Research Article

Comparative Effects of NaCl and Polyethylene Glycol on Seed Germination of Four Native Species for Landscaping under Arid Environment

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Abstract | Due to the increasing scarcity of water, the trend is shifting towards using indigenous species for sustainable landscaping. In this study, we evaluated the germination response under osmotic stresses for four native species i.e. *Atriplex leucoclada, Senna italica, Tetraena mandavillei* and *Tephrosia apollinea*. Two osmotic agents (OA) i.e. NaCl and PEG 6000 and four osmotic levels (OL) i.e. 0, -0.2, -0.4 and -0.6 MPa were tested for each species. Data was collected for different germination traits including germination percentage, germinating index, mean daily germination, mean germination time, promptness index, germination stress tolerance index, coefficient of velocity of germination and germination rate. Osmotic stress significantly decreased most of the germination traits, while mean germination time increased with decreasing OL in all four species. *A. leucoclada* showed significant interactive effect of OA and OL for GP. GP of *A. leucoclada* was higher in PEG treatment but decreased at -0.6 MPa while NaCl had the lower GP but did not show any decrease with decreasing OL of NaCl. Contrary to this *S. italica* was adversely affected by PEG as compared to NaCl. Decreasing OL also decreased the GP of *S. italica*. *T. apollinea* and *T. mandavillei* were found to be resistant to both iso-osmotic conditions of PEG and NaCl. However, GP of *T. apollinea* and *T. mandavillei* decreased with decreasing OL. *T. apollinea* and *T. mandavillei* stood out as the best under both induced salt and drought stress at the germination stages. It is concluded that all four-selected species successfully germinated under maximum osmotic potential understudy which is not suitable for landscape species. All four investigated species can be further evaluated for field performance under stress conditions so can be recommended for mass vegetation and as a substitute to exotic landscaping species.

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Introduction

Landscaping in hot-arid environments faces many environmental stresses like salt and water stress. The rapid urbanization in various parts of the globe has increased the urban water demand especially for domestic and landscape consumption (Wu and Tan, 2012). Water demand will increase even more due to increase in temperature and evaporation because of climatic change (Alam et al., 2017).

The UAE has sub-tropical climate and limited water resources and is highly susceptible to climate change impacts as water resources are deficit and temperature is expected to increase in coming few years (Zamin et al., 2019). Landscape and forest plantation in UAE annually consume about 709 million m^3 of water for irrigation (Shahin and Salem, 2014). 70% of the country main source is ground water on the other hand, this source is non-renewable and was predictable to vanish in next 16 to 36 years (Shahin and Salem, 2015; EAD, 2009). The major future concern related to the green sector in the UAE is the increasing water requirements for landscaping sector while the groundwater supply being vanished (Shahin and Salem, 2014).

As water scarcity problem is increasing, trend is shifting towards water efficient landscaping (Paine et al., 1992). Green sector depends mostly on imported exotic species which are mostly from the temperate and semi-temperate regions. These plants are difficult to adopt in arid environment (Alam et al., 2017). These exotic species have adverse impacts on ecosystem and community characters, as production of these exotic species requires high amount of water to grow and survive (EAD, 2009). As water scarcity problem is increasing, landscaping with native and indigenous plants is getting increased importance due to their lower water requirements and associated ecological benefits (Alam et al., 2017; Bhat et al., 2009).

The use of stress tolerant native plants is an important component of water conserving- landscape (Paine et al., 1992). Bodle (2001), Haehle (2004) and Hostetler et al. (2003) suggested that native species should outperform then exotic species in their native habitat. Native plants have potential to resist stress conditions (Hopkins and Al-Yahyai, 2015). Native plant species exhibit the ability to adjust or grow under salt and water conditions as compared to their cultivated relatives (Zamin and Khattak, 2018; Fiedler, 2006; Stephens et al., 2006; Ochoa et al., 2009; Morales et al., 2001) e.g. ornamental characteristics of cultivated and wild *Limonium* spp. differently affected by salt stress (Morales et al., 2001). However, species performance for native plants is unknown in maintained landscapes (Anella, 2000).

Salt and water stress delay the seed germination (Bajji et al., 2002) as well as affect germination percentage (Delachiave and Pinho, 2003). Each species has specific value of water potential below which germination does not occur (Bewley and Black, 1994). A saline soil is that one when electrical conductivity (EC) of the saturation extract (ECe) in the root zone exceed 4 dS m^{-1} (approximately 40 mM NaCl) at 25 °C and has exchangeable sodium of 15%. Most crop plants reduce growth and yield at this ECe (Munns, 2005; Jamil et al., 2011; Richards, 1954).

Controlled laboratory environment is more appropriate to evaluate and improve stress tolerance of large population prior to field testing (Almaghrabi, 2012). This will also help to standardize propagation techniques which are still unknown for most of the native plant species (Alam et al., 2017). Osmotic potential had significant effect on germination and seedling growth traits, which can be used to differentiate between sensitive and tolerance cultivars under osmotic stress. Osmotic stress can be due to salt and drought which can be created in laboratory using NaCl and Polyethylene glycol 6000 (PEG 6000) (Kalefetogllu et al., 2009).

Both salt and water stress may have an impact on the minerals mobilization (Bajji et al., 2002). The negative effects of salt stress on germination were also supposed to be related to its osmotic component rather than salt toxicity (Bajji et al., 2002; Kaya et al., 2006). However, Kaya et al. (2006) reported higher germination percentage and mean germination time in PEG than in NaCl. *Zygophyllum simplex* seeds were moderately salt tolerant during germination (Khan and Ungar, 1997a). Additionally, seeds of *Zygophyllum qatarense* reduced germination rate and final germination percentage by increasing salinity (Khan and Ungar, 1997b). However, no significant difference occurred between the effects of NaCl and Mannitol solutes on germination percentages of *Atriplex halimus*. Published work suggest that some species are affected either by NaCl or PEG, while some other species affected by both. However, most of the studies relate to results on individual species (Khalid and Cai, 2011; Okçu et al., 2005).

