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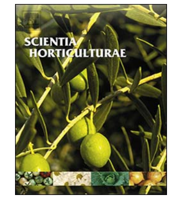

Salinity effect on some of the morphophysiological traits of three plantago species (*Plantago* spp.)

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ABSTRACT

In order to study the effect of salinity on morphological and physiological traits of psyllium, narrow leaf plantain and great plantain, an experiment was conducted as a factorial experiment based on the randomized complete block design with four replications at Research Greenhouse of Faculty of Agriculture, Ferdowsi University of Mashhad. Treatments included of three plantago species (*Plantago psyllium*, *P. lanceolata* and *P. major*) and six salinity levels (0, 50, 100, 150, 200, and 250 mM). Results showed, the interaction of salinity and plantago species was significant on all traits except shoot/root ratio, Fo, stomatal conductance, MPI, RWC, photosynthesis, and Na content. Great plantain was the most tolerant and psyllium was the most sensitive species to salinity stress. It is indicated that, in 300 mmol/L levels of salinity, plantago species growth had stopped and the plants could not complete their life cycle.

1. Introduction

Plantain is a name commonly applied to refer to a series of medicinal plants within the plantago genus which belongs to the well-known plantaginaceae family (Koyro, 2006). Plantain which is rich in beta carotene and calcium, provides ascorbic acid and vitamin K. Moreover, allantoin, apigenin, aucubin, baicalein, linoleic acid, oleanolic acid, sorbitol, and tannin are some important chemicals found in plantain (Smekens and Van Tienderen, 2001; Ronsted et al., 2002). Psyllium is a species of medicinal importance, generally grown in India, Pakistan and Iran with seeds commercially used for the production of mucilage. Psyllium is used in relieving chronic constipation, bowel cancer and gastrointestinal irritation it is also used in antitussive and anti-inflammatory drugs (Kala, 2015). Psyllium is also effective in reducing cholesterol level due to the existence of mucilage in the seeds (Gupta et al., 1994). Psyllium is native to Mediterranean regions, narrow leaf plantain is native to Eurasia and great plantain is native to Eurasia and North Africa (Al Hassan et al., 2014).

Salinity is one of the major environmental factors which limits the crop productivity and it is considered acting as the main source of yield reduction (Munns and Tester, 2008). Salinity affects 19.5% of irrigated and 2.1% of dry land agriculture across the globally (FAO, 2000). It is estimated that about one-third of the world's cultivated land is affected by salinity (Kaya et al., 2002). Salinization usually plays a primary role in soil degradation, which consequently reduces agricultural productivity (Zhang et al., 2014). The adverse effects of soil salinity in plants growth include ions toxicity, osmotic stress, nutritional disorders, and it also hampers the water uptake by the seeds and plants (Mooring et al., 1971; Zhu, 2001; Al-Thabet et al., 2004). The decrease in water uptake by the seeds and plants can cause physiological drought in both seedling and whole plant (Koyro and Eisa, 2008). Thus, such effects results either in death of the plant or plant yield reduction (Kala, 2015).

Some researchers have examined the impact of different salinity levels on morphological and physiological properties of plantago species. The findings revealed that by increasing salinity, the plant-parameters associated with the plant's morphological growth decreased considerably. Most reports suggest that salinity has reduced the plant growth and biomass production. Subsequently the reduction in the growth and productivity depends on the concentration of salts in which an increase in salt concentration leads to a greater growth reduction. Some experiments have indicated that the plantago genus can tolerate moderate levels of salinity (Koyro, 2006; Kala, 2015; Shekofteh, 2015; Al Hassan et al., 2014; Singh and Pal, 2000; Khaliq et al., 2011), thus; cultivation of plantago species in moderate levels of saline soils is recommended. In order to cope with the negative effects of salinity on plant's growth and productivity, the plant cells must readjust their osmotic potential to prevent water loss (Shabala et al., 2000).

Salinity is a global issue by which a wide geographical area of Iran has been affected. Statistically, Iran has the highest percentage of saline soils in the world after China, India, and Pakistan (Qureshi et al., 2007). In Iran, 44.5 million hectares of lands are affected with different levels

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of salinity (Banaei et al., 2005). Salt-affected lands could be beneficially utilized for the cultivation of medicinal plants, however little work has been done on medicinal plants to explore the possibility of using saline soils (Khaliq et al., 2011). Therefore, studying salt tolerance of the medicinal plants in order to be cultivated in saline lands is valuable. However; there has not been enough data in medicinal plants regarding the relationship between ion accumulation and morphological and physiological changes and its subsequent plant injuries with salt stress. The main objective of this study was to evaluate the effect of salinity on the morphological and physiological traits as well as ion concentration of three plantago species.

2. Materials and methods

2.1. Experimental design

In order to study the effect of salinity on morphological and physiological traits of psyllium (*Plantago psyllium* L.), narrow leaf plantain (*P. lanceolata* L.), and great plantain (*P. major* L.) an experiment was conducted in 2014 at the Research Greenhouse in the Faculty of Agriculture, Ferdowsi University of Mashhad, Iran (Lat 36° 15′ N, Long 59° 28′ E; 985 m Altitude). This study was carried out as a factorial experiment based on randomized complete block design with four replications. Treatments included three plantago species (*Plantago psyllium*, *P. lanceolata* and *P. major*) and six salinity levels (50, 100, 150, 200, and 250 mM plus non-saline water selected as the control). In this experiment, salinity levels were included 300 mM. But in 300 mM level of salinity, growth of three plantago species had stopped and all the plants were died. So, for statistical analysis, 300 mM salinity level was deleted.

