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The effect of Diammonium Phosphate Fertilization on Salinity Tolerance of Maize (*Zea mays* L.)

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Abstract

A greenhouse experiment was carried out to examine the effect of phosphorus fertilization on the tolerance of maize (*Zea mays* L.) to different soil salinity levels in 2011 at Mohaghegh Ardabili University in Ardabil- Iran. Five levels of phosphorus (0, 20, 40, 80 and 160 kg P ha^{-1}asdiammonium phosphate) and 10 salt levels (0.75, 1.20, 2.29, 3.30, 4.25, 5.11, 6.19, 8.80, 10.88 and 14.00 dSm^{-1}) were investigated as a factorial combination with a randomized complete blocks design with three replications. The results showed that stem diameter, leaf number and area, leaves chlorophyll index and shoot and root dry weights at 60 days after germination were significantly increased with phosphorus applications but were decreased with increasing soil salinity levels. Shoot and root phosphorous concentrations were increased with increasing soil salinity and phosphorus level. The maize plants treated with 80 kg P ha^{-1} produced higher shoot and root dry matter over other levels. Maximum stem diameter, leaf number and area, leaves chlorophyll index were obtained by using 160 kg P ha^{-1}. The interactive effects salinity and phosphorous on chlorophyll index and dry weight of shoot and root was significant, whereas other growth indices were not markedly changed. Application of phosphorus fertilizer mitigated the negative influences of salinity, causing the corn growth be increased.

***Key words*:** Growth parameters, Maize, Phosphorus, Salinity, Soil

1. Introduction

Agricultural crops may be exposed to different environmental stresses which limits their growth and productivity during their growth period. Among these factors, drought and salinity are the most severe ones (Bohnert *et al*., 1995). It has been estimated that more than 20% of all cultivated lands around the world contain levels of salts high enough to cause salt stress on crop plants (Boyer, 1982; Yeo and Flowers, 1982). This is particularly the problem of agriculture in arid and semiarid regions of the world (Flowers and Yeo, 1995; Chomczynski and Sacci, 1987; Keiffer, and Ungar, 1997; Szaboles, 1987; Nelson *et al*., 1998). Excess salt in the soil may adversely affect plant growth either through osmotic inhibition of water uptake by roots or specific ion effects. Specific ion effects may cause direct toxicity or, alternatively, the insolubility or competitive absorption of ions may affect plant nutritional balance (Greenway and Munns, 1980). Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts required by plants. P deficiency affects not only plant growth and crop yield, but also the quality of fruit and formation of seeds. Because of its importance for plant growth it is critical to ensure that the crop has adequate amounts of P, which can be supplied by commercial fertilizers or animal manures (Bronson *et al*., 2001). After wheat and rice, maize (Z*ea mays* L.) is the third most important cereal crop and it is grown all over the world under a wide range of environmental conditions (Paterniani, 1990). Salt stress affects many physiological aspects of plant growth. Shoot growth was reduced by salinity due to inhibitory effects of salt on cell division and enlargement in growing points (Mccue and Hanson, 1990). Net photosynthesis rate was decreased due to the reduction in photosynthesis and increase in respiration per unit of leaf area. Studies on physiological salt tolerance mechanisms revealed that plants may reduce detrimental effects of salts by the control of salt uptake (Wye Jones, 1980), reducing damage under excessive ion uptake (Yeo and Flowers, 1982; Oertli, 1968), and osmotic adjustment (Jeschke, 1984). In general, phosphorus deficiency in crop plants growing in alkaline soils is caused primarily by very low levels of available phosphorus and soil moisture, that is, when the mobility of P is limited and root growth is restricted (Marschner, 1995). Plant growth behavior is influenced by the application of P (Hajabbasi and Schumacher, 1994; Gill *et al*., 1995; Kaya *et al*., 2001). P application increases the plant height, grain weight per cob, dry matter and grain yields (Sharma and Sharma, 1989; Mullar and Weigert, 1991; Singh and Dubey, 1991; Sharma and Gupta, 1998). Higher P application reduces the sodium absorption ratio and increases crop production in saline sodic soils (Chaudhry *et al*., 1992).

The main objective of this study was to determine the growth and yield response of maize cultivars to different levels of P under saline conditions.

2. Matrials and Methods

Initial soil samples (0-30 cm) were collected from 45 different points of Zaranas basin in Ardabil, Iran. The coordinates of sample sites were recorded using a hand-held Global Position System (GPS) instrument. Then, 10 soil samples with different natural salinity levels and different physical and chemical properties were selected for the experiment. The Geographical locations of selected points were shown in figure 1. All soil samples (100 kg from each one) were air-dried and passed through a 2-mm stainless steel sieve. Soil pH was measured in the saturated paste using a pH-meter (Metrohm, model 644), electrical conductivity (EC) in saturated paste extract by EC-meter (Metrohm, model 691), calcium carbonate equivalent (CCE) through neutralizing with acid and titration with NaOH (Gupta, 2004). Organic carbon (OC) and soil texture were determined by the wet oxidation method (Nelson and Sommers, 1982) and hydrometer method (Jones, 2001), respectively. Total nitrogen was determined by Kjeldahl method. Available P was extracted with sodium bicarbonate and determined via colorimetric method. Available potassium extracted with ammonium acetate and soluble sodium in saturation extract were also determined through flame photometry (Jones, 2001) (Table 1).

