Pak. J. Bot., 49(2): 413-419, 2017.

SCREENING DATE PALM CULTIVARS FOR SALINITY TOLERANCE USING PHYSIOLOGICAL INDICES

SEYYED SAMIH MARASHI[1,4*], JAFAR HAJILOU[1], SEYYED JALAL TABATABAEI[2], FARIBORZ ZARE NAHANDI[1] AND MAHMOUD TOORCHI[3]

[1]*Department of Horticultural Sciences, Faculty of Agriculture, University of Tabriz, Tabriz, Iran*
[2]*Department of Horticultural Sciences, Faculty of Agriculture, Shahed University, Tehran, Iran*
[3]*Department of Breeding & Biotechnology, Faculty of Agriculture, University of Tabriz, Tabriz, Iran*
[4] *Date Palm and Tropical Fruits Research Center, Horticultural Sciences Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Ahwaz, Iran*
[*]*Corresponding author's email: samihmarashi@tabrizu.ac.ir*

Abstract

Salinity is a major environmental constraint for plant growth and crop production worldwide. Selection of salt tolerant cultivars of date palm as a fruit crop of high salt tolerance and an extremely important strategic crop in arid and semi-arid regions of the world is quite necessary for the most economical use of salt affected soils in these regions. In present study, five commercial Iranian date palm cultivars were screened for salt tolerance using 10 physiological indices, in a pot experiment under greenhouse condition. Levels of 0, 60, 120, 180, 240 and 300 mM NaCl were hydroponically applied on 1-year old plants derived through tissue culture. Stress tolerance indices related to total fresh and dry weights, root fresh and dry weights, shoot fresh and dry weights, leaf area, collar growth, intact leaf and leaf water content were calculated. The data were subjected to analysis of variance and comparison of means. Then, calculation of total means and cluster analysis of the cultivars based on all tested indices and correlation between indices were performed. The results showed that the cultivars usually revealed different behaviors for reduction trend of each stress tolerance index in response to increase of salinity. Overall, the group of Zahidi, Piarom and Dayri cultivars exhibited more salt tolerance and better performance in saline conditions than the group of Kabkaab and Istamaran cultivars. Furthermore, all examined indices can be used in screening date palm cultivars for salt tolerance among which the indices related to root fresh and dry weights, shoot fresh and dry weights, leaf area and intact leaf percent are the most efficient ones.

Key words: Date palm cultivars, Physiological indices, Salinity tolerance, Screening.

Introduction

Salinity in soil or water is one of the major stresses and, especially in arid and semi-arid regions, can severely limit crop production. The deleterious effects of salinity on plant growth are associated with low osmotic potential of soil solution, nutritional imbalance, specific ion effect, or a combination of these factors (Ashraf & Harris, 2004). Scientists have already proposed various strategies to overcome salinity problem (Rasheed *et al.*, 2015). The most economical and feasible strategy to utilize salt affected soils is to use salt tolerant plants either natural or artificially improved through selection and breeding (Ashraf & Ahmad, 1999).

Formerly, the available germplasms of many plant species such as wheat (Ashraf & McNeilly, 1988; Zafar *et al.,* 2015), sorghum (Kausar *et al*., 2012), some other grasses (Ashraf *et al.,* 2006), cotton (Ashraf & Ahmad, 1999), lentil (Ashraf & Waheed, 1993), canola (Ulfat *et al.*, 2007), hot pepper (Ziaf *et al.,* 2009), guar (Rasheed *et al.*, 2015) and olive (Marin *et al*., 1995) have been screened for salinity tolerance using physiological indices and the salt tolerant cultivars or genotypes have been identified for further studies or cultivation on salt-affected lands.

Date palm (*Phoenix dactylifera* L.) is considered as a fruit crop of high salt tolerance (Kozlowski, 1997; Zaid, 1999). It is more salt tolerant than barley and may be the most salt tolerant of all crop plants. Barley is usually grown in the cool season; in contrast, date palms grow faster in hot weather when salinity has the most adverse influence on plants (Furr, 1975). Moreover, the date fruit, produced largely in the hot arid regions of South West Asia and North Africa, is marketed all over the world as a high-value confectionery and fruit crop and remains an extremely important subsistence crop in most of the desert regions (Zaid, 1999). However, attempts to use date palm biodiversity to screen against salinity tolerance have been limited and therefore are of urgent priority (Alhammadi & Kurup, 2012). So, the objectives of the present study were to assess genetic variability of salinity tolerance among five Iranian date palm cultivars using physiological indices at early vegetative growth stage in order to identify the more salt tolerant cultivar(s) which may be grown on salt-affected lands and to investigate the most efficient indices which may be useful in screening for salt tolerance in future breeding programs.

