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Amelioration of salinity stress in wheat (*Triticum aestivum* L) by foliar application of phosphorus

Mejoramiento del estrés de salinidad en trigo (*Triticum aestivum* L) mediante la aplicación foliar de fósforo

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Abstract. Salinity adversely affects physiological and biochemical processes in plants. Plants might have different methods to decrease the harmful effects of salinity, such as the accumulation of osmolytes and antioxidant compounds. An experiment was conducted in the Department of Biological Sciences, University of Sargodha, Pakistan to determine the effect of different levels of phosphorus (P) on wheat under saline conditions. Data of shoot and root fresh and dry weights, chlorophyll contents, different ion accumulation and yield components of wheat were collected. When different levels of phosphorus were applied on wheat plant under saline conditions, phosphorus reduced the effect of salinity. Applications of phosphorus decreased Na^+ uptake and increased potassium concentrations, chlorophyll contents and enhanced growth of wheat plants under saline and non-saline conditions. This indicated that application of phosphorus stabilized the physiology of the wheat plants, as phosphorus activated potassium transport in wheat plants. Therefore, application of phosphorus had a positive effect on yield of the wheat plants. In conclusion, all these investigations showed that phosphorus induced the salt tolerance in wheat plants.

Keywords: Salinity; Phosphorus; Foliar spray; Amelioration.

Resumen. La salinidad afecta negativamente a los procesos fisiológicos y bioquímicos en las plantas. Las plantas pueden tener diferentes métodos para disminuir los efectos perjudiciales de la salinidad, tales como acumulación de osmolitos y compuestos antioxidantes. Se realizó un experimento en el Departamento de Ciencias Biológicas, Universidad de Sargodha, Pakistán para determinar el efecto de diferentes niveles de fósforo en el trigo bajo condiciones salinas. Se recogieron datos de diferentes parámetros tales como los pesos seco y fresco de tallo y raíces; contenido de clorofila, y la acumulación de diferentes iones y componentes del rendimiento de trigo. Cuando se aplicaron diferentes niveles de fósforo en plantas de trigo bajo condiciones salinas, el fósforo redujo los efectos de la salinidad. Las aplicaciones de fósforo disminuyeron la absorción de Na^+ e incrementaron las concentraciones de potasio, contenidos de clorofila y mejoró el crecimiento de plantas de trigo bajo condiciones salinas y no salinas. Esto indicó que la aplicación de fósforo estabilizó la fisiología de las plantas de trigo, desde que el fósforo activó el transporte de potasio en plantas de trigo. Luego, la aplicación de fósforo tuvo un efecto positivo en el rendimiento de las plantas de trigo. En conclusión, estas investigaciones mostraron que el fósforo indujo la tolerancia a la sal en plantas de trigo.

Palabras clave: Salinidad; Fósforo; Spray foliar; Mejora.

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INTRODUCTION

Salinity is a worldwide problem and is particularly serious in arid and semi-arid regions of the world, where most developing countries are located (Khan et al., 1999). Abiotic stresses are a major threat to plant growth and productivity. Adverse effects of salinity have been noted on plant physiology and biochemistry, which ultimately reduce yield. This is a very serious threat in agriculture (Ashraf et al., 2008; Munns & Tester, 2008). Almost 20% of cultivated areas of the world, and half of the world irrigated lands are stressed by salinity (Chinnusamy et al., 2005). In Pakistan, almost 6.3 million hectares of land are salinity affected. This corresponds to about of 14% of irrigated lands and yield losses due to salinity reach 64% (Afzalet al., 2005). Although all soils contain some amount of soluble salts from multivarious nature, their concentrations might increase to levels where they become a threat to land degradation (Wiebe et al., 2005).

Salt stress perturbs a multitude of physiological processes including photosynthesis. For example, a significant reduction in photosynthesis was found in *Brassica* (Naziret al., 2001) and wheat species (Raza et al., 2006). However, the degree of salt-induced reduction in photosynthetic capacity depends on amount of (1) photosynthesizing tissue (leaf area), (2) photosynthetic pigments and (3) stomatal regulation (Dubey, 2005). High levels of salinity significantly reduce pigment contents in leaves (Al-Sobhi et al., 2006). In shoots, high concentrations of Na^+ cause a range of osmotic and metabolic problems for plants. Leaves are more vulnerable than roots to Na^+, simply because Na^+ and Cl^- accumulate to higher concentrations in shoots than roots (Tester & Davenport, 2003). Higher amounts of Na^+ also reduce nutrient uptake (Marschner, 1995; Gratten & Grieve, 1999; Ashraf, 2004; Flower & Flower, 2005).

