



Influence of Temperature and Salinity Stress on Seed Germination and Seedling Growth of Soybean (*Glycine max* L.)

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ABSTRACT

Background: The high salt level of a germinating environment can lead to reduced, delayed, and even complete inhibition of germination and seedling growth due to osmotic action and/or ion toxicity. Based on this viewpoint, the aim of this study was to investigate germination temperature and salinity effects on germination and early seedling growth of soybean, which can be sown as first and second crops.

Methods: Soybean seeds were subjected to NaCl induced saline germinating media prepared in petri dishes under two different germination temperatures (20±2 and 25±2°C). Thirty sterilized seeds per petri dish were sown in ten salt treatments (0, 100, 150, 250, 750, 1000, 2250, 5000, 7500 and 10000 ppm NaCl L⁻¹). The study was carried out according to the completely randomized design with four replications.

Result: Lower temperature promoted seed germination, while the high temperature significantly inhibited the seed germination at all NaCl doses tested. As a result, 25°C temperatures, which can only be measured at the time of the second sowing, have been found to negatively affect germination and also increase the negative effects of salt. Due to the moderate tolerance of soybeans to salt stress, the germination rate was positively affected up to 750 ppm NaCl L⁻¹ dose and resulted in severe reductions in subsequent doses. Also, the tolerance of soybean was negatively influenced by the interaction of temperature and NaCl concentration.

Key words: Germination, Salinity, Seedling vigor index, Soybean, Temperature.

INTRODUCTION

Biotic or abiotic agents that negatively affect the growth and development of plants in normal living environments are evaluated as stress factors. The two essential environmental factors that currently reduce plant productivity in common are drought and salinity (Jamil *et al.* 2006).

Salinity is a major abiotic stress factor that reduces plant productivity on both irrigated and non-irrigated agricultural lands especially in semi-arid, arid countries and throughout the world (Chaitanya *et al.* 2014). Most of the world's soils are not cultivated, but a significant portion of the cropland is affected by salt. Over 7% of the world's land is affected by either sodicity or salinity (Mahmood *et al.* 2010). According to The Food and Agriculture Organization of the United Nations, of the existing world agricultural land, 45 million ha (19.5%) of the irrigated agricultural area of 230 million ha and 32 million (2.1%) ha of the dry agricultural area of 1.500 million ha are affected by salt. Soil salinity is the main reason that the plant-water economy is hampered. The plant uses more energy and consumes less water during periods when the concentration of salt in the root zone remains. This results in a loss of yield and quality in terms of plant production. There is a need for hardy plant species and varieties to reduce these losses in salty soils (Altuner *et al.* 2020). As is known, some plants are moderately tolerant of saline conditions, while many plants are negatively affected by even low salt levels. Salinity negatively affects plant growth and productivity at all stages of development (Miladinov *et al.* 2020).

Seed germination is a first and very important stage in the life cycle of plants. Germination is one of the most vital

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periods for a product exposed to salinity (Dutta and Bera, 2014). Salinity effects seed germination *via* external osmotic production which prevents water absorption and Na⁺ and Cl⁻ ions' toxic effects (Turhan and Ayaz, 2004). Therefore, the salt tolerance of seeds during germination is critical for plants to grow in saline soils (Khan *et al.* 2000). Furthermore, it is known that in the germination and development of many plants, higher temperature interacts with salinity and increases the effect of stress conditions (Nedjimi, 2013). So, in cases where the salinity problem in the soil cannot be solved in the short term, the most basic approach to be followed is to identify salt-resistant species (Oral *et al.* 2019).