The seeds were planted in plastic pots (with 17 cm diameter), filled with a mixture of sand and clay loam soil (1:1; v/v). Some physical and chemical properties of the soil are shown in Table 1. After development of the second true leaf, plants were thinned to five plants with uniform height per pot and each pot was irrigated by 100 mL of a water supplied with N:P:K (20:20:20) fertilizer (concentration of $2\,g\,L^{-1}$). Sodium chloride (NaCl), magnesium sulphate (MgSO4), magnesium chloride ($MgCl_2$), and calcium chloride ($CaCl_2$) with the ratio of 6:2:1:1 were the composition of the saline water respectively. Main chemical properties of the waters are shown in Table 2. Saline water was added 4 weeks after sowing (after plant establishment in pots) and continued to before plant harvest. High levels of salinity was gradually added, so that, the highest salinity treatment could be achieved after 5 times of irrigation. Furthermore, we have allowed the saline solutions to be drained freely to avoid nutrient depletion. The Plants were grown under greenhouse conditions with a 16 h day/8 h night period at 30 ± 4/18 ± 2 °C and relative humidity ranged from 45 to 65%.

2.2. Morphological traits measurements

Several morphological traits including; plant's fresh and dry weight, plant's height, leaf area, root dry weight, plant dry weight, and shoot/root weight ratio were measured. Plant material from each replicate was harvested and separated into leaf and root fractions. The leaf area was measured by a leaf area meter (Model Li-3100c COA). Aboveground parts and roots were separated and dried in an oven for 48 h at 68 °C and weighed.

Table 1
Some physical and chemical properties of the soil used in the experiment.

Texture	EC dS m^{-1}	pH	O.C%	O.M%	Total N%	Available P ppm	Available K ppm
Sandy Loam	1.45	7.65	0.31	0.53	0.034	2.5	53

2.3. Physiological traits measurements

The juvenile and adult leaves were used to evaluate the physiological traits. Net photosynthetic rate of the leaves was measured in three plants per pot with a photosynthesis system (Model LCA4, Analytical Development Company, England). Stomatal conductance was measured in all five plants per pot using a digital porometer (Leaf Porometer Model SC-1, Decagon Devices, USA) and chlorophyll index was measured in five plants per pot with chlorophyll-content meter (Minolta, Model SPAD 502, Japan). Leaf chlorophyll fluorescence parameters were measured using Plant Efficiency Analyser (Handy PEA, Hansatech Instruments, OS1-FL Model, Norfolk, UK). Leaves were dark-adapted for 30 min prior to fluorescence measurements. Both minimal fluorescence level in the dark-adapted state (Fo), and maximal fluorescence (Fm) were measured. Values of various fluorescence (Fv = Fm-Fo) and maximum quantum efficiency of PSII photochemistry (Fv/Fm) were calculated from Fo and Fm.

Relative water content (RWC) was determined from 10 leaf discs of the youngest fully expanded leaves. The leaf discs were weighed and then immediately floated in double distilled water for 24 h in Petri dishes. Turgid weights of leaf discs were obtained after removing superficially adhering droplets. Then dry weights were measured after drying them at 68oC for 48 h. Relative water content was calculated as:

RWC (%) = (FW-DW/TW-DW) × 100 (Netonda et al., 2004)

where FW, DW, and TW are the fresh, dry and turgid weight, respectively.

2.4. Membrane permeability index

Electrolyte leakage was used to assess membrane permeability using an electrical conductivity meter. In order to remove surface contamination of leaf samples, they washed with distilled water twice. Then 1 cm segments of leaf samples were placed in individual stopper vials containing 20 mL of distilled water. These samples were incubated on a shaker (100 rpm) for 6 h. Electrical conductivity (EC1) was read after incubation. Then the samples were placed in an autoclave at 110 °C for 20 min to determine the second reading (EC2). The membrane permeability index was calculated as:

MPI = (1 − (EC1/EC2)) × 100 (Sairam et al., 2002)

2.5. Ion analyses

The concentration of calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) as well as ash percentage of plants, were analyzed in subsamples of dried plant materials, which were ground in a mill grinder. Later 0.3 g of ground plant samples were placed into furnace at 600 °C for 4 h and then digested in HCl. Potassium and sodium elements were measured with a flame photometer (Jenway, PFP-7),while calcium and magnesium cations were measured using titration method by EDTA (0.01 normal) (Ryan et al., 2001).

2.6. Statistical analysis

In order to investigate the response of the three plantago species to different levels of soil salinity, the data was examined by the two-way analysis of variance, and the differences between means ($p \leq 0.05$) were assessed by Fisher's protected least significance difference (LSD). Statistical analysis of the data was performed using SAS 9.1 software and the figures were drawn using Excel software.

3. Results and discussions

It has been concluded that salinity induces morphological and

Table 2
Main chemical properties of the water used in the experiment.