The experiment was conducted in a randomized complete block design in a factorial combination with three replications in the greenhouse, at Mohaghegh Ardebili University in Ardabil. Experiment factors were soil salinity at 10 levels (0.75, 1.20, 2.29, 3.30, 4.25, 5.11, 6.19, 8.80, 10.88 and 14.00 dSm^{-1}) and P at five levels (0, 20, 40, 80 and 160 kg P ha^{-1}). Having transfered 4.5 kg of soil into the pots, P treatments were applied as diammonium phosphate. Seven corn seeds of 'Konsur' (*Zea mays* L.) variety were sown at the depth of 3 cm, during 2011 growing season. Soil moisture was controlled at field capacity by weighing the pots during the growth period. To determine the field capacity of each soil sample, the amounts of soil placed in separate pots and were saturated and covered by plastic sheets. After removal of gravity water, the moisture content of the pots was considered as field capacity. At three leaf stage, the number of plants was reduced to four per pot. The nitrogen fertilizer (200 kg ha^{-1}) in the form of urea was applied after the germination stage (one third of whole required amount the application). The rest of nitrogen fertilizer was applied in two stages with 20 days interval. At the end of the 10^{th} week, stem diameter, leaf area and leaf chlorophyll index (SPAD Minolta – Japan – model 502) (Hiscox and Israelstam, 1978) were determined. Then the plants were harvested from soil surface and washed with tap and distilled water, and dried at of 65°C for 48 h. Dry weights of the shoot and the root and P concentrations of the shoot and the root were measured. Statistical analysis of data including analysis of variance and Duncan's multiple range test was performed using SAS software (SAS Inc., Cary, NC).

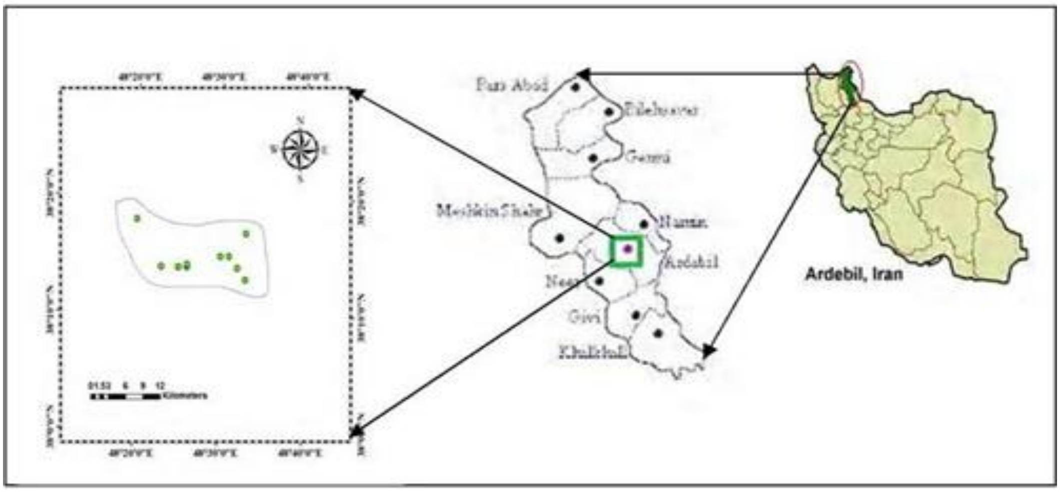

Fig1: The Geographical locations of selected sampling points

Table 1: physical and chemical properties of the selected soil samples

Soil properties	Salinity (dSm^{-1})									
	0.75	1.20	2.29	3.30	4.25	5.11	6.19	8.80	10.88	14.00
pH	7.19	7.39	8.09	7.13	7.88	8.62	8.59	8.73	8.69	9.47
Nitrogen (%)	0.084	0.200	0.49	0.059	0.220	0.098	0.105	0.007	0.189	0.094
Phosphorus (mg/kg)	16.80	38.91	15.91	17.25	16.36	27.74	16.36	19.99	19.53	27.74
Potassium (mg/kg)	990	3101	3329	1864	2827	3679	915	2565	932	829
Sodium (mg/kg)	201	193	601	302	392	870	982	954	4500	4600
Organic Carbon (%)	0.741	1.716	1.072	1.033	1.131	0.491	0.624	0.780	0.409	0.399
CCE (%)	2.0	1.6	5.9	5.2	9.2	7.9	10.0	11.8	8.3	14.6
Sand (%)	39.00	31.33	31.00	37.00	41.33	64.65	41.00	49.00	40.65	44.65
Silt (%)	29.33	40.00	42.33	29.33	44.00	26.33	44.33	35.33	36.33	36.33
Clay (%)	31.67	28.67	26.67	33.67	14.67	9.05	14.67	15.67	23.02	19.02
Soil texture	Clay loam	Loam	Loam	Clay loam	Loam	Sandy loam	Loam	Loam	Loam	Loam

3. Results and Discussion

Salinity and P application significantly affected stem diameter, leaf number and area, chlorophyll index of leaves, dry weight of shoot and root and P concentrations of shoot and root. Their interactive effects on stem diameter, leaf number and area and P concentrations of shoot and root were non-significant, whereas interactive effects on the chlorophyll content of leaves and dry weight of shoots, were significant ($p<0.01$) (Table 2).