Exogenous application of osmoprotectants, plant growth regulators, antioxidants and fertilizers have been reported to successfully mitigate the adverse effects of salinity on plants (Kefeli, 1981; Janda et al., 1999; Shalata & Neumann, 2001). Phosphorus (P) in plants is deficient in most of our soils, which reduce crop production (Memon, 1996). Phosphorus deficiency in soil decreases yield (Wissuwa et al., 1998). Phosphorus is the second major nutrient for plant growth as it is an integral part of different biochemicals like nucleic acids, nucleotides, phospholipids and phosphoproteins. Phosphate compounds act as “energy currency” within plants (Russell, 1981; Tisdale et al., 1985). Supplementary phosphorus has a role in alleviation of the adverse effects of high salinity on whole plant biomass for a variety of crop plants (Kaya et al., 2003). Phosphorus nutrition appeared to modify the effects of salinity upon growth of glycophytic plants (Champergnol, 1979).There was a significant increase in the starch content and cob index in maize due to foliar application of P (Leach & Hameleers, 2001). When initial P deficiency symptoms appeared 25 days after sowing in wheat, higher doses of ammonium phosphate as a foliar spray gave the greatest reduction in P deficiency and highest yields (Haloi, 1980).

Phosphorus and salinity act antagonistically. Phosphorus lessens the effects of salinity, and induces salt tolerance in plants (Neiman & Clark, 1976; Cedraet al., 1977; Garget al., 2005). It has been observed that Phosphorus fertilization reduces the concentration of Na^+ in shoots and grains. It results in better survival, growth and yield in rice (Qadar, 1998) and wheat (Salim et al., 1999). By increasing the supply of Phosphorus to a saline medium it tended to decrease the concentration of Na^+ in rice (Aslam et al., 1996; Asch et al., 1999), sunflower (Malik et al., 1999), spinach (Kaya et al., 2001a) and wheat (Abid et al., 2002).

Wheat (*Triticum aestivum* L.) is a major food crop for more than one third of the world population (Shiraz et al., 2001). It is the most important food for two billion people (36% of the world population). Worldwide wheat provides nearly 55% of the carbohydrates, and 20% of food calories consumed globally (Brieman & Graur, 1995).

The objective of this experiment was to study the effect of foliar application of phosphorus to determine the physiological changes produced in wheat plants exposed to saline conditions.

MATERIALS AND METHODS

An experiment was conducted in the Department of Biological Sciences, University of Sargodha, Pakistán, during 2009-2010. The experiment was laid down on a completely randomized design with two factor factorial arrangement (3 P levels x 2 salinity levels) and three replicates. Levels of phosphorus applied exogenously as a foliar spray at the vegetative stage of wheat were 0, 400, 800 mg/L to determine whether phosphorous application could mitigate the effects of salinity stress on wheat (*Triticum aestivum* L.). The source of phosphorus was ammonium phosphate. Salinity levels were 150 mmol and a control (0 mmol). The different salinity levels were adjusted in accordance with the saturation percentage of soil. Seeds of the wheat cultivars were obtained from the Ayub Agricultural Research Institute, Faisalabad, and sown in pots. Each pot was filled with 5 kg well mixed soil. Three plants were harvested from each pot at each sampling time.

Data Collection. Data were collected for plant height, shoot and root lengths, shoot and root fresh and dry weights, number of leaves, leaf area, chlorophyll a and b (mg/g f. wt) and total chlorophyll contents. Potassium, Calcium, Sodium, Magnesium and phosphorus concentrations in shoots and roots of wheat plants, and grain yield per plant were also determined.

Chlorophylls content determination. Chlorophylls a and b were determined following Arnon (1949). Fresh leaves were cut into 0.5 cm segments and extracted over night with 80%

acetone at -10 °C. The extract was centrifuged at 14000×g for 5 min and the absorbance of the supernatant was read at 480, 645, and 663 nm using a spectrophotometer**.**

Determinations of ions. For ion detection, ground material (0.01 g) was digested according to Wolf (1982). Dried ground material (0.1 g) was taken in each digestion tube and 2 mL of concentrated H_2SO_4 were added; it was then incubated overnight at room temperature. Thereafter, 0.5 mL of H_2O_2 (35%) was poured down to the sides of the digestion tube, ported the tubes in a digestion block and heated at 350 °C until fumes were produced and continued to heat for another 30 minutes. The digestion tubes were removed from the block and cooled. Then 0.5 mL of H_2O_2 was slowly added and tubes were placed back into the digestion block.

