ºC temperature. Coleoptile length at 30 ºC was 4.72 cm at 12 hours light, while it was 4.29 cm at 24 hour. The effect of light at high-temperature on plumula length was negative, but continuous light at low-temperature was positive (Fig. 13). Plumula lengths of different grain-shape corns varied according to increased salt concentrations. The plumula length of popcorn showed a regular decrease by increased salt concentrations. Dent corn had higher plumula length in 25 mM NaCl than 0 mM NaCl. The negative effect of the concentration of 50 mM NaCl on plumula length of sweet corn was lower than 25 and 100 mM NaCl (Fig. 14). Popcorn showed the best response among different grain shape corns at 17 ºC and 30 ºC for plumula length. Plumula length of popcorn was 7.43 cm at 17 ºC and 7.77 cm at 30 ºC. The plumula length of dent and sweet corn were 1.80 cm and 2.43 cm for 17 ºC and 0.26 cm and 5.48 cm at 30 ºC respectively. The high temperature had a negative effect on plumula length of dent corn (Fig. 15).

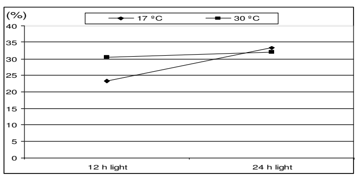

Figure 1 Light x temperature interaction related to germination speed.

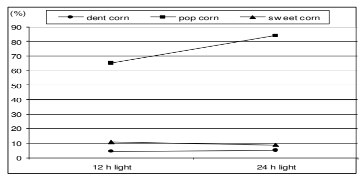

Figure 2 Light x genotype interaction related to germination speed.

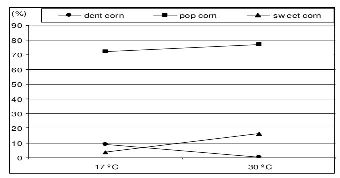

Figure 3 Temperature x genotype interaction related to germination speed.

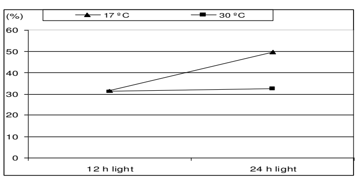

Figure 4 Light x temperature interaction related to germination rate.

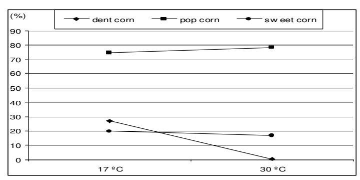

Figure 5 Temperature x genotype interaction related to germination rate.

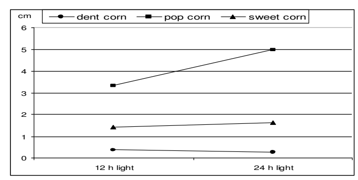

Figure 6 Light x genotype interaction related to radicula length.

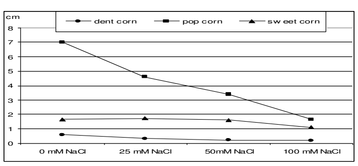

Figure 7 Salt concentration x genotype interaction related to radicula length.

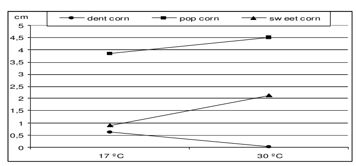

Figure 8 Temperature x genotype interaction related to radicula length.

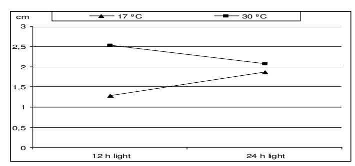

Figure 9 Temperature x genotype interaction related to coleoptile length.

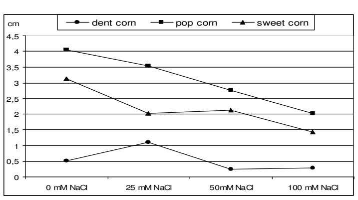

Figure10 Salt concentration x genotype interaction related to coleoptile length.

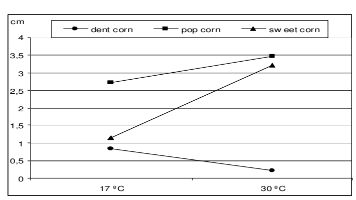

Figure 11 Temperature x genotype interaction related to coleoptile length.

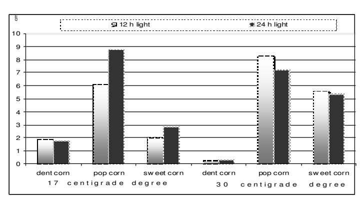

Figure 12 Light x temperature x genotype interaction related to coleoptile length.

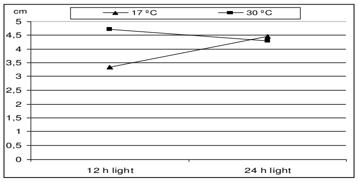

Figure 13 Light x temperature interaction related to plumula length.

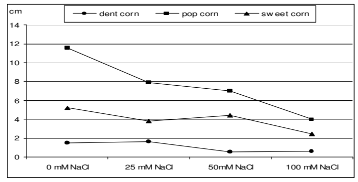

Figure 14 Salt concentration x genotype interaction related to plumula length.