Salinity mM	EC dS m^{-1}	pH	So_4	Cl	Co_3	Ca	Mg	Na	SAR %
			Meq.l^{-1}						
0	1.39	7.29	3.10	10.41	0	1.30	7.80	3.40	1.59
50	6.07	7.54	25.07	50.42	0	4.62	38.54	27.53	5.93
100	10.06	7.40	50.15	100.83	0	9.25	77.08	55.05	8.37
150	14.37	7.66	75.22	151.24	0	13.88	115.62	82.57	10.26
200	16.66	7.70	100.30	201.66	0	18.52	154.16	110.10	11.85
250	19.77	7.76	125.37	252.09	0	23.12	192.72	137.63	13.25

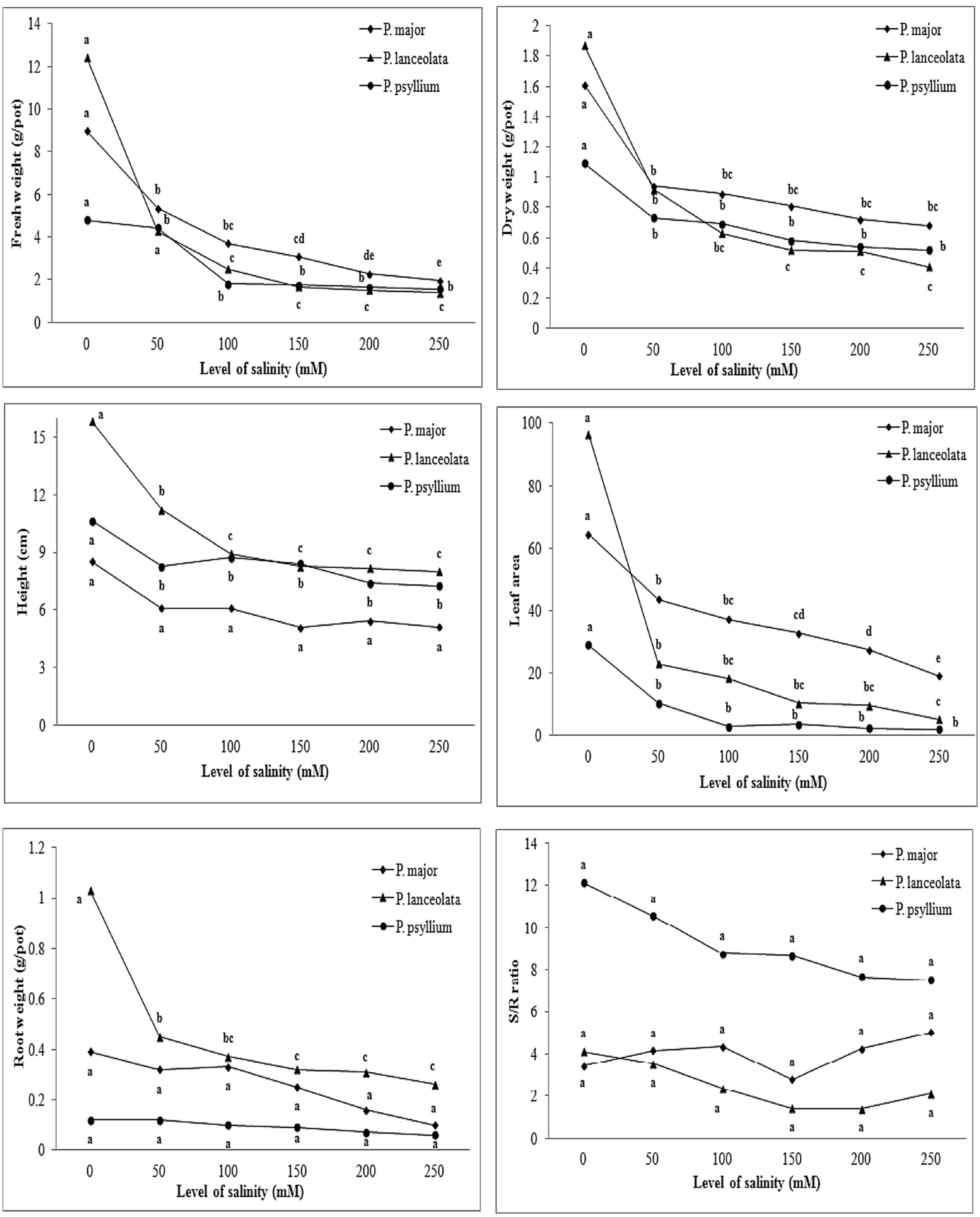

Fig. 1. Changes in morphological traits of three plantago species in different salinity levels.
*In each species, means with different letters are significant at 5% probability level.