The above step was repeated until the cold digested material was colorless. The volume of the extract was maintained up to 50 mL in volumetric flasks. The extract was filtered and used for K^+, Na^+, Ca^{2+}.

Statistical analysis. The data for all the parameters were analyzed by analysis of variance technique (Steel & Torie, 1980). Differences for various parameters were compared by using the Least Significant Differences test at 0.05 level of probability by Minitab.16.

RESULTS

The saline medium significantly reduced the plant height of wheat (Tables 1 and 3). Application of different rates of phosphorus reduced the effect of salinity on plant height (Table 3). Under non-saline conditions, the treatment with 800 kg P/ha significantly increased plant height. Under saline conditions, the same trend of phosphorus on plant height was noted (Table 3). Overall, phosphorus application as foliar spray decreased the effect of salinity on wheat plants growing under saline conditions.

Application of different concentrations of phosphorus as foliar spray reduced the effect of salinity on shoot length of wheat plants. Among different levels of phosphorus, 800 kg P/ha alleviated the effects of salinity, and increased the shoot length of wheat plants under non-saline conditions (Table 3). In case of saline conditions, 400 kg P/ha showed better results than 800 kg P/ha, alleviating the salinity effects (Table 3). Overall, phosphorus application as foliar spray alleviated the effect of salinity on shoot length of wheat plant (Table 3). Application of different concentrations of phosphorus alleviated the effect of salinity on root length of wheat plants (Table 3).

Among the different rates of phosphorus, 400 kg P/ha alleviated the effects of salinity and increased the root length of wheat plants under non-saline conditions (Table 3). The same trend of root length was noted under saline conditions (Table 3). Under non-saline conditions, 400 kg P/ha had significantly increased the root length as compare to 800 kg P/ha. Under saline conditions same trend of phosphorus on root length was noted (Table 1). Overall, results indicated that phosphorus alleviated the effect of salinity with respect to root length (Table 3).

Analysis of variance of the data presented in Table 1 indicated that the saline medium significantly reduced the shoot fresh weight of wheat plants. Among the different levels of phosphorus, 800 kg P/ha applied as foliar spray increased the shoot fresh weight of wheat plants under non-saline conditions (Table 3). However, the same trend of increase in shoot fresh weight was noted under saline conditions (Table 3). Overall, results indicated that phosphorus alleviated the effect of salinity in regard to shoot length.

Analysis of variance of the data presented in Table 1 indicated that saline growth medium significantly reduced the root fresh weight of wheat plants. Foliar application of different levels of phosphorus alleviated the effect of salinity (Table 3). Under non-saline conditions, 800 kg P/ha was more effective in increasing the root fresh weight of wheat plants as compared to 400 kg P/ha. Under saline conditions, both concentrations of phosphorus had no effect on root fresh weight of wheat plants.

Analysis of variance of the data indicated that saline growth medium significantly affected the shoot dry weight of wheat plants (Table 1). Application of different concentrations of phosphorus reduced the effects of salinity on shoot dry weight (Table 3). Under non-saline conditions, 400 kg P/ha showed a better effect on shoot dry weight of wheat than 800 kg P/ha. Under saline conditions, 800 kg P/ha was more effective in increasing the shoot dry weight. Overall, results indicated that phosphorus alleviated the effect of salinity in regard to shoot dry weight (Table 3).

Analysis of variance indicated that the saline growth medium significantly affected the root dry weight of the wheat plants (Table 3). Application of different concentration of phosphorus reduced the effects of salinity on root dry weight (Table 3). Under non-saline conditions, 800 kg P/ha were more effective in increasing the root dry weight of wheat plants. The same trend of root dry weight of wheat plants was noted under saline conditions (Table 3). Overall, results indicated that phosphorus alleviated the effect of salinity in regard to root dry weight (Table 3).

Analysis of variance of the data presented in Table 1 indicated that the saline growth medium significantly affected the number of leaves on wheat plants (Table 1). Application of different concentration of phosphorus reduced the effect of salinity on number of leaves (Table 3). Under non-saline and saline conditions the same effect of foliar application of phosphorus at both concentrations 800 kg P/ha and 400 kg P/ha was noted (Table 3). Comment on P influence effect on root length may also apply to number of leaves, either as a direct or indirect effect.