In the current experiment, several wild species were assessed together under different levels of iso-osmotic salt (NaCl) and water (PEG) stress. Germination responses of different species were compared. The main objective was to evaluate the germination behavior of pre-selected species under salt and water stress condition before recommending them for mass vegetation and as a substitute to exotic landscaping species.

Materials and Methods

Study area, plant selection and seed collection

Plant species both from Pakistan as well as UAE were assessed for their government and municipalities recommendations, survival rate, habitat, growth rate, life forms, inflorescence and customer demand. Plant species most suitable for landscaping and supposed to have salt and water stress tolerant were selected for germination studies. Fresh mature seeds of selected shrubs were collected from wild population of UAE during 2016-2017. The trial was conducted at Plant Physiology Lab, Department of Biology, UAE University, Al Ain, Abu Dhabi, UAE. Native plant species were pre-evaluated for germination trial under salt and water stress conditions. Four plant species that germinated well contrary to exotic glycophytes in stress conditions were selected for this experiment.

Preparation of osmotic solutions

Four osmotic levels (OL; S0, S1, S2, and S3 of 0 (control), -0.2, -0.4 and -0.6 MPa; respectively) of two osmotic agents (OA; i.e. NaCl and PEG 6000) were used for germination test. Four different concentrations of NaCl i.e. 0, 50, 100, 150 mM were used to get solution of desired osmotic potential, which was confirmed in an automatic cryoscopic osmometer (Osmomat 030 Model; Gonotec, Berlin, Germany). The S0 level represent the control, S1 level represent the lowest salinity in irrigation water, S2 is the existing level in the farmer's fields, S3 is the maximum salinity level suggested by the extension services. Polyethylene glycol (PEG 6000) solutions of different osmotic levels similar to NaCl were prepared by adding PEG 6000 using Michel and Kaufmann (1973) equation.

$$\Psi os = [-(1.18x10^{-2})\ C - (1.18\ x10^{-4})\ C^2 + (2.67x10^{-4})\ CT + (8.39X\ 10^{-7})\ C^2 T]/10$$

Where;

Ψos = osmotic potential (MPa); C= osmotic agent concentration (grams of PEG 6000/liter of water); T = temperature (^{o}C).

Seed germination studies

Seeds were initially treated for few seconds with 1.0 percent mercuric chloride solution. In each petri dish a twofold layer of blotting paper was used and thereafter 25 mature seeds of equal size of each species were placed at similar distances from each other on blotting paper. A solution of 10 ml of respective treatment was added in each petri dish. These petri dishes were then kept in an incubator at 25 ^{o}C. Germination was counted when the radicle length was 2 mm. Three grams of the seeds were placed in petri dishes for each treatment solution. After 24 hours, seeds were re-weighed to calculate water absorption or imbibition rate (Heather et al., 2010).

Parameters studied

Parameters studied during the experiment are presented in Table 1.

Experimental design

The experiment was conducted in two factors split plot (2 X 4) design with Randomized Complete Block Design (RCBD) arrangement for each species. The experiment was replicated thrice and 25 seeds per replicate. First factor was osmotic agent (OA; i.e. NaCl and PEG), the second was osmotic level (OL; 0, -0.2, -0.4, -0.6, MPa). For statistical analysis, the data was transformed to square roots as x= $\sqrt{X/100}$ to meet variance assumptions. Data was subjected to analysis of variance (ANOVA) procedures (SAS Institute Inc., 1988) and LSD test was applied at 5% probability level to compare the differences among treatment means.

Results and Discussion

A. leucoclada

Local/ Arabic name: Ragal: GP and PI were significantly ($P \leq 0.05$) affected by the OA and OL interaction. MGT and CVG were significantly ($P \leq 0.05$) affected only by OL. GI, MDG, GSI and GR were significantly ($P \leq 0.05$) affected both by OA and OL. GP and PI was higher for PEG treatment as compared to NaCl. However, decreased in above parameters due to decreasing OLs was more in PEG as compared to decrease in NaCl. GI, MDG, GSI and GR were higher for PEG than the NaCl treatment and decreased with decreasing OLs. MGT increased with decreasing OLs and CVG decreased with decreasing OLs.

The GP showed significant interaction ($P \leq 0.05$) for OA*OL (Table 2). Highest GP was recorded for control (98.89%) followed by control 96 % for PEG -0.2 MPa, while the lowest GP was 22.22% recorded at NaCl -0.6MPa (Figure 1b). The Germination Index was significantly affected by OA and OL at $P \leq 0.05$ (Table 2). Overall, GI was higher for PEG

Table 1: *Parameters studied during experiment.*

S. No	Parameter	Formula	Description	Reference
1	Imbibition rate (IR)	IR = (Wf – Wi)/Wi x 100	IR = imbibition rate, Wi = Initial weight of the seeds and Wf= Final weight of the seeds.	(Heather et al., 2010)
2	Germination Percentage (GP)	GP= Ng / Nt x 100	Ng=Total number of seeds germinated, Nt=Total number of seeds.	(Kader, 2005)
3	Germination index (GI)	GI = Σ(Gt/Tt)	Gt is number of the germinated seeds in the t day, Tt is time corresponding to Gt in days	(Hu et al., 2005)
4	Mean daily germination (MDG)	MDG=GP / d,	GP = Germination percentage, d = maximum days to final germination	(Almaghrabi, 2012).
5	Mean germination time (MGT)	MGT= Σn.D /Σn	n= number of seeds newly germinated on day D, D= days counted from start of trial, Σn= final germination	(Ellis and Roberts, 1980)
6	Promptness index (PI)	PI = nd2 (1.0) + nd4 (0.8) + nd6 (0.6) + nd8 (0.4) + nd10 (0.2)	Where nd2, nd4, nd6, nd8 and nd10 shows percentage seeds germinated after 2, 4, 6, 8, and 10 days.	(Sapra et al., 1991).
7	Germination stress tolerance index (GSI)	GSI. (%) = [P.I of stressed seeds / P.I control seeds] x 100	Where GSI = Germination stress tolerance index, P.I. = Promptness index	(Bouslama and Schapaugh, 1984)
8	Coefficient of Velocity of Germination (CVG)	CVG=ΣNi / ΣNiTi x 100	Ni is the number seeds germinated on each day, Ti is number of days from beginning of experiment	(Scott et al., 1984).
9	Germination rate (GR)	GR=Timson germination index = ΣG/t,	"G" is seed germination percentage at two days' interval and "t" is total germination time (days)	(Damalas et al., 2019)

