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Effect of Temperature, Iso-Osmotic Concentrations of NaCl and PEG Agents on Germination and Some Seedling Growth Yield Components in Rice (*Oryza sativa* L.)

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Abstract: This study was conducted to evaluate seed performance under controlled condition and main aim is to show the effects of NaCl, polyethylene glycol (PEG)-8000, temperature (20, 25 and 30°C) and their interactions on Seed Germination (SG) and Seedling Growth (SDG) of a single rice (*Oryza sativa*) cultivar which is the name of Kalat. It was obtained from one field harvested in 2008. Seeds were treated with the iso-osmotic concentrations of NaCl or PEG (0, -0.2, -0.4, -0.6 and -0.8 MPa) and exposed to the three temperatures (Namely, 20, 25 and 30°C) for 10 days. There were significant solution types (NaCl or PEG)×temperature×osmotic potentials interactions ($p<0.05$) on the FG, the Germination Rate (GR), the Radicle Length (RL), the Hypocotyl Length (HL), the Seedling Dry Weight (SDW) and the Fresh Weight (FW) indicating that the rice seeds responded differently to salt, drought and temperature changes. The highest values of germination parameters were obtained with no osmotic potential (0 MPa) and increases in osmotic potential either by NaCl or PEG inhibited germination indices. The results indicated that the reduction of germination characteristics was much greater for the PEG induced stress compared to the NaCl induced stress at all osmotic and all thermal levels. In addition, the rice seeds exhibited strong effect of change in temperature on germination characteristics. The deleterious effect of NaCl and PEG was more pronounced at 20 and 30°C compared to 25°C. The examined rice cultivar was more tolerant of NaCl salinity and water stress stimulated by the PEG in the germination stage than in the seedling developmental phase.

Key words: NaCl, PEG, osmotic stress, temperature, abiotic stress

INTRODUCTION

Plants are constantly confronted with various biotic and abiotic stress factors such as low or high temperature, salt, drought, flooding, heat, oxidative stress and heavy metal toxicity (Mahajan and Tuteja, 2005; Achuo *et al*., 2006; Jaleel *et al*., 2007). Climate change stemmed from anthropogenic perturbations has led to accelerated occurrence of some stress factors. Among the stages of the plant life cycle, seed germination and seedling emergence and establishment are key processes in the survival and growth of plants (Hadas, 2004). Seeds and seedlings of plants are more prone to stress than adults due to being exposed to higher extreme environmental fluctuations at or near the soil surface (Dodd and Donovan, 1999). Out of the stress factors, drought and salinity are major abiotic constraints that pose serious threat to crop production throughout the world (Zhu, 2001; Hu and Schmidhalter, 2005; Soltani *et al*., 2006; Yang *et al*., 2007). It has been estimated that over 26 and 20% of cultivated lands worldwide are affected by drought and salinity stresses (Flowers and Flowers, 2005; Çiçek and Çakırlar, 2008). Moreover, salinity is responsible for degradation of 2 million hectares of world agricultural lands every year (Çiçek and Çakırlar, 2008). Salt stress is more acute in arid and semiarid regions (Sadat Noori and McNeilly, 2000; Al-Karaki, 2001; Villa-Castorena *et al*., 2003) where are typically featured by high evaporation rate, low rainfall, high water table and salty irrigation water.

Increasing salinity can influence seed germination by creating osmotic effect, which impedes seed water uptake or through toxic effects of specific ions such as Na^+, Cl^- and SO_4^{2-} (Al-Karaki, 2001; Tobe *et al*., 2003; Kaya *et al*., 2006; Shaikh *et al*., 2007). Resulting in both retardation or delayed seed germination (Song *et al*., 2006; Guan *et al*., 2009). Low water potential in soil medium caused by either soil salinity or water deficit, leading to late and inadequate germination and associated failure of stand establishment adversely affects crop productivity (Willenborg *et al*., 2005). NaCl as ionic stress agent and PEG as non-ionic stress agent have been widely used to study agronomic crops, halophytes and wild species response to salt and drought stresses during germination stage tomato