Stem diameter was significantly enhanced with increasing P levels, whereas soil salinity caused it to be decreased markedly (Figures 2a and 2b). The highest stem diameter was recorded at salinity level of 0.75 dSm^{-1} (6.86 mm) and P application of 160 kg P ha^{-1} (6.26 mm). The lowest stem diameter obtained from the salinity level of 14.00 dSm^{-1} (3.07 mm) and P level of 0 kg P ha^{-1} (4.25 mm). The detrimental effects of salinity on stem diameter were offset by P application. The results revealed that maize plants have the potential to increase stem diameter with P fertilizer applications under saline conditions. The results also revealed that maize plants treated with high P levels were least affected by salinity at the later stages of growth. The increasing trend in stem diameter of maize plants with an increase in P application requires further research with higher levels of phosphorus. This result is in accordance with those of Francois et al. (1990) who reported that stem diameter of Kenaf plants decreased with increasing salinity levels.

Table2: The variance analysis of the effects of different treatments on the growth indices of corn plant

Sources of variation	df	MS							
		Steam diameter	Leaf number	Leaf area	Leaf chlorophyll	Shoot dry matter	Root dry matter	Shoot P concentration	Root P concentration
Salinity	9	78.36	82.28	459481.88	2112.29	73.53^{**}	17.7^{**}	0.107^{**}	0.135^{**}
P level	4	**	**	**	**	5.98^{**}	2.05^{**}	0.53^{**}	0.149^{**}
Salinity× P	36	52.53	4.42^{**}	87423.91^{*}	695.68^{**}	0.432^{**}	0.23^{**}	0.036^{ns}	0.013^{ns}
level	98	**	0.02^{ns}	*	32.49^{**}	0.13	0.01	0.012	0.009
Error		0.93^{ns}	0.02	4232^{ns}	8.61				
		1.18		3904.707					
CV (%)	-	20.29	14.94	50.07	9.95	12.77	8.22	26.86	26.99

The results showed that the leaf number and area were decreased with increasing salinity and were increased with P application (Fig 3a, 3b, 4a and 4b). The maximum leaf number [5.08] and area [239.5 cm^2] were produced from salinity level of 0.75 dSm^{-1} and P application at the rate of 160 kg P ha^{-1}, respectively. The lowest leaf number and area (1.16 and 17.07 cm^2 respectively) were produced by P application at the rate of 0 kg P ha^{-1} and salinity level of 14.00 dSm^{-1}. Increasing salinity level from 0.75 to 14.00 dSm^{-1} reduced the leaf area about 92 percent. The leaf area was highly affected by salinity. The results of research showed that an increase in P nutrition stimulated tillering that directly related to leaf formation on main stems due to P availability (Payne *et al.*, 1991; Gutie'rrez-boem and Thomas, 1998). With regard to P role in creation of leaf and its area, Gutie'rrez-boem and Thomas (1998) reported that deficiently of P decreased the creation of leaf and inhibition of cells development decreased leaf area.