Table 2: *Mean square (from ANOVA analysis) for different germination parameters (IR: Imbibition Rate; GP: Germination Percentage; GI: Germination Index; MDG: Mean Daily Germination; MGT: Mean Germination Time; PI: Promptness Index; GSI: Germination Stress Tolerance Index; CVG: Coefficient of Velocity of Germination; GR: Germination Rate) for A. leucoclada. Significance (*) was assessed at P≤0.05.*

Source	Mean squares								
	IR	GP	GI	MDG	MGT	PI	GSI	CVG	GR
OA	0.00	1.51593*	0.05563*	0.09646*	0.00006	1.10138*	0.49127*	0.00797	0.09646*
OL	0.000376	0.81203*	0.06165*	0.14821*	0.00515*	1.02941*	1.67966*	0.08533*	0.14821*
OA*OL	0.00	0.25951*	0.00745	0.01804	0.00021	0.16481*	0.08067	0.0051	0.01804

Table 3: *Mean square (from ANOVA analysis) for different germination parameters (IR: Imbibition Rate; GP: Germination percentage; GI: Germination Index; MDG: Mean Daily Germination; MGT: Mean Germination Time; PI: Promptness Index; GSI: Germination Stress Tolerance Index; CVG: Coefficient of Velocity of Germination; GR: Germination Rate) for S. italica. Significance (*) was assessed at P≤0.05.*

Source	Mean squares								
	IR	GP	GI	MDG	MGT	PI	GSI	CVG	GR
OA	0.00247	0.06091*	0.01846*	0.02887*	0.00441	0.08073*	0.33308	0.00508	0.02887*
OL	0.00105	0.155*	0.03651*	0.0706*	0.0079*	0.25658*	0.71968*	0.09398	0.0706*
OA*OL	0.00065	0.03968	0.00273	0.0083	0.00119*	0.04937*	0.21058	0.27513*	0.0083

(11.14%) and lower for NaCl (6.71%). GI decreased with decreasing OL. GI was 15.83 %, 9.16 %, 7.79% and 2.93% for control, -0.2 MPa, -0.4 MPa and -0.6 MPa; respectively (Figure 1c). ANOVA for OA and OL showed statistically significant (P≤0.05) results for MDG (Table 2). PEG solutions had MDG of 22.32 % while NaCl had 13.78 %. For different OL, MDG was 32.96, 19.91, 13.35 and 5.98 % for control, -0.2 MPa, -0.4 MPa and -0.6 MPa; respectively (Figure 1d). OL have significant affect (P≤0.05) on MGT (Table 2).

