

## Effect of Salinity Stress on Growth Parameters of Potato Genotypes

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**Abstract:** This study aims at examining the effect of salinity stress on some growth parameters of diploid potato genotypes and determining the heritability of these traits and their association. Ninety four potato genotypes which were progeny from a cross between parents C and E were evaluated in hydroponics with a salinity level of 120 mM NaCl. The experiment was arranged in RCBD with five replications; three of them were salt treated and the remaining was control. Different growth parameters were measured and counted at different periods of salt stress. Variance and correlation analysis were conducted using GenStat statistical software. Heritability of measured traits was also calculated from ANOVA outputs. Potato genotypes showed reduction in growth parameters due to salinity stress. The result indicated that the highest reduction (75%) was observed on shoot fresh weight followed by leaf area (72%), shoot dry weight (69%), root dry weight (64%), root fresh weight and shoot length (49%). The number of new leaves developed between six and thirteen days after salt stress showed reduction by 53% under salt stress relative to the control. Heritability of growth parameters ranged from 46% to 83% under control and from 69% to 90 % under salt stress condition. The highest heritability was observed for root/shoot dry weight ratio (90%) and leaf area (86%) under salt stress. Leaf area showed strong positive correlation with all measured growth parameters with the exception of root/shoot dry weight ratio both under treated and untreated condition. Salt stress affects development of new leaves in the potato genotypes later than six days of stress. The study suggests further study on evaluation of the genotypes under various salinity levels and the presence of substances in osmotic adjustment. Furthermore, studying the association between salt tolerance and analysis results of tissue Na<sup>+</sup> and K<sup>+</sup> may give information whether the salt tolerance is due to the tolerance to Na<sup>+</sup> concentration or exclusion of this ion.

**Key words:** Salinity • Growth parameters • Salinity tolerance • Heritability

### INTRODUCTION

Salinity is one of the major abiotic stresses affecting agricultural production worldwide. Based on the FAO database, more than 6% of the world's total land area, which is about 20% of cultivated land, was affected by salt [1, 2]. Agricultural production in the dry land accounts for about half of the world's land. This production system largely depends on irrigation practices [3]. However, irrigation contributes to the development of salinity by raising the water table, which brings salts from deeper layers of the soil and concentrates in the root zone [1]. This leads to the decrease in osmotic potential of the soil and interferes with the water uptake of roots. Moreover, the use of poor quality water due to the limited availability of fresh water

can also cause the problem of salinity in some areas [4, 5]. Likewise, long-term accumulation of salts in arid and semi-arid areas, weathering of parental rocks and deposition of oceanic salts carried in wind and rain are other possible causes of salinity [1]. The day-to-day natural processes and human activities play a paramount role in the growth of this worldwide problem. Hence, the increase in salinization together with the current global climate change poses a threat to the food supply for the rapidly growing population of the world [1, 3, 5] by limiting the growth and productivity of food crops like potato

Potato (*Solanum tuberosum* L.) is an herbaceous perennial plant grown for its swollen underground stem called tuber. The crop is believed to be originated in the Andes of South America [6]. In terms of productivity and

nutritional value potato is the fourth most important food crop in the world [7, 8] next to rice, wheat and maize. Currently, potato is grown worldwide under different climatic conditions. China is the first in production followed by Russian Federation, India and USA [8].

The production of potato like other crops is affected by a number of biotic and abiotic stresses among which salinity is one of the major abiotic stresses. This abiotic stress has a major impact on food production. Therefore it is important to improve salinity tolerance of the crops that provide the largest food source globally. Potato is moderately sensitive to salinity stress [9, 10] and a salinity level of 2.0-3.0 dS/m is reported to cause a reduction in growth and up to 50% of yield loss [10]. This indicates the remarkable effect of salinity in yield reduction and economic loss on potato production. Therefore, development of tolerant genotypes to this abiotic stress is crucial to maintain yield of potato.