Soybean is a product of high agricultural value whose cultivation and production are limited by salinity, one of the abiotic environmental stress factors (Ramana *et al.* 2012), has a relatively wide variation in salt tolerance among its genotypes (Wang and Shannon, 1999). Therefore, soybean species is classified as moderately salt-tolerant plants and soybean yield decreases when the soil salinity exceeds 5ds/m (Ashraf and Wu, 1994). Soybean species show a range of salt tolerance capability (Phang *et al.* 2008), but high salt damages the entire life cycle of soybeans. The degree of salt tolerance varies among the different stages of soybean species' development. The seedling stage of soybeans is considered more susceptible to salt stress than the germination stage (Hosseini *et al.* 2002). The germination of soybean seeds was delayed in low salt (0.05% and 0.1% NaCl) conditions (Phang *et al.* 2008). Additionally, salinity influences germination rate, germination percentage, and seedling growth in diverse ways depending on species of plants (Jamil and Rha, 2004). One of the factors affecting germination for plants planted as the first and second crop is the germination temperature. High temperature speeds up the movement of molecules, causing the bonds between large organic molecules to loosen and the biological membranes to become more fluid. Therefore, high temperatures increase the passage of salt minerals through the flexible cell membrane, resulting in greater penetration of salt into plant cells. The salinity level above the salinity tolerance of plants disrupts seed germination, reduces nodule formation, delays plant development and reduces crop yield. Given the information presented above, an investigation was carried out to determine the influences of temperature and salinity stress on the germination and seedling growth parameters of *Glycine max* L.

MATERIALS AND METHODS

The study was conducted under the uniform condition in the library of the Department of Field Crops, Kahramanmaraş Sutcu Imam University, Turkey, in 2016. The uniform-sized seeds of Gapsoy soybean (*Glycine max* L.) cultivar were used as a material in this study. After their surfaces were sterilized with 5% NaOCl (sodium hypochlorite) solution for five minutes and rinsed in tap water, 30 soybean seeds were left to germinate under two different germination temperatures (20±2 and 25±2°C). In closed, sterilized Petri dishes, each with two Whatman filter papers were soaked with 15 ml of different salt concentrations (TDS (Total Dissolved Solids in water): 0, 100, 150, 250, 750, 1000, 2250, 5000, 7500 and 10000 ppm NaCl L⁻¹). The seeds were considered germinated by the emergence of the radicle. The seeds were allowed to maintain the germination in each replicate for measurements of radicle and hypocotyls lengths at the end of the experiment. After 14 days germinated seeds were taken out from the petri dishes, final germination percentages and some other basic germination and seedling growth properties such as germination index, radicle length, plumule length, seedling length, radicle fresh weight,

plumule fresh weight, seedling fresh weight, radicle dry weight, plumule dry weight, seedling dry weight and seedling vigor index were determined.

The germination percentage and germination index were calculated by the following formulas:

Germination percentage (GP) =

$$\frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

The germination index was calculated after the 14th day of germination by the following equation (Karim *et al.* 1992).

Germination Index (GI) =

$$\frac{\text{Germination \% in each treatment}}{\text{Germination \% in the control}} \times 100$$

Seedling vigor index =

$$\text{Seedling length (cm)} \times \text{Germination percentage \%}$$

(Rathi and Madan, 2019)

The seedling length was measured with a ruler. Similarly, the length of the radicle and plumule were measured with a measuring band after both separated. Then, these two pieces weighed to determine fresh weight. The germinated seeds' samples were kept at 70°C for 24 hours for weighing to achieve seedling dry weight (Moosavi *et al.* 2014). The seedling vigor index was obtained by multiplying the seedling length by the germination percentage.

Statistical analysis

The statistical analysis for the investigated treatment factors, temperatures and NaCl concentrations, were carried out by using SAS statistical software one-way analysis of variance (Anova) according to the completely randomized experimental design procedures. Least significant difference (LSD) analysis was performed from Post hoc multiple comparison tests to screen the differences among the levels of NaCl interacted with both germination temperatures in each studied parameter at the 5% significance level. Additionally, the Pearson Correlation analysis was performed to evaluate the relationships among the observed parameters.

