American Journal of

Plant Physiology

ISSN 1557-4539

Academic
Journals Inc.

www.academicjournals.com

American Journal of Plant Physiology 5 (2): 102-109, 2010
ISSN 1557-4539 / DOI: 10.3923/ajpp.2008.81.88

Response of Cowpea Plants Grown Under Salinity Stress to PK-Foliar Applications*

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Abstract: Pot experiment was conducted in the greenhouse of the National Research Centre to study the effect of two doses (50 and 100 mg L^{-1}) of PK foliar fertilization in the form of K_2PO_3 on leaf nutrient concentrations and growth parameters of cowpea (*Vigna unguiculata* L.) grown under two diluted Mediterranean seawater levels (3.0, 6.0 dS m^{-1}) in the irrigation water in addition to tap water (0.4 dS m^{-1}) as control. Diluted seawater as irrigation led to significant decreases of macro and micronutrients concentrations in the leaves of cowpea plants. Plant height, number of green leaves, fresh and dry weights were also negatively affected with high significance ($p_{0.05}$) as the plants irrigated with saline water. PK-foliar fertilization in the form of K_2PO_3 could increase P, K and other macro- and micronutrient concentrations in the leaves of the salt-stressed plants. The most effective dose was the 100 mg L^{-1} K_2PO_3 with the lower salinity level (3.0 dS m^{-1}). Making the plants more tolerant to salinity stress, PK-foliar fertilization could improve plant growth parameters and increase plant heights, number of green leaves, fresh and dry weights.

Key words: Cowpea, salinity, PK-foliar application, nutrient concentrations, growth

INTRODUCTION

Salt stress condition is an osmotic which is apparently similar to that brought by water deficit (Almoguera *et al*., 1995). Most of crop plants are classified as glycophytes cannot tolerate high concentrations of salts in the root medium (Hussein *et al*., 2007a). Injurious ions such as Na^+ and Cl^- negatively affect nutrient uptake and balance (Sairam and Tyagi, 2004; Hussein *et al*., 2007b). As the saline soils generally have higher concentrations of Na^+ than K^+ and Ca^{2+}, a passive accumulation of Na^+ in shoots and roots is occurred (Bohra and Doerffling, 1993). Accumulation of Na^+ in roots reduces K^+ uptake (Cramer *et al*., 1985; Lacerda *et al*., 2003) and Na^+ presence in higher concentrations in xylem restricts K^+ translocation from root to shoot (Engels and Marschner, 1992) which resulting in low K^+ shoot content. Transport of Ca, Mg and total nitrogen were also reported to be inhibited with NaCl-salinity (Tremaat and Munns, 1986).

Cowpea is a predominately hot weather crop widely grown in eastern Africa and southeast Asia primarily as leafy vegetable. Steele *et al*. (1985) estimated that protein content of the leafy cowpea parts consumed annually in Africa and Asia is equivalent of 5 million tons and that this represents as mush as 30% of the total food legume production in the lowland tropics. Cowpea is inherently more drought and salinity tolerant than other crops but it still suffers considerable damage due to frequent drought and salinity stresses in different regions where rainfall is scanty and irregular (Singh *et al*., 2003).

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**Originally Published in American Journal of Plant Physiology, 2008*

Foliar fertilization can increase tolerance of plants to salinity by compensating the deficient nutrients in the plant tissues (El-Fouly *et al*., 2002; Shaaban *et al*., 2004). Sugar beet plants grown under high stress conditions could grow well and produce higher yields when sprayed with potassium (Tehrani and Malakouti, 1997).

The present research studied the response of cowpea plants irrigated with diluted seawater under greenhouse conditions to PK-foliar fertilization.

MATERIALS AND METHODS

Pot experiment was conducted in the greenhouse of the National Research Centre, Dokki, Cairo, Egypt during the two successive winter seasons 2004 and 2005 to study the response of cowpea (*Vigna unguiculata* L.) grown under two levels of salinity stress.