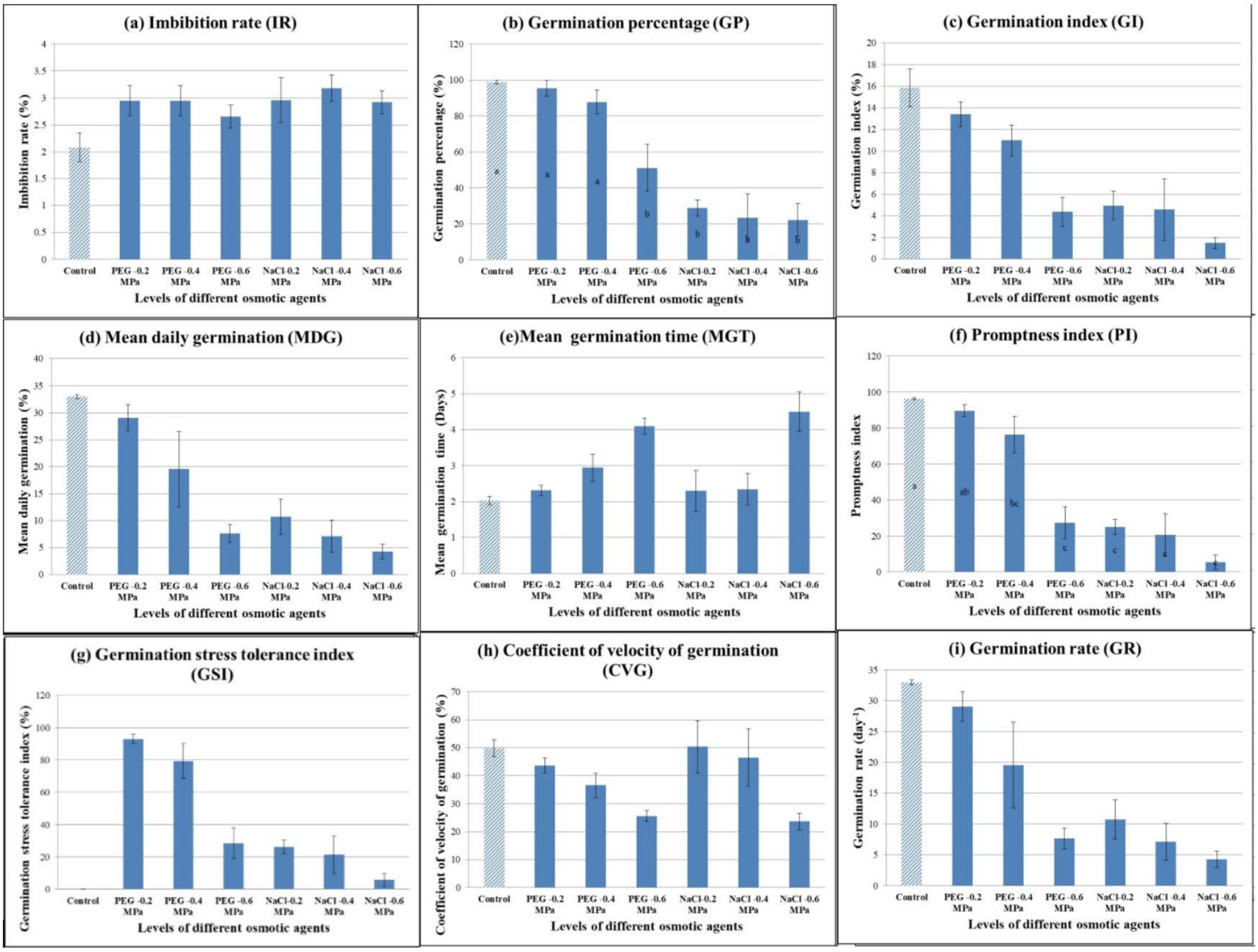

Figure 1: *Means of the different germination parameters for A. leucoclada under three osmotic levels of PEG and NaCl. Means with different letters are significantly different at P≤0.05.*

MGT was 2.02, 2.30, 2.64 and 4.3 days for control, -0.2 MPa, -0.4 MPa and -0.6 MPa; respectively (Figure 1e). Interaction of OA and OL also affected the promptness index (P≤0.05; Table 2). Highest PI (96.22) was observed for control while lowest (5.44) was observed for NaCl at -0.6MPa water potential (Figure 1f).

The ANOVA revealed a significant effect of OA and OL (P≤0.05) for GSI (Table 2). PEG treatment had GSI of 50.22 % and NaCl had GSI of 13.26 %. GSI was 59.96, 50.39 and 17.02 for -0.2, -0.4 and -0.6 MPa; respectively (Figure 1g). CVG significantly affected (P≤0.05) by OL (Table 2). Maximum CVG (50%) was observed for the control while the minimum (i.e. 25%) was recorded for -0.6MPa (Figure 1h). GR was also significant for OA and OL at P≤0.05 (Table 2). PEG had GR of 22.32 day^{-1} and NaCl had GR of 13.78 $day^{-1.}$ Control treatment had maximum GR of 32.96 day^{-1} while minimum GR was 5.98 day^{-1} recorded by -0.6MPa followed.

S. italica

Local/ Arabic name: Ishraj: GP, GI, MDG, and GR were significantly (P≤0.05) affected by the OA and OLs. MGT, PI and CVG were significantly (P≤0.05) affected by the OA and OL interaction. While GSI was affected by OLs only.

GP, GI, MDG and GR were decreased more for NaCl then the PEG and decreased with decreasing OL. MGT increased with decreasing OL. However,MGT increased more in PEG than the NaCl. PI and CVG decreased more by decreasing OLs of PEG as compared to decreasing OLs of NaCl. GSI also decreased with decreasing OLs.

The GP was significantly affected (P≤0.05) both by OA and OL (Table 3). PEG and NaCl had 24.44 and