RESULTS AND DISCUSSION

The data obtained as a result of applications of different germination temperatures and salinity levels to the soybean seeds are shown in Tables 1 and 2. The simple scatter plot matrices between seedling vigor index and other studied features are monitored in Fig 1 A-H.

Germination percentage

The results showed that the germination temperatures had a significant (5%) effect on the germination percentage. Germination percentages obtained from different temperature environments were determined as 41.3% (GT1) to 42.5% (GT2) in Table 1. In terms of its effect on germination percentage, there were statistically very significant (1%) differences among salinity levels and the common effects of the factors. The highest germination percentage (70.0%)

was obtained with 750 ppm NaCl L⁻¹ dose from 20°C, while the lowest germination rate (20.0%) was obtained with 10000 ppm NaCl L⁻¹ dose from 25°C (Table 1).

Germination index

As seen in Table 1, it was observed that there were statistically very significant (1%) difference between the temperatures in terms of germination indices. The highest germination index (3.59) was determined under 20°C, while the lowest (2.98) was calculated under 25°C. In Table 1, it was determined that there were statistically very significant (1%) variations among the salinity levels and effects of the interactions of the factors on the germination index. The highest germination indices (5.43 and 5.18) were determined under both temperatures' applications from 750 and 250 ppm NaCl L⁻¹ while the lowest (1.43) was found in 25°C from 10000 ppm NaCl L⁻¹ (Table 1).

Radicle length

As a result of the variance analysis of the radicle lengths, it was seen that there was a significant (1%) statistical difference between the temperatures applied. While it was observed that the highest radicle length (1.62 cm) was measured under 20°C, the lowest value (1.36 cm) was obtained from 25°C treatment (Table 1). Statistically (1%) significant variations were found among the salinity levels and common effects of both factors on radicle lengths. The highest radicle length (2.63 cm) was seen at 20°C from the fifth dose of salinity, while the lowest radicle length (0.24 cm) was measured at the tenth dose from 25°C temperature (Table 1).

Plumule length

When plumule lengths are examined in Table 1, it is seen that there are statistically significant differences between the

Table 1: The means and the LSD groups of GP, GI, RL, PL, SL, RFW properties of soybean variety (Gapsoy).

Germination temperature (°C)	Salt doses (ppm)	GP (%)	*,**	GI	*,**	RL (cm)	*,**	PL (cm)	*,**	SL (cm)	*,**	RFW (g)	*,**
GT1	SD1	40.0	e-h	2.92	fg	1.65	f	5.70	de	7.35	cd	26.4	cd
	SD2	41.0	e-g	4.08	d	2.13	d	4.46	h	6.59	e	23.9	de
	SD3	46.0	De	4.83	b	1.94	e	6.75	b	8.69	b	26.5	c
	SD4	51.0	bc	4.44	c	1.68	f	5.30	f	6.97	d	26.5	c
	SD5	70.0	a	5.43	a	2.63	a	7.13	a	9.76	a	49.4	a
	SD6	49.0	cd	3.09	f	1.38	g	5.99	d	7.37	d	29.4	b
	SD7	41.0	e-g	2.96	f	1.23	i	5.63	e	7.33	d	29.1	b
	SD8	34.0	i	4.06	d	1.70	f	4.06	i	5.28	g	21.7	f
	SD9	28.0	j	2.06	jk	0.86	k	3.94	j	4.91	h	18.4	g
	SD10	25.0	k	2.01	k	0.98	j	3.93	j	4.80	h	14.7	h
	Average	42.5	A	3.59	A	1.62	A	5.29	A	6.91	A	26.6	A
GT2	SD1	37.0	f-i	3.15	f	0.87	jk	3.68	j	4.55	h	22.2	ef
	SD2	36.0	g-i	2.52	hi	1.56	f	4.70	gh	6.26	ef	14.9	h
	SD3	37.0	g-i	2.67	gh	1.35	h	4.99	g	6.34	ef	22.6	ef
	SD4	67.5	a	5.18	a	2.45	b	6.26	c	7.71	c	29.2	b
	SD5	54.0	b	3.77	e	2.36	c	4.21	i	6.57	e	24.1	de
	SD6	52.0	bc	3.67	e	1.89	e	4.09	i	5.98	f	25.8	cd
	SD7	42.0	ef	2.87	fg	1.33	h	3.96	ij	4.93	h	14.9	h
	SD8	35.0	hi	2.37	i	0.97	j	2.41	k	3.74	i	11.1	i
	SD9	32.0	i	2.22	j	0.56	l	1.31	l	1.87	j	11.0	i
	SD10	20.0	l	1.43	l	0.24	m	1.09	m	1.32	k	6.9	j
	Average	41.3	B	2.98	B	1.36	B	3.67	B	4.93	B	18.3	B
LSD (5%) for GT		1.258	*	0.072	**	0.031	**	0.079	**	0.085	**	0.466	**
LSD (5%) for SD		2.814	**	0.161	**	0.069	**	0.177	**	0.190	**	1.041	**
LSD (5%) for GT × SD		7.959	**	0.456	**	0.194	**	0.501	**	0.538	**	2.944	**
CV (%)		6.719		4.906		4.607		3.956		3.211		4.635	

