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Effect of Salinity on Phosphorus Induced Zinc Deficency in Pepper (*Capsicum annuum* L.) Plants

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Abstract: The combined effects of NaCl salinity and increasing rates of P on the Zn nutrition of pepper were studied. The applied P increased fruit yield in the absence of salinity, but decreased it in the presence of salinity. Fresh and dry weights of the plants were increased by the applied P and decreased by salinity. Both salinity and increasing levels of P (except 300 mg kg^{-1}) decreased the Zn concentrations and Zn uptake of the plants. Zinc deficiency symptoms were observed at P levels of 300 and 500 mg kg^{-1}, a result which was more pronounced under saline conditions. Leaf P concentrations tended to increase with increasing P levels, to a greater extent under saline conditions. Salinity and increased levels of applied P increased the tissue Na concentrations. Salinity also increased the Cl concentrations of the plants.

Biber (*Capsicum annuum* L.) Bitkisinde Fosforun Yolaçtığı Çinko Noksanlığı Üzerine Tuzluluğun Etkisi

Özet: Biber bitkisinin çinko beslenmesi üzerine NaCl tuzluluğu ve artan oranlarda uygulanan fosforun etkisi araştırılmıştır. Tuzsuz koşullarda uygulanan P meyve ağırlığının artmasına sebep olurken, tuzlu koşullarda meyve ağırlığı uygulanan P ile azalmıştır. Tuzluluk ve artan düzeylerde uygulanan P (300 mg P kg^{-1} hariç) bitkilerin Zn kapsamı ve alımını azaltmıştır. Özellikle tuzlu koşullarda 300 ve 500 mg kg^{-1} P uygulamasında bitkiler, Zn noksanlığına ait belirtiler göstermiştir. Yaprakların P kapsamı artan düzeylerde uygulanan fosfora bağlı olarak artmıştır. Bu artışlar, tuzlu koşullarda daha belirgin olmuştur. Tuzluluk ve artan düzeylerde uygulanan P bitki dokularının Na kapsamlarını artırmıştır. Bitkilerin Cl kapsamları da tuzluluğa bağlı olarak artış göstermiştir.

Introduction

Zinc deficiency is a common nutritional disorder of plants grown on soils having high pH and phosphate content or after applications of high doses of phosphorus fertilizers (1). In addition, organic matter, water situation, texture and sorption capacity of the soils also effect zinc nutrition of plants (2). In the literature, P-Zn interactions are called P induced Zn deficiency (3, 4). The mechanisms of this interaction could be explained as suggested by Parker et al., (1): decreased solubility of soil Zn may result from enhanced sorption of Zn by hydrous oxides; dilution effect of P by the increase in dry matter production stimulated by P; the root cell membrane permeability is increased under Zn deficiency, which might be related to the functions of Zn in cell membranes, and, according to Bergman (2), high P levels inhibit acropetal translocation of Zn^{+2} . Zn levels in the leaves are effected most, while the uptake of Zn^{+2} ions by the root is less affected.

Zinc plays an important role in the control of P absorption in higher plants, preventing excessive P uptake by roots and the transport of P from roots to leaves (5).

At high levels of P, Zn deficiency symptoms in leaves may be masked by symptoms of P toxicity. Phosphorus toxicity symptoms are manifested by leaf blade puckering and marginal necrosis of the older leaves. The simulatenous occurrence of P-toxicity and Zn deficiency symptoms has caused some differences in interpretation of leaf symptoms attributed to P toxicity, Zn deficiency and/or P-enhanced Zn deficiency (4).

Salinity increases the P uptake of the plants, and so plants in saline media were found to be more sensitive to P toxicity (6, 7) and consequently Zn deficiency. The objective of this study was to determine the role of NaCl salinity on P-Zn interaction in the pepper plant.