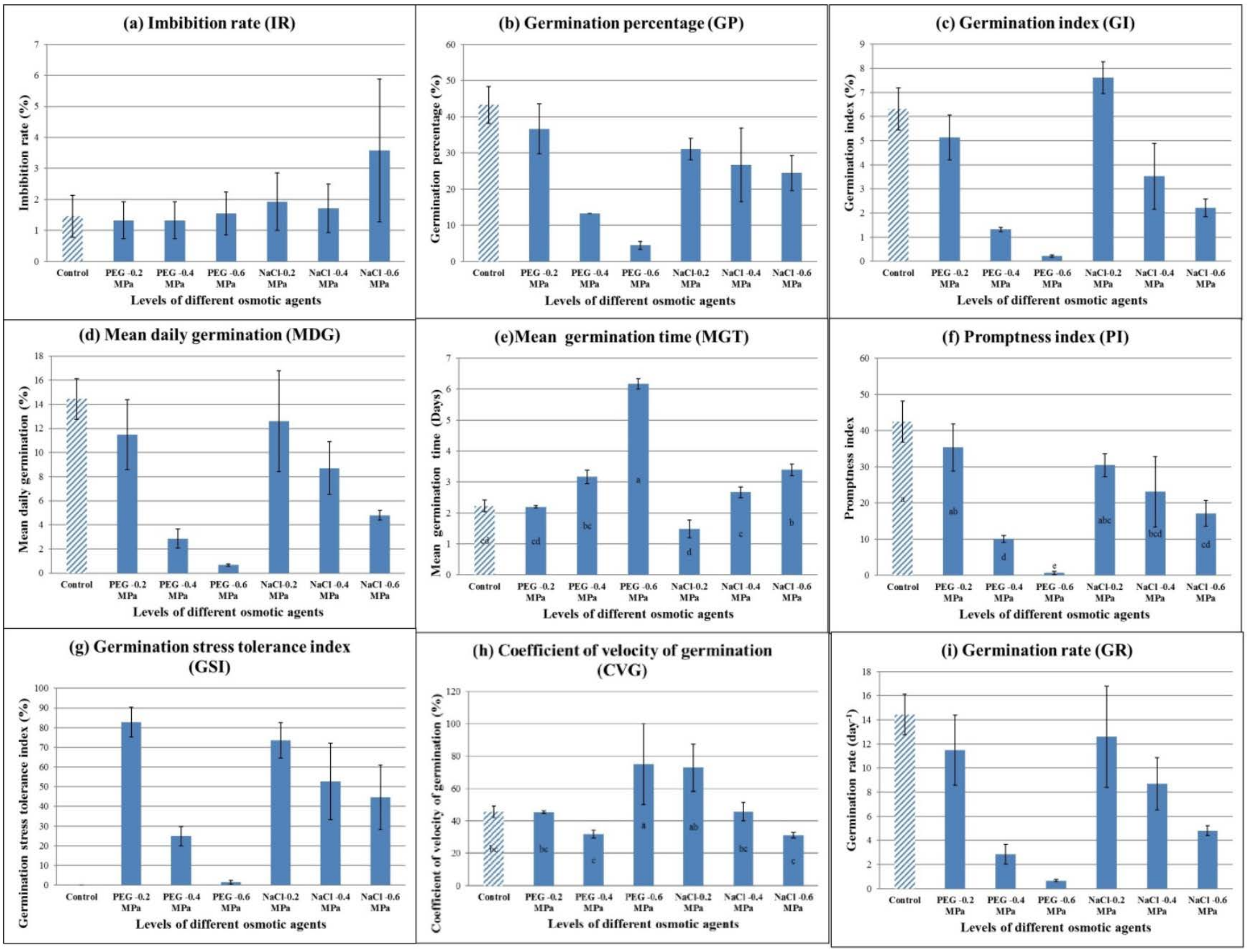

Figure 2: *Means of the different germination parameters for S. italica under three osmotic levels of PEG and NaCl. Means with different letters are significantly different at P≤0.05.*

31.39 % GP respectively, while different OL had GP of 43.33, 33.89, 20.00 and 14.44 % for control -0.2, -0.4 and -0.6 MPa water potential respectively (Figure 2b).

For the GI ANOVA showed a significant effect of OA and OL at P≤0.05 (Table 3). GI was 3.25 and 4.92 % for PEG and NaCl. GI was 6.32, 6.38, 2.42 and 1.22 % for Control, -0.2, -0.4 and -0.6 MPa; respectively (Figure 2c). MDG was significantly affected (P≤0.05) by OA and OL (Table 3). Mean daily germination was 10.13 day^{-1} for NaCl and 7.36 day^{-1} for PEG. Control had the maximum MDG of 14.44 day^{-1} while -0.6 MPa had the minimum MDG of 2.73 day^{-1} (Figure 2d). MGT was significantly affected by OL and OA at P≤0.05 (Table 3). Highest MDG was 6.17 % at PEG -0.6MPa and lowest MDG was 1.48 % for NaCl -0.2 MPa (Figure 2e). The PI also showed a significant impact (P≤0.05) of OL and OA interaction (Table 3). Highest PI (42.44) was recorded for Control while lowest (0.64) was observed for PEG -0.6 MPa solution (Figure 2f). Different OL affected the GSI at P≤0.05 (Table 3). PEG -0.2 MPa had observed the maximum GTI of 78.20 % while PEG -0.6 MPa had minimum GTI of 23.01 % (Figure 2g). ANOVA revealed a significant interactive effect (P≤0.05) of OA and OL on CVG (Table 3). CVG was observed as 75% for PEG -0.6 MPa and minimum (31.2%) was recorded for NaCl -0.6 MPa (Figure 2h). GR was affected significantly (P≤0.05) by different OA and OL (Table 3). Average of GR for PEG was 1.41 day^{-1} NaCl was 2.17 day^{-1}. Maximum GR was recorded for -0.6 MPa i.e. 2.56 day^{-1} while minimum was recorded for control i.e. 1.45 day^{-1} (Figure 2i).

T. apollinea

Local/ Arabic name: Zafra: GP, GI, MDG, PI, GSI and GR were significantly affected by the OLs and has no significant effect of OA. MGT had a significant interactive effect of OS and OL. IR and CVG had non-significant effect of OA and OL. GP, GI, MDG, PI, GSI and GR reduced with reducing water potential. However, MGT increased with decreasing OL. This increase in MGT was more prominent in NaCl as compared to PEG.

T. apollinea revealed a significant effect (P≤0.05) of OL on GP (Table 4). The average GP was 38.89, 30.56, 23.33 and 12.78 % for control, -0.2, -0.4 and -0.6 MPa; respectively (Figure 3b). GI also affected significantly (P≤0.05) by different OL (Table 4). GI decreased with decreasing water potential of PEG and NaCl and was 3.92, 3.92, 2.23 and 0.89 % for control, -0.2, -0.4 and -0.6 MPa; respectively (Figure 3c). MDG was significantly affected by the different OL levels at P≤0.05 (Table 4). As OL decreased, so did MDG