Analysis of variance indicated that the saline growth medium significantly affected the leaf area of the wheat plants (Table 2). Applications of different concentration of phosphorus reduced the effect of salinity on leaf area of wheat plants (Table 3). Application of phosphorus as foliar spray (400 kg P/ha) under non-saline conditions increased the leaf area of wheat plants. However, in the case of saline conditions, 800 kg P/ha showed more significant effects on leaf area than 400 kg P/ha of the wheat plants (Table 3). Overall, result indicated that phosphorus alleviated the effect of salinity in regard to leaf area of wheat plants (Table 3).

Application of different concentration of phosphorus reduced the effect of salinity on chlorophyll "a" (Table 3). Under non-saline conditions, 400 kg P/ha significantly increased the chlorophyll "a" compared to 800 kg P/ha. Under saline conditions, the same trend of phosphorus on chlorophyll "a" was noted (Table 3). Analysis of variance of the data presented in Table 2 indicated that saline medium significantly affected the chlorophyll "b" of the wheat plant (Table 2). Application of different concentration of phosphorus reduced the effect of salinity on chlorophyll "b" (Table 3). Under non-saline conditions, 800 kg P/ha had significantly increased the chlorophyll "b" as compared to 400kg P/ha. Under saline conditions the same trend of phosphorus on chlorophyll "b" was noted (Table 3). Analysis of variance of the data indicated that the saline medium significantly affected the total chlorophyll of the wheat plants (Table 2). Application of different concentrations of phosphorus reduced the effect of salinity on total chlorophyll of wheat plants (Table 3). Under non-saline conditions, 400 kg P/ha significantly increased total chlorophyll compared to 800 kg P/ha. Under saline conditions, the same trend of phosphorus on total chlorophyll was noted (Table 3).

Analysis of the variance indicated that saline growth medium significantly affected the concentration of sodium in shoots of the wheat plants (Table 2). Application of different concentration of phosphorus as foliar spray reduced the effect of salinity on shoot sodium (Table 3). Analysis of variance of the data presented in Table 2 indicated that saline growth medium significantly increased the root sodium contents of the wheat plants (Table 2). Foliar application of different rates of phosphorus reduced the effect of salinity on root sodium (Table 3). Under non-saline conditions, 800 kg P/ha decreased the root sodium content, and under saline conditions the same trend of root sodium content was noted (Table 3).

Analysis of variance indicated that the saline medium significantly affected the shoot potassium of the wheat plants (Table 2). Application of different concentrations of phosphorus reduced the effect of salinity on shoot potassium (Table 3). Under non-saline conditions, 400 kg P/ha significantly increased the shoot potassium compared to 800 kg P/ha. Under saline conditions 800 kg P/ha increased the shoot potassium compared to 400 kg P/ha (Table 3). P and salinity interaction was significant so effects differed for different levels of the factors.

Analysis of variance of the data presented in Table 2 indicated that the saline medium significantly affected the root potassium of the wheat plants (Table 2). Application of different concentration of phosphorus reduced the effect of salinity on root potassium (Table 3). Under non-saline conditions, 400 kg P/ha significantly increased the root potassium compared to 800 kg P/ha. Under saline conditions, the same trend of phosphorus on root potassium was noted (Table 3).

Analysis of variance of the data presented in Table 2 indicated that the saline medium significantly affected the shoot calcium concentration of wheat (Table 2). Application of different concentration of phosphorus reduced the effects of salinity on shoot calcium (Table 3). Under non-saline conditions, 800 kg P/ha had significantly increased the shoot calcium compared to 400 kg P/ha. Under saline condition the same trend of phosphorus on shoot calcium was noted (Table 3).

Analysis of variance of the data presented in Table 2 indicated that the saline growth medium significantly reduced the root calcium of the wheat plants (Table 2). Application of different concentrations of phosphorus reduced the effect of salinity on root calcium (Table 3). Under non-saline conditions, 800 kg P/ha increased the root calcium to some extent

Table 1. Mean squares from analysis of variance (ANOVA) of the data for plant height, shoot length, root length, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, number of leaves/plant.
Tabla 1. Cuadrados medios del análisis de varianza (ANOVA) de los datos de altura de la planta, longitud del tallo y de las raíces, peso fresco del tallo y las raíces, peso seco del tallo y las raíces, y número de hojas por planta.