Materials and Methods

Experimental conditions: The experiment was carried out at university of Tabriz in Iran in a greenhouse with average air temperature and relative humidity of 25°C and 44%, respectively under natural sunlight. Levels of 0, 60, 120, 180, 240 and 300mM NaCl were applied to screen out 5 commercial Iranian date palm cultivars i.e. “Istamaran”, “Dayri”, “Zahidi”, “Kabkaab” and “Piarom”, for salt tolerance using 10 physiological indices. An experimental unit was a 1-year old plant derived from tissue culture cultivated hydroponically in an 8-liter pot containing perlite: vermiculite mixture (4:1 v/v). The plants were daily irrigated with half strength Hoagland solution containing the above mentioned salt levels for 4 months and then harvested.

Physiological indices: Collar diameter was measured at the beginning and the end of the experiment and its increase was calculated as collar growth. Each plant was separated in root, stem and leaves at harvest and its leaf area and fresh weights of the plant parts were immediately measured. Moreover, number of intact leaves (leaves having 50% or more of green blades) and injured leaves (old leaves having less than 50% of green blades) were recorded and intact leaf percentage in each plant was calculated as: "(number of intact leaves /sum of number of intact and injured leaves) × 100". Then, the plant parts were dried in oven at 80°C to a constant weight and their dry weights were recorded. Sum of fresh (dry) weights of stem and leaves was considered as shoot fresh (dry) weight. Leaf water content was calculated using the equation: "(fresh weight – dry weight) / dry weight". Total fresh and dry weights stress tolerance indices (TFWSTI & TDWSTI), root fresh and dry weights stress tolerance indices (RFWSTI & RDWSTI), shoot fresh and dry weights stress tolerance indices (SFWSTI & SDWSTI), leaf area stress tolerance index (LASTI), collar growth stress tolerance index (CGSTI), intact leaf percent stress tolerance index (ILPSTI) and leaf water content stress tolerance index (LWCSTI) were calculated using the following formula (Ashraf *et al.*, 2006):

TFWSTI	= (Total fresh weight of stressed plants / Total fresh weight of control plants) × 100
TDWSTI	= (Total dry weight of stressed plants / Total dry weight of control plants) × 100
RFWSTI	= (Root fresh weight of stressed plants / Root fresh weight of control plants) × 100
RDWSTI	= (Root dry weight of stressed plants / Root dry weight of control plants) × 100
SFWSTI	= (Shoot fresh weight of stressed plants / Shoot fresh weight of control plants) × 100
SDWSTI	= (Shoot dry weight of stressed plants / Shoot dry weight of control plants) × 100
LASTI	= (Leaf area of stressed plants / Leaf area of control plants) × 100
CGSTI	= (Collar growth of stressed plants / Collar growth of control plants) × 100
ILPSTI	= (Intact leaf percentage of stressed plants / Intact leaf percentage of control plants) × 100
LWCSTI	= (Leaf water content of stressed plants / Leaf water content of control plants) × 100

Statistical analysis: The experimental layout was factorial in a completely randomized design with 3 replications. The data obtained were subjected to analysis of variance and comparison of means by LSD test. Then, cluster analysis of cultivars via complete linkage method and correlation analysis between indices were performed using SAS 9.1 software.