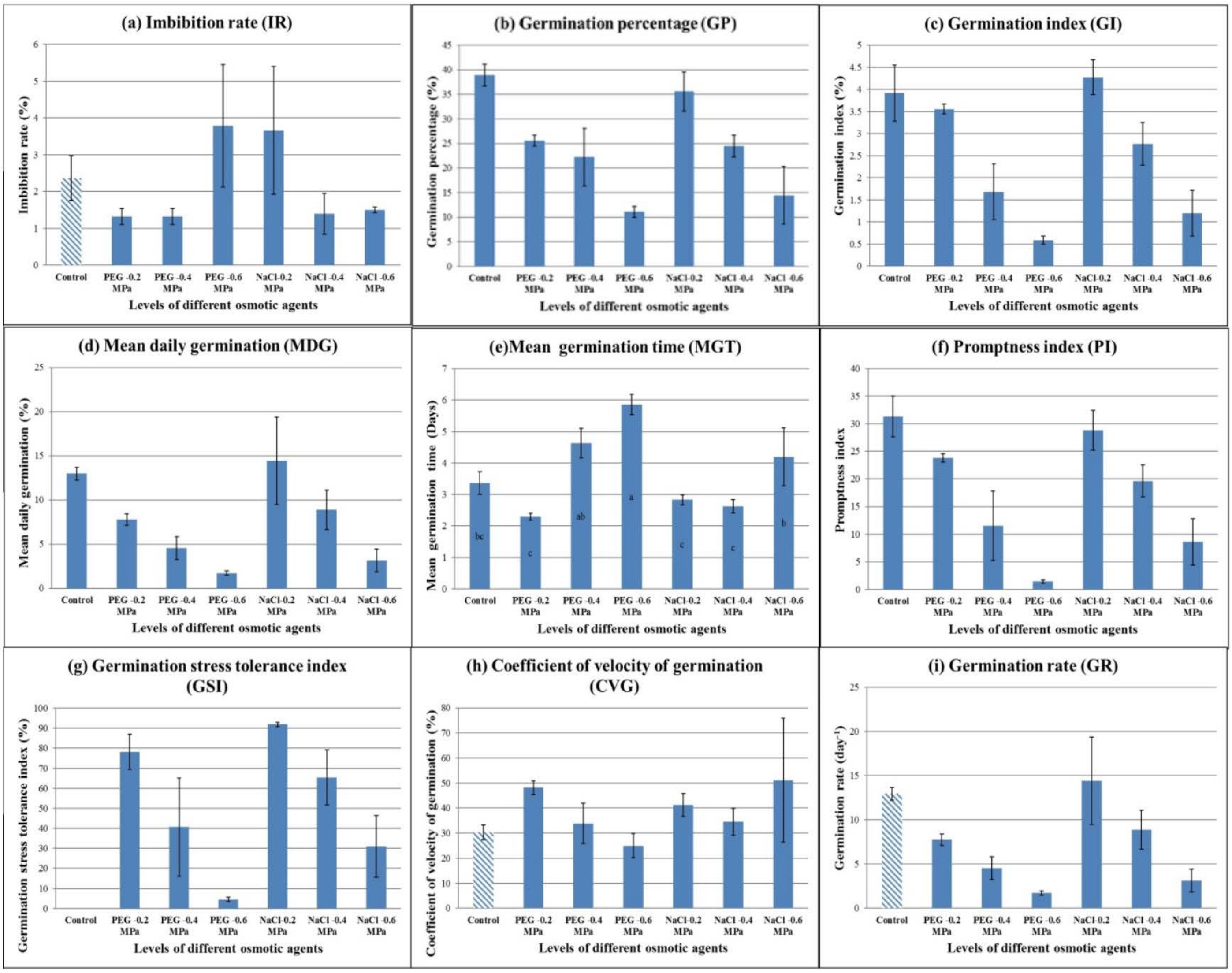

Figure 3: *Means of the different germination parameters for T. apollinea under three osmotic levels of PEG and NaCl. Means with different letters are significantly different at P≤0.05.*

Table 4: *Mean square (from ANOVA analysis) for different germination parameters (IR: Imbibition Rate; GP: Germination Percentage; GI: Germination Index; MDG: Mean Daily Germination; MGT: Mean Germination Time; PI: Promptness Index; GSI: Germination Stress Tolerance Index; CVG: Coefficient of Velocity of Germination; GR: Germination Rate) for T. apollinea. Significance (*) was assessed at P≤0.05.*

Source	Mean squares								
	IR	GP	GI	MDG	MGT	PI	GSI	CVG	GR
OA	0.00	0.01089	0.00256	0.01785	0.00225*	0.04043	0.29326	0.03407	0.29326
OL	0.00217	0.11027*	0.0164*	0.05615*	0.00413*	0.19585*	1.01771*	0.02857	1.01771*
OA*OL	0.00439	0.00318	0.0004	0.00305	0.00167*	0.00673	0.00631	0.05721	0.00631

(Figure 3d). The average of MDG was 12.96, 11.11, 6.72 and 2.42 % for control, -0.2, -0.4 and -0.6 MPa; respectively. For MGT ANOVA showed a significant interactive result (P≤0.05) for OA and OL (Table 4). Maximum MGT was 5.86 days for PEG -0.6 MPa and minimum MGT was 2.3, 2.63 and 2.83 days for PEG -0.2, NaCl -0.4 and NaCl -0.2 MPa; respectively (Figure 3e). Different OL also affected (P≤0.05; Table 4) the PI. Highest PI was 31.31 and 26.32 for control and -0.2 MPa; respectively. Minimum PI (5.01) was recorded for -0.6 MPa (Figure 3f). GSI was significantly affected (P≤0.05) by different OL (Table 4). Average GTI for different OLs was 85, 53 and 17.85 % for -0.2, -0.4 and -0.6 MPa; respectively (Figure 3g). GR of *T. apollinea* was significantly affected (P≤0.05) by OL at P≤0.05 (Table 4). Highest GR (12.96 day^{-1}) was observed for control.

Tetraena mandavillei (Hadidi) Beier and Thulin Syn. Zygophyllum mandavillei (Moq.)

Local/ Arabic name: Haram: For *T. mandavillei* most of the measured parameters i.e. GP, MDG, MGT, PI and GR were significantly affected by OL of different OA. GI had an interactive effect of OA and OL while IR, GSI and CVG were not significantly affected by OA or OL. GP, MDG, PI and GR were significantly decreased with decreasing OL and MGT increased with decreasing OL (Table 5).