GP: Germination percentage, GI: Gemination index, RL: Radicle length, PL: Plumule length, SL: Seedling length, RFW: Radicle fresh weight; GT1: 20°C, GT2: 25°C, Salt doses (SD1: Control, SD2: 100 ppm NaCl L⁻¹ SD3: 150 ppm NaCl L⁻¹, SD4: 250 ppm NaCl L⁻¹, SD5:750 ppm NaCl L⁻¹, SD6: 1000 ppm NaCl L⁻¹, SD7: 2250 ppm NaCl L⁻¹, SD8: 5000 ppm NaCl L⁻¹, SD9: 7500 ppm NaCl L⁻¹, SD10: 10000 ppm NaCl L⁻¹).

*: The means in the same column, expressed in lowercase and indicated with different letters, are statistically different from each other within the P<0.05 error limits according to Duncan's test.

**: The means in the same column, expressed in the capital and indicated with different letters, are statistically different from each other within the P<0.05 error limits according to LSD test.

applied temperatures (1%). The highest plumule length was measured as 5.29 cm from 20°C temperature treatment. There were statistically significant (1%) differences between salinity levels and the effects of interactions of factors on plumule lengths. The highest plumule length was seen in the fifth dose of salinity at 20°C, while the lowest (7.13 cm) was observed in tenth salinity levels as 1.09 cm at 25°C (Table 1).

Seedling length

As seen in Table 1, it is seen that there is a statistically very significant difference (1%) between the temperatures' conditions in terms of seedling lengths. The highest seedling length was measured from 20°C temperature application 6.91 cm, while the lowest value was determined for 25°C as 4.93 cm (Table 1). When the effect of salinity levels and common effects of both factors on seedling lengths are examined from Table 1, it is seen that there are statistically significant variations (1%) among salt doses and the interaction of both factors. The highest seedling length was measured as 9.76 cm from the fifth level of salinity at 20°C temperature, while the lowest value was observed as 1.32 cm from the tenth salt dose at 25°C (Table 1).

Radicle fresh weight

When the average fresh weights of the radicles are examined from Table 1, it is seen that there is a significant difference (1%) between the temperature applications. The maximum radicle fresh weight (26.6 g) was determined at 20°C temperature, while the lowest value (18.3 g) was observed under the 25°C temperature condition. In Table 1, it can be observed that there are statistically significant (1%) differences among the salt doses and interaction effects of the factors on the radicle fresh weights. The highest radicle fresh weight (49.4 g) was seen in the treatment of the fifth salt dose, while the lowest value (6.9 g) was seen in the tenth treatment (Table 1).