Source of variation	Degree of freedom	Plant height	Shoot length	Root length	Shoot fresh weight	Root fresh weight	Shoot dry weight	Root dry weight	Number of leaves/ plant
Salinity (S)	1	53.39 *	47.045 *	28.125 **	1.2283 *	0.1554 ***	0.108 *	0.0369 *	2.0 *
Phosphorus (P)	2	12.54 *	3.034*	9.282 *	0.0695 ns	0.0114 ns	0.008 *	0.0198 *	3.50 ***
Salinity x P	2	6.76 ns	9.785 ns	4.702 ns	0.0707 ns	0.0069 ns	0.010 ns	0.0004 ns	0.50 ns
Error	12	13.67	7.990	1.828	0.1405	0.004	0.013	0.003	0.166

compared to 400 kg P/ha. Under saline conditions, the same trend of foliar application of phosphorus on root calcium was noted (Table 3).

Analysis of variance of the data presented in Table 2 indicated that the saline medium significantly affected the grain yield of the wheat plants (Table 2). Application of different concentrations of phosphorus reduced the effect of salinity on grain yield of wheat plants (Table 3). Under non-saline conditions, 800 kg P/ha as foliar spray application increased grain yield of the wheat plants compared to 400 kg P/ha. Under saline conditions, 400 kg P/ha increased the grain yield of wheat plants compared to 800 kg P/ha (Table 3).

Table 2. Mean squares from analysis of variance (ANOVA) of the data for leaf area/plant, chlorophyll a, chlorophyll b, total chlorophyll, sodium in shoot, sodium in root, potassium in shoot, potassium in root, calcium in shoot, calcium in root, grain yield/plant.
Tabla 2. Cuadrados medios del análisis de varianza (ANOVA) de los datos de área foliar/planta, clorofilas a y b, clorofila total, sodio en tallo y en raíces, potasio en tallo y raíces, calcio en tallo y en raíces, y rendimiento de grano/planta.

Source of variation	Degree of freedom	Leaf Area/ Plant	Chlorophyll a	Chlorophyll b	Total chlorophyll	Na in shoot	Na in root	K in shoot	K in root	Ca in shoot	Ca in root	Grain yield/ plant
Salinity (S)	1	29.440 *	0.040 **	0.014 *	0.102 **	0.0595 *	0.0897 **	0.0522 ***	0.0153 *	0.0015 **	0.0260 ***	0.520 ***
Phosphorus (P)	2	3.677 ns	0.012 *	0.036**	0.049 *	0.0014 ns	0.0166 ns	0.0066 ***	0.0239 *	0.0016 ***	0.0269 ***	0.004 *
Salinity x P	2	1.647 ns	0.007 *	0.0009	0.007	0.0030 ns	0.0001 ns	0.0018 *	0.0016 ns	0.0004 *	0.0117 ***	0.040
Error	12	4.098	0.004	0.002	0.005	0.0078	0.007	0.0004	0.0041	0.0001	0.0001	0.015

Table 3. Influence of foliar application of phosphorus on plant height; shoot, root length; shoot, root fresh weight; shoot, root dry weight; number of leaves/plant; leaf area; chlorophyll a, b and total; Na, K and Ca in shoots and roots, and grain yield/plant under saline and non-saline conditions.
Tabla 3. Influencia de la aplicación foliar de fósforo en la altura de la planta; longitud del tallo y las raíces; peso fresco del tallo y las raíces; peso seco del tallo y las raíces; número de hojas/planta; área foliar; clorofilas a, b y total; Na, K y Ca en tallos y raíces, y rendimiento de grano/planta bajo condiciones salinas y no salinas.