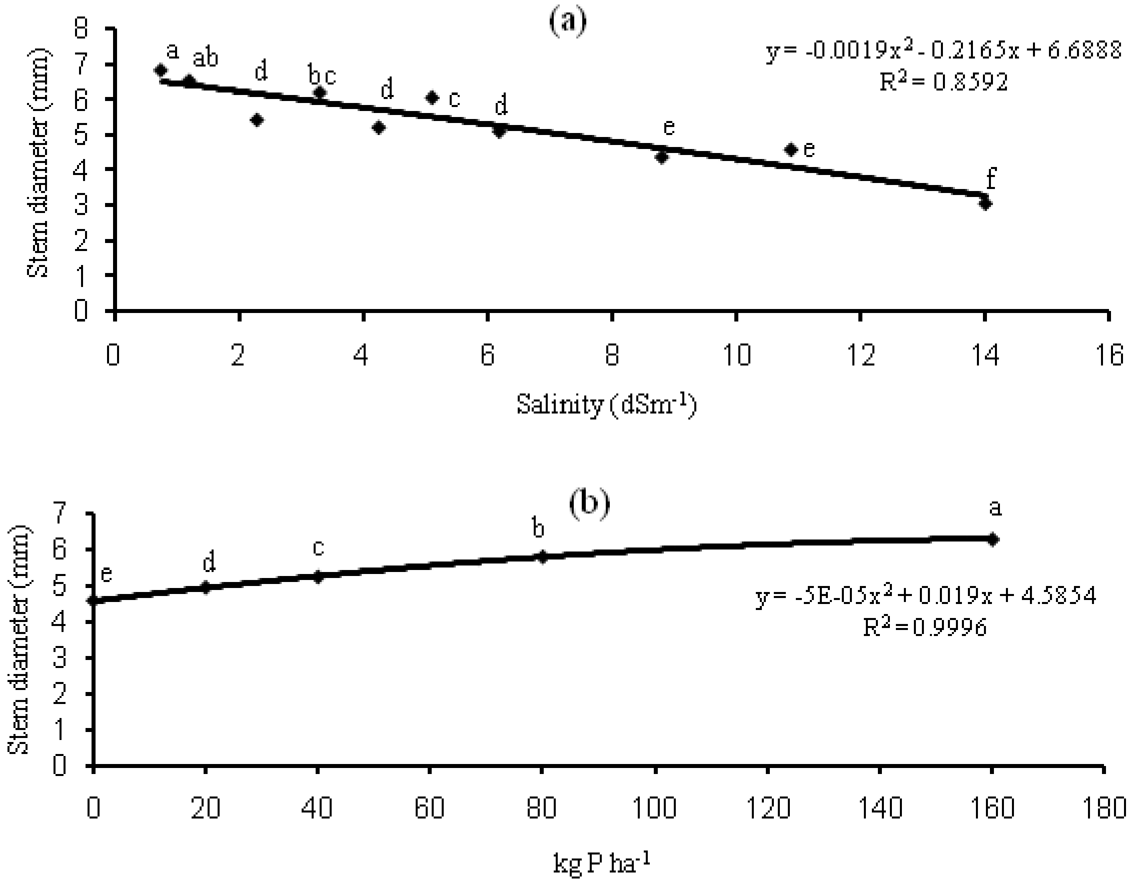

Fig 2: The effect of soil salinity (a) and phosphorus (b) on stem diameter

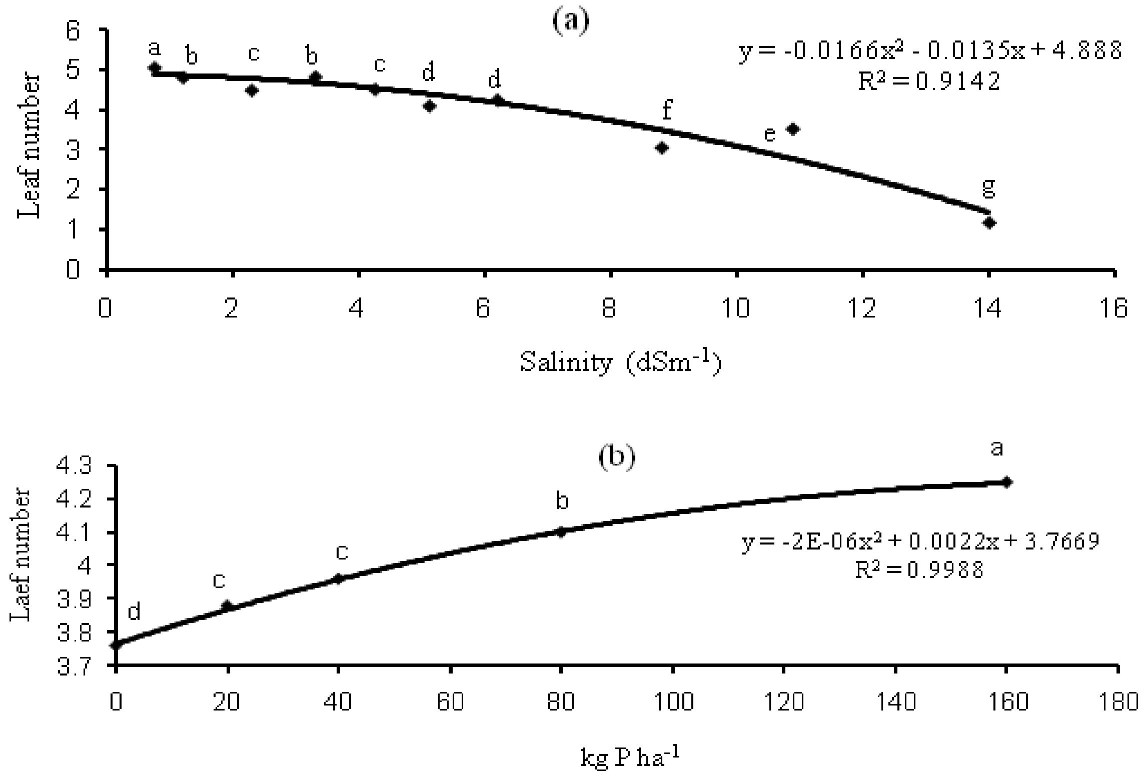

Fig 3: The effect of soil salinity (a) and phosphorus (b) on leaf number

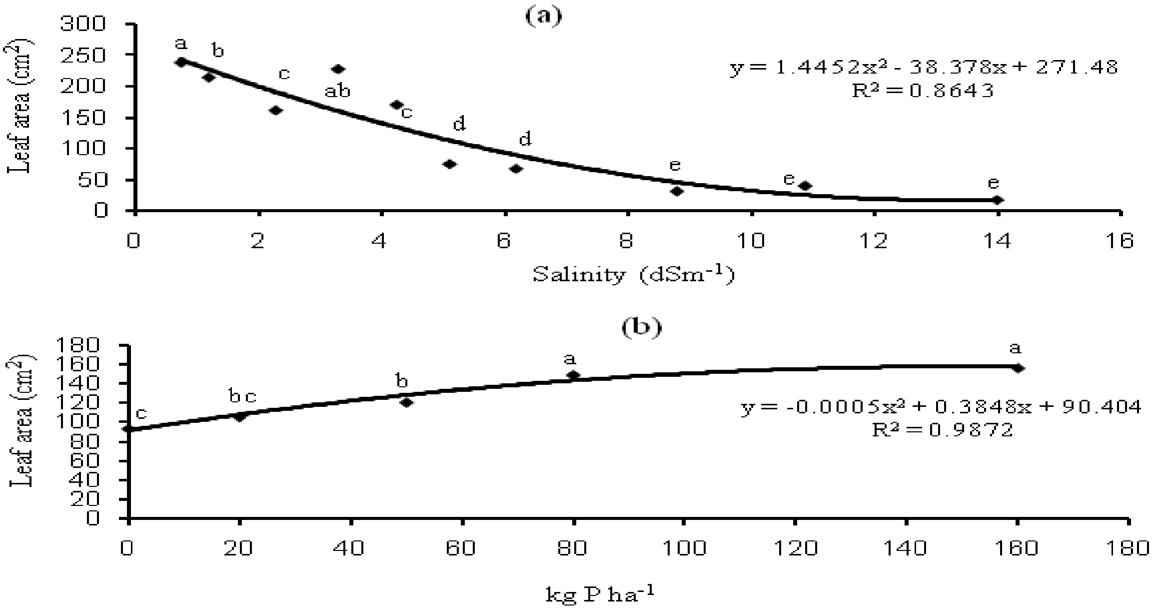

Fig 4: The effect of soil salinity (a) and phosphorus (b) on leaf area

The maximum leaf chlorophyll index was observed in the EC of 1.2 dSm^{-1} (34.39) and its lowest amount was obtained in 14.00 dSm^{-1} (13.45) (Figure 5a). EC levels below 3.3 dSm^{-1} had negligible effect, causing only 3% decrease in this trait. From EC of 4.25 to 14.00 dSm^{-1} leaf chlorophyll index was reduced about 45 percent. These results are in agreement with Bar-tal *et al.* (1991) for corn, Satti and Al- Yahyi (1995) for tomato, Kaya *et al.* (2001) in cucumber and pepper, Leidi and Saize (1997) for cotton. Prasad (1997) reported leaf chlorophyll index decreased with increasing salinity. The reduction in leaf chlorophyll content under salinity stress has been attributed to the destruction of chlorophyll pigments and the instability of the pigment protein complex (Levit, 1980). It is also attributed to the interference of salt ions with the de novo synthesis of proteins, the structural component of chlorophyll, rather than the breakdown of chlorophyll (Jaleel *et al*., 2007). The superlative