Plumule fresh weight

As a result of the variance analysis of the plumule fresh weight, it was seen that there was a significant (1%) statistical difference between the temperatures' conditions. While it was observed that the highest plumule fresh weight (436.7 g) was measured at 20°C, the lowest value (386.7 g) was weighed from the 25°C treatment (Table 2). Statistically (1%) significant differences were found among the salinity levels and common effects of both factors on the plumule fresh weight. The highest plumule fresh weight (562.3 g) was seen at 20°C from the fifth level of salinity, while the lowest plumule fresh weights (236.2 and 236.5 g) were measured at the tenth dose of salt application at 20 and 25°C temperatures (Table 2).

Seedling fresh weight

As seen in Table 2, it can be determined that there is a statistically very significant difference (1%) between the conditions of temperatures in terms of the seedling fresh weight. The highest seedling fresh weight was determined from 20°C temperature application as 489.8 g, while the

lowest value was determined for 25°C as 405.0 g (Table 2). When the effect of salinity levels and common effects of both factors on the seedling fresh weight are examined from Table 2, it is seen that there are statistically significant variations (1%) among salinity levels and the interaction effects of both factors. The highest seedling fresh weight was measured as 591.4 g from the fifth level of salinity at 20°C temperature, while the lowest values were observed as (250.9 and 247.6 g) from the tenth salt doses at both temperature treatments (Table 2).

Radicle dry weight

When the average dry weights of the radicles are examined from Table 2, it is seen that there is a significant difference (1%) between the temperature treatments. The maximum radicle dry weight (4.9 g) was observed at 20°C temperature, while the lowest value (3.8 g) was seen under 25°C temperature conditions. In Table 2, it can be observed that there are statistically significant (1%) differences among the salinity levels and interaction effects of the factors on the radicle dry weights. The highest radicle dry weight (7.4 g) was seen in the treatment of the fifth salt dose, while the lowest value (1.8 g) was seen in the tenth treatment at 25°C (Table 2).

Plumule dry weight

As a result of the variance analysis of the plumule dry weight, it was seen that there was a significant (1%) statistical difference between the effects of the temperatures. While it was observed that the highest plumule dry weight (86.5 g) was observed at 20°C, the lowest value (81.3 g) was weighed from the 25°C treatment (Table 2). Statistically (1%) significant differences were found among the salt doses and common effects of both factors on the plumule dry weight. The highest plumule dry weight (99.9 g) was seen at 20°C from the fifth dose of salt, while the lowest plumule fresh weights (48.9 and 50.2 g) were measured at the tenth salinity levels at 20°C and 25°C temperatures (Table 2).

Seedling dry weight

As seen in Table 2, it can be determined that there is a statistically very significant difference (1%) between the effects of the temperatures in terms of the seedling dry weight. The highest seedling dry weight was determined from 20°C temperature application as 91.8, while the lowest value was determined for 25°C as 84.9 g (Table 2). When the effect of salinity levels and common effects of both factors on the seedling dry weight are examined from Table 2, it can be observed that there are statistically significant differences (1%) among salt doses and the interaction effects of both factors. The highest seedling dry weight was measured as 105.1 g from the fifth level of salinity at 20°C temperature, while the lowest values were observed as (52.0 and 52.5 g) from the tenth salinity levels at the both temperatures treatments (Table 2).

Seedling vigor index

As shown in Table 2, it can be determined that there is a statistically very significant difference (1%) between the

temperature treatments in terms of the seedling vigor index. The highest seedling vigor index was observed from the 20°C temperature treatment as 316.3 g, while the lowest value was determined for 25°C temperature as 234.2 g (Table 2). When the effect of salinity levels and common effects of both factors on the seedling vigor index are examined from Table 2, it is seen that there are statistically significant variations (1%) among salinity levels and the interaction effects of both factors. The highest seedling vigor indices were calculated as 663.5 and 653.3 g from the fifth level of salinity at 20°C temperature and fourth level at 25°C, while the lowest value was determined as (26.5 g) from the tenth salinity level at 25°C temperature treatment (Table 2).