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(*Solanum lycopersicum* L.) mutants (Fellner and Sawhney, 2001); durum wheat (*Triticum durum* Desf.) (Almansouri *et al*., 2001) phaseolus (Jeannette *et al*., 2002); sorghum (*Sorghum bicolor* L.) (Kader and Jutzi, 2002); caldén (*Prosopis caldenia* Burk) (De Villalobos *et al*., 2002); oakleaf goosefoot (*Chenopodium glaucum* L.) (Duan *et al*., 2004); argentine screwbean (*Prosopis strombulifera*) (Sosa *et al*., 2005); oat (*Avena fatua* L.) (Willenborg *et al*., 2005); cowpea (*Vigna unguiculata* L.) (Murillo-Amador *et al*., 2006); sugar beet (*Beta vulgaris* L.) (Jafarzadeh and Aliasgharzad, 2007); rice (*Oryza sativa* L.) (Aqeel Ahmad *et al*., 2007). The PEG-induced inhibition of germination has been attributed to osmotic stress (Dodd and Donovan, 1999; Sidari *et al*., 2008). Temperature plays a crucial role in many biological and physiological processes of plants (Al-Ahmadi and Kafi, 2007; Berti and Johnson, 2008). The temperature changes have major impact on a number of processes which regulate seed germinability, including membrane permeability and the activity of membrane-bound as well as cytosolic enzymes (Tlig *et al*., 2008) and its interaction with the variable soil water content in the surface layers of the soil, where crop seeds are sown, is critically important in terms of germination onset and rate (Khan *et al*., 2000; Finch-Savage *et al*., 2001). Salinity-temperature interaction, in particular, determines seed germination pattern in many salt-affected environments (Khan and Gulzar, 2003; Al-Khateeb, 2006; Song *et al*., 2006). Rice (*Oryza sativa* L.) is the second main stable food in Iran following common wheat (*Triticum aestivum* L.). However, its production has been drastically decreased due to salinity and drought, especially in those areas that rice is directly sown into puddled and leveled soil. Rice (*Oryza sativa* L.) is considered as a salt sensitive crop compared to other cereals but its sensitivity to salinity varies greatly with developmental stage (Zeng and Shannon, 2000) and among cultivars (Quijano-Guerta and Kirk, 2002). Kalat cultivar used in this study is locally cultivated in the Northeastern parts of Iran which is currently experiencing difficulties with the soil salinization and frequent droughts. Therefore, it is necessary to evaluate the rice seeds response to such abiotic stresses.

The aim of this study is to investigate the effects of osmotic stress generated by NaCl or PEG and combined effects of these stress factors with temperature on germination characteristics and SDG of rice (*Oryza sativa* L.) cultivar during seed germination.

MATERIALS AND METHODS

This study was carried out at the Faculty of Agriculture, Islamic Azad University of Mashhad, Iran from May till August 2008. Seeds of Kalat cultivar were used in this study. It was provided from one field harvested in 2008 at Kalat region, Iran. Germination tests and seedling evaluation were performed according to ISTA guidelines (Kaya *et al*., 2006). Seeds were surfaced sterilized in 1% sodium hypochlorite solution for 1 min, then were rinsed two times for one minute with sterile distilled water (Alam *et al*., 2002). The experiment was a completely randomized design with a factorial arrangement consisting of two osmotic solutions (PEG or NaCl), five osmotic potentials (0, -0.2, -0.4, -0.6 and -0.8 MPa) and three constant temperature degrees (20, 25 and 30°C) with three replications. Osmotic potential levels for the PEG-8000 were obtained using the method described by Michel and Kaufmann (1973) and for the NaCl were created based on the van't Hoff's equation (Ben-Gal *et al*., 2009):

$$\Pi = iMRT$$

where, Π is osmotic potential (MPa), i is the van't Hoff factor (moles of particle in solution per moles of dissolved solute), M is molarity of the solute (mol L^{-1}), R is the universal gas law constant (8.314×10^{-6} m^{-3} MPa mol^{-1} K^{-1}) and T is temperature (298K).