Results and Discussion

A general view on the effects of different levels of NaCl salt and date palm cultivars on the examined stress tolerance indices (Tables 1-10) showed that all studied physiological characteristics which are recognized as key parameters of biomass production in date palm (Aljuburi, 1992; Alhammadi & Edward, 2009; Kurup *et al.*, 2009; Darwesh & El-Banna, 2011) were adversely affected by salinity. Overall means of all stress tolerance indices even at the lowest level of NaCl salt (60 mM) were less than 100% (control) and decreased significantly with increase in salinity. However, the date palm cultivars usually exhibited different behaviors for reduction trend of each stress tolerance index (its start and slope) in response to increase of salinity. This fact, for a given index, resulted in some variations among salt levels in ranks related to mean values of different cultivars and ultimately determined ranks of cultivars based on overall means. These findings have been frequently supported in literature for many plant species including date palm (Aljuburi, 1992; Alhammadi & Edward, 2009; Kurup *et al.*, 2009; Ziaf *et al.*, 2009; Kausar *et al.*, 2012; Zafar *et al.*, 2015). As studied here, salt tolerance is usually assessed as the percent biomass production in saline versus control conditions over a prolonged period of time (Munns, 2002). So, the cultivar(s) showing better performance for each experimented parameter (at a salt level or overall) can be considered as more salt tolerant based on the special related aspect and may implicate the existence or higher activity of a specific mechanism of salt tolerance in such cultivar(s). Zahidi cultivar showed significantly higher mean of total fresh weight stress tolerance index (TFWSTI) than Kabkaab and Piarom, only at 240 mM NaCl level. For total dry weight stress tolerance index (TDWSTI), Dayri was significantly better than Kabkaab at 180 mM salt level and similarly Zahidi had upper situation as compared to Kabkaab and Piarom at 240 mM. However, based on means of salt levels other than the above mentioned levels and overall means, all cultivars performed equally for both indices (Tables 1 and 2).

Zahidi cultivar exhibited significantly higher mean values of root fresh and dry weights stress tolerance indices (RFWSTI and RDWSTI) than Piarom, only at 240 mM NaCl level. Nevertheless, according to means of other salt levels and overall means, all cultivars showed similar performance for both indices (Tables 3 and 4).

For shoot fresh weight stress tolerance index (SFWSTI), Piarom cultivar as compared to Kabkaab at 60 mM NaCl level, Piarom followed by Kabkaab as compared to Istamaran at 120 mM, Dayri in respect of Istamaran and Kabkaab at 180 mM and Zahidi in respect of Kabkaab at 240 mM exhibited significantly better performance. But, there was no significant difference among cultivars at 300 mM salinity level. Overall, Dayri, Zahidi and Piarom showed priority than Istamaran and Kabkaab with respect to SFWSTI (Table 5). Piarom cultivar as compared to Kabkaab at 60 mM salt level and Istamaran at 120 mM, Dayri as compared to Istamaran and Kabkaab at 180 mM and Zahidi as compared to Kabkaab at 240 mM showed significantly higher mean values of shoot dry weight stress tolerance index (SDWSTI). However, the cultivars performed equally at 300 mM salinity level. Overall, Piarom followed by Zahidi exhibited the best performance among all cultivars for this index (Table 6).