Saline soils are managed for agricultural production by applying different soil and water management practices [11]. Applying surface irrigation to leach the salts accumulated in the root zone and soil amendments with gypsum to improve the soil texture and drainage are some of the options to manage saline soils. However, these soil reclamation approaches are expensive to deal with the problem of salinity. Therefore, breeders should attempt to develop crops which can tolerate salinity stress using different crop improvement approaches. Marker assisted selection and biotechnology together with conventional breeding were reported as a good approaches to cope with the problem of salinity [11]. This in turn requires the availability of salt tolerant plants as well as variability in salt tolerance between genotypes of the same species [3]. Hence, the presence of tolerant plants or variability in salt tolerance offers the possibility for breeders to identify genes responsible for tolerance and transfer these to commercial cultivars. This requires knowledge on the mechanisms determining salinity tolerance and the availability of tools to measure the response of the plants to salinity. Therefore, the current study aims at examining the effect of salinity stress on the growth parameters of diploid potato genotypes and determining the heritability of these traits and their association.

## MATERIALS AND METHODS

**Plant Material and Experimental Set up:** Ninety four potato genotypes were used in this experiment. The genotypes were progeny from a cross between parents C and E. Planting materials were prepared *in vitro*

using MS medium. Axillary shoots taken from each genotype were sterilized and cultured in the media. The cultures were kept under 16 h photoperiod, 21°C temperature and Photosynthetic Photon Flux (PPF) of 33.75  $\mu\text{molm}^{-2}\text{s}^{-1}$  supplied by fluorescent light. After two weeks, the plantlets were transferred to hydroponics in greenhouse.

The experiment was conducted in an 8 x 8 (64 m<sup>2</sup>) greenhouse compartment located at Radix, Uniform, Wageningen University, latitude 52°N. Potato plantlets were transplanted on 17<sup>th</sup> June (Replications 1, 2 and 3) and 18<sup>th</sup> June (Replications 4 and 5), 2009 in small rockwool slabs. The plantlets in the rockwool slabs were planted in a tray with a circular whole (24 hole per tray, 8 plants per tray) and dipped in the hydroponics.

The experiment was arranged in RCBD with five replications out of which three of them were salt treated (replication 1, 3 and 5) and the rest (replication 2 and 4) were control treatments. Per box, there were 8 plants (8 genotypes). The remaining 16 holes were filled with rockwool slabs to avoid evaporation through the open holes. Therefore, a total of 480 plants were planted including two of the parents. One of the genotypes (genotype 447), died after some days in replication 3 and 4 and replaced with parent E and C respectively. The growing condition in the greenhouse was 18/15.6°C day/night temperature, 16 h day length and 60 /80% day/night RH.

The hydroponics was prepared by filling a box with approximately 22 liters of standard nutrient solution on the planting dates (17 and 18 June, 2009). The nutrient solution contains the cations K<sup>+</sup> 7.9, Ca<sup>2+</sup> 3.9, Mg<sup>2+</sup> 1.6, NH<sub>4</sub><sup>+</sup> 0.6 and Na<sup>+</sup> 0.4 (mmol/l); the anions NO<sub>3</sub><sup>-</sup> 11.0, SO<sub>4</sub><sup>2-</sup> 2.9, PO<sub>4</sub><sup>3-</sup> 1.94, HCO<sub>3</sub><sup>-</sup> 0.4 and Cl<sup>-</sup> 0.3 (mmol/l); the micro nutrients Fe 24, Mn 12, B 9.8, Zn 4.4, Cu 0.7 and Mo 0.3 ( $\mu\text{mol/l}$ ) and Si 0.02 mmol/l. The nutrient solution had an EC of 2.1 mS/cm and a pH of 5.7.

A salinity level of 120 mM NaCl was selected to observe the response of genotypes. The treatment was started after thirteen days of adaptation time (transplanting); on 30 June 2009 (for replication 1 and 3). On this date the control treatment (replication 2) was refreshed with the standard nutrient solution while 60 mM of NaCl was added to the standard nutrient solution and applied to replications 1 and 3 after removing the previous media (the standard nutrient solution filled on the planting date). On the next date (1 July 2009) 120 mM NaCl was added to the standard nutrient solution and applied to the boxes of replications 1 and 3 after removing the previous media with the 60 mM NaCl. On 1 July 2009 the media of

replication 4 was refreshed and 60 mM NaCl was applied to replication 5. On the next day (2 July 2009) 120 mM NaCl was applied to the boxes of replication 5 after changing the previous media of 60 mM NaCl. The growing media (hydroponic solution) of all replications was refreshed for the second time on 8 July 2009 with the respective treatments i.e. with 120 mM NaCl for the salt treated boxes (replications 1, 3 and 5) and with standard nutrient solutions for the control treatments (replications 2 and 4).