Twenty rice seeds were placed and germinated into sterilized petri dishes (Π= 9 cm) on Whatman No.1 filter paper. Each petri dish was moistened with 10 mL of distilled water (control) or the respective test solutions (Song *et al*., 2006). The Petri dishes were covered with lids and placed in incubators in the dark at the 20, 25 and 30°C (Guan *et al*., 2009). The solutions (the NaCl and PEG-8000) were changed every other day to keep the primary water potential. Germination counting was done at 24 h intervals for 10 days (Kaya *et al*., 2008). Seeds were considered as germinated when radicle had protruded 2 mm through the seed coat. After 10 days of incubation, FG (%), GR (seeds day^{-1}), RL (mm), HL (mm), seedling FW (g $seedling^{-1}$) and DW (g $seedling^{-1}$) were determined (Murillo-Amador *et al*., 2002). Rate of germination (seeds day^{-1}) was estimated using Maguire`s equation (Pezzani and Montana, 2006):

$$Rs = \sum Si/Di$$

where, Rs is GR (the number of germinated seeds per day), Si is the number of germinated seeds at each counting and Di is number of days until the nth count. Dry weights of seedlings (g $seedling^{-1}$) were measured after drying samples at 70°C for 48 h in an oven (Okçu *et al*., 2005).

After completion of the germination tests non-germinated seeds were transferred to distilled water at the initial temperatures for further 5 days to determine the toxic effects of the solutions on germination (Khan *et al*., 2001). The obtained data were analyzed using the MSTAT-C statistical software and the differences between means were compared by Duncan's multiple range at probability level of 5% (Jafarzadeh and Aliasgharzad, 2007).

RESULTS AND DISCUSSION

Germination: Results of the analysis of variance (ANOVA) for the FG and GR showed that there were significant differences between all treatments and their interactions, except solutions×temperature interaction for the FG (Table 1). At 20°C under -0.8 MPa, NaCl and PEG treatments, the FG was declined to 49.9 and 90% of control, respectively, while at 25°C under -0.8 MPa NaCl and PEG concentration 88 and 50% of seeds germinated, respectively. The decrease in the FG under the highest level of NaCl was 25% of control treatment at 30°C, while this value under PEG treatment was 85% of control (Table 2). Transfer of non- germinated seeds from PEG solution to the distilled water resulted in 100% germination recovery at all temperatures and osmotic potential levels. But there was little germination recovery for the NaCl solution, particularly at the 20 and 30°C under the moderate and highest salinity levels (data not shown). At the 25°C and osmotic potential of -0.8 MPa, the GR of NaCl-treated seeds was 3.9 seeds day^{-1}, while the GR of PEG-treated seeds was 1.2 seeds day^{-1}. At 30 and 20°C under -0.8 Mpa NaCl the GR was 2.2 and 0.6 seed day^{-1}, respectively. For -0.8 MPa, PEG treatment on the GR was 0.2 and 0.1 seeds day^{-1} at the 30 and 20°C, respectively (Table 3).

Seedling growth: The ANOVA for the RL and HL parameters showed that all factors and all interactions were significant (Table 4). The reduction in the RL at the 25°C under the moderate and highest osmotic potentials of NaCl (-0.4 and -0.8 MPa) varied between 18 and 32% of control treatment, while at the same temperature and comparable osmotic potentials in the PEG the reduction varied between 50 and 75% of control treatment, respectively. At the 20 and 30°C under the -0.4 MPa PEG, the RL was decreased by approximately 62% when it was compared with their respective control treatments. Also at the 20 and 30°C under -0.4 MPa, NaCl the decrease of the RL varied between 39 and 42% of their respective control treatments (Table 5). The NaCl treatment at the 25°C under osmotic potentials of the -0.4 and -0.8 MPa, declined the HL to 28.1 and 54.3% of control treatment, respectively, while the PEG treatment at similar temperature and comparable osmotic potentials declined the HL to 70.2 and 85.1% of control. -0.4 MPa, NaCl stress at the 20 and 30°C decreased the HL by about 47.1 and 43.4% of their respective control treatments, while -0.4 MPa, the PEG stress at the 20 and 30°C caused a reduction of 77.5 and 84% in the HL when it was compared with their respective control treatments. Moreover, no the HL was recorded at the 20°C above osmotic potential of -0.4MPa, the PEG and at the 30°C at the -0.8MPa, the PEG solution (Table 6).