Table 1. Total fresh weight stress tolerance index (TFWSTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	94.8 ab	74.8 c-i	71.8 d-j	68.2 f-j	55.1 j	72.9 A	5
Dayri	87.4 a-e	83.6 a-h	86.1 a-g	67.5 g-j	60.7 ij	77.1 A	3
Zahidi	93.1 a-c	83.2 a-h	78.0 b-i	83.5 a-h	68.5 e-j	81.2 A	1
Kabkaab	86.1 a-g	90.3 a-d	67.7 g-j	61.2 ij	64.7 h-j	74.0 A	4
Piarom	101.6 a	86.7 a-f	74.4 c-i	63.4 ij	65.4 h-j	78.3 A	2
Mean	92.6 A	83.7 B	75.6 BC	68.8 CD	62.9 D		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Table 2. Total dry weight stress tolerance index (TDWSTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	93.2 a-d	75.8 c-g	77.8 b-g	77.3 b-g	64.7 g	77.8 A	3
Dayri	91.0 a-e	86.1 a-f	96.6 ab	79.2 b-g	70.5 e-g	84.7 A	2
Zahidi	93.9 a-c	86.5 a-f	83.2 a-g	92.6 a-d	75.9 b-g	86.4 A	1
Kabkaab	85.3 a-g	92.9 a-d	72.7 d-g	66.9 fg	69.3 fg	77.4 A	4
Piarom	103.3 a	95.1 a-c	81.7 b-g	71.2 e-g	80.9 b-g	86.4 A	1
Mean	93.3 A	87.3 AB	82.4 BC	77.4 CD	72.3 D		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Table 3. Root fresh weight stress tolerance index (RFWSTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	104.2 ab	86.6 a-h	83.3 a-h	78.6 d-h	64.8 h	83.5 A	4
Dayri	93.2 a-e	95.5 a-e	90.8 a-g	73.3 e-h	68.3 gh	84.2 A	3
Zahidi	101.1 a-d	92.4 a-f	86.7 a-h	94.1 a-e	80.9 c-h	91.0 A	1
Kabkaab	92.7 a-f	102.6 a-c	82.1 b-h	73.4 e-h	83.8 a-h	86.9 A	2
Piarom	104.9 a	89.9 a-g	79.6 d-h	70.2 f-h	73.1 e-h	83.5 A	4
Mean	99.2 A	93.4 AB	84.5 BC	77.9 CD	74.2 D		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Table 4. Root dry weight stress tolerance index (RDWSTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	99.8 ab	85.8 a-d	87.7 a-d	83.1 a-d	72.0 d	85.7 A	4
Dayri	94.5 a-d	101.5 a	102.4 a	84.2 a-d	79.4 a-d	92.4 A	2
Zahidi	98.6 a-c	92.6 a-d	89.1 a-d	100.7 ab	86.9 a-d	93.6 A	1
Kabkaab	87.2 a-d	101.5 a	83.9 a-d	76.3 b-d	86.9 a-d	87.1 A	3
Piarom	99.4 ab	89.2 a-d	78.8 a-d	74.4 cd	80.7 a-d	84.5 A	5
Mean	95.9 A	94.1 AB	88.4 A-C	83.7 BC	81.2 C		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Table 5. Shoot fresh weight stress tolerance index (SFWSTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	84.7 ab	62.0 c-e	59.2 c-f	56.9 c-f	44.6 f	61.5 B	4
Dayri	81.8 ab	72.0 bc	81.5 b	61.8 c-e	53.3 d-f	70.1 A	2
Zahidi	84.0 ab	72.7 bc	68.1 b-d	71.3 bc	54.4 d-f	70.1 A	2
Kabkaab	80.1 b	79.2 b	54.5 d-f	50.2 ef	47.3 ef	62.3 B	3
Piarom	98.2 a	83.4 ab	69.0 b-d	56.5 c-f	57.5 c-f	72.9 A	1
Mean	85.8 A	73.8 B	66.5 BC	59.4 C	51.4 D		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Table 6. Shoot dry weight stress tolerance index (SDWSTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	89.9 a-e	70.8 e-h	72.8 d-h	74.5 c-h	61.1 h	73.8 BC	4
Dayri	89.6 a-f	79.9 b-h	94.3 a-c	77.2 c-h	66.9 gh	81.6 A-C	3
Zahidi	91.6 a-d	83.4 b-g	80.3 b-h	88.5 a-f	70.5 e-h	82.8 AB	2
Kabkaab	84.4 b-g	88.9 a-f	67.5 gh	62.5 h	61.2 h	72.8 C	5
Piarom	105.3 a	98.2 ab	83.2 b-g	69.6 f-h	81.1 b-h	87.5 A	1
Mean	92.2 A	84.2 AB	79.6 BC	74.4 CD	68.1 D		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Table 7. Leaf area stress tolerance index (LASTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	90.3 a-d	69.2 f-k	67.0 g-l	65.7 h-l	50.6 l	68.6 C	4
Dayri	91.4 a-d	75.3 d-i	86.5 b-e	71.7 e-j	61.6 i-l	77.3 B	3
Zahidi	98.1 a-c	83.3 c-g	81.2 c-h	86.0 b-f	66.6 g-l	83.0 AB	2
Kabkaab	82.9 c-g	86.0 b-f	63.8 i-l	53.6 kl	54.8 j-l	68.2 C	5
Piarom	103.8 a	101.4 ab	93.9 a-c	73.2 e-i	68.9 g-k	88.2 A	1
Mean	93.3 A	83.0 B	78.5 B	70.0 C	60.5 D		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Table 8. Collar growth stress tolerance index (CGSTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	95.1 a	80.4 b-h	78.8 c-h	68.1 h-l	57.7 lm	76.0 A	3
Dayri	89.8 a-c	82.7 a-f	86.4 a-e	65.9 i-l	61.7 j-m	77.3 A	1
Zahidi	82.9 a-f	82.5 a-f	73.8 f-j	75.6 d-i	50.7 m	73.0 A	5
Kabkaab	92.3 ab	88.2 a-d	69.9 g-l	71.2 f-k	60.5 k-m	76.4 A	2
Piarom	92.0 ab	80.9 b-g	74.4 e-i	60.7 k-m	61.0 k-m	73.8 A	4
Mean	90.4 A	82.9 B	76.7 C	68.3 D	58.2 E		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Piarom cultivar as compared to Kabkaab at 60 mM NaCl level, Istamaran, Dayri and Zahidi at 120 mM, Istamaran and Kabkaab at 180 mM, Zahidi as compared to Istamaran and Kabkaab at 240 mM and Piarom as compared to Istamaran at 300 mM exhibited significantly higher values for leaf area stress tolerance index (LASTI). Generally, Piarom, followed by Zahidi and Dayri showed better performance than Istamaran and Kabkaab for this index (Table 7). The decreased rate of leaf growth after an increase in soil salinity is primarily due to the osmotic effect of the salt around the roots (Munns & Tester, 2008). For collar growth stress tolerance index (CGSTI), Dayri had significantly higher position than Zahidi and Kabkaab at 180 mM salt level and similarly Zahidi had upper situation as compared to Piarom at 240 mM. However, according to means of salt levels other than the above mentioned levels and overall means, all cultivars performed equally with respect to CGSTI (Table 8).