**Measured Parameters:** In this experiment different growth parameters (plant height, shoot length, leaf area, shoot fresh weight, root length, root fresh weight, shoot dry weight and root dry weight) were measured and numbers of leaves (living, yellow + wilted and dead leaves) were counted for both the control and salt treatments over time. The number leaves were counted on 6 and 7 July 2009 for replications 1, 2 and 3. A label was placed on the tip of the shoot after counting. Then new leaves above the label were counted on 13 July 2009 and summed up with the living leaves counted on 6 and 7 July 2009 for analysis. Plant height was measured zero and seven days after salt treatment.

The genotypes were harvested on 16<sup>th</sup> (replication 1 and 2), 17<sup>th</sup> and 18<sup>th</sup> (Replication 3, 5 and part of replication 4) and 20 (the remaining boxes of replication 4) July 2009. After carefully removing the plants out of the hydroponics, the root was gently cleaned to separate it from the rockwool. Subsequently, the water left on the roots dried with tissue and growth parameters were measured. The parameters measured at harvest were: shoot length (cm), root length (cm), leaf area (cm<sup>2</sup>), shoot fresh weight (g), root fresh weight (g), shoot dry weight and root dry weight (g). Leaf area was measured using leaf area meter (LI-COR model 3100). Dry weight was measured after oven drying shoots and roots separately at 70 °C for 72 hours. Root/shoot dry weight ratio were calculated from the dry weights of root and shoot.

**Statistical Analysis:** Analysis of variance (ANOVA) and correlation analysis were conducted using GenStat statistical software. One-way ANOVA was carried out for the salt treated and control treatments to observe the presence of genotypic differences. Heritability of measured traits was calculated from one-way ANOVA outputs to determine the percentage variation due to the genetic factor. Two-way ANOVA was carried out to examine the interaction between genotype and treatment.

In both cases (one-way and two-way ANOVA), 5% probability level ( $P = 0.05$ ) was used to test the significant differences between genotypes, treatment effects and interactions.

## RESULTS

Overall genotypes showed reduction in growth parameters in response to salinity stress. Although growth parameters were reduced under salt stress condition, variability among genotypes was observed (result not shown).

**Effect of Salinity on Plant Height:** At the initial period of salt treatment (zero days after salt stress) genotype and treatment showed no significant ( $P = 0.898$ ) interaction effect and no significant ( $P = 0.771$ ) treatment effect on plant height; however genotypes showed significant ( $P < 0.001$ ) differences (Table 1) in plant height. Seven days after salt stress, genotype and treatment showed significant ( $P < 0.001$ ) interaction effect on plant height (Table 1). The variation in plant height ranged from 4.0-20.2 (cm) under control and from 4.6-12.7 (cm) under salt stress condition. Relative to the control, genotypes showed 22.4% reduction in plant height under salt stress (Table 1).

**Effect of Salinity on Growth Parameters at Harvest:** After sixteen days of salt stress treatment, genotype and treatment showed significant ( $P < 0.001$ ) interaction effect on shoot length, shoot fresh weight, root fresh weight, leaf area, shoot dry weight, root dry weight and root/shoot dry weight ratio (Table 2). Root length was not significantly affected by the interaction between genotype and treatment ( $P = 0.998$ ) and the main effect of treatment ( $P = 0.462$ ); however, genotypes showed significant ( $P < 0.001$ ) differences in root length (Table 2).

Relative to the control, shoot fresh weight showed the highest reduction (74.6%) under salt stress followed by leaf area (71.9%), shoot dry weight (69.4%), root dry weight (63.6%), root fresh weight (49.5%) and shoot length (49.2%). Root length showed the lowest relative reduction under salt stress (3.9%) whereas the value of root/shoot dry weight ratio increased (17.6%) under salt stress (Table 2).

**Effect of Salinity on Number of Leaves:** Six days after salt treatment genotype and treatment showed no significant ( $P = 0.086$ ) interaction effect on number of living leaves. The effect of treatment was also not significant

Table 1: Effect of salinity on plant height (cm) measured zero and seven days after salt stress

Days after salt treatment	Control		Salt treated		Two-way ANOVA <i>P</i> - value			Relative reduction (%)	C.V (%)
	Mean <sup>1</sup>	Range	Mean	Range	G <sup>3</sup>	T <sup>4</sup>	G * T <sup>5</sup>		
0	6.9	3.4-10.3	6.8	3.8-9.5	<0.001	ns <sup>2</sup>	ns	1.5	14.5
7	11.6	4.0-20.2	9.0	4.6-12.7	<0.001	0.054	<0.001	22.4	14.9

<sup>1</sup> Mean values are averages of 94 genotypes over 2 and 3 replications for the control and salt treated conditions respectively.