of this index was obtained in the 160 kg P ha^{-1} P level (32.76) and its lowest amount was obtained in zero P level (26.59) (Figure 5b). The interaction of salinity and P showed similar results (Table 3a). Application of 160 kg P ha^{-1} increased 20 percent leaf chlorophyll index compared to the control. The results of Kaya *et al.* (2001) showed that application of P fertilizer under saline conditions, increased leaf chlorophyll index. (Table 3b).

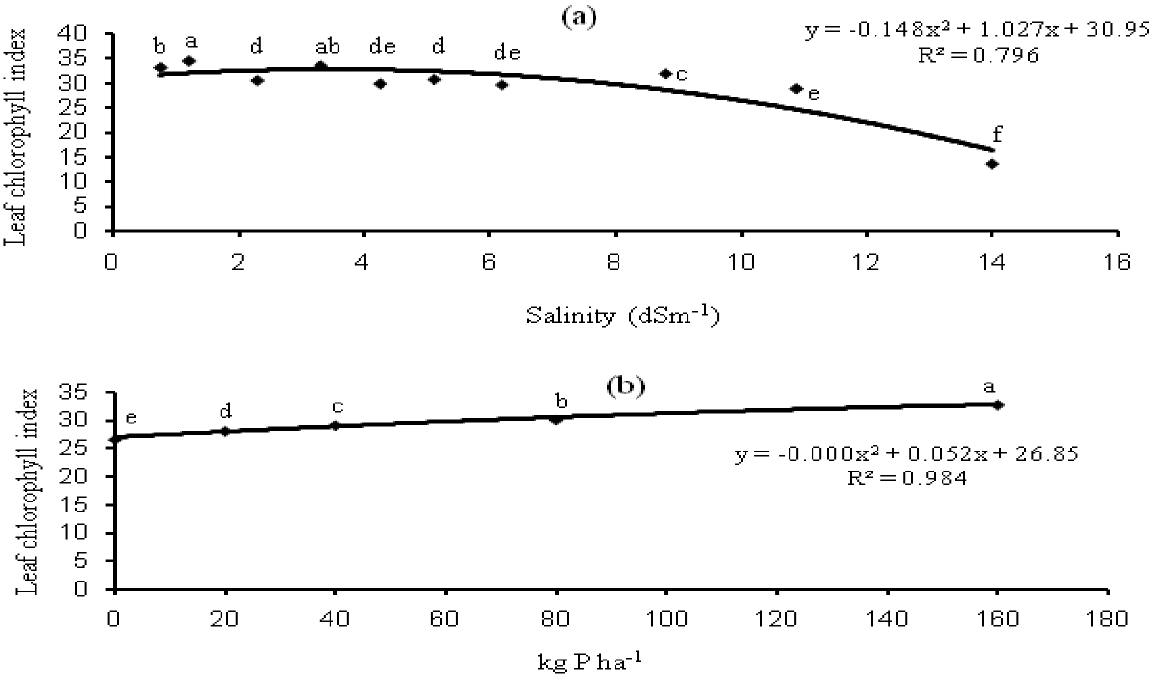

Fig 5: The effect of soil salinity (a) and phosphorus (b) on leaf chlorophyll index

Table 3: The interaction of soil salinity and phosphorus on leaf chlorophyll index

kg P ha^{-1}	Salinity (dSm^{-1})									
	0.75	1.20	2.40	3.30	4.25	5.11	6.19	8.80	10.88	14.00
0	29.80^{k-p}	32.63^{c-l}	28.36^{o-r}	31.00^{g-o}	27.35^{p-r}	29.59^{l-p}	25.76^{r}	28.60^{m-r}	26.34^{qr}	6.18^{w}
20	31.10^{g-o}	33.41^{a-i}	29.11^{m-p}	32.67^{c-l}	28.80^{m-r}	29.81^{k-p}	29.65^{l-p}	29.95^{j-p}	27.40^{p-r}	9.94v
40	33.17^{b-k}	33.89^{a-h}	29.81^{k-p}	33.30^{b-j}	30.61^{h-p}	30.44^{i-p}	29.01^{m-q}	31.09^{q-o}	28.08^{o-r}	11.88^{u}
80	35.09^{a-e}	35.38^{a-d}	31.55^{f-n}	34.13^{a-g}	30.05^{i-p}	30.60^{h-p}	30.92^{g-o}	34.02^{b-g}	29.64^{l-p}	17.63^{t}
160	36.00^{ab}	36.63^{a}	33.07^{b-k}	35.89^{a-c}	31.80^{e-m}	32.54^{d-l}	32.10^{o-m}	34.85^{b-f}	32.08^{d-m}	22.64^{s}