Piarom cultivar exhibited significantly higher mean of intact leaf percent stress tolerance index (ILPSTI) than Istamaran only at 240 mM NaCl level. But, there was no significant difference among cultivars at other salinity levels. Overall, Zahidi showed better performance than Dayri and Kabkaab for ILPSTI (Table 9). Increase in the rate of senescence of older leaves have been considered as a plant response to ion-specific toxicity resulted by salinity, due to either high leaf Na^+ concentrations or to low tolerance of the accumulated Na^+ (Munns & Tester, 2008). Apparently, Zahidi is more salt tolerant than other tested cultivars with respect to this response (Table 9).

Istamaran and Kabkaab cultivars followed by Piarom as compared to Dayri at 60 mM NaCl level, Kabkaab as compared to Zahidi at 120 mM and Kabkaab as compared to Piarom at 300 mM exhibited significantly higher values for leaf water content stress tolerance index (LWCSTI). However, the cultivars performed equally at other salinity levels. Generally, Kabkaab showed superiority to Zahidi regarding this index (Table 10). Water is essential for the survival and growth of plants. Dehydration usually causes severe changes and disorganization of membranes and organelles, mechanical rupture of cell membranes and degradation of protoplasm (Ashraf *et al.*, 2006). The decreased leaf water content can decrease leaf area due to a reduction in turgidity of leaves causing less light interception and also suppress stomatal conductance which indirectly can restrict the photosynthetic rates and ultimately resulted in reduced plant growth rate and dry matter accumulation (Ziaf *et al.*, 2009). So, a cultivar having higher Leaf water content in saline condition may be seemed more tolerant to osmotic stress caused by salinity due to more water absorption. But, the confliction between the results of LWCSTI with all other indices can implicate that it likely interfere salt tolerance in another manner.

Table 9. Intact leaf percent stress tolerance index (ILPSTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	96.1 a-d	105.4 a	93.6 a-e	85.2 c-e	89.4 a-e	93.9 AB	3
Dayri	94.2 a-e	93.7 a-e	97.3 a-d	87.0 b-e	77.7 e	90.0 B	5
Zahidi	104.1 a	101.8 a-c	101.9 a-c	93.4 a-e	91.2 a-e	98.5 A	1
Kabkaab	95.8 a-d	92.2 a-e	95.4 a-d	90.5 a-e	80.8 de	90.9 B	4
Piarom	91.3 a-e	100.4 a-c	90.3 a-e	102.3 ab	90.1 a-e	94.9 AB	2
Mean	96.3 A	98.7 A	95.7 A	91.7 AB	85.8 B		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Table 10. Leaf water content stress tolerance index (LWCSTI) of five Iranian date palm cultivars.

Cultivar	NaCl level (mM)					Mean	Rank
	60	120	180	240	300		
Istamaran	94.8 a	88.3 a-e	81.9 d-h	76.2 f-i	72.6 ij	82.8 AB	2
Dayri	83.2 d-h	89.9 a-d	83.0 d-h	79.4 e-i	75.3 h-j	82.1 AB	4
Zahidi	89.9 a-d	83.4 d-h	83.5 d-h	76.1 g-i	72.1 ij	81.0 B	5
Kabkaab	95.7 a	92.6 a-c	75.3 h-j	83.7 c-h	78.5 f-i	85.2 A	1
Piarom	93.9 ab	85.1 b-f	81.9 d-h	84.4 c-g	67.0 j	82.5 AB	3
Mean	91.5 A	87.9 A	81.1 B	79.9 B	73.1 C		

Each value represented inside the table is the mean of 3 replicates recorded. Means followed by the same letters are not significantly different at $p<0.05$. Middle letters have been deleted (a-g = abcdefg)

Table 11. Total means and final ranks of five Iranian date palm cultivars based on mean values of all stress tolerance indices.