<sup>2</sup> Non significant.

<sup>3</sup> Genotype, <sup>4</sup> Treatment, <sup>5</sup> Genotype by treatment interaction.

Table 2: Effect of salinity on growth parameters sixteen days after salt treatment (measured at harvest)

Parameters	Control		Salt treated		Two-way ANOVA <i>P</i> - value			Relative reduction (%)	C.V (%)
	Mean <sup>1</sup>	Range	Mean	Range	G <sup>3</sup>	T <sup>4</sup>	G * T <sup>5</sup>		
Shoot length (cm)	25.2	6.2-45.8	12.8	5.0-22.1	<0.001	0.008	<0.001	49.2	21.5
Root length (cm)	22.8	1.5-34.5	21.9	2.5-33.9	<0.001	ns <sup>2</sup>	ns	3.9	23.9
Shoot fresh weight (g)	23.553	0.48-57.06	5.991	0.166-14.019	<0.001	0.005	<0.001	74.6	45.6
Root fresh weight (g)	4.258	0.074-13.395	2.152	0.14-4.478	<0.001	0.002	<0.001	49.5	39.2
Leaf area (cm <sup>2</sup> )	399	9.2-1007.9	112	1.2-250.3	<0.001	0.006	<0.001	71.9	36.6
Shoot dry weight (g)	2.376	0.066-4.696	0.727	0.028-1.653	<0.001	0.002	<0.001	69.4	39.2
Root dry weight (g)	0.360	0.005-0.877	0.131	0.008-0.287	<0.001	0.002	<0.001	63.6	39.7
Root/shoot dry weight	0.17	0.08-0.40	0.20	0.09-0.71	<0.001	ns	<0.001	-17.6	25.2

<sup>1</sup> Mean values are averages of 94 genotypes over 2 and 3 replications for the control and salt treated conditions respectively.

<sup>2</sup> Non significant.

<sup>3</sup> Genotype, <sup>4</sup> Treatment, <sup>5</sup> Genotype by treatment interaction.

Table 3: Heritability of plant height measured zero and seven days after salt treatment under control and salt treated conditions. Values are calculated from one-way ANOVA outputs

Parameters	Days after treatment	Treatment	V <sub>g</sub> <sup>1</sup>	V <sub>e</sub> <sup>2</sup>	H (%) <sup>3</sup>	<i>P</i> -value
Plant height	0	Control	1.17	0.56	67.7	<0.001
		Salt	1.21	0.30	80.0	<0.001
	7	Control	5.22	1.94	72.9	<0.001
		Salt	2.09	0.49	80.8	<0.001

<sup>1</sup> Genetic variance.

<sup>2</sup> Environmental variance.

<sup>3</sup> Heritability.

<sup>4</sup> Non significant.

( $P = 0.074$ ), however genotypes showed significant ( $P < 0.001$ ) differences in number of living leaves (Data not shown). Genotype and treatment showed no significant ( $P = 0.666$ ) interaction effect on the number of dead leaves after six days of salt treatment. Moreover, the main effects of genotype ( $P = 0.108$ ) and treatment ( $P = 0.325$ ) on the number of dead leaves were also not significant after similar period of salt stress. The interaction between genotype and treatment ( $P = 0.981$ ) and the main effects of genotype ( $P = 0.653$ ) and treatment ( $P = 0.495$ ) on the number of yellow + wilted leaves were also not significant.

Thirteen days after salt stress, genotype and treatment showed significant ( $P = 0.013$ ) interaction effect on total number of living leaves (Table 3). For the number

of dead leaves the interaction between genotype and treatment ( $P = 0.645$ ) and the main effect of treatment ( $P = 0.238$ ) were not significant; however, genotypes showed significant ( $P < 0.001$ ) differences. The interaction between genotype and treatment ( $P = 0.958$ ), the main effects of genotype ( $P = 0.455$ ) and treatment ( $P = 0.292$ ) on the number of yellow + wilted leaves were not significant. Genotype and treatment showed significant ( $P < 0.001$ ) interaction effect on the number of new leaves developed between six and thirteen days after salt stress (Data not shown).