Materials and Methods

Pepper (*Capsicum annuum* L.) plants were grown in a glashouse under natural light conditions. Pepper seeds were germinated and grown in polyethylene tubes containing a peat: perlite (1:1) mixture. The-week-old seedlings were transplanted at a rate of one plant per pot

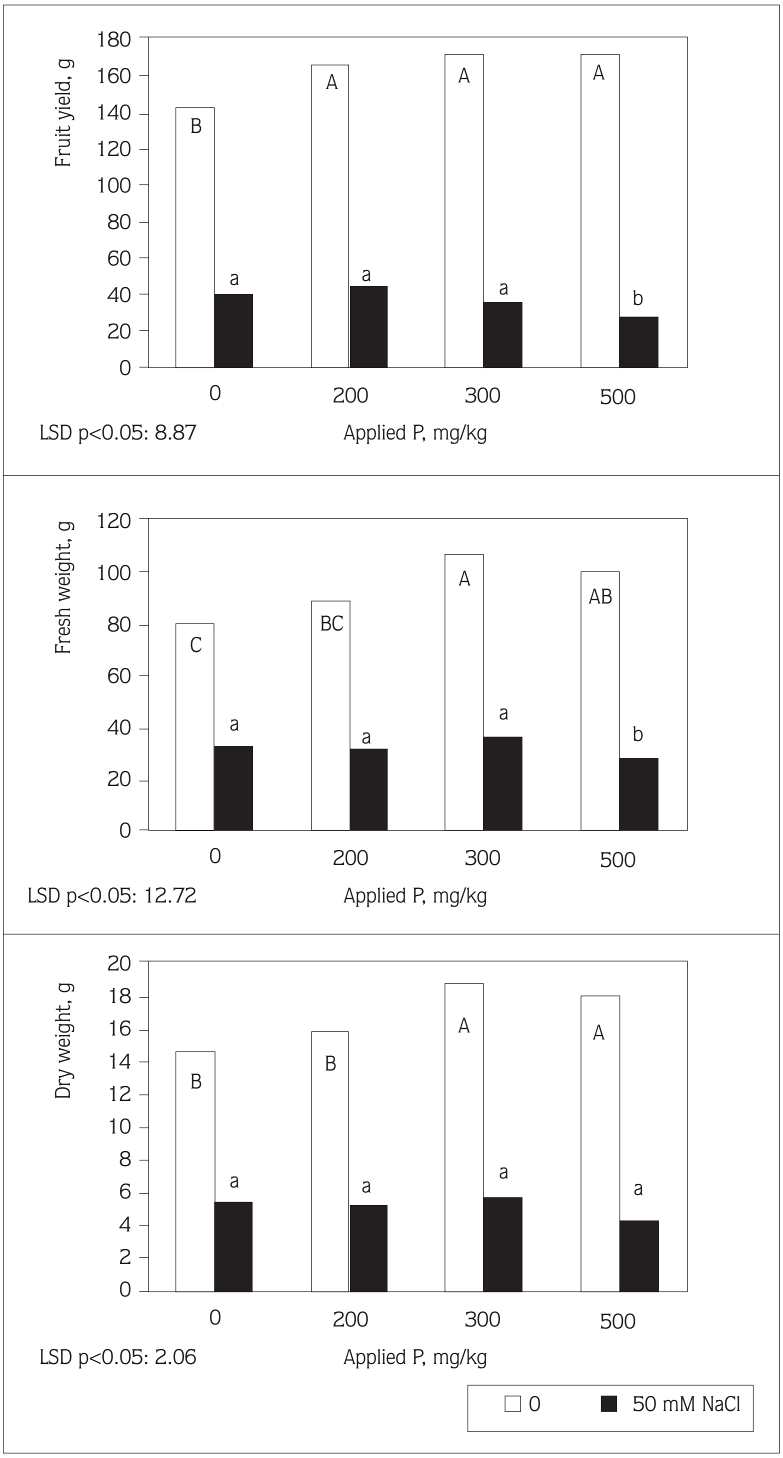

Figure 1. Fruit yield, fresh and dry weight of pepper plant as affected by salinity and phosphorus. Means followed by same letters are not siginificantly different (Duncan's multiple range test, $p<0.05$), capital letters for the comparison of 0 mM NaCl and small letters 50 mM NaCl.

filled with 4000 g of air-dried soil. The texture of the soil was loamy clay, the $CaCO_3$ 5.75%, pH (1:2.5 water) 7.61, EC 0.56 dS m^{-1}, organic matter 1.07% and total N 0.15%. The concentrations of NH_4OAc-extractable K, Ca and Na were 450, 4800 and 60 mg kg^{-1}, respectively. $NaHCO_3$-extractable P was 10.70 mg kg^{-1} and DTPA-extractable Zn was 0.57 mg kg^{-1}.