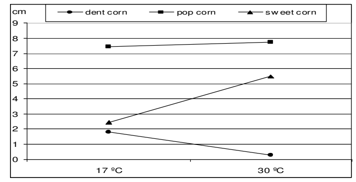

Figure 15 Temperature x genotype interaction related to plumula length.

DISCUSSION

Differences among two light treatments were approximately 8% for germination speed of the corn seeds. The finding of Zia and Khan (2004) that there was a statistically significant difference among the corn seeds germinated at different light periods was consistent with our findings. The continuous light and 12 h light: 12 h dark treatments for germination rates of the corn were significant. This is in agreement with the finding of Godoi and Takkai (2004) that corn seeds germinate in light environment as well as in dark environment. Germination rate in light environment was higher compared to dark environment was also stated by Ulukapı et al. (2008). Dan and Briks (2007) stated that light and dark environments didn't have any significant effect on germination rate but they considerably affected radicula length. Although this finding was consistent with our own results in terms of radicula length, there was a difference between their findings and ours and it might be due to the materials used in the studies. Because, the effect of light levels on seeds may vary depend on genotypes (Yılmaz, 2008).

The effects of temperature on radicula length, plumula length and vigor index parameters were insignificant. Since these parameters were the mean values at 17 ºC and 30 ºC, salt concentrations might have affected these parameters. As temperature increased, negative effect of salt concentrations on germination appeared. Therefore, the effect of salt concentrations became less on germination at 17℃ compared to at 30℃ (Rahman et al., 2000). The finding of Esechie (1994) that temperature had a significant effect on germination criteria was consistent with our own findings. That the germination speed on the fourth day at 30 ºC (31.22%) and that of the eighth day at 30 ºC (31.91%) weren't different from each other in our study was consistent with the finding of Kaçar (1989) that the effect of light on light –intensive plant seeds at low temperature was positive but as temperature increased this effect disappeared. Qu et al. (2008) stated that the factor of salinity couldn't be evaluated by alone in germination and growth of seeds but such environmental factors as temperature and light should also be taken into consideration. As temperature increased, coleoptile length was increased. Kırtok (1998) reported that temperature (10-30℃) had a linear effect on root and stem growth during germination. It was detected that different salt concentrations affected radicle, coleoptile and plumula lengths of the corn seeds significantly but they did not have any effect on germination speed, germination rate and vigor index parameters. As salt concentration was increased, radicula, coleoptile and plumula lengths were observed to decrease significantly. Shonjani (2002), Dumlupınar et al. (2007), Xiao-Xia et al. (2008) and Turkyilmaz et al. (2011) stated that as salt concentration increased, germination rate, germination speed and radicula length decreased and seedling growth was inhibited. Dağüstü (2003) and Dumlupınar et al. (2007) also stated that salt concentrations decreased the plumula length. Radic et al. (2007) stated that there was an inverse proportion between increase in salt concentration and germination and seedling growth. Statistically significant differences were observed among the germinated corn types [dent (P3394), popcorn (local variety of Çanakkale) and sweet corn (Sunshine)] in terms of all investigated traits. Carpici et al. (2009) stated that corn types had different responses to the environmental factors in germination conditions. It was also stated by Taslak et al. (2007) that the corn types showed significant differences in terms of germination speed and germination rate. Corn types had different responses to salt concentrations (Dağüstü, 2003; Tort and Turkyilmaz, 2003)

Light x temperature interaction had a significant effect on the investigated traits (germination speed, germination rate, coleoptile length, plumula length). This finding was consistent with the finding of Yılmaz (2008) that there was an interaction between light and temperature in terms of germination. In our study it was observed that light, temperature and salt concentrations had different effects on germination traits. That the corn types responded to temperature changes differently in germination experiments was also stated by some researchers (Sheikh and Mahmoud, 1986; Zia and Khan, 2004). In previously conducted studies (Esechie, 1994; Mahmoud et al., 1983; Baskin and Baskin, 1988; Noe and Zedler, 2000; Khan et al., 2001) it was also stated that corn types gave different responses to temperature, light, salt and humidity.

With the coming of cross-boundary corn seed, grown widespread after 1970s and using of genetically modified types after 1980s, local variance has been in danger of extinction. Regional varieties are not being used commonly due to less yielding. The micro-mutations in the process of evolution are being major change in nature over time. The genotypes occurred as a result of these changes in the nature can be adapted with nature and stress conditions, and then they developed their defense mechanism and their race is survived. Therefore, the genes obtained in the process of natural evolution, if they had been obtained through unnatural ways, they may be a threat for nature in the future. The gene of resistance that transferred to the cultural varieties from genetically modified organisms has different properties. In particularly, the transfer of these toxin-producing bacterial race resistance genes would disrupt the ecological balance and biological diversity would lead to a decrease (Belon and Berthaud, 2004). That of using plant origin genes in plants may contribute to natural balance as positive. The local varieties for gene centers of cultivated plants and the origin of the plants that are common in case of hybridization between species in the regions are even more important. Use of local varieties in plant breeding will increase the genetic diversity (Mudry and Kraic, 2007; Dumlupınar et al. 2011).

As a result of the study, it was determined that competitive power of popcorn (local variety of Çanakkale) was higher in terms of germination traits compared to hybrid types and it was more successful under adverse conditions. Therefore, greater importance should be given to local varieties in corn-related studies to improve grain yield and quality traits of corn. The problems resulting from global warming and climate change, make genetic resources more important. Local varieties will become more important low- potential areas.

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