Seedling weight (g $seedling^{-1}$): The ANOVA for the seedling FW and DW showed significant differences between all factors and their interactions except temperature×osmotic potential for the SDW (Table 7). The decrease in the seedling FW at the 25 and 30°C under the

Table 1: Variance analysis results of the seed germination and germination rate in used rice cultivar

		Germination percentage			Germination rate		
SOV	df	MS	F-value	p-value	MS	F-value	p-value
Solutions (A)	1	8313.611	135.42	0.0000*	36.226	551.88	0.0000*
Temperature (B)	2	5143.611	83.78	0.0000*	51.636	786.66	0.0000*
Osmotic potential (C)	4	7467.639	121.64	0.0000*	54.718	833.61	0.0000*
A×B	2	116.944	1.90	0.1577	1.135	17.28	0.0000*
A×C	4	1743.472	28.40	0.0000*	2.391	36.42	0.0000*
B×C	8	297.431	4.84	0.0001*	0.938	14.28	0.0000*
A×B×C	8	145.764	2.37	0.0272*	0.373	5.68	0.0000*
Error	60	61.389			0.066		

*Significant at p-value of 0.05

Table 2: Effects of NaCl, PEG and temperature on germination percentage (%)

	NaCl			PEG		
Osmotic potential (MPa)	20°C	25°C	30°C	20°C	25°C	30°C
0	93.33^{ab}	100.00^{a}	100.00^{a}	93.33^{ab}	100.00^{a}	100.00^{a}
-0.2	80.00^{bcd}	95.00^{ab}	83.33^{bcd}	73.33^{def}	95.00^{ab}	86.66^{abcd}
-0.4	76.66^{cde}	91.66^{ab}	76.66^{cde}	41.66^{ij}	86.66^{abcd}	65.00^{efh}
-0.6	55.00^{ghi}	90.00^{abc}	76.66^{cde}	25.00^{k}	60.00^{fgh}	38.33^{j}
-0.8	46.66^{hij}	88.00^{abcd}	75.00^{cde}	10.00^{l}	50.00^{hij}	15.00^{kl}

Means with similar superscript letter(s) are not significantly different ($p<0.05$)

Table 3: Effects of NaCl, PEG and temperature on germination rate (seeds day^{-1})

	NaCl			PEG		
Osmotic potential (MPa)	20°C	25°C	30°C	20°C	25°C	30°C
0	4.24^{ef}	6.56^{a}	6.76^{a}	4.24^{ef}	6.56^{a}	6.76^{a}
-0.2	3.19^{h}	6.10^{b}	5.86^{bc}	2.06^{j}	4.98^{d}	4.22^{ef}
-0.4	2.43^{ij}	5.46^{c}	4.3^{ef}	0.84^{l}	3.65^{g}	2.71^{i}
-0.6	1.48^{k}	4.48^{e}	3.50^{gh}	0.58^{lm}	2.31^{ij}	1.51^{k}
-0.8	0.65^{lm}	3.90^{fg}	2.24^{j}	0.14^{n}	1.27^{k}	0.29^{mn}

Means with similar superscript letter(s) are not significantly different ($p<0.05$)

Table 4: Variance analysis results of the radicle and hypocotyl lengths in used rice cultivar