Although the interaction effects were not always significant, the relative reduction in number of living (healthy) leaves increased from 25.1% after six days of salt treatment to 32.8% after thirteen days of salt treatment

Table 4: Heritability of parameters measured at harvest (16 to 18 days after salt treatment). Values are calculated from one-way ANOVA outputs

Parameters	Treatment	V <sub>g</sub> <sup>1</sup>	V <sub>e</sub> <sup>2</sup>	H (%) <sup>3</sup>	P-value
Shoot length (cm)	Control	31.36	17.42	64.3	<0.001
	Salt	6.76	1.45	82.3	<0.001
Root length (cm)	Control	31.86	16.32	66.1	<0.001
	Salt	42.75	8.67	83.1	<0.001
Shoot fresh weight (g)	Control	88.46	48.78	64.5	<0.001
	Salt	6.38	1.30	83.0	<0.001
Root fresh weight (g)	Control	1.08	0.22	82.9	<0.001
	Salt	3.13	1.40	69.1	<0.001
Leaf area (cm <sup>2</sup> )	Control	2641.5	8995	74.6	<0.001
	Salt	2593.3	427	85.9	<0.001
Shoot dry weight (g)	Control	0.63	0.39	61.9	<0.001
	Salt	0.089	0.018	82.9	<0.001
Root dry weight (g)	Control	0.016	0.009	63.4	<0.001
	Salt	0.003	0.001	81.2	<0.001
Root/shoot dry weight	Control	0.001	0.002	45.5	<0.001
	Salt	0.005	0.000	89.5	<0.001

<sup>1</sup> Genetic variance.

<sup>2</sup> Environmental variance.

<sup>3</sup> Heritability.

(Table 3). The number of living leaves increased from 19.5 to 27.1 under control and from 14.6 to 18.2 under salt treated condition when the stress period was extended from six to thirteen days. The number of new leaves developed between six and thirteen days after salt stress showed 52.6% reduction under salt stress relative to the control.

### Heritability of Parameters

**Plant Height:** Genotypes showed significant ( $P < 0.001$ ) differences in plant height after zero and seven days of salt treatment both for the control and salt stress condition. Heritability of plant height (80.8%) increased after seven days of salt stress (Table 3).

**Growth Parameters Measured at Harvest:** Genotypes showed significant ( $P < 0.001$ ) differences in all growth parameters (shoot length, root length, shoot fresh weight, root fresh weight, leaf area, shoot dry weight, root dry weight and root/shoot dry weight ratio) measured at harvest under control and salt stress condition (Table 4). The heritability of all growth parameters measured at harvest increased under salt stress except root fresh weight. The heritability of growth parameters ranged from 45.5% to 82.9% under control and from 69.1% to 89.5% under salt stress condition. The highest heritability was observed for root/shoot dry weight ratio (89.5%) and leaf area (85.9%) under salt stress condition (Table 4).

### Correlation Between Parameters

**Control:** Leaf area showed strong positive correlation with shoot fresh weight ( $r = 0.93$ ), shoot dry weight ( $r = 0.92$ ), root dry weight ( $r = 0.82$ ), root fresh weight ( $r = 0.78$ ), root length ( $r = 0.63$ ) and shoot length ( $r = 0.57$ ), however it showed a moderate negative correlation ( $r = -0.38$ ) with root/shoot dry weight ratio (Table 10). Root dry weight showed strong positive correlation with root fresh weight ( $r = 0.94$ ), shoot dry weight ( $r = 0.81$ ), shoot fresh weight ( $r = 0.79$ ) and root length ( $r = 0.59$ ). It showed a moderate positive correlation ( $r = 0.44$ ) with shoot length (Table 10). Root fresh weight showed strong positive correlation with shoot dry weight ( $r = 0.79$ ), shoot fresh weight ( $r = 0.75$ ) and root length ( $r = 0.63$ ). It showed a moderate positive correlation ( $r = 0.39$ ) with shoot length (Table 5). Root length showed strong positive correlation with shoot dry weight ( $r = 0.69$ ), shoot fresh weight ( $r = 0.62$ ) and moderate positive correlation with shoot length ( $r = 0.44$ ), but it showed negative correlation ( $r = -0.51$ ) with root/shoot ratio (Table 5). Root/shoot dry weight ratio showed a moderate negative correlation with shoot length ( $r = -0.49$ ), shoot dry weight ( $r = -0.49$ ) and shoot fresh weight ( $r = -0.38$ ). Shoot dry weight showed strong positive correlation with shoot fresh weight ( $r = 0.93$ ) and shoot length ( $r = 0.65$ ). Shoot fresh weight showed strong positive correlation ( $r = 0.69$ ) with shoot length (Table 5).