Salinity levels (mmol)	**0**			**150**		
Phosphorus levels (kg/ha)	**0**	**400**	**800**	**0**	**400**	**800**
Plant height (cm)	26 ± 2.1	28 ± 2.3	30 ± 2.0	25 ± 2.5	26 ± 2.1	28 ± 2.2
Shoot length (cm)	16 ± 1.3	17 ± 1.7	19 ± 1.2	15 ± 1.6	16 ± 1.8	14 ± 1.4
Root length (cm)	12 ± 1.2	14 ± 0.9	10 ± 1.2	8 ± 0.8	10 ± 1.0	5 ± 0.09
Shoot fresh weight (g/ plant)	3 ± 0.6	3.6 ± 0.8	5.4 ± 0.7	2.5 ± 0.2	2.3 ± 0.1	3.4 ± 0.1
Root fresh weight (g/plant)	2.4 ± 0.13	2.3 ± 0.19	3.4 ± 0.16	1 ± 0.05	1.2 ± 0.08	2 ± 0.06
Shoot dry weight (g/ plant)	1.4 ± 0.05	1.6 ± 0.07	1.5 ± 0.05	1.2 ± 0.02	2.2 ± 0.01	1.3 ± 0.02
Root dry weight (g/plant)	1 ± 0.01	0.8 ± 0.06	1.2 ± 0.03	0.7 ± 0.06	0.6 ± 0.04	0.8 ± 0.05
Number of leaves/plant	7 ± 1.2	8 ± 1.7	8 ± 1.9	6 ± 1.6	8 ± 1.8	8 ± 1.7
Leaf area (cm^2)/plant	8.1 ± 1.7	8.5 ± 1.7	7.5 ± 1.4	3.5 ± 0.9	4 ± 0.08	5 ± 0.06
Chlorophyll a (mg/g f. wt)	0.47 ± 0.08	0.55 ± 0.06	0.46 ± 0.06	0.37 ± 0.05	0.38 ± 0.07	0.36 ± 0.04
Chlorophyll b (mg/g f. wt)	0.3 ± 0.06	0.31 ± 0.04	0.36 ± 0.07	0.20 ± 0.03	0.29 ± 0.05	0.32 ± 0.03
Total Chlorophyll (mg/g f. wt)	0.77 ± 0.04	0.86 ± 0.05	0.82 ± 0.06	0.57 ± 0.03	0.68 ± 0.06	0.66 ± 0.04
Shoot Na (mg/g d. wt)	0.63 ± 0.08	0.63 ± 0.06	0.63 ± 0.06	0.8 ± 0.05	0.5 ± 0.03	0.6 ± 0.04
Root Na (mg/g d. wt)	0.61 ± 0.04	0.63 ± 0.02	0.60 ± 0.05	0.68 ± 0.06	0.80 ± 0.03	0.60 ± 0.03
Shoot K (mg/g d. wt)	0.6 ± 0.03	0.67 ± 0.02	0.65 ± 0.03	0.55 ± 0.05	0.56 ± 0.01	0.59 ± 0.03
Root K (mg/g d. wt)	0.72 ± 0.05	0.80 ± 0.06	0.78 ± 0.04	0.7 ± 0.02	0.78 ± 0.02	0.80 ± 0.01
Shoot Ca (mg/g d. wt)	0.68 ± 0.01	0.59 ± 0.03	0.7 ± 0.02	0.3 ± 0.02	0.2 ± 0.009	0.5 ± 0.04
Root Ca (mg/g d. wt)	0.35 ± 0.03	0.3 ± 0.01	0.32 ± 0.02	0.25 ± 0.02	0.3 ± 0.01	0.32 ± 0.02
Grain yield /plant (g)	2.8 ± 0.02	3.0 ± 0.01	3.2 ± 0.02	2.4 ± 0.01	2.6 ± 0.04	2.4 ± 0.02

DISCUSSION

Plant growth and development are affected by salinity (Naheed et al., 2007). Salinity adversely affects the process of photosynthesis. Salinity also affects seedling growth. Adverse effects of salinity on seedling growth could also be measured in relation to seedlings fresh and dry weight (Khodary, 2004). Salinity causes slow or less mobilization of reserve foods, and cell division and enlargement is minimized (Tezara et al., 2003).

There is a decrease in height of plants grown in saline medium. Root and shoot growth are also reduced by salinity. Fresh and dry weight of plants roots, shoots and leaves decreased by salinity. This result is in accordance with Singla & Garg (2005). Phosphorus has a significant effect to reduce the adverse effects of salinity on growth. As phosphorus increased, it ameliorated the effect of salinity on shoot length and dry weight of different parts of plants. Our findings are in agreement with those of Knight et al. (1992).

Generally, adequate concentrations of nutrients are required for normal plant growth, and below them, growth of plants is affected. Nutrient activity or availability is reduced under salt stress conditions, and the optimal concentration of essential nutrients by plants is increased (Marchner, 1995). As phosphorus concentration increases in the media, uptake of these elements is improved and that of sodium is reduced (Shibli et al., 1998).

High shoot sodium has been associated with a tolerance decrease in relatively salt tolerant plants (Knight et al., 1992). Concentration of sodium increases in leaves and that of calcium decreases (Shibli et al., 1998). Sodium competes with potassium for uptake through a common transport system, and does this effectively since sodium concentrations are usually greater than those of potassium in saline environments. It is also reported that the sensitivity of some crops to salinity is due to their inability to keep sodium and chloride out of the transpiration stream (Gorham et al., 1990).

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