The correlation among the investigated parameters

A correlation analysis was performed to accurately identify the relationships between all the studied properties of

soybeans. Correlations between most of the parameters studied were found to be significant (1%) due to interactions from different temperatures and salt doses. The simple scatter plot and curves of correlation matrices between seedling vigor index and other studied properties were presented in Fig 1. As can be seen from Fig 1, it is observed that there are generally positive interactions among all the features studied and that there was no negative interaction. The seedling vigor index was found to have a strong positive linear relationship ($r^2 = 0.861$) with an 86% germination percentage, ($r^2 = 0.817$) an 82% germination index, ($r^2 = 0.764$) an 76% radicle length, ($r^2 = 0.802$) an 80% seedling length, ($r^2 = 0.697$) an 70% radicle fresh weight and ($r^2 = 0.671$) an 67% radicle dry weight, respectively (Fig 1 A-E; G). When Fig 1 F and H are examined, it is determined that the seedling vigor index has a significant, weak positive correlation with

Table 2: The means and the Duncan groups of PFW, SFW, RDW, PDW, SDW and SVI properties of soybean variety (Gapsoy).

Germination temperature (°C)	Salt doses (ppm)	PFW ^{*,**} (g)	SFW ^{*,**} (g)	RDW ^{*,**} (g)	PDW ^{*,**} (g)	SDW ^{*,**} (g)	SVI ^{*,**}
GT1	SD1	560.8 ab	587.2 ab	4.4 ef	94.0 a-c	98.4 a-c	294.4 de
	SD2	387.3 gh	411.2 f	5.2 d	84.6 de	89.8 d-g	270.3 d-f
	SD3	487.3 c	513.8 c	4.8 e	92.2 bc	97.0 bc	486.5 b
	SD4	451.5 d	478.1 d	5.7 b	92.9 bc	98.6 ab	362.2 c
	SD5	562.3 a	591.4 a	7.4 a	99.9 a	105.1 a	663.5 a
	SD6	532.5 b	571.8 b	5.2 d	97.3 a	102.7 a	359.5 c
	SD7	527.5 b	561.9 b	5.4 cd	90.0 c	98.4 bc	302.1 d
	SD8	436.8 de	472.8 d	4.2 f	83.5 e	88.2 fg	163.2 jk
	SD9	454.4 d	458.5 de	3.4 h	81.5 e	87.6 fg	145.9 k
	SD10	236.2 j	250.9 i	3.1 i	48.9 g	52.0 i	115.6 l
	Average	463.7 A	489.8 A	4.9 A	86.5 A	91.8 A	316.3 A
GT2	SD1	462.8 cd	485.0 cd	3.8 g	78.4 e	82.2 g	168.5 i-k
	SD2	422.1 ef	437.0 ef	3.2 hi	88.8 cd	92.0 c-f	226.0 gh
	SD3	434.6 de	457.2 de	4.4 f	84.5 de	88.9 e-g	234.9 fg
	SD4	481.9 c	511.2 c	5.3 d	92.7 bc	96.1 bc	653.3 a
	SD5	398.1 fg	422.2 f	5.6 bc	87.4 cd	96.4 bc	354.6 c
	SD6	407.9 fg	422.8 f	5.4 cd	90.9 c	94.5 b-d	251.6 e-g
	SD7	397.2 fg	422.9 f	3.4 h	83.0 e	92.7 c-e	194.4 hi
	SD8	363.5 h	273.8 h	2.4 k	95.1 ab	88.4 fg	172.7 ij
	SD9	262.8 i	370.4 g	2.6 j	62.4 f	65.0 h	59.8 m
	SD10	236.5 j	247.6 i	1.8 l	50.2 g	52.5 i	26.5 n
	Average	386.7 B	405.0 B	3.8 B	81.3 B	84.9 B	234.2 B
LSD (0.05) for GT		7.160 **	7.039 **	0.078 **	1.428 **	1.466 **	9.34 **
LSD (0.05) for SD		16.010 **	15.741 **	0.174 **	3.194 **	3.278 **	20.88 **
LSD (0.05) for GT × SD		45.282 **	44.521 **	0.492 **	9.033 **	9.270 **	59.06 **
CV (%)		3.765	3.518	4.021	3.806	3.710	7.58

