Effect of Potassium Fertillization on Yield and Mineral Element Acquisition of Four Potato Cultivars Grown Under Salt Stress

Elkhatib,H.A.[1], A.M.Khalaf-Allah[2], A.M. El-Sharkawy[2]

ABSTRACT

Despite the importance of K nutrition in increasing plant tolerance to salinity, not much is known on K fertilization of potatoes (*Solanum tuberosum*) grown under salt stress. In a 2-yr study, the responses of four potato cultivars grown under salt stress were examined over a range of 0 to 600 kg ha^{-1} K fertilizer application. Increasing K fertilization rate resulted in successive and significant increments on vegetative growth and total tuber yield of all cultivars. Cultivar Diamont produced the highest foliage dry weight and tuber yield followed by Alpha and Spunta, meanwhile King Edward gave the lowest yield.

Potassium additions increased significantly N, P, Na and K concentrations in potato leaves and had fairly consistent effect on lowering tissue concentration of Ca and Mg in all potato cultivars studied. This indicated that there was definite antagonistic effect related to cation balance involved among these nutrients. Correlations between K application level and tuber yield of all cultivars were significant in both seasons. Increasing K supply proved to be necessary to improve tolerance of potato cultivars grown under salt stress.

INTRODUCTION

The increasing scarcity of water in dry areas is a well recognized problem. Therefore, the use of saline water for irrigation is becoming an increasingly important issue in arid regions. Irrigation with such water introduces salts in to the soil solution and may impose a stress on growing crops that can lead to decreased yield (Hoffman, 1988).

The strategies now available to cope with salinity are to select potentially useful germplasm and/or alter K fertilization process to increase the crop's ability to tolerate saline conditions (Caro et al. 1991; Oertli, 1992, ; Finck, 1998). However, little information is available on the effect of K fertilization on salt stressed potatoes. Therefore, the objectives of these two year experiments were: (i) to evaluate the responses of four potato cultivars grown under salt stress to K fertilization and (ii) to study the implication of K nutrition on the acquistion of the major nutrients in these cultivars.

MATERIALS AND METHODS

Lysimeter experiments

Two experiments were conducted at the soil salinity laboratory at Alexandria, Egypt; using lysimeter plots with the dimensions of 0.6 by 0.6 by 0.4 m deep. The bottom of each lysimeter plot was provided with an outlet drain to facilitate leaching. Each plot was filled with 40 kg sandy loam soil whose physical and chemical properties are presented in table (1). Soil physical and chemical properties were determined as follows:

Soil pH and EC in saturation paste extract; $CaCO_3$ content by the volumetric calcimeter method (Soil Conservation Service, 1972); soluble cations and anions by methods in the USDA Handbook 60 (Richards, 1954) and particle size distribution by the hydrometer method (Gee and. Bauder, 1986)

The investigated treatments in both experimens consisted of the combinatons among four K levels (0, 200, 400 and 600 kg/ha) and four potato cultivars (King Edward, Spunta, Alpha. and Diamont). Potassium fertilizer was added in the form of potassium sulphate in two equal parts, at 35 and 55 days from planting. In addition to the indicated K levels, all plots received P at the rate of 50 kg P/ ha prior to planting in the form of superphosphate and N at the rate of 200 kg N/ ha as urea. Potassium and nitrogen fertilizers were banded at the same time, 5 cm apart on both sides of seed beds. Commercial certified sprouted tuber seeds were planted in the lysimeter plots on october 20, 1994 and February 20, 1995; in the fall and summer growing seasons, respectively. The used experimental design was a split – plot system in randomized complete blocks, with four replicates, where cultivars represented the main plots and K levels were the sub – plots. Each sub- plot contained three plants spaced at 40 cm.

[1] Department of Horticulture, Collge of Agriculture, Damanhour, Alexandria University, Egypt.

[2] Department of Vegetable Crops, College of Agriculture, El- Shatby, Alexandria University, Egypt. Received October 22, 2006, Accepted December 23, 2006.