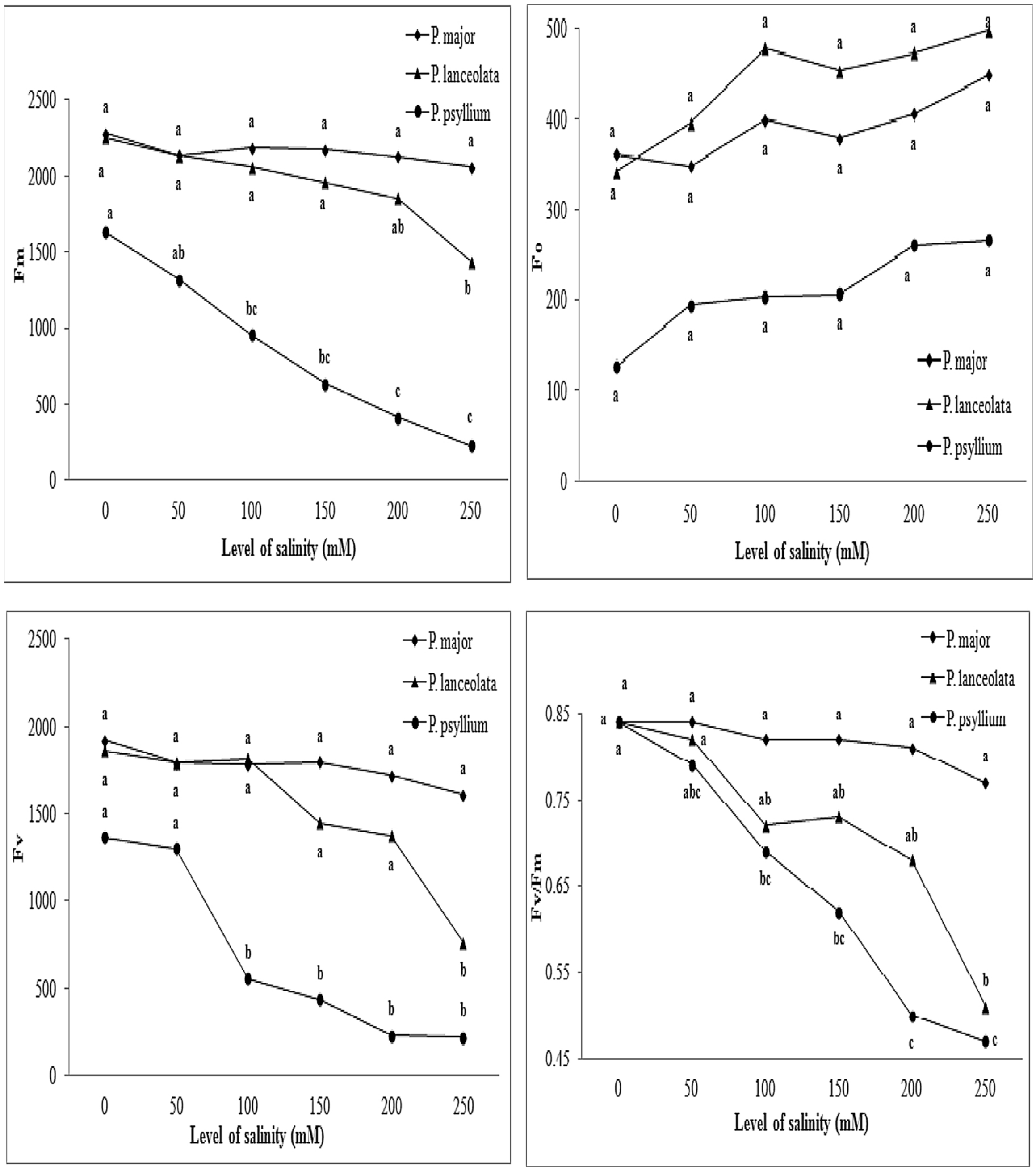

Fig. 2. Changes in chlorophyll fluorescence parameters of three plantago species in different salinity levels.
*In each species, means with different letters are significant at 5% probability level.

physiological changes in plantago species. The effect of salinity levels was not significant on shoot/root ratio, Fo, Fv/Fm, chlorophyll index, RWC, and MPI. Whereas, other previously mentioned traits were significantly affected by salinity. By increasing salinity levels, all the measured traits decreased significantly in plantago species, except dry matter, Fo, RWC, ash%, and Na (Figs. 1–4). Additionally, there was a significant difference between the three plantago species for all the measured traits, except for Fv/Fm, stomatal conductance, photosynthesis, and Mg concentration (Table 3). Based on our findings, the interaction of salinity and plantago species was significant in all the traits except shoot/root ratio, Fo, stomatal conductance, MPI, RWC, photosynthesis, and Na (Table 3).

Among the three plantago species, psyllium was the most sensitive to salinity stress. There was a significant difference between psyllium and the other two plantago species in terms of fresh weight, leaf area, root weight, Fm, Fo, Fv, chlorophyll index, and RWC (Table 4). Although the great plantain was more tolerant than narrow leaf plantain, this advantage was not significant in most of the traits (Table 4). Great plantain behaves as a typical glycophyte, therefore, it is not extremely sensitive to salt but this species has never been found in natural saline habitats (Al Hassan et al., 2014). Consequently, a significant difference between these two species was not observed in response to salinity for most traits including plant dry weight, plant height, leaf area, root weight, Fv, chlorophyll index, MPI, RWC, K, Na, and K/Na (Table 4). It is indicated that, in 300 mM level of salinity, the growth of three species had stopped and the plants could not complete their life cycle. It denotes that the three plantago species were able to complete their life cycle at salinity levels of lower than 300 mM.