Soil was salinized by adding 50 mmol NaCl kg^{-1} soil levels. Phosphorus was applied at rates of 0, 200, 300 and 500 mg kg^{-1} as H_3PO_4. Nitrogen and K were applied to all post at rates of 300 and 278 mg kg^{-1} as $(NH_4)_2SO_4$

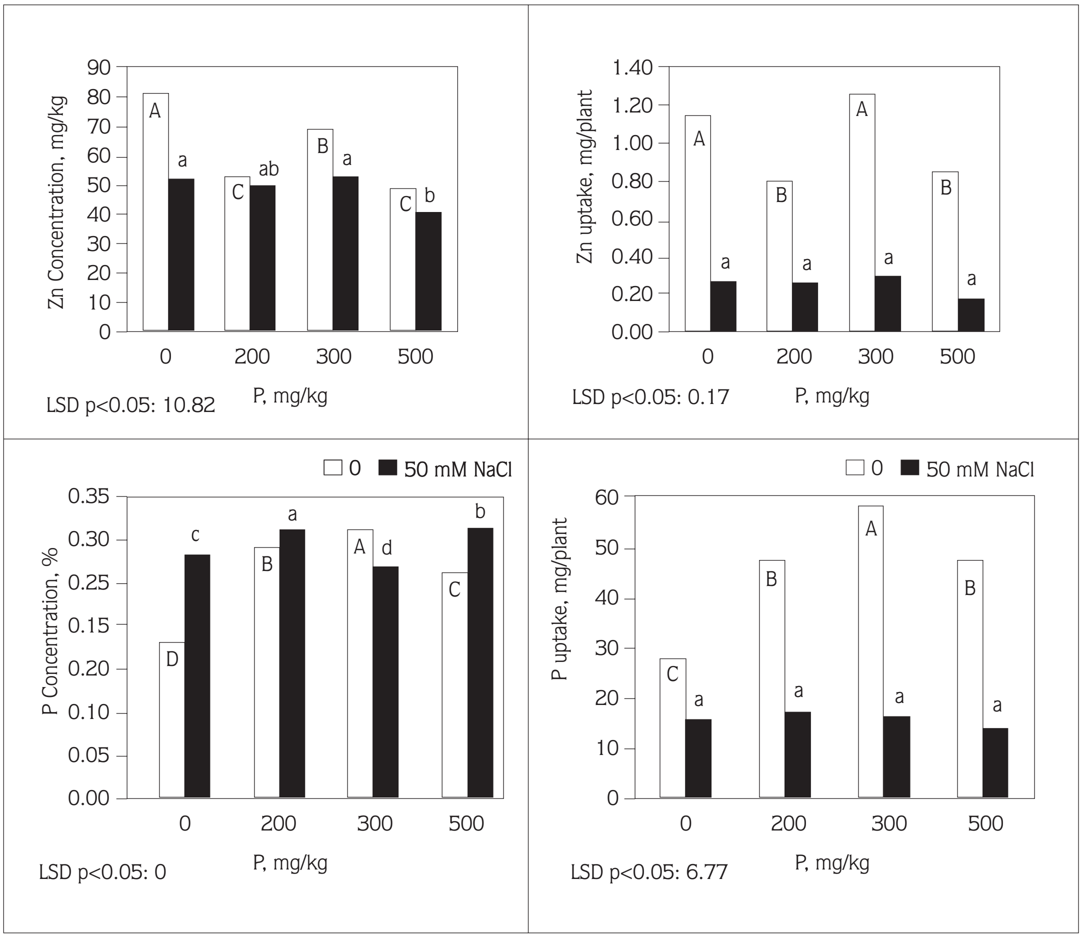

Figure 2. Zinc and P concentrations and uptake of pepper plants as affected by salinity and phosphorus. Means followed by same letters are not significantly different (Duncan's multiple range test, p<0.05), capital letters for the comparison of 0 mM NaCl and small letters 50 mM

Table 1. F values of experimental data as effected by the interaction between salinity and phosphorus.

		F values of the experimental data										
Source	Df	Fruit Yield	Fresh Weight	Dry Weight	Zn Conc.	Zn Uptake	P Conc.	P Uptake	Na Conc.	Na Uptake	Cl Conc.	Cl Uptake
P	3	7.83 **	4.39 *	3.54 *	14.66 **	10.06 **	12.77 **	15.66 **	7.90 **	51.87 **	2.44 ns	3.30 ns
Salinity	1	3508 **	411 **	554 **	29.68 **	339 **	12.63 **	329 **	7.03 *	423 **	282 **	275 **
PxSal.	3	18.93 **	3.53 *	4.12 *	4.70 *	5.02 *	11.23 **	15.48 **	0.51 ns	33.60 **	2.54 ns	0.96 ns