		Radicle length			Hypocotyl length		
SOV	df	MS	F-value	p-value	MS	F-value	p-vale
Solutions (A)	1	4736.427	151.53	0.0000*	3369.672	313.38	0.0000*
Temperature (B)	2	19023.969	608.64	0.0000*	5659.136	526.30	0.0000*
Osmotic potential (C)	4	5521.033	176.63	0.0000*	4106.862	381.93	0.0000*
A×B	2	819.768	26.22	0.0000*	319.478	29.71	0.0000*
A×C	4	360.307	11.52	0.0000*	246.717	22.94	0.0000*
B×C	8	372.395	11.91	0.0000*	271.471	25.24	0.0000*
A×B×C	8	71.320	2.28	0.0333*	32.379	3.011	0.0066*
Error	60	21.256			10.753		

*Significant at p-value of 0.05

Table 5: Effects of NaCl, PEG and temperature on radicle length (mm)

	NaCl			PEG		
Osmotic potential (MPa)	20°C	25°C	30°C	20°C	25°C	30°C
0	27.53^{efg}	92.96^{a}	75.26^{b}	27.53^{efg}	92.96^{a}	75.26^{b}
-0.2	20.73^{fghi}	88.36^{a}	63.53^{c}	17.10^{ghij}	68.96^{bc}	47.93^{d}
-0.4	15.96^{hijk}	75.93^{b}	45.70^{d}	10.53^{jkl}	46.33^{d}	29.23^{ef}
-0.6	12.13^{ijk}	69.03^{bc}	34.33^{e}	7.96^{jkl}	32.56^{e}	17.46^{ghij}
-0.8	9.33^{jkl}	63.16^{c}	27.36^{efg}	1.40^{l}	22.66^{fgh}	6.13^{kl}

Means with similar superscript letter(s) are not significantly different ($p<0.05$)

Table 6: Effects of NaCl, PEG and temperature on hypocotyl length (mm)

	NaCl			PEG		
Osmotic potential (MPa)	20°C	25°C	30°C	20°C	25°C	30°C
0	21.76^{h}	62.36^{a}	59.70^{a}	21.76^{h}	62.36^{a}	59.70^{a}
-0.2	14.43^{ij}	53.80^{b}	41.00^{cd}	9.76^{jkl}	38.70^{de}	21.36^{h}
-0.4	11.50^{jk}	48.83^{c}	33.80^{ef}	4.90^{lm}	18.60^{hi}	9.23^{jkl}
-0.6	7.86^{kl}	37.80^{de}	23.93^{gh}	0.00^{m}	13.73^{ijk}	5.16^{lm}
-0.8	4.5^{lm}	28.53^{fg}	14.33^{ij}	0.00^{m}	9.30^{jkl}	0.00^{lm}

Means with similar superscript letter(s) are not significantly different ($p<0.05$)

highest NaCl level ranged between 39 and 58% of their respective control treatments, while for the PEG stress at the 20 and 30°C under the highest concentrations the decrease was about 91% of their respective control treatments. At the 20°C, a 52 and 67% decrease in the seedling FW was observed in the moderate osmotic potentials of the NaCl and the PEG (-0.4 MPa), respectively (Table 8).

At the 25 and 30°C the highest osmotic potential of the NaCl resulted in a reduction in the SDW by only about 19% when it was compared with their respective control treatments, while the decrease in the SDW at the 25 and 30°C under the highest PEG level fluctuated between 42 and 83% of control treatment. At the 20°C, the SDW exhibited a decrease of 40% at -0.8 MPa, NaCl, while the PEG at similar temperature and comparable osmotic potential diminished the SDW by 85% of control (Table 9).