The growth of three plantago species decreased significantly in high salinity levels. In addition, physiological traits such as stomatal

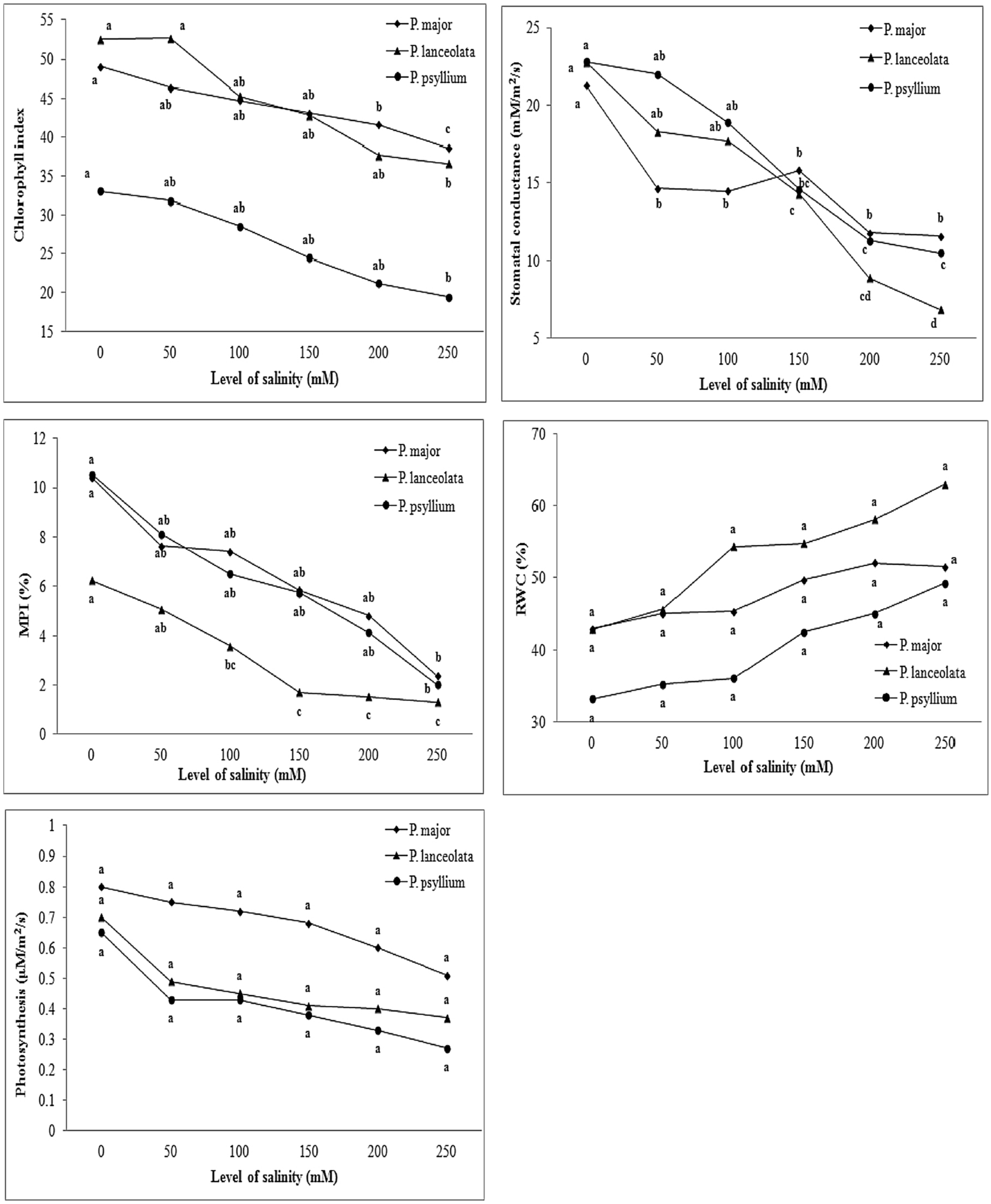

Fig. 3. Changes in physiological traits of three plantago species in different salinity levels.
*In each species, means with different letters are significant at 5% probability level.

conductance, photosynthesis, MPI, and chlorophyll index were affected strongly by high salinity levels (Table 5). Aboveground and the root's fresh and dry weight decreased by increasing of salinity in all the three species, although this reduction was more significant in *P. major* compared to *P. lanceolata* or *P. psyllium* (Fig. 1). By increasing salinity, a remarkable decrease in plant height was detected. Water is a major factor in plant growth and salinity causes water deficiency in plants by raising soil solution osmotic stress. Hence, water stress reduces plant height and weight. The reduction in dry weight occurs due to an increase of salinity, which influences plant growth and yield by exerting osmotic pressures and ionic effects. In addition salinity limits water uptake and may cause nutrient imbalances and toxicities in plants. All these factors can minimize plant growth and yield (Koyro, 2006). Grigore et al. (2012) showed that NaCl clearly had a substantial effect during the reproductive phase of life cycle, including fresh and dry weight of Plantago crassifolia. Nevertheless, since salt stress forces plants to spend additional energy, fewer energy sources are available for the development of morphological and physiological traits in this area (Cheesman, 1988). In our study, the presence of divalent cations in form of magnesium sulphate, magnesium chloride, and calcium chloride in the saline water can mitigate the deleterious effects of NaCl. Grigore et al. (2012) also demonstrated that both divalent cations such as Ca^{2+} or Mg^{2+} have protective roles against the effects of salt stress in plants.