Table 1. Physical and chemical properties of the used soil

Sand	Silt	Clay	$CaCO_3$	pH	EC	Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^-	SO_4^-	Cl^-
%					dS m^{-1}	cmol m^{-3}						
78.0	11.0	11.0	28.0	8.2	2.3	8.6	1.9	7.8	4.7	3.5	8.2	11.3

Tap water was applied to each plot after planting. Saline water irrigations were started at 21 days from planting in both seasons. The electrical conductivity of the used saline irrigation water was 9.38 dSm^{-1}.The irrigation regime followed the procedure recommended for the area during fall and summer growing seasons. The amount of applied water was increased by 20% to encourage adequate leaching to prevent salt accumulation in the root zone. Common cultural practices; such as cultivation, pest and disease control were applied as required by the crop and the growing season. Plants within each treatment were harvested on January 30, 1995 and May 30, 1995; in the fall and summer seasons respectively and the following parameters were recorded: total tuber yield per plant, average tuber weight, and average number of tubers per plant.

Mineral contents

Mature healthy leaves were sampled from each cultivar, washed, dried at 70 °C and finely ground in a blender. Samples of dry leaves were digested in concentrated sulphuric acid and standarized by additions of hydrogen peroxide until the digest remained clear. The Na, Ka, Ca, and Mg were determined by atomic absorption spectrophotometry. Phoshorus was analyzed by molybdovanadate-yellow colorimetry (Jackson, 1958) and nitrogen was determined according to the method of Evenhuis and De waard (Evenhuis and De waard, 1980).

Statistical analyses

All obtained data were subjected to proper statistical analyses of the used design according to Snedecor and Cochran (1980). Mean values were compared using least significnt differences (LSD) at 5% level.

RESULTS AND DISCUSSION

Vegetative growth

The effect of cultivars and K additions on the foliage dry weights of potato plants grown under salt stress is shown in Table 2. In both seasons, the foliage dry weights of potato plants were significantly affected by cultivars and K additions. Diamont and Alpha cultivars had the highest foliage dry weights meanwhile King Edward and Spunta were the lowest in both seasons.

Increasing K fertilization from 0 to 400 kg / ha resulted in positive increases in foliage dry weights of potato plants in both seasons. Increasing K application level from 400 to 600 kg / ha decreased to some extent mean foliage dry weights in both seasons. However, the recorded values were significantly higher than those of the control and 200 kg K level. These results have practical significance, since they indicated that application of K to a certain level may help plants to tolerate saline conditions.

Total yield, average weight and number of tubers per plant.

Total yield and average tuber weight reflected significant differences among the studied four potato cultivars in both seasons. The highest total yield per plant was produced by Diamont cultivar; whereas King Edward gave the lowest yield as shown in Table (2). The results, generally indicated that increasing K fertilization level in both seasons, resulted in successive and significant increments on total yield. Concering average tuber weight, the data listed in Table (2), illustrated that increasing K level increased average tuber weight, signifiicantly, in fall 1994 and, relatively in summer 1995 seasons. Increasing K level from 0 to 600kg K/ ha resulted in pronounced increments on total yield; reached 64.7 and 48.3 % in fall and summer seasons, respectively. Whereas, average tuber weights were increased by 38.7 and 8.7 % only; in fall and summer seasons, respectively. These results, generally, support those of Beringer et al. (1990), who indicated that application of potassium sulfate resulted in a significant increase in tuber yield.

Singnificant effects for the interactions between potato cultivars and K fertilization levels on total yield were noticed in both seasons (Table 2). At the three K application levels of 200, 400 and 600 kg K / ha, Diamont cultivar produced the highest yield, followed by Alpha; meanwhile, King Edward gave the lowest yield. Such interactions could be attributed to differences in genetic constituents as well as in salinity tolerance among the four studied cultivars. Similar

Table 2. Tuber yield and vegetative growth of four potato cultivars, grown under stress as affected by K fertilization levels in two seasons.