Table 5: Correlation between parameters measured at harvest under control condition

	Leaf area	Root DW <sup>1</sup>	Root FW <sup>2</sup>	Root Length	Root /Shoot	Shoot DW	Shoot FW	Shoot length
Leaf area	-							
Root DW	0.82	-						
Root FW	0.78	0.94	-					
Root Length	0.63	0.59	0.63	-				
Root/Shoot	-0.38	-0.06	-0.10	-0.51	-			
Shoot DW	0.92	0.81	0.79	0.69	-0.49	-		
Shoot FW	0.93	0.79	0.75	0.62	-0.38	0.93	-	
Shoot length	0.57	0.44	0.39	0.44	-0.49	0.65	0.69	-

<sup>1</sup> Dry weight.

<sup>2</sup> Fresh weight.

Table 6: Correlation between parameters measured at harvest under salt stress condition

	Leaf area	Root DW <sup>1</sup>	Root FW <sup>2</sup>	Root Length	Root/Shoot	Shoot FW	Shoot DW	Shoot length
Leaf area	-							
Root DW	0.78	-						
Root FW	0.76	0.97	-					
Root Length	0.67	0.67	0.71	-				
Root/Shoot	-0.35	-0.02	-0.03	-0.34	-			
Shoot FW	0.94	0.85	0.83	0.67	-0.32	-		
Shoot DW	0.94	0.80	0.78	0.68	-0.40	0.97	-	
Shoot length	0.56	0.49	0.51	0.55	-0.46	0.62	0.65	-

<sup>1</sup> Dry weight.

<sup>2</sup> Fresh weight

**Salt Treated:** Leaf area showed strong positive correlation with shoot fresh weight ( $r = 0.94$ ), shoot dry weight ( $r = 0.94$ ), root dry weight ( $r = 0.78$ ), root fresh weight ( $r = 0.76$ ), root length ( $r = 0.67$ ) and shoot length ( $r = 0.56$ ), but a moderate negative correlation ( $r = -0.35$ ) with root/shoot dry weight ratio (Table 6). Root dry weight showed strong positive correlation with root fresh weight ( $r = 0.97$ ), shoot fresh weight ( $r = 0.85$ ), shoot dry weight ( $r = 0.80$ ) and root length ( $r = 0.67$ ). It showed a moderate positive correlation ( $r = 0.49$ ) with shoot length (Table 6). Root fresh weight showed strong positive correlation with shoot fresh weight ( $r = 0.83$ ) and shoot dry weight ( $r = 0.78$ ), root length ( $r = 0.71$ ) and shoot length ( $r = 0.51$ ); (Table 6). Root length had positive correlation with shoot fresh weight ( $r = 0.67$ ), shoot dry weight ( $r = 0.68$ ) and shoot length ( $r = 0.55$ ), but it showed a moderate negative correlation ( $r = -0.34$ ) with root/shoot dry weight ratio (Table 6). Root/shoot dry weight ratio showed a moderate negative correlation with shoot length ( $r = -0.46$ ), shoot dry weight ( $r = -0.40$ ), shoot fresh weight ( $r = -0.32$ ). Shoot fresh weight showed strong positive correlation with shoot dry weight ( $r = 0.97$ ) and shoot length ( $r = 0.62$ ). Shoot dry weight showed positive correlation ( $r = 0.65$ ) with shoot length (Table 6).

## DISCUSSION

The current study aimed at examining the effect of salinity stress on the growth parameters of diploid potato genotypes and determining the heritability of these traits and their association. Accordingly ninety four diploid potato genotypes, which are progenies from a cross between C and E parents, were examined based on growth parameters under hydroponics condition. Hydroponics was chosen to study the response of the genotypes to salt stress because it provides a uniform salinity environment and reduces the interaction with other environmental factors. Furthermore, the study under hydroponics provides the opportunity to measure root parameters more easily than under field condition and it gives an insight to predict the response under field condition.