PFW: Plumule fresh weight, SFW: Seed fresh weight, RDW: Radicle dry weight, PDW: Plumule dry weight, SDW: Seed dry weight, SVI: Seedling vigor index; GT1: 20°C, GT2: 25°C; SL: Salt Doses (SL1: Control, SL2: 100 ppm NaCl L⁻¹, SL3: 150 ppm NaCl L⁻¹, SL4: 250 ppm NaCl L⁻¹, SL5: 750 ppm NaCl L⁻¹, SL6: 1000 ppm NaCl L⁻¹, SL7: 2250 ppm NaCl L⁻¹, SL8: 5000 ppm NaCl L⁻¹, SL9: 7500 ppm NaCl L⁻¹, SL10: 10000 ppm NaCl L⁻¹)

*: The means in the same column, expressed in lowercase and indicated with different letters, are statistically different from each other within the P<0.05 error limits according to LSD test.

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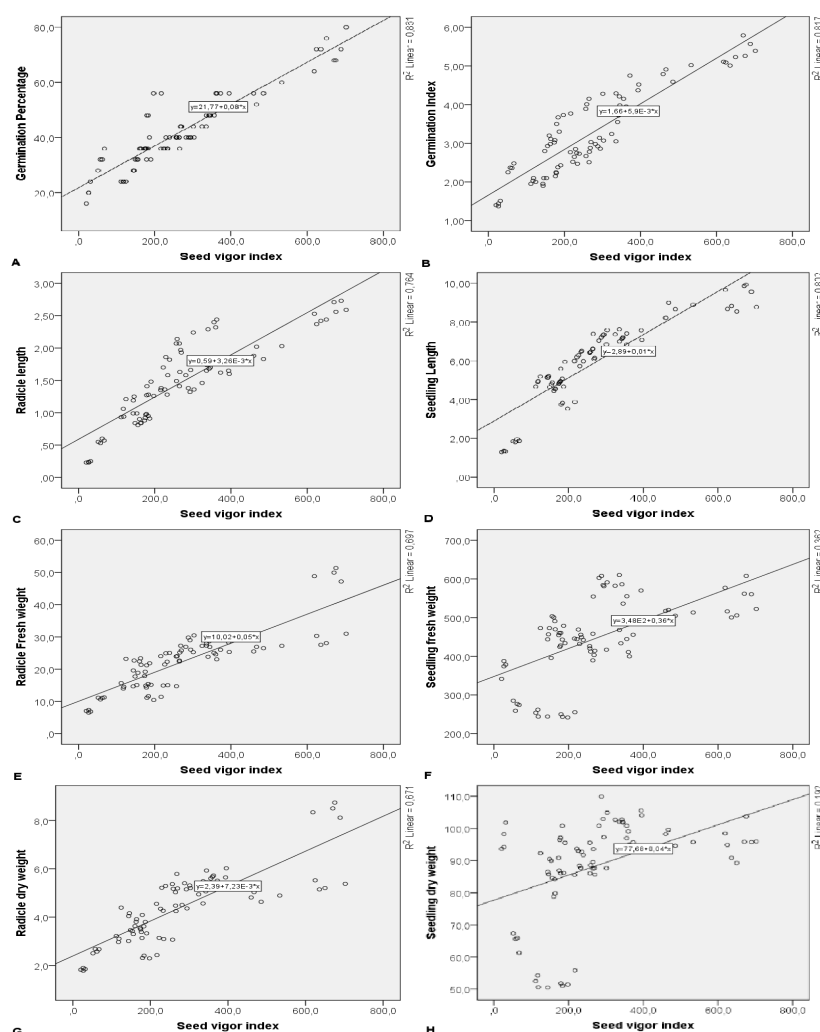