Main Effects	Foliage dry weight/plant(g)		Tuber yield (g)/plant		Avg. tuber weight (g)		Avg. No of tubers/plant	
	Fall	Summer	Fall	Summer	Fall	Summer	Fall	Summer
Cultivar								
Spunta	9.9	17.1	134.0	115.8	31.7	28.8	4.3	4.0
King Edward	8.4	16.7	106.0	104.9	16.4	19.2	6.6	5.4
Alpha	13.0	17.9	150.5	104.9	21.6	21.3	7.1	6.4
Diamont	14.0	18.6	174.7	143.0	27.7	22.2	6.3	6.4
K application level (kg/ha)								
0	9.2	12.9	104.3	96.1	19.9	21.8	5.4	4.5
200	11.5	17.0	132.0	120.0	23.1	22.8	5.9	5.5
400	12.9	20.9	157.7	139.8	26.8	23.3	6.3	6.0
600	11.7	19.5	171.8	142.5	27.6	23.7	6.6	6.1
L.S.D. (0.05								
Cultivar	1.0	1.2	6.84	16.97	3.7	2.5	0.79	0.91
K level	0.84	0.96	8.77	9.48	1.8	NS	0.53	0.55
Cultivar x K level	1.7	1.92	17.5	18.96	3.5	NS	NS	NS

NS: Not Significant at $P < 0.05$.

results were obtained by Draycott and Durrant (1976), who reported that application of K to sugar beet plants gave heavier roots than the control, under salt stress, and explained such an effect to be due to antagonistic effect to Na as well as furnishing an adequate amount of K to sugar beet plants.

The average number of tubres per plant was significantly affected by cultivars of potato plants in both seasons, (Table 2). Spunta cultivar had the lowest average number of tubers per plant in both seasons meanwhile Alpha and Diamont produced the highest number of tubers per plant. Comparison between means indicate that number of tubers per plant was significantly increased by increasing K fertilization level in both fall and summer seasons. However, the interaction between cultivars and K level did not significantly affect the average number of tubers per plant in both seasons.

Chemical Composition

Nitrogen and phoshorus

_Significant differences in leaf N and P concentrations among cultivars were noticed in both seasons(Table 3). King Edward leaves contained the highest P concentrations among cultivars in both seasons. However leaf N concentrations in the cultivars studied did not show consistent trend in both seasons.

Effect of K fertilization level on leaf P and N concentrations of potato plants are shown in Table (3). Potassium fertilization significantly increased N and P concentration in potato leaves in both seasons. Correlations of tissue N with tuber yield were significant for Spunta, Alpha and Diamont in both seasons (Table 4). However, the correlations of tissue P with tuber yield were significant for all cultivars in fall season 1994 but not in summer season 1995. The effects of the interaction between cultivars and K fertilizaion rate on the leaf elemental content of N were significant in both season. (Table 3). Monroe et al. (1964) and Ajay et al. (1970) found that K enhanced N assimilation in the plants. These studies indicated the importance of supplying adequate K for efficient N use.

Wagner (1979) emphasized the importance of P – K interactions, in the maximum yield proudction. Adepetu and Akapa (1977) working with cowpea, found a potential P- K interacion in the uptake phase. They suggested that since K deficiency markedly decrease P uptake, a specific P ion absorption site exists that is activated by K.

Sodium and potassium

Effects of cultivars and K fertilization rate on leaf elemental content of Na and K were significant in both seasons (Table 3). Diamont cultivars did absorb more K and Na than Alpha, King Edward and Spunta cultivars In both seasons,. Tuber yield of all cultivars except King Edward correlated better with K leaf content than with Na leaf content in both seasons (Table 4). Although plants selectively absorb and translocate K in preference to Na, the degree of selectivity varies among species as well as among cultivars within a species. Kafkafi (1984) found that the roots of the salt tolerant species had a higher affinity for K^+, in exchange for Na, than the salt sensitive species.