Cultivar	Total mean	Final rank
Istamaran	77.6	5
Dayri	81.3	3
Zahidi	84.1	1
Kabkaab	78.1	4
Piarom	83.3	2

As our results showed (Tables 1-10), some changes in overall ranks of cultivars for salt tolerance among different stress tolerance indices have also been presented in most of previous reports (El-Hendawy *et al.,* 2005; Ashraf *et al.,* 2006; Ulfat *et al.,* 2007; Ziaf *et al.,* 2009; Kausar *et al.*, 2012; Rasheed *et al.,* 2015; Zafar *et al.,* 2015). According to these reports, plant cultivars may be ranked for salt tolerance using a single physiological parameter, however, ranking for salt tolerance based on multiple parameters has been proved more efficient and useful technique. Therefore, total means of five Iranian date palm cultivars calculated based on mean values of all examined stress tolerance indices and the related final ranks showed that Zahidi and Istamaran had the highest and the lowest salt tolerance among the cultivars, respectively. However, according to the total means, it seems that there is not a high genetic variability in salt tolerance among the cultivars (Table 11). Cluster analysis of the date palm cultivars based on the cultivar averages of all stress tolerance indices divided them statistically in two distinct groups. The group of Zahidi, Piarom and Dayri cultivars exhibited more salt tolerance than the group of Kabkaab and Istamaran cultivars (Fig. 1). The use of cluster analysis in screening a crop germplasm for salt tolerance based on multiple indices has been emphasized in many reports (Ulfat *et al.,* 2007; Rasheed *et al.*, 2015; Zafar *et al.*, 2015).

The results of correlation analysis among different stress tolerance indices revealed that except the non-significant correlation between ILPSTI with RDWSTI and LWCSTI, there were significant positive correlations among all indices. Intact leaf percent stress tolerance index (ILPSTI) had the least values of significant and positive correlations with other indices. Variation in correlations among different stress tolerance indices has been previously reported (Ashraf *et al.*, 2006; Zafar *et al.*, 2015). Moreover, the correlations between TFWSTI and SFWSTI and also TDWSTI and SDWSTI with RFWSTI, RDWSTI, LASTI, CGSTI, ILPSTI and LWCSTI were very close to each other, respectively (Table 12). These results showed that some of the indices specially those having more strong correlations with other indices can probably be deleted from calculating total means of indices due to their parallel effects.

Therefore, new total means of the tested date palm cultivars were repeatedly calculated based on mean values of various combinations of indices and the related rankings of the cultivars and also new cluster analyses of the cultivars according to the mean values of these combinations were conducted (for brevity's sake data not shown). Then, the similarities between ranking and clustering of cultivars based on each combination of indices were precisely compared to those based on all studied indices (Table 11 & Fig. 1). The results indicated that deletion of TFWSTI, TDWSTI, CGSTI and LWCSTI caused no changes in ranking and clustering of date palm cultivars based on all indices. Moreover, the same indices show no significant or considerable difference among cultivars based on their overall means (Tables 1, 2, 8 and 10). So, it is evident that the combination of RFWSTI, RDWSTI, SFWSTI, SDWSTI, LASTI and ILPSTI as the most efficient indices must be utilized together in screening date palm cultivars for salt tolerance. RFWSTI, RDWSTI, SFWSTI and SDWSTI have been recommended in most of previous reports as screening indices for stress tolerance (Ulfat *et al.*, 2007; Kausar *et al.*, 2012; Rasheed *et al.*, 2015; Zafar *et al.*, 2015). Furthermore, suitability of many biochemical or physiological indicators for salt tolerance may be assessed according to such indices (Ulfat *et al.*, 2007).

Table 12. Pearson correlation coefficients between different stress tolerance indices.