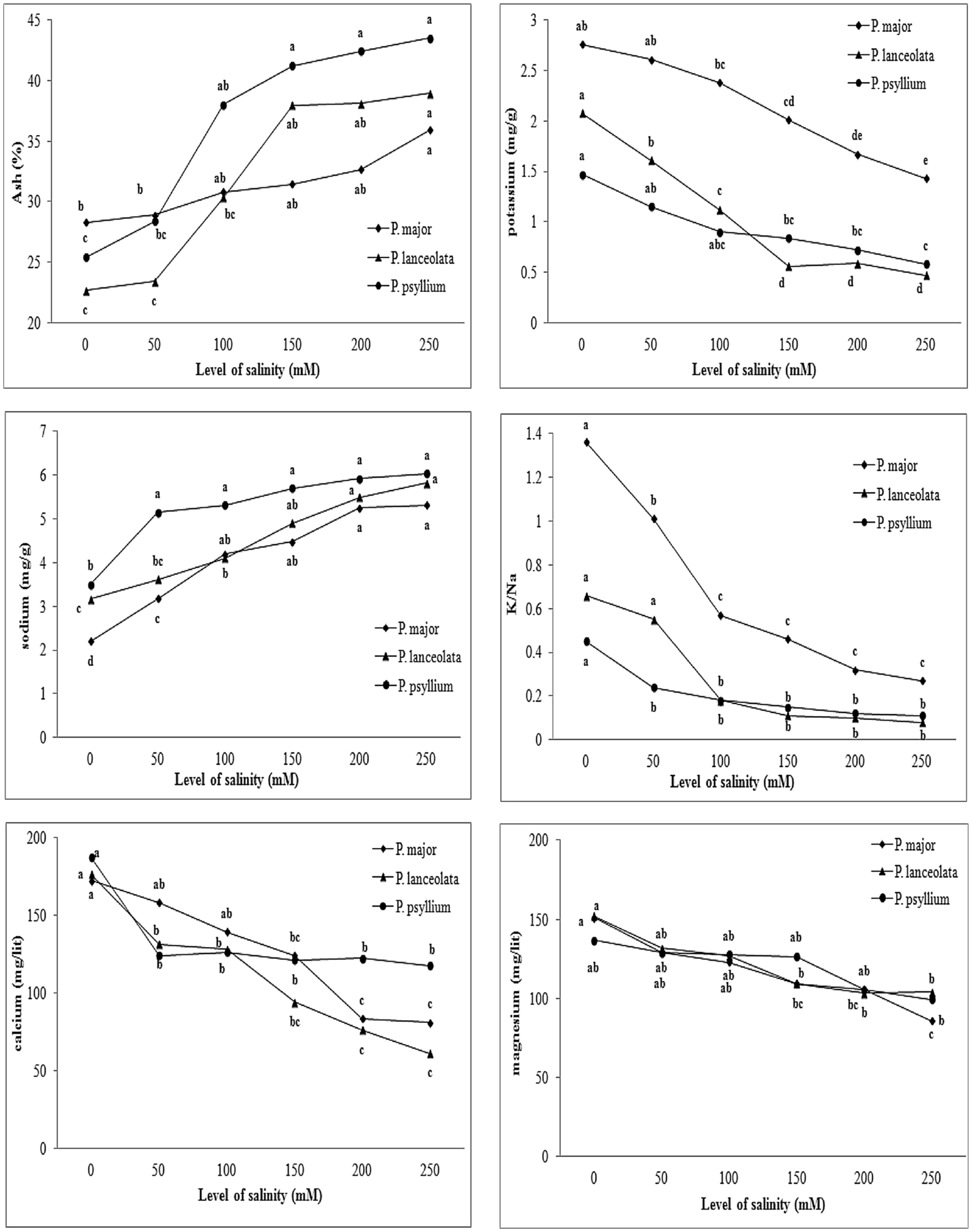

Fig. 4. Changes in ash and ion content of three plantago species in different salinity levels.
*In each species, means with different letters are significant at 5% probability level.

The results also showed that by increasing salinity, Fo, RWC, ash%, and Na and Mg concentration have increased, although it was not significant for Fo, RWC and Mg concentration traits (Table 5). Unexpectedly, it was observed that RWC was not affected by salinity. At higher salinity levels, a distinct decrease in leaf area, fresh and dry weight was observed in which it had led to a decrease in stomatal conductance and photosynthesis. The results obtained are compatible with those reported by Eisa et al. (2012), Khaliq et al. (2011), Shekofteh (2015), Kamkar and Rahimi (2012), and Al Hassan et al. (2014). Such structural and morphological changes are very efficient in reducing water loss on plant level and plant growth (Koyro, 2006). Based on our results, physiological traits of plantago speciese were less affected by salinity compared with morphological traits.

Salt tolerance threshold,that is the initial significant reduction in the maximum expected traits (Shannon and Grieve, 1999) in great plantain, was observed at 100, 150, 200 and 250 mM for potassium content and K/Na ratio, calcium content, Chlorophyll index, and for MPI respectively. Plant height, root weight, all chlorophyll fluorescence

Table 3
Analysis of variance of the effect of different levels of salinity on morphological and physiological traits of plantago species.