Seeds were sown in December, 1st in metallic tin pots 35 cm diameter and 50 cm depth. The inner surface of the pots was coated with three layers of bitumen to prevent direct contact of the metal with soil. Every pot contained 30 kg clay loam soil. Two kilograms of gravel (particles 2-3 cm in diameter) were placed in the bottom to make the movement of water from the base upward. Plants were thinned twice (8 and 12 days after sowing) to leave 5 uniform plants per pot. Calcium super phosphate (15.5% P_2O_5) and potassium sulfate (48.5% K_2O) in the rate of 6.0 and 3.0 g pot^{-1}, respectively were added in two equal splits (before sowing and two weeks later). The pots received N-fertilization in the rate of 6.86 g pot^{-1} as ammonium sulfate (20.6% N) in two equal splits (2 weeks after sowing and 2 weeks later).

Treatments

Irrigation with diluted Mediterranean seawater (Table 1) in two concentrations (3.0 and 6.0 dS m^{-1}) started at 20 days after sowing, while tap water (0.4 dS m^{-1}) is considered as control. Every treatment contained 6 replicates. Potassium di-Hydrogen Phosphate (KH_2PO_3) in the concentrations of 50 and 100 mg L^{-1} was sprayed at 20 and 30 days after sowing.

Sampling and Analysis

Soil

A representative soil sample was taken just before sowing, air dried, ground and sieved through 2.0 mm sieve and analyzed (Table 2). Mechanical analysis was carried out using the hydrometer method (Bauyoucos, 1954), pH and Electric Conductivity (EC): Water extract (1 soil: 2.5 water) method (Jackson, 1973), $CaCO_3$: Calcimeter method (Black, 1965), Organic Matter (OM): potassium dichromate method (Walkley and Black, 1947). Phosphorus (P) was extracted using sodium bicarbonate (Olsen *et al*., 1954). Potassium (K) and Magnesium (Mg) were extracted using ammonium acetate method (Chapman and Pratt, 1978). Iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were extracted using DTPA method (Lindsay and Norvell, 1978).

Table 1: Cation and anion components of sea water

Components	Concentration
Cations (mM)	
Na^+	457.000
K^+	9.700
Mg^{++}	56.000
Ca^{++}	10.000
Anions (mM)	
Cl^-	536.000
SO_4^{--}	28.000
HCO_3^-	2.300
Total soluble salts (mg L^{-1})	32.000

Table 2: Soil chemical and physical characteristics

Physical characteristics		Nutrient concentrations	
pH	8.3	**Exchangeable macronutrients**	
EC (dS m^{-1})	0.8	**(mg 100 g^{-1} soil)**	
$CaCO_3$ (%)	1.6	P	5.2*
O.M. (%)	0.1**	K	37.9*
Sand (%)	14.0	Mg	30.7*
Silt (%)	28.0	**Available micronutrients**	
Clay (%)	58.0	**(mg kg^{-1} soil)**	
Texture	Clay loam	Fe	11.0*
		Mn	9.0*
		Zn	3.3*
		Cu	10.2*

*Adequate, **Low

Shoots

Shoot samples were taken at the age 45 days after sowing. The shoots were separated into stems and leaves, washed with tap water, 0.01 N HCl and bi-distilled water, respectively, dried at 70°C for 24 h, weighed and ground. A part of the plant material was dry-ashed in a Muffel furnace at 550°C for 6 h. The ash was digested in 3 N HNO_3 and the residue was then suspended in 0.3 N HCl (Chapman and Pratt, 1978). A part of the sample was weighed and oven dried at 105°C for 24 h, then weighed again and the dry weight was calculated.

Nutrient Measurements

Nitrogen was determined using Kjeldahl-method; phosphorus was photometrical determined using the molybdate-vanadate method according to Jackson (1973). Potassium and Ca^{++} were measured using Dr. Lang-M8D Flame-photometer. Magnesium, Mn^{++}, Zn^{+} and Cu^{+} were determined using the Perkins-Elmer Atomic Absorption Spectrophotometer.

Evaluation of the Nutrient Status

Soil nutrient status was evaluated according to the sufficient concentrations of Ankerman and Large (1974).