Overall, the application of the NaCl and PEG at different thermal levels decreased germination characteristics. Considerable variation in the rice SG response to temperature alterations and solute type was observed. Temperature and osmotic moist stress interacted with one another in the germination of rice seed. Germination indices were less affected at the 25°C, particularly under salinity stress and any decrease or increase from this level was associated with accelerated effects of two stress factors. This indicates that, moving away from optimal to over-optimal or sub-optimal germination temperature significantly increases of the rice sensitivity to salt or drought stress. This observation is consistent with the studies on a range of plant species such as red swampfire (*Salicornia rubra*) (Khan *et al*., 2000); carrot (*Daucus carota* L.) (Finch-Savage *et al*., 2001); kochia (*Kochia scoparia*) (Khan *et al*., 2001); globe artichoke (*Cynara carduncculus*) (Mauromicale and Licandro, 2002); canola (*Brassica napus* L.) (Willenborg *et al*., 2004); mesquite (*Prosopis juliflora*) (El-Keblawy and Al-Rawai, 2005); desert grass (*Panicum turgidum* Forssk) (Al-Khateeb, 2006); alfalfa (*Medicago ruthenica* L.) (Guan *et al*., 2009) where the injury effects of NaCl or PEG are generally less severe at optimum temperature. It can be proposed that enzymatic functions of seeds are more sensitive to stressful condition when temperature is not convenient. Furthermore, higher temperature could promote ions activities especially Na^+ and Cl^- which results in ions fluxes through cell

Table 7: Variance analysis results of the seedling fresh and dry weights in used rice cultivar

		Seedling fresh weight			Seedling dry weight		
Source of variation	df	M.S	F	p-value	M.S	F	p-value
Solutions (A)	1	1.326	207.03	0.0000*	0.125	96.59	0.0000*
Temperature (B)	2	4.958	386.94	0.0000*	0.194	149.94	0.0000*
Osmotic potential (C)	4	7.840	305.92	0.0000*	0.115	88.61	0.0000*
A×B	2	0.241	18.84	0.0000*	0.004	3.34	0.0419*
A×C	4	0.492	19.20	0.0000*	0.024	18.22	0.0000*
B×C	8	0.166	3.23	0.0040*	0.002	1.84	0.0856
A×B×C	8	0.113	2.20	0.0392*	0.003	2.12	0.0468*
Error	60	0.384			0.001		

*Significant at p-value of 0.05

Table 8: Effects of NaCl, PEG and temperature on seedling fresh weight (g seedling^{-1})

Osmotic	NaCl			PEG		
potential (MPa)	20°C	25°C	30°C	20°C	25°C	30°C
0	0.88^{def}	1.53^{a}	1.28^{b}	0.88^{def}	1.53^{a}	1.28^{b}
-0.2	0.51^{i}	1.22^{b}	0.91^{cde}	0.41^{ijkl}	1.01^{cd}	0.77^{fgh}
-0.4	0.42^{ijk}	1.18^{b}	0.83^{efg}	0.28^{klm}	0.73^{gh}	0.47^{ij}
-0.6	0.32^{klm}	1.04^{c}	0.67^{h}	0.20^{mn}	0.48^{ij}	0.31^{klm}
-0.8	0.27^{lm}	0.91^{cde}	0.53^{i}	0.08^{n}	0.34^{jklm}	0.10^{n}

Means with similar superscript letter(s) are not significantly different (p<0.05)

Table 9: Effects of NaCl, PEG and temperature on seedling dry weight (g seedling^{-1})

Osmotic	NaCl			PEG		
potential (MPa)	20°C	25°C	30°C	20°C	25°C	30°C
0	0.34^{def}	0.47^{a}	0.46^{a}	0.34^{def}	0.47^{a}	0.46^{a}
-0.2	0.31^{fg}	0.46^{a}	0.44^{ab}	0.27^{gh}	0.45^{a}	0.42^{abc}
-0.4	0.30^{fg}	0.44^{ab}	0.43^{abc}	0.24^{hi}	0.37^{cd}	0.35^{def}
-0.6	0.24^{gh}	0.42^{abc}	0.39^{bcd}	0.19^{i}	0.31^{efg}	0.27^{gh}
-0.8	0.20^{il}	0.38^{cd}	0.37^{cde}	0.05^{j}	0.27^{gh}	0.08^{j}

Means with similar superscript letter(s) are not significantly different (p<0.05)

membrane and the increased risk of toxicity to seed germination process. High osmoticum levels such as the PEG agent, high salinity and low temperature impair water absorption and transport in seeds (Fellner and Sawhney, 2001).