No.	Traits	Mean of square				
		Block	Species	Salinity	Species × Salinity	Error
1	Fresh weight	2.22^{ns}	14.75**	85.90**	11.44**	1.25
2	Dry weight	0.11^{ns}	0.37**	1.50**	0.17**	0.04
3	Height	0.67^{ns}	97.94**	38.58**	5.87*	2.20
4	Leaf area	237.38**	5244.30**	4774.41**	716.14**	56.25
5	Dry matter	6.52^{ns}	188.81**	564.38**	69.97**	8.24
6	Root weight	0.02^{ns}	0.79**	0.18**	0.10**	0.01
7	Shoot/Root ratio	36.98^{ns}	422.25**	29.90^{ns}	38.46^{ns}	28.02
8	F_m	40918.5^{ns}	11628817.79**	915998.59**	302764.66*	137768.26
9	F_o	27569.79^{ns}	489630.26**	13469.02^{ns}	28851.99^{ns}	30569.95
10	F_v	17453.27^{ns}	7716980.06**	1143943.51**	337882.96**	80909.90
11	F_v/F_m	0.01^{ns}	0.06^{ns}	0.04^{ns}	0.08**	0.02
12	Chlorophyll index	42.29^{ns}	843.20**	135.56^{ns}	133.81*	56.23
13	Stomatal conductance	23.68^{ns}	11.55^{ns}	193.02**	13.31^{ns}	15.80
14	MPI	8.27^{ns}	117.40**	25.26^{ns}	21.53^{ns}	11.29
15	RWC	26.21^{ns}	596.14**	161.86^{ns}	45.35^{ns}	93.16
16	Photosynthesis	0.01^{ns}	0.17^{ns}	0.15*	0.07^{ns}	0.04
17	Ash	1.00^{ns}	151.07*	317.83**	77.95*	31.19
18	K	0.14^{ns}	11.34**	3.15**	0.27**	0.08
19	Na	0.38^{ns}	4.76**	10.78**	1.17^{ns}	0.58
20	K/Na	0.003^{ns}	1.28**	0.80**	0.09**	0.03
21	Ca	2195.95*	2979.40*	6665.55**	4027.18**	736.3
22	Mg	814.55^{ns}	100.20^{ns}	1891.36**	1008.61*	386.06

MPI: Membrane Permeability Index, RWC: Relative Water Content.
**,* and ns: significant at the 0.01, 0.05 level of probability and no significant, respectively.

Table 4
Mean comparisson of morphological and physiological traits between three plantago species.

Traits	Great plantain	Narrowleaf plantain	Psyllium	LSD
Fresh weight	4.05	3.99	2.66	0.65
Dry weight	0.94	0.81	0.70	0.12
Height	6.05	10.06	8.45	0.86
Leaf area	37.48	27.16	8.33	4.35
Dry matter	26.06	26.31	31.04	1.66
Root weight	0.26	0.46	0.09	0.05
Shoot/Root ratio	4.50	2.49	10.55	3.07
F_m	2160.70	1949.40	863.30	215.11
F_o	390.63	491.88	209.92	101.33
F_v	1770.04	1508.04	683.46	164.85
F_v/F_m	0.82	0.73	0.74	0.11
Chlorophyll index	41.06	44.56	32.42	3.46
Stomatal conductance	14.56	14.79	14.72	2.19
MPI	7.15	3.28	8.14	1.78
RWC	47.77	53.13	34.21	5.45
Photosynthesis	0.51	0.47	0.45	0.14
Ash	31.34	31.91	36.51	3.12
K	2.24	1.07	0.94	0.15
Na	4.11	4.85	4.99	0.42
K/Na	0.67	0.28	0.21	0.09
Ca	126.22	111.00	132.97	15.26
Mg	117.30	121.24	120.75	10.81

MPI: Membrane Permeability Index, RWC: Relative Water Content.

parameters such as Fm, Fo, Fv, Fv/Fm, RWC, and photosynthesis were not affected by salinity to 250 mM in great plantain. However for other traits, salt tolerance threshold was observed at 50 mM salinity (Figs. 1–4). In narrow leaf plantain, salt tolerance threshold was observed at 100 mM for MPI and K/Na ratio, at 150 mM for Stomatal conductance, and for Fm, Fv, Fv/Fm, and chlorophyll index it is indicated at 250 mM. Chlorophyll fluorescence parameters such as Fo and Fv/Fm, RWC, and photosynthesis were not affected by salinity to 250 mM in this species. For other traits it was observed at 50 mM salinity (Figs. 1–4). However in psyllium species, salt tolerance threshold was observed at 100 mM for fresh weight, Fv, and potassium content, at 150 mM for Fm, Fv/Fm, stomatal conductance, and at 250 mM for MPI and chlorophyll index. Similar two other species, salt tolerance threshold was not observed to 250 mM salinity for root weight, chlorophyll fluorescence parameter such as Fo, RWC, and photosynthesis in psyllium specie. For other traits it was observed at 50 mM of salinity (Figs. 1–4). Salt tolerance threshold for Quinoa (*Chenopodium quinoa* Willd.) was observed at 200 mM NaCl (Eisa et al., 2012).