Statistical Analysis

Data were statistically analyzed using the method described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Effect of Salinity

Salinity of irrigation water dramatically affected nutrient concentrations in cowpea leaves. Concentrations of N, P, K, Mg and Ca were decreased with salinity dose increment (Fig. 1). Micronutrients concentrations were also declined as salinity level of irrigation water increased (Fig. 1). The most effected were nitrogen, phosphorus, potassium, calcium manganese and zinc. Osmotic potential created by saline ions at the root medium restricted water and nutrient elements flow into roots (Munns, 2002). Accumulation of Na^{+} in roots found to reduce K^{+} uptake and translocation from root to shoot (Cramer *et al*., 1985; Engels and Marschner, 1992; Maiti *et al*., 2006; Graboov, 2007). Calcium, magnesium and nitrogen transport was also reported to be inhibited due to salinity (Tremaat and Munns, 1986; Maiti *et al*., 2006). Due to nutrient deficiency and/or harmful effects of the saline toxic ions, growth parameters of cowpea plants were negatively affected. Plant heights, number of green leaves per plant, fresh and dry weight were significantly decreased, especially with the high salinity level (6.0 dS m^{-1}) (Table 3) which is characteristic to plants irrigated with saline water

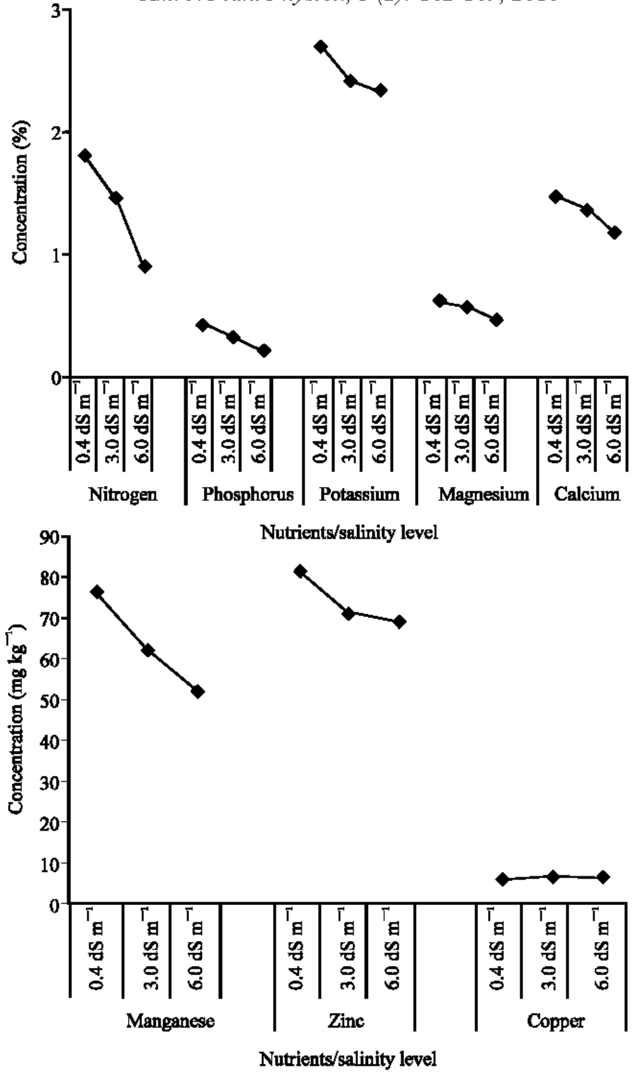

Fig. 1: Macro and micronutrients concentration in cowpea leaves as affected by salinity of the irrigation water

Table 3: Effect of PK-foliar fertilizer on growth parameters of cowpea plants grown under two levels of salinity in the irrigation water (n = 12)