The results showed that an increase in salinity levels, shoot and root dry weights were decreased significantly (Fig 6a). The maximum shoot and root dry weights were produced with an EC of 0.75 dSm^{-1} (5.90 and 2.85 $gpot^{-1}$) and the lowest of these properties were produced in EC of 14.00 dSm^{-1} (0.22 and 0.10 $gpot^{-1}$), respectively. By increasing soil salinity level from 0.75 to 14.00 dSm^{-1}, shoot and root dry matters were decreased 96 percent. The results showed that the shoot and root dry matters were strongly affected by soil salinity. Demir Kaya and Ipek (2003) reported that safflower (*Carthamus tinctorius* L.) shoot dry weight decreased with increasing salinity. Najafi and Sarhangzadeh (2012) reported that corn fresh and dry weight of both shoot and root, leaves chlorophyll index and plant height were decreased significantly by increasing the level of salinity.

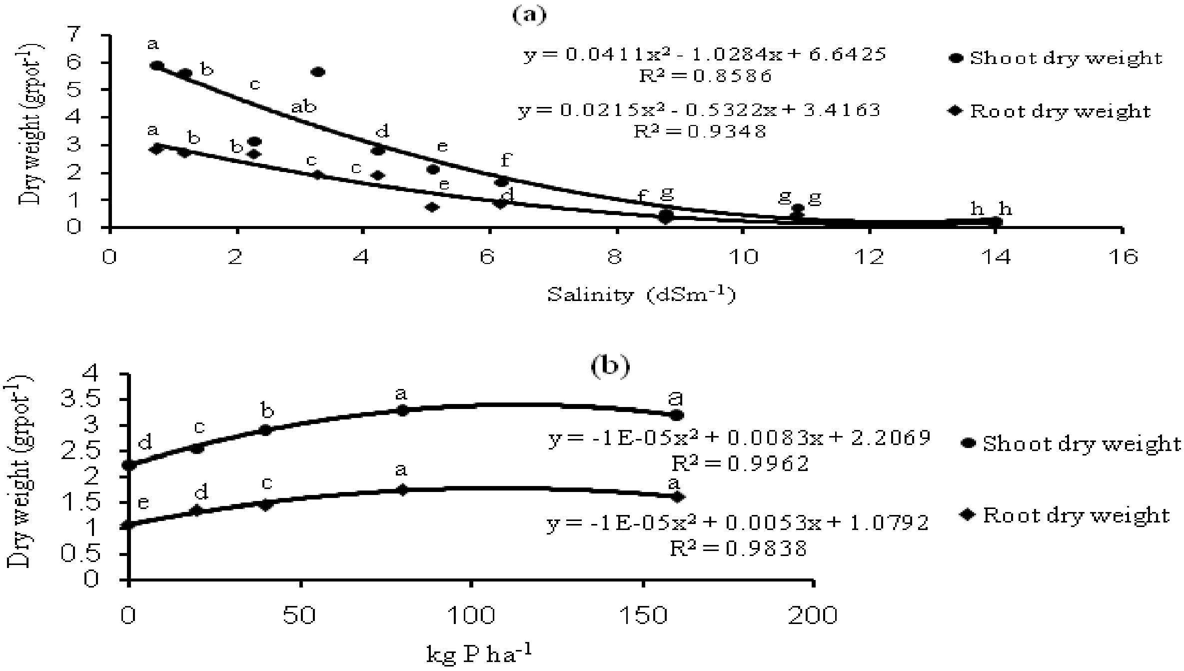

Fig 6: The effect of soil salinity (a) and phosphorus (b) on shoot and root dry matter

It is obvious that P levels significantly affected the shoot and root dry matters (Fig 6b). The shoot and root dry matters were increased with increasing rate of P to 80 kg P ha^{-1} in salt affected soil, but higher P application (160 kg P ha^{-1}) did not improve plants shoot and root dry matters. These results are in agreement with those obtained by Mullar and Weigert (1991) who reported that dry matter yield increased with P applications.

The combined effects of soil salinity and P showed that the highest shoot and root dry weights were produced from EC of 0.75 dSm^{-1} and P rate of 80 kg P ha^{-1}. The control treatment produced the lowest shoot and root dry weights (Tables 4 and 5). The results of research showed that P application increases the dry matter and grain yield (Sharma and Sharma, 1989; Mullar and Weigert, 1991; Singh and Dubey, 1991; Sharma and Gupta, 1998). Higher P application reduces the sodium absorption ratio and increase crop production in saline sodic soils (Chaudhry *et al.*, 1992). At low levels of salinity, the highest dry matter of corn was produced by phosphorus application at the rate of 80 kg P ha^{-1} while by increasing salinity level to above 5.11 dSm^{-1} the highest dry matter was observed at the P rate of 160 kg P ha^{-1}. This result showed the positive effect of high P levels on maize dry matter in the saline soils (Aslam Khan et al., 2005). At the EC level above 5.11 dSm^{-1} the dry matter of corn decreased significantly. Since the P initial concentration at the levels of 0.75, 1.20 and 3.30 dSm^{-1} were greater than the levels of 2.29 and 4.25 dSm^{-1}, the highest the dry matter of corn in the 0.75 to 2.29 dSm^{-1} treatments was at the P rate of 80 kg P ha^{-1} while the treatment 2.29 and 4.25 dSm^{-1} had the highest dry matter at the P rate of 160 kg P ha^{-1}. Aslam Khan et al. (2005) showed that the height yield of corn was observed at the 75 kg P ha^{-1} while with the application rate of 100 kg P ha^{-1} decreased its yield.