It is important to mention that maximum concentration of nutrients such as potassium, calcium, and magnesium in the leaves of the three plantago species was observed in non-saline conditions (Fig. 4). Low and high salinity levels led to a significant decrease of the K, Ca, and Mg concentrations (Fig. 4). The reduction slope of magnesium concentration with the increase of salinity, was less than calcium and potassium (Fig. 4). The change pattern in the concentration of magnesium, calcium, potassium, and sodium were similar in the three plantago species. In response to salinity stress, the concentration of the essential ions such as K, Ca, and Mg in three plantago species has decreased (Fig. 4). It is indicated that minimum value of the mentioned nutrients reached in the maximum salinity levels. Koyro (2006) also reported that in high salinity conditions, the concentration of Ca, K, Mg, and nitrate in *Plantago coronopus* L. has decreased transiently. At all salinity levels, Na concentration in adult leaves was higher than of those grown in control condition (Fig. 4). The mineral composition changes towards Na and Cl uptake in the leaves which is the first reaction of the plants to salinity. In addition, the increase in Na content and the decrease in the concentration of K, Ca, and Mg could cause ion imbalance in the plants. According to our findings, maximum ion imbalance was observed in psyllium,which was in agreement with those reports by Zhang et al. (2014). Although three plantago species survived and completed their life cycle even at high salinity level (250 mM), some visual symptoms of ion deficiency and/or toxicity were observed in the adult leaves.

In this study, we have compared the different responses of the three plantago species to salt tolerance. Overall, salinity had no significant effect on height, root weight, shoot/root ratio, and all chlorophyll fluorescence parameters such as Fm, Fo, Fv, Fv/Fm, RWC, and also photosynthesis in the great plantain. Moreover, salinity did not have any significant effect on shoot/root ratio, Fo, Fv/Fm, RWC, and photosynthesis in the narrow leaf plantain species and on root weight,

Table 5
Mean comparisson of morphological and physiological traits between different salinity levels.

Traits	0	50	100	150	200	250	LSD
Fresh weight	8.60	4.52	2.62	2.18	1.80	1.67	0.92
Dry weight	1.52	0.79	0.68	0.67	0.62	0.59	0.17
Height	11.67	8.52	7.46	7.24	7.38	6.84	1.21
Leaf area	63.31	25.65	19.48	15.60	13.15	8.72	6.15
Dry matter	20.38	19.09	27.23	31.00	33.45	35.66	2.35
Root weight	0.50	0.21	0.28	0.27	0.20	0.16	0.08
Shoot/Root ratio	8.64	6.27	5.88	5.55	4.43	4.29	4.34
F_m	2015.80	1904.30	1664.50	1548.50	1572.20	1241.40	304.21
F_o	323.25	334.83	360.75	372.83	375.50	417.67	143.30
F_v	1692.60	1649.70	1238.00	1276.80	1200.20	865.90	233.13
F_v/F_m	0.84	0.78	0.77	0.71	0.67	0.76	0.13
Chlorophyll index	42.32	49.55	44.96	40.36	42.07	37.57	7.28
Stomatal conductance	22.02	17.06	16.10	14.50	10.23	9.34	3.79
MPI	6.99	6.36	6.18	4.55	3.05	1.94	5.08
RWC	43.92	44.30	49.85	56.39	55.07	53.16	10.62
Photosynthesis	0.70	0.49	0.37	0.44	0.41	0.40	0.23
Ash	25.66	27.54	35.09	35.84	37.35	38.02	4.42
K	2.10	1.98	1.44	1.09	1.05	0.83	0.22
Na	2.96	3.97	5.03	5.20	5.25	5.45	0.59
K/Na	0.82	0.59	0.30	0.23	0.20	0.15	0.13
Ca	156.33	131.33	126.00	132.83	107.33	86.54	21.59
Mg	102.72	107.62	118.55	128.84	124.30	136.54	15.28

MPI: Membrane Permeability Index, RWC: Relative Water Content.

shoot/root ratio, Fo, RWC, and photosynthesis in the psyllium species (Figs. 1–4). The traits that were not affected by salinity can explain the greater tolerance to salt stress which was exhibited by great plantain compared to the other two species. Accordingly, the results indicate that great plantain is a promising salt-tolerant species in terms of biomass production and can be grown productively under moderate to high saline conditions of the Caspian sea.

Salt tolerance in plants is a complex process that could change morphological traits along with physiological and biochemical processes. These changes include; leaf area reduction, reduction in cell development, stomatal closure, photosynthetic limitation and delayed growth. Adaptation processes,for instance ion transport and replacement, synthesis and accumulation of osmotic solutions for the osmotic regulation and the alteration of proteins in repairing the cells, have led to plant survival and growth in saline environments (Khaliq et al., 2011). Morphological traits are a suitable and useful indicator while physiological traits are a simple and fast indicator for assessment of salinity effects in plantago species. The results of the present study indicated that maximum growth traits such as plant fresh and dry weight, plant height, leaf area and root weight were observed under no-saline conditions. All in all, morphological traits were the most variable among the three plantago species.

4. Conclusions

Due to the large surface area of saline and the increasing number of dry areas caused by climate conditions and according to the lack of rainfall and high evapotranspiration rates in most parts of Iran, the assessment of the plants response to salinity appears to be of significance (Kafi et al., 2010). Consequently, understanding how some potential halophyte crops, especially medicinal plants, can manage salinity has become a controversial issue. The aim of this study is to engineer crops which can be grown on such soils (Rengasamy et al., 2003). Ultimately, however psyllium did not appear to be tolerant to high levels of salinity, *P. major* and *P. lanceolata* had shown adequate tolerance to severe salt stress. Plantago species can probably survive at salinities higher than Caspian seawater. These species especially *P. major* can be used in cultivating marginal salted soils. *P. major* is a perennial glycophyte which is considered an important medicinal plant, it appears to be much more salt tolerant than the other two species. Thereby, these results demonstrate that irrigation of *P. major* with Caspian seawater is possible.

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