Salinity treatment	Foliar fertilizer treatment	Plant height (cm)	No. of green leaves/plant	Shoot fresh weight (g plant^{-1})	Shoot dry weight (g plant^{-1})
Tap water (0.4 dS m^{-1})	Tap water	64.0a	12.50a	88.2a	22.97a
	50 mg L^{-1} PK	109.5b	16.50b	94.9a	25.73ab
	100 mg L^{-1} PK	116.5b	21.00c	100.8b	29.42b
	$LSD_{0.05}$	9.0	3.18	9.75	4.47
3.0 dS m^{-1}	Tap water	69.0a	13.50a	110.7a	23.82a
	50 mg L^{-1} PK	98.0b	19.50b	113.9a	34.61b
	100 mg L^{-1} PK	130.5c	25.00c	127.8b	39.28c
	$LSD_{0.05}$	9.0	2.90	9.72	3.60
6.0 dS m^{-1}	Tap water	52.5a	6.00a	42.2a	7.70a
	50 mg L^{-1} PK	47.5a	8.00a	49.0a	9.55a
	100 mg L^{-1} PK	45.5a	8.50a	54.3a	16.38b
	$LSD_{0.05}$	9.0	3.89	9.7	4.51

Mean values with the same letter(s) are not statistically significant

(Meiri and Shalhevet, 1973; Izzo *et al*., 1991; Munns, 1993; Maiti *et al*., 2006). However, other investigations suggested that this effect might be due to disturbance in growth regulators (Brenant *et al*., 2007), photosynthesis and protein building (Debuba *et al*., 2006), enzymes activity (Thapon *et al*., 2008) or antioxidant defense (Xie *et al*., 2008).

Effect of PK-Foliar Fertilization

Nutrient concentrations in the leaves of cowpea plants grown under salinity stress of irrigation water were significantly increased as the plants received twice dosing of 100 mg L^{-1} K_2PO_3 as foliar supplements (Fig. 2, 3). As P and K uptakes and translocation were inhibited by salinity stress conditions in the root medium, PK-foliar fertilization may become the most suitable remedy for their deficiency in the shoot tissues (Shaaban *et al*., 2004). Furthermore, adequate concentrations of both elements in the foliar fertilized leaves improved uptakes of other nutrients to reach the sufficiency levels for plant growth and development (El-Fouly *et al*., 2002). Consequently, sufficient concentrations of nutrients, especially nitrogen enabled the plant mechanism regulations to synthesize considerable concentrations of metabolites to overcome the harmful effects of the saline ions (Kao, 1997). As salinity caused dehydration which inhibits photosynthesis of stressed plants, K-foliar supplementations can partially reverse such dehydration effects (Pier and Berkowitz, 1987).

PK-foliar fertilization positively affected growth parameters of cowpea grown under salinity stress conditions. Plant heights, number of green leaves per plant and both fresh and dry weights were significantly increased as the plants received PK-foliar fertilization (Table 3). The most effective dose was 100 mg L^{-1} with the lower salinity level (3.0 dS m^{-1}). As potassium is mostly responsible about cell turgor, PK-foliar fertilization led to better increases of fresh weight than dry weight (Lindhauer, 1989). Lindhauer (1985) showed also that K^+-fertilization besides increasing the dry matter production and leaf development, greatly improved the retention of water in the plant tissues even under severe stress conditions. Kabir *et al*. (2007) support this finding, but Hussein and El-Greatly (2007)