The inhibition of GR was stronger at different levels of the NaCl and PEG solutions compared to the FG percentage. This result corroborates other studies showing that osmotic stress primarily reduces rate of germination rather than germination percentage (Alam *et al*., 2002; Atak *et al*., 2006; Kaya *et al*., 2008). Velocity of the reduction in the values of germination and seedling growth of rice was more profound under the PEG solute than the NaCl, irrespective of temperature changes. Similar results were found in durum wheat (*Triticum durum* Desf.) by Almansouri *et al*. (2001) in cowpea (*Vigna unguiculata* L.) by Murillo-Amador *et al*. (2002) in saxaul (*Haloxylon ammodendron*) by Tobe *et al*. (2004) in pea (*Pisum sativum* L.) by Okçu *et al*. (2005) and in sunflower (*Helianthus annuus* L.) by Kaya *et al*. (2006). Tobe *et al*. (2004) and Kaya *et al*. (2006) mentioned that the uptake of external ions (Na^+, Cl^-) by the seed, maintaining a water potential gradient which allows water uptake during seed germination under NaCl stress. Salt and drought stress inhibited the growth of hypocotyl more than radicle. This observation is supported by other studies on corn (*Zea mays* L.) (Parmar and Moore, 1968); rice (*Oryza sativa* L.) (Alam *et al*., 2002); Phaseolus (Jennertte *et al*., 2002); triticale (x Triticosecale Wittmack) (Atak *et al*., 2006). Parmar and Moore (1968) attributed less adverse effects of the NaCl and PEG on radicle growth to the greater dependence of the radicle on the seed reserve storage and less dependence on water uptake. However, these findings are inconsistent with those of Jamil *et al*. (2007) who, observed that the reduction in RL of radish seeds by increased salinity was more prominent compared to the HL. It appears that in most crop seeds such as corn (*Zea mays* L.), pea (*Pisum sativum* L.) and rice (*Oryza sativa* L.) HL is more adversely affected than RL by both toxic and osmotic effects as compared to other plants.

The results of this study showed a greater inhibition of HL and RL in comparison to germination phase by decreasing osmotic potential with NaCl and PEG induced stress. This is in conformity with findings from Khajeh Hosseini *et al*. (2002) in soybean; Okçu *et al*. (2005) in pea (*Pisum sativum* L.) (2005) and Kaya *et al*. (2008) in chickpea (*Cicer arietinum* L.) who observed that NaCl or PEG had greater inhibitory effects on seedling development than germination. Khajeh Hosseini *et al*. (2002) and Alam *et al*. (2002) suggested that cell division, which is a post-germination phenomenon responsible for seedling elongation and development, is more sensitive to the NaCl or PEG compared to cell expansion, which drives germination. The seedling FW (g seedling^{-1}) and DW (g seedling^{-1}) were diminished as a result of decrease in seedling growth under osmotic stress. However, the DWs were less affected than fresh weights in the NaCl and PEG. Murillo-Amador *et al*. (2002) in cowpea (*Vigna unguiculata* L.) reported that the SDW decreased with lower magnitude compared to the seedling FW under varying levels of NaCl and PEG.

In conclusion, the results of this study revealed that the rice (*Oryza sativa* L.) germination was very responsive to temperature alterations and temperature was main source of variation of the SDG. This is important in terms of predicting germination time under variable conditions of the temperature and soil moisture (Finch-Savage *et al*., 2001) which would be helpful for farmers in taking management decisions. On the one hand, below temperature values of the 20°C in combination with osmotic stress greatly reduced the FG percentage and the GR as well as the SDG. On the other hand, increasing temperature from 25 to 30°C accentuated the deleterious effects of the osmotic stress on the measured traits. Best germination value was obtained at 25°C. Moreover, used rice cultivar in this study was better able to cope with salinity stress during the germination and SDG stages when the optimal temperature of the 25°C prevailed. On the other hand, seed germination was found to be less sensitive to the NaCl and PEG agents than subsequent stages. Furthermore, investigated all germination parameters responses to the PEG treatment appeared to have been osmotically induced, rather than toxic effects of the NaCl.

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