Fig 1: Simple scatter plot matrices between seedling vigor index and other studied properties.

seedling fresh weight and seedling dry weight. Thus, it is seen that the seedling vigor index has significant and positive linear relationships ($r^2 = 0.362$ and $r^2 = 0.192$) with the seedling fresh weight and the seedling dry weight.

The study was confined to determine the effect of temperature and salinity levels on germination percentage, germination index, radicle length, plumule length, seedling length, radicle fresh weight, plumule fresh weight, radicle dry weight, plumule dry weight, seedling dry weight and seedling vigor index of *Glycine max* L. According to the findings of the research, the effects of salinity on all parameters of germination and seedling growth characteristics of soybean seeds were found to be statistically significant (Table 1 and 2). Analysis of variance showed that there were significant variations between germination temperatures and among the salt concentrations during the germination and seedling stages. And also, as shown in Table 1 and 2, it appears that the interaction effects of germination temperatures and salt concentrations on all the parameters studied showed statistically significant (5%) differences. However, all observed parameters were positively affected

by NaCl till SL5 (750 ppm NaCl L⁻¹), but they were diminished by SL6 - SL10 NaCl concentrations (Table 1). As is known, 750 ppm NaCl L⁻¹ of the total dissolved solids in water can have detrimental effects on sensitive crops, but salinity tolerant or moderately tolerant crops may not be sensitive to this concentration. Soybean species tolerate the salinity to a specific level due to its moderately salt-tolerant properties and soybean yield decreases when the soil salinity exceeds this specific level (Ashraf and Wu, 1994) at all temperature regimes (Gulzar *et al.* 2001). When the results of the trials are examined from Table 1 and 2, it was determined that the effect of salt stress increases when the temperature level increases in all the properties examined and it was found that the highest values at 25°C were determined from the fourth salinity level. Thus, it was observed that the increase in temperature compared to 20°C reduced the tolerance of soybean plants to salt stress. In rare plant species, the change of necessary temperature has little effect on germination, while others are very sensitive to temperature regimes (Gulzar *et al.* 2001). The results showed that the response of germination percentage,

germination index, radicle length, seedling length, and root fresh weight to salt stress under 25°C temperature conditions was severe than 20°C. The radicle and seedling length are reported to be important features in salt stress sensitivity assessment (Jamil *et al.* 2006). Khan and Ungar (1997) reported that in the high-temperature regime, there was an interaction with the high salt concentration, which hinders germination. Similar results have been reported by many researchers (Gulzar *et al.* 2001). After a tolerated saline level, the decrease of growth in radicle and seedling can be related to NaCl toxicity and disproportion in nutrient absorption by seedlings. According to the results of some previous studies, salinity reduces water absorption and growth of radicle and seedling (Khan, 1998; Nedjimi, 2013). Salinity is reported to significantly reduce nutrient absorption and root growth rate (Gulzar *et al.* 2001).

CONCLUSION

The germination attributes of soybean varied between germination temperatures under salt stress in this experiment. The above results suggest that seeds of soybean can germinate well and rapidly at a lower level of salt (≤ 750 ppm NaCl L⁻¹) under 20°C germination temperature, but the germination percentage of the seeds decreases at a higher level of salt (10000 ppm NaCl L⁻¹). 750 ppm NaCl L⁻¹ salt concentration is better for all observed attributes at 20°C. It was observed that the tolerance to salinity decreased as the germination temperature increased. Additionally, it has been shown that the soybean reacts differently to increased salinity concentrations under different temperatures. It is concluded that significant positive correlations were observed among observed properties of soybean variety under effects of salinity concentrations at different temperatures.

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