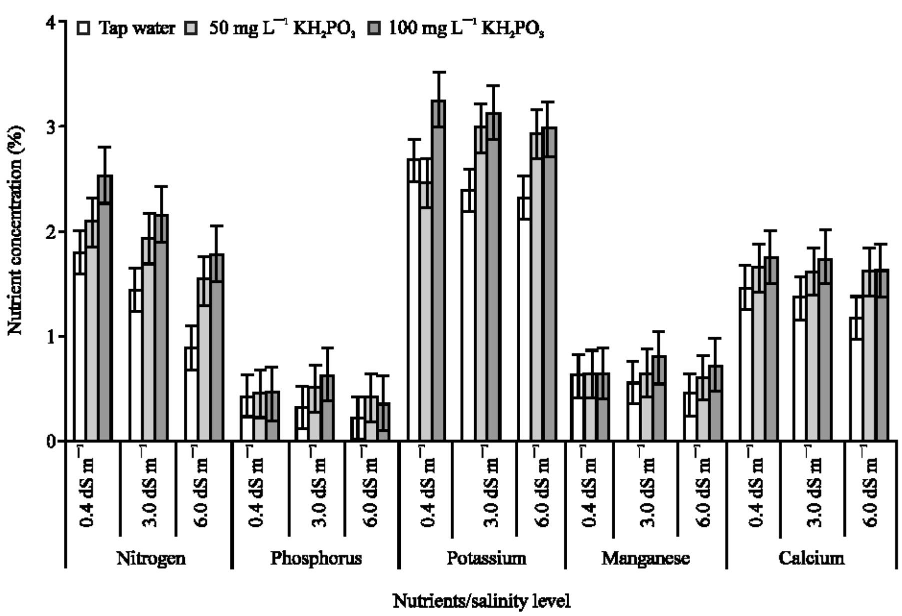

Fig. 2: Macronutrients concentrations in cowpea leaves as affected by salinity level in the irrigation water and PK-foliar fertilization

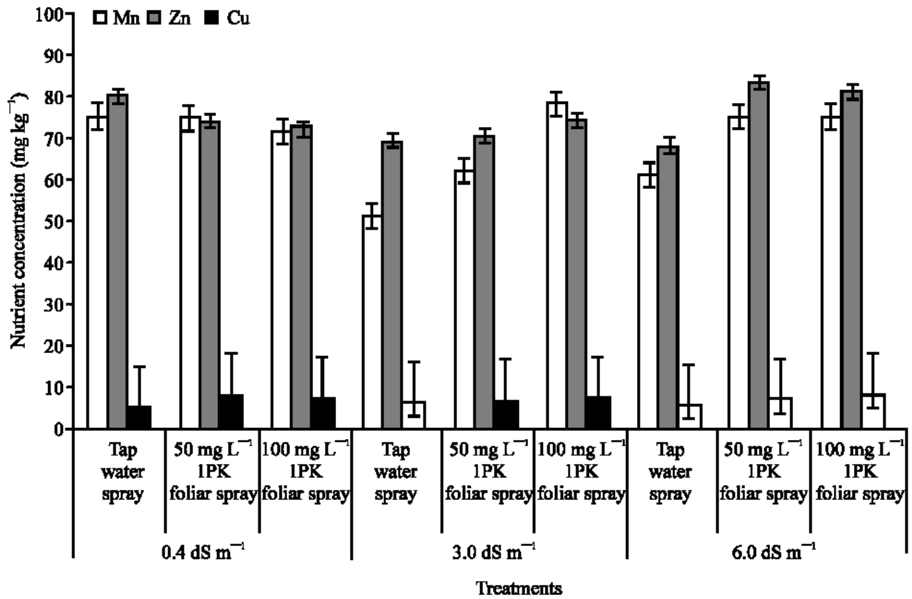

Fig. 3: Micronutrients concentrations in cowpea leaves as affected by salinity level in the irrigation water and PK-foliar fertilization

attributed this phenomenon to the effect of PK on endogenous harmony. Meanwhile, Williams and Kafkafi (1995) demonstrated that K-shortage in the root medium can be alleviated by K-foliar fertilization, especially at the higher demands during fruit-stage.

CONCLUSIONS

Salinity of diluted seawater as irrigation water led to significant decreases of macro and micro-nutrients concentrations in the leaves of cowpea plants. Plant height, number of green leaves, fresh and dry weights were negatively affected significantly as the plants irrigated with saline water. PK-foliar fertilization in the form of K_2PO_3 could increase P, K and other macro- and micronutrient concentrations in the leaves. Making the plants more tolerant to salinity stress, PK-foliar fertilization could improve plant growth parameters.

ACKNOWLEDGMENTS

The authors wish to thank staff members of the project Micronutrients and other Plant Nutrition Problems in Egypt and its principle investigator Prof. Dr. Mohamed M. El-Fouly for their support during the course of this study.

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