The average GP was 23.3%, 16.7%, 15.5% and 18.3% for control, -0.2, -0.4 and -0.6 MPa; respectively (Figure 4b). GI was significantly affected (P≤0.05) by interaction of OA and OL (Table 5). Maximum GI was 4 % for control and minimum GI was 1.78 % for NaCl -0.6 MPa (Figure 4c). MDG was also significantly affected (P≤0.05; Table 5) by the different OL. As OL decreased so did the MDG (Figure 4d). The average of MDG was 7.78, 5.14, 4.53 and 3.35 % for control, -0.2, -0.4 and -0.6 MPa; respectively (Figure 4d). ANOVA analysis of MGT showed a significant effect (P≤0.05) for different OL (Table 5). MGT was 1.83, 2.21, 1.7 and 2.76 days for control, -0.2, -0.4 and -0.6 MPa; respectively (Figure 4e). ANOVA results (Table 5) showed that OL affected the PI at P≤0.05. PI decreased with decreasing OL. PI was 23.33, 15.56, 15.22 and 15.81 for control, -0.2, -0.4 and -0.6 MPa; respectively (Figure 4f). GR of *T. mandavillei* was significantly affected by OL at P≤0.05 (Table 5). Average GR was 7.78, 5.14, 4.53 and 3.35 day^{-1} for -0.2, -0.4 and -0.6 MPa; respectively (Figure 4i).

Iso-osmotic solutions of NaCl and PEG caused different effects on seed germination of different species (Tobe et al., 2001). *A. leucoclada* was found to be tolerant to PEG as compared to NaCl during germination stage. It may be due to the reason that, NaCl caused osmotic stress by reducing the amount of available water and at the same time cause toxicity by Na and Cl ions. Similar results are reported by Shaygan et al. (2017) in *Atriplex halimus* who recorded 31% GP for PEG and 3% GP for iso-osmotic NaCl. The present results are in line with Afzali et al. (2006) for *Matricaria chamomilla*, Shahriari et al. (2015) for *Alyssum hamalocarpum* and Katembe et al. (1998) for *Atriplex prostrata* and *A. patula*.

Contrary to *A. leucoclada*, *S. italica* was found resistant to NaCl as compared to PEG. *S. italica* was adapted to salinity more efficiently during germination stage compared to iso-osmotic PEG. The explanation of the higher inhibitory effect of PEG than NaCl lies in ion or solute entry into the seed. Unlike PEG, NaCl may readily cross the cell membrane into the cytoplasm of the cell (Katembe et al., 1998). Entering ions lower the seed osmotic potential which facilitates hydration of the seed by allowing a higher seed matric potential than the osmotic potential of the solution surrounding the seed (Roundy et al., 1985). In PEG, hydrolysis of storage compounds could lower the internal osmotic

Table 5: *Mean square (from ANOVA analysis) for different germination parameters (IR: Imbibition Rate; GP: Germination percentage; GI: Germination Index; MDG: Mean Daily Germination; MGT: Mean Germination Time; PI: Promptness Index; GSI: Germination Stress Tolerance Index; CVG: Coefficient of Velocity of Germination; GR: Germination Rate) for T. mandavillei. Significance (*) was assessed at P≤0.05.*

Source	Mean squares								
	IR	GP	GI	MDG	MGT	PI	GSI	CVG	GR
OA	0.00295	0.00073	0.0001889*	0.00216	0.00001	0.00113	0.01285	0.02896	0.00216
OL	0.00035	0.0116*	0.00246*	0.01101*	0.00129*	0.01451*	0.00372	0.09439	0.01101*
OA*OL	0.00047	0.00208	0.00213*	0.00178	0.00057	0.00317	0.05453	0.06493	0.00178