	TFWSTI	TDWSTI	RFWSTI	RDWSTI	SFWSTI	SDWSTI	LASTI	CGSTI	ILPSTI	LWCSTI
TFWSTI	-									
TDWSTI	0.956 **	-								
RFWSTI	0.956 **	0.893 **	-							
RDWSTI	0.883 **	0.888 **	0.944 **	-						
SFWSTI	0.957 **	0.935 **	0.833 **	0.747 **	-					
SDWSTI	0.918 **	0.977 **	0.802 **	0.771 **	0.953 **	-				
LASTI	0.884 **	0.883 **	0.753 **	0.663 **	0.935 **	0.919 **	-			
CGSTI	0.754 **	0.655 **	0.660 **	0.533 **	0.789 **	0.664 **	0.655 **	-		
ILPSTI	0.286 *	0.258 *	0.235 *	0.164 ns	0.302 **	0.277 *	0.332 **	0.315 **	-	
LWCSTI	0.524 **	0.344 **	0.458 **	0.309 **	0.554 **	0.334 **	0.456 **	0.667 **	0.183 ns	-

** = Significant at $p<0.01$; * = Significant at $p<0.05$; ns = Non significant

TFWSTI = Total fresh weight stress tolerance index; TDWSTI = Total dry weight stress tolerance index; RFWSTI = Root fresh weight stress tolerance index; RDWSTI = Root dry weight stress tolerance index; SFWSTI = Shoot fresh weight stress tolerance index; SDWSTI = Shoot dry weight stress tolerance index; LASTI = Leaf area stress tolerance index; CGSTI = Collar growth stress tolerance index; ILPSTI = Intact leaf percent stress tolerance index; LWCSTI = Leaf water content stress tolerance index

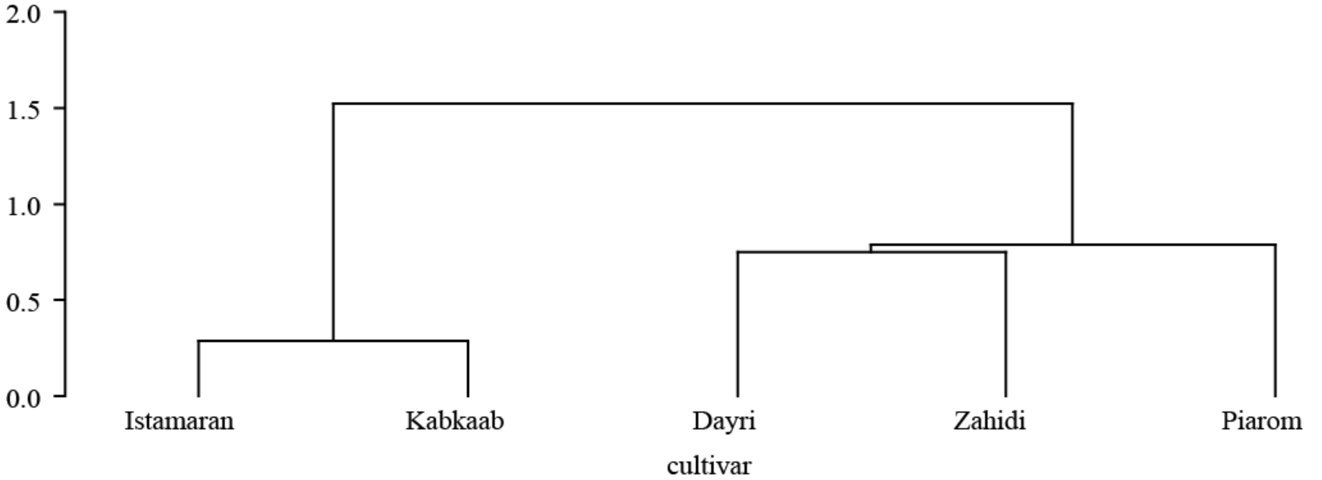

Fig. 1.Cluster analysis of date cultivars based on the cultivar averages of all stress tolerance indices.

Conclusions

According to our findings, it is concluded that the group of Zahidi, Piarom and Dayri cultivars exhibited more salt tolerance and better performance in saline conditions than the group of Kabkaab and Istamaran cultivars. Moreover, all examined physiological indices can be used in screening date palm cultivars for salt tolerance among which the indices related to root fresh and dry weights, shoot fresh and dry weights, leaf area and intact leaf percent are the most efficient and reliable ones.

References

Alhammadi, M.S. and G.P. Edward. 2009. Effect of salinity on growth of twelve cultivars of the United Arab Emirates date palm. *Commun. Soil Sci. Plant Anal.,* 40: 2372-2388.

Alhammadi, M.S. and S.S. Kurup. 2012. Impact of salinity stress on date palm (*Phoenix dactylifera* L.) - A Review. In: *Crop Production Technologies.* (Ed.): Sharma, P. In Tech. http://www.intechopen.com.