*: p<0.05; **: p<0.01; ns: non significant

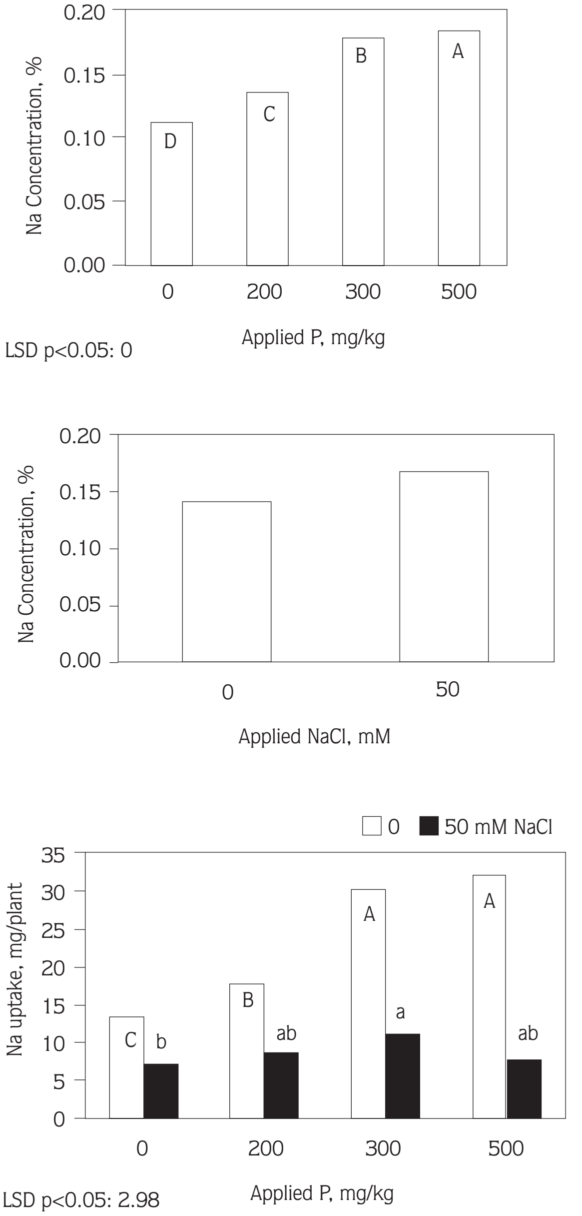

Figure 3. Sodium concentration and uptake of pepper plant as affected by salinity and phosphorus. Means followed by same letters are not significantly different (Duncan's multiple range test, $p<0.05$), capital letters for the comparison of 0 mM NaCl and small letters 50 mM NaCl.

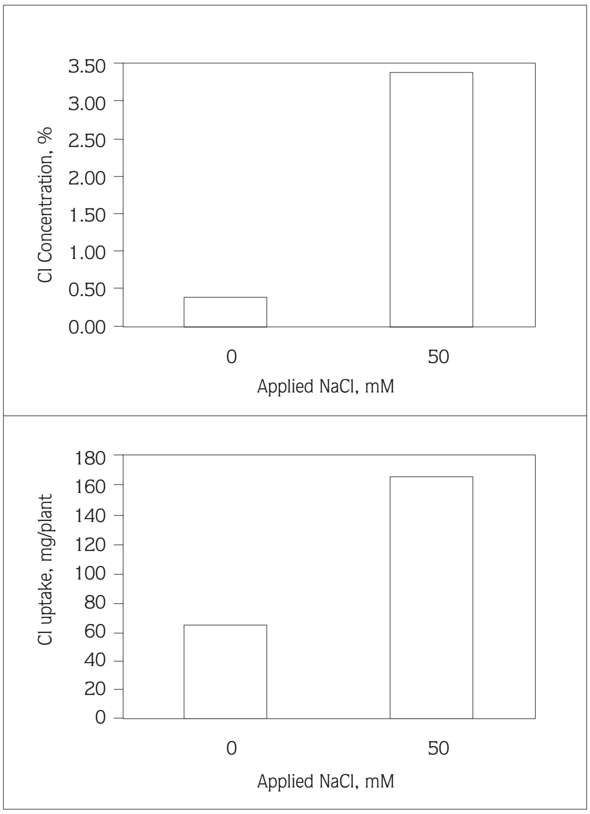

Figure 4. Chloride concentration and uptake of pepper plant as affected by salinity.

and KNO_3.