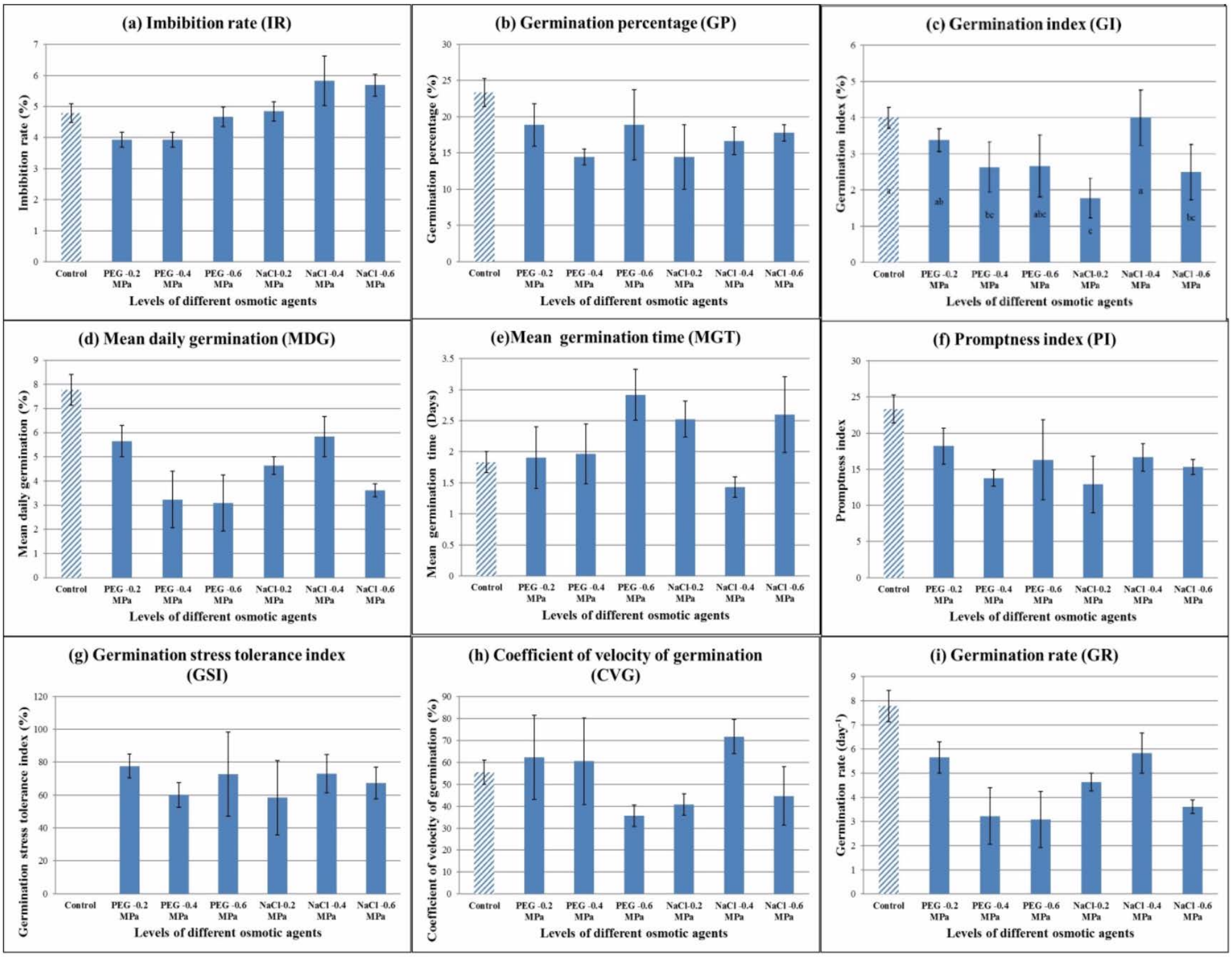

Figure 4: *Means of the different germination parameters for T. mandavillei under three osmotic levels of PEG and NaCl. Means with different letters are significantly different at P≤0.05.*

potentials of the seed sufficiently for water entry (Hampson and Simpson, 1990). Although, NaCl causes osmotic stress by reducing the amount of available water, and at the same time the toxicity of Na and Cl ions, in this study saline stress had a lesser effect on the germination of seeds than hydric stress simulated with PEG at the same osmotic potentials. Also, Na^+ ions accumulated in the seed embryo create the difference in water potential between the substrate and the seed, allowing water uptake during germination (Shitole and Dhumal, 2012). One explanation of this reduction could be that plants grown in PEG containing media may had suffered from hypoxia because of a large viscosity possibility that a boundary layer of oxygen depleted solution may form around the roots (Verslues et al., 2006). El-Keblawy and Al-Shamsi (2008) reported similar results for *Haloxylon Salicornicum* with no significant differences in germination at lower concentrations of NaCl (0-300 mM).

T. apollinea and *T. mandavillei* showed similar response to iso-osmotic conditions of both PEG and NaCl. Both species showed similar tolerance to both salt and drought stress induced by NaCl and PEG. Although decreasing water potential decrease most of germination parameters, all the species studied still germinated successfully even under lowest OL studied in this experiment.

Khan and Ungar (1997a) also indicated that *Z. simplex* seeds are tolerant to moderate salinity but its germination is reduced by increasing salinity. Ismail (1990) also reported negative effects of increasing salinity on germination of *Z. qatarense*. Agami (1986) reported reduced germination for *Z. dumosum* by increasing salinity but still occur even at 0.5 M NaCl. Except for *A. leucoclada* for all other species including *S. italica*, *T. apollinea* and *T. mandavillei* did not showed any ionic effect of salt stress and the inhibitory effect can be attributed to the osmotic effect of PEG and

NaCl. According to Zhang and Kirkham (1995) polyethylene glycol (PEG) induced water stress on the plants. Water deficit imposed either by drought or salinity brings about severe growth retardation and yield loss of crops (Zhang et al., 2010). It was claimed that NaCl had a less effect on the germination and seedling growth of cowpea than PEG (Murillo-Amador et al., 2002) and seed germination was severely diminished by water stress induced by mannitol in sugar beet (Sadeghian and Yavari, 2004). Ungar (1978) also reported that inorganic ions are not inhibitory compared to mannitol and polyethylene glycol (PEG) in several halophytes and seeds were mainly affected by osmotic stress rather than specific ion toxicities (Zhang et al., 2010). It can be assumed that inhibition in germination at equivalent water potentials of NaCl and PEG was mainly due to an osmotic effect rather than NaCl toxicity (Okçu, et al., 2005).

Conclusions and Recommendations

Both salt and water stress are supposed to have negative effect on the germination of any species. However, our study revealed that response to same level of salinity and drought stress during germination can vary for each species. A species can be affected more either by NaCl or PEG like *S. italica* and *A. leucoclada* respectively. While some species like *T. mandavillei. T. apollinea* may have similar negative effect of both NaCl and PEG and did not exhibited ion toxicity. Species under study were found to reduce the germination by increasing osmotic stress level. However, germination was not inhibited completely even under highest osmotic stress which is not recommended for most of cultivated plant species. This minimal effect of osmotic stress due to salt and water stress can be related to genetic potential of native plant species to resist the osmotic stress. Information gained from this study will further improve our understanding of the germination behavior of native plant species and can help to develop sustainable strategies for its commercial propagation. We can also recommend direct seeding and germination of native plants as an effective and economically viable solution for revegetation of plant communities where salinity and water stress are major issues.

We conclude that for sustainable landscaping using all the four species should be promoted as a substitute of exotic species in arid zones under salt and water stress conditions. These species can be studied further for their field performance under extreme salt and water stress conditions.

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Novelty Statement

Native plants comprise of many alternate landscape species having ability to germinate and grow under stressful conditions of salinity and drought.

Author's Contribution

HA conducted the research, JZK supervised the research study and helped in results and discussion while TSK co-supervised the site activities of the study and overall manuscript development

Conflict of interest

Authors confirm that there is no conflict of interest.

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