Aljuburi, H.J. 1992. Effect of sodium chloride on seedling growth of four date palm varieties. *Ann. Arid Zone,* 31(4): 259-262.

Ashraf, M. and T. McNeilly. 1988. Variability in salt tolerance of nine spring wheat cultivars. *J. Agron. Crop Sci.,* 160: 14-21.

Ashraf, M. and A. Waheed. 1993. Screening of local/exotic accessions of lentil (*Lens culinaris* Medic.) for salt tolerance at two growth stages. *Plant Soil*, 128: 167-176.

Ashraf, M. and S. Ahmad. 1999. Exploitation of intra-specific genetic variation for improvement of salt (NaCl) tolerance in upland cotton (*Gossypium hirsutum* L.). *Hereditas,* 131: 253-256.

Ashraf, M. and P.J.C. Harris. 2004. Potential biochemical indicators of salinity tolerance in plants. *Plant Sci.,* 166: 3-16.

Ashraf, M.Y., K. Akhtar, F. Hussain and J. Iqbal. 2006. Screening of different accession of three potential grass species from Cholistan desert for salt tolerance. *Pak. J. Bot.,* 38: 1589-1597.

Darwesh, R.S.S. and A.A. El-Banna. 2011. Role of potassium and salinity effects on growth and chemical compositions of date palm plantlets. *Arab Univ. J. Agri. Sci.,* 19(1): 233-244.

El-Hendawy, S.E., Y. Hu, G. M. Yakout, A. M. Awad, S.E. Hafiz and U. Schmidhalter. 2005. Evaluating salt tolerance of wheat genotypes using multiple parameters. *Eur. J. Agron.,* 22: 243-253.

Furr, J.R. 1975. Water and salinity problems of Abadan island date gardens. *Date Growers' Inst. Rep.,* 52: 14-17.

Kausar, A., M.Y. Ashraf, I. Ali, M. Niaz and Q. Abbass. 2012. Evaluation of sorghum varieties/lines for salt tolerance using physiological indices as screening tool. *Pak. J. Bot.,* 44(1): 47-52.

Kozlowski, T.T. 1997. *Responses of woody plants to flooding and salinity*. Tree Physiology Monograph No.1. Heron Publishing.

Kurup, S.S., Y.S. Hedar, M.A. Al Dhaheri, A.Y. El-Hewiety, M.M. Aly and G. Alhadrami. 2009. Morpho-physiological evaluation and RAPD markers – assisted characterization of date palm (*Phoenix dactylifera* L.) varieties for salinity tolerance. *J. Food Agri. Environ.*, 7 (3-4): 503-507.

Marin, L., M. Benlloch and R. Fernández-Escobar. 1995. Screening of olive cultivars for salt tolerance. *Sci. Hort.*, 64: 113-116.

Munns, R. 2002. Comparative physiology of salt and water stress. *Plant Cell Environ.*, 25: 239-250.

Munns, R. and M. Tester. 2008. Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol.*, 59: 651-681.

Rasheed, M.J.Z., K. Ahmad, M. Ashraf, F. Al-qurainy, S. Khan and H.R. Athar. 2015. Screening of diverse local germplasm of guar [*Cyamopsis tetragonoloba* (L.) Taub.] for salt tolerance: a possible approach to utilize salt-affected soils. *Pak. J. Bot.*, 47(5): 1721-1726.

Ulfat, M., H.R. Athar, M. Ashraf, N.A. Akram and A. Jamil. 2007. Appraisal of physiological and biochemical selection criteria for evaluation of salt tolerance in canola (*Brassica napus* L.). *Pak. J. Bot.*, 39(5): 1593-1608.

Zafar, S., M.Y. Ashraf, M. Niaz, A. Kausar and J. Hussain. 2015. Evaluation of wheat genotypes for salinity tolerance using physiological indices as screening tool. *Pak. J. Bot.*, 47(2): 397-405.

Zaid, A. 1999. *Date Palm Cultivation*. Technical Paper No.156, Rome: FAO pulications.

Ziaf, K., M. Amjad, M.A. Pervez, Q. Iqbal, I.A. Rajwana and M. Ayyub. 2009. Evaluation of different growth and physiological traits as indices of salt tolerance in hot pepper (*Capsicum annum* L.). *Pak. J. Bot*., 41(4): 1797-1809.

(Received for publication 28 February 2017)