The results of the current study revealed significant interaction effect of genotype and treatment on growth parameters except root length (Tables 1 and 2). Growth parameters like plant height, shoot fresh weight, leaf area, shoot dry weight, root dry weight, root fresh weight and shoot length showed remarkable reduction due to salt stress. Similar results were reported by several authors [2, 5, 9, 12, 13]. In contrast, root length was hardly affected

by salt stress in our study (Table 2). This might be because of the limited availability of space for the growth of roots in order to see the clear treatment effect on root length. It showed the lowest (3.9%) relative reduction (Table 2). Moreover, less severe reduction in root length than shoot length due to salt stress was also reported for potato cultivars on the study by [10, 14] under *in vitro* condition. Shoot fresh weight and leaf area showed the highest relative reduction due to salt stress with values of 74.6% and 71.9% respectively (Table 2). In line with this result, significant effect of salinity in shoot fresh weight was reported by [9] on potato and high reduction in leaf area was reported by [15] on tomato and [2] on faba bean (*Phaseolus vulgaris* L.). Moreover, [13] reported the adverse effect of salinity on shoot fresh and dry weights and a reduction of 60-63% shoot fresh weight of soybean due to salt stress. The current result also showed high relative reduction in shoot (69.4%) and root (63.6%) dry weights due to salt stress. However, the reduction in shoot dry weight was more than root dry weight (Table 2). Similar results were reported by [12] in their studies of salinity effect on sugar beet and cabbage. In the current study, root length was not affected by salt stress whereas root dry weight was significantly affected. This indicates that the effect of salinity on root dry weight in our experiment might be resulting more from its effect on root branching rather than root length. Among all growth parameters root/shoot dry weight ratio showed an increase due to salt stress (Table 2). Similar to this result, [16] reviewed an increase in this parameter due to salt stress in cotton and [2] on bean (*Phaseolus vulgaris* L.). The increase in root/shoot dry weight ratio can be explained by the higher reduction in shoot dry weight than root dry weight under salt stress.

In the current study the interaction between genotype and treatment and the treatment effects on the number of dead leaves were not significant after six and thirteen days of salt stress; however, genotypes showed significant differences after thirteen days of salt stress. This may indicate that the effect of salt stress on the senescence of potato leaves may not be observed until six to thirteen days after salt stress. On the other hand, the interaction between genotype and treatment and treatment effects on the number of living leaves after six days of salt stress were not significant but, significant interaction effects were observed after thirteen days of salt stress. Strong positive correlations ( $r = 0.75$  control,  $r = 0.68$  salt treated) were also observed between total number of living leaves and new leaves developed between six to thirteen days after salt stress (data not shown). This result suggests that the differences in the total number of living leaves between treatments is due to

the differences in the number of new (young) leaves developed between six to thirteen days after salt stress. A reduction of 32.8% in number of living leaves was observed after thirteen days of salt stress relative to the control. In agreement with this result, a significant reduction in number of leaves due to salt stress was also reported by [12] on sugar beet and cabbage. Furthermore, the effect of salinity in reducing leaf area is greater than its effect on the total number living of leaves (Tables 2). Thus, maintaining high leaf area is more important than number of leaves for salinity tolerance, since the correlation between leaf area and growth parameters is strong, but weak correlations were observed between total number of living leaves and growth parameters (data not shown).

## CONCLUSION

Genotypes showed high reduction in growth parameters in response to salt stress. The highest reduction was observed for shoot fresh weight and leaf area. Under hydroponics condition root length was not affected by salt stress. Although high reduction in growth parameters was observed in response to salt stress, there was high genetic variability in this potato population. Moreover, high heritability was observed under salt stress than control condition. Until thirteen days after salt stress, no effect was observed on the number of dead leaves. This indicates that the effect of salt stress on leaf senescence of the potato genotypes may be observed later than the specified period of stress. The effect of salt stress on number of living leaves was not observed till six days after salt stress. This parameter was affected by salinity after a stress period of thirteen days. This suggests that salt stress affects development of new (young) leaves in the potato genotypes later than six days of salt stress. Finally, the study suggests further study on evaluation of the genotypes under various salinity level and the presence of substances involved in osmotic adjustment. Furthermore, studying the association between salt tolerance and analysis results of tissue  $\text{Na}^+$  and  $\text{K}^+$  may give information whether the salt tolerance is due to the tolerance to  $\text{Na}^+$  concentration or exclusion of this ion.

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