After transplantation, the experiment was conducted for 12 weeks. Mature fruits were collected and their fresh weights were measured during the experiment. After economic yield term was finished, plants were harvested, weighed, washed, divided into leaf and stem and subsequently dried at 70°C. Only the leaf samples were ground for mineral element determination.

Phosphorus, Na and Zn concentrations were assayed in concentrated HNO_3 and $HClO_4$ (4:1) digested samples. Sodium was measured by flame photometer and Zn by AAS. Phosphorus was measured by molybdate-vanadate colorimetric method (8). Water extractable Cl was determined by potentiometric titration with $AgNO_3$ as described by Lambert and DuBois (9).

The experimental design was completely random with four replicates and the data were analyzed by ANOVA and the differences were compared by LSD test (Duncan's multiple range test, $_{p<0.05}$). Both statistical tests were carried out with a MINITAB package program.

Results

The response of the pepper plant to 0 and 50 mM NaCl in factorial combinations with 0, 200, 300 and 500 mg kg^{-1} P was tested in this study. The results are shown in Figurs 1-4 and the variance analyses (F values) of the experimental data are shown in Table 1.

Identical Zn deficiency symptoms were observed at

300 and 500 mg kg^{-1} P treatments, to a greater extent under saline conditions than under non-saline conditions. However, the deficiency symptom is slightly reflected to the yield parameters.

Regardless of P rates, applied P increased fruit yield significantly in the absence of salinity as compared to the control. In saline conditions, fruit yield slightly decreased after a P level of 300 mg kg^{-1}. Fresh and dry weights of the plants increased up to a P level of 300 mg kg^{-1} and then decreased at the highest P level (500 mg kg^{-1} P) in non-saline conditions. There were also slight decreases after a P level of 300 mg kg^{-1} in fresh and dry weights in saline conditions, but these were not statistically significant (Figure 1).

Salinity decreased Zn concentration and uptake at all P levels (except 300 mg kg^{-1}). In general, tissue Zn concentrations decreased with increasing P levels under both saline and non-saline conditions. Zinc uptake was decreased by P application except 300 mg kg^{-1} in non-saline conditions. However, the differences in saline conditions were not significant (Figure 2).

Leaf P concentrations and P uptake of the plants increased quadratically with increasing P levels. In general, phosphorus content of the leaf tissue was greater under saline conditions than under non-saline conditions (Figure 2). Phosphorus uptake were decreased by salinity. The effects of the applied P levels on P uptake were not found to be significant in saline conditions.

Increasing levels of applied P and salinity increased Na concentrations in the leaf tissues. The sodium uptake of the plants as affected by P levels increased up to a P level of 300 mg kg^{-1} and decreased after this level under saline conditions, while it showed a linear increase under non-saline conditions (Figure 3).

Tissue Cl concentrations and uptake increased significantly with salinity. However, they did not respond regularly to the applied P (Figure 4).

Discussion

The highest rates of P caused decreases in the fruit yield and fresh and dry weights of the plants. This effect was more pronounced in the presence of salinity. These results are in agreement with the previous reports (6, 7). Decreases in growth parameters as a result of salinity are explained in detail in Cusido et al., (10), Flowers and Yeo (11) and Güneş et al., (12). Salinity depresses the growth of plants by affecting water absorption as well as biochemical processes such as N and CO_2 assimilation and protein biosynthesis or high concentration of potentially toxic ions such as Cl and Na (13).

Decreasing tissue Zn concentrations and uptake could be the result of increased P in the tissues by the combined effect of salinity and the appiled P. As suggested by Millikan et al., (14) and Loneragan et al., (3), the increased P supply induces a higher physiological P-enhanced Zn requirement or physiological inactivation of Zn in the tissues by the increases in P supply (13).

Both salinity and increasing P increased leaf P and Na concentrations. The increase of plant P by salinity may be due to the increased availability of P in the soil or the synergistic effect of Na, which is involved in P uptake and/or transport to the shoots or vice versa (6, 7).

Concentrations and uptake of Cl were increased by salinity. This confirms the findings of Joshi (16), Cusido et al., (10) and Güneş et al., (12).

From the above results, it could be suggested that Zn dreficiency is a more serious nutritional problem as a consequence of the increasing availability of P or the synergistic effect of Na on the uptake and translocation of P under NaCl salinity conditions.

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