Table 4: The interaction effect of soil salinity and phosphorus on shoot dry matter

kg P ha^{-1}	Salinity (dSm^{-1})									
	0.75	1.20	2.40	3.30	4.25	5.11	6.19	8.80	10.88	14.00
0	4.58^{f}	4.6^{f}	2.40^{i-k}	4.52^{f}	2.28^{i-l}	1.54^{mn}	1.18^{no}	0.28^{p}	0.56^{op}	0.09^{p}
20	5.18^{d-f}	5.00^{ef}	2.60^{h-j}	5.18^{d-f}	2.78^{hi}	1.75^{k-n}	1.67^{l-n}	0.45^{p}	0.66^{op}	0.11^{p}
40	6.48^{ab}	5.73^{cd}	3.29^{gh}	5.62^{c-e}	2.87^{hi}	2.21^{i-m}	1.52^{mn}	0.47^{p}	0.72^{op}	0.16^{p}
80	6.89^{a}	6.75^{a}	3.66^{g}	6.42^{ab}	3.18^{gh}	2.39^{i-k}	1.83^{k-n}	0.82^{op}	0.81^{op}	0.20^{p}
160	6.39^{ab}	6.06^{bc}	3.74^{g}	6.63^{ab}	2.84^{hi}	2.69^{h-j}	2.06^{i-m}	0.49^{op}	0.82^{op}	0.24^{p}

Table 5: The interaction effect of soil salinity and phosphorus on root dry matter

kg P ha^{-1}	Salinity (dSm^{-1})									
	0.75	1.20	2.40	3.30	4.25	5.11	6.19	8.80	10.88	14.00
0	1.62^{jk}	2.07^{gh}	2.36^{ef}	1.10^{l}	1.67^{i-k}	0.31^{t-v}	0.67^{p-r}	0.11^{vw}	0.40^{st}	0.04^{w}
20	2.45^{e}	2.79^{d}	2.81^{d}	1.40^{l}	1.70^{ij}	0.55^{rs}	0.78^{p-q}	0.25^{t-w}	0.37^{s-u}	0.09^{vw}
40	3.09^{c}	2.80^{d}	2.69^{d}	1.55^{jk}	1.79^{hi}	0.81^{op}	0.86^{n-p}	0.26^{t-w}	0.47^{r-t}	0.10^{vw}
80	3.63^{a}	3.14^{c}	2.78^{d}	2.89^{d}	2.08^{gh}	1.03^{m}	0.97^{m-o}	0.43^{st}	0.41^{st}	0.14^{vw}
160	3.42^{b}	2.86^{d}	2.80^{d}	$2.23f^{g}$	1.91^{gh}	0.94^{m-o}	0.98^{mn}	0.44^{st}	0.59^{q-s}	0.15^{u-w}

The results showed that the P concentration of shoot and root was increased with increasing salinity and P application (Fig 7a, 7b, 8a and 8b). However, the effect of different salinity levels on shoot and root P concentrations was not significant. The higher shoot and root P concentration by salinity may be due to the increased availability of phosphorus in the soil or synergistic effect of Na, which is involved in P uptake and/or transport to the shoot and root that called "concentration effect" (Grattan and Maas, 1988). Singh et al. (1992) reported that application of P increased shoot and root P concentration in *Indian mustard*. The results showed that phosphorus application provides nutrient balance in saline soils. A similar result was reported by Singh et al. (1992). They reported an increase in grain yield with P application in saline soils.

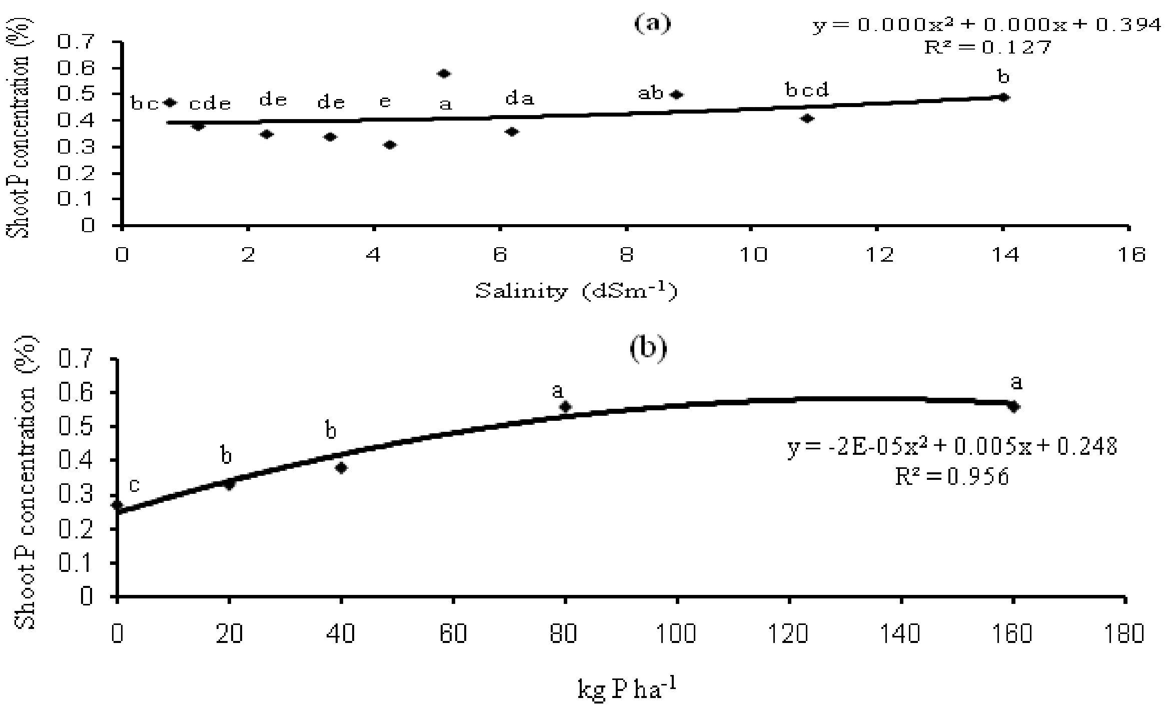

Fig 7: The effect of soil salinity (a) and phosphorus (b) on shoot P concentration

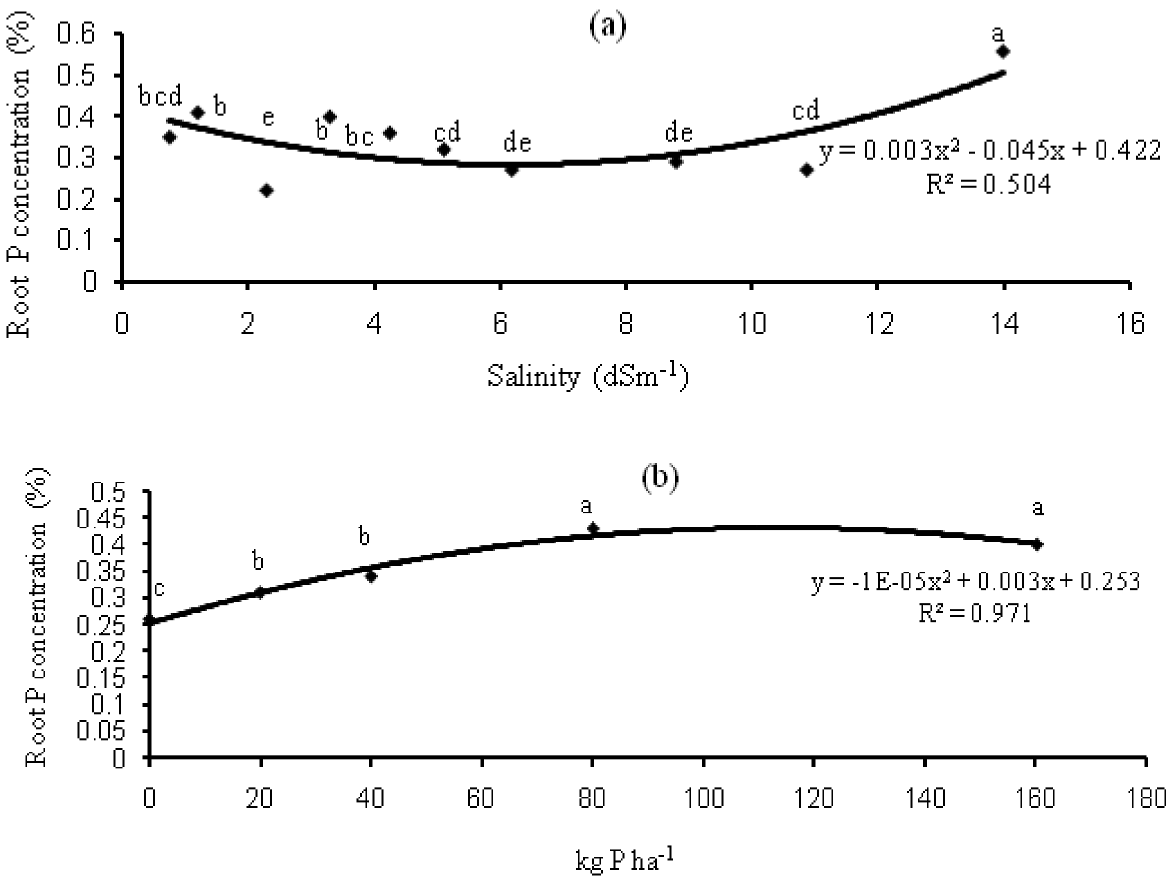

Fig 8: The effect of soil salinity (a) and phosphorus (b) on root P concentration

4. Conclusions

The results showed that the applications of phosphorus increased the growth indices of corn, while increasing salinity decreased them. The consumption of phosphorus fertilizer also decreased the negative effects of salinity and increased the corn yield by improving plant nutritional status. Corn planting is not suitable in EC higher than 5.11 dSm^{-1}. Application of P fertilizer at the rate of 80 kg P ha^{-1} in low salinity and 160 kg P ha^{-1} in moderate salinity is recommended for better growth of corn plant.

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