The effects of the interaction between cultivars and applied K on the leaf elemental content of K and Na were significant in both seasons (Table 3). Tissue K concentration increased significantly and linearly with increasing K level. Correlations between K application

Table 3. Mineral content of potato leaves in two seasons as affected by K fertilization level and cultivars

Main effects and interaction	Conc.(g/kg dry wt.)		Conc.(mmol/ kg dry wt.)				Conc. (g/kg dry wt).		Conc. (mmol/kg dry wt)			
	N	P	K	Na	Ca	Mg	N	P	K	Na	Ca	Mg
	Fall 1994						Summer 1995					
Cultivar												
Spunta	65.0	1.21	1166	122	200	1527	66.7	1.85	1046	92	185	1076
King Edward	72.0	1.47	1157	148	169	1480	77.7	2.0	1040	101	175	987
Alpha	65.0	1.61	852	158	173	1523	77.7	1.69	968	99	21	887
Diamont	67.2	1.49	1192	176	208	1565	72.6	2.86	1133	145	171	894
K level (kg/ha)												
0	61.1	1.11	816	140	215	1833	62.6	1.85	791	87	206	1090
200	65.4	1.44	1029	145	198	1572	73.4	2.16	975	118	189	961
400	69.0	1.54	1229	154	171	1400	80.5	2.3	1338	115	175	923
600	73.0	1.68	1352	165	165	1280	78.2	2.1	1293	117	163	871
L. S. D. (0.05)												
Cultivar	1.91	0.18	77.6	15	26	NS	4.0	0.07	50	9.4	15.4	26
K level	1.50	0.13	42.5	7.4	9.5	708	4.6	0.1	54	8.0	10.8	34
Cultivar x K level	2.99	NS	85.0	15	19	141.6	9.2	0.2	108	16.0	21.7	68

NS: Nonsignificant at $P< 0.05$.

Table 4. Correlation of leaf elemental content against tuber yield of four potato cultivars grown under salt stress in two seasons.

Tuber Yield	N	P	K	Na	Ca	Mg
			Fall 1994			
Spunta	0.651*	0.843***	0.935***	NS	-0.853***	-0.674*
King Edward	0.586*	0.567*	NS	NS	NS	NS
Alpha	0.855***	0.835***	0.940***	0.649*	NS	-0.903***
Diamont	0.788**	0.863***	0.944***	0.657*	-0.835***	-0.890***
			Summer 1995			
Spunta	0.635*	NS	0.684**	NS	NS	-0.661**
King Edward	NS	NS	NS	0.616**	NS	-0.627**
Alpha	0.860***	NS	0.884***	0.746**	-0.659**	-0.727**
Diamont	0.885***	NS	0.898***	0.596*	-0.766**	-0.726**

NS,*, **, ***: Non- significant or significant at < 0.05, 0.01, or0.001 respectively.

level and tuber yield of all cultivars were significant in both seasons (Table 4).

The obtained results could be explained on the basis that high salt concentrations in the soil imposed an osmotic stress on the crop and reduced availability of soil water to the roots. If high salt concentration is not accompanied by low proportions of K, improved supply of K would be necessary to improve tolerance towards salt stress through accumulation of organic solutes in roots generating higher osmotic pressure of cell sap which favours water uptake in the cell (Beringer, 1980). This would explain the strong crorrlations obtained between K level and tuber yield. Finck (1976) concluded that for optimal K nutrition of wheat under saline condition, K fertilizer rates should be 20 to 50% higher than under nonsaline conditions.

Calcium and magnesium

Cultivars differed significantly in their ability to abosrb Ca in both seasons (Table3). However, the effect of cultivars on Mg in leaves was not significant in fall season. Leaf tissue content of Ca and Mg decreased significantly with increasing K level (Table3).These results are consistent with those of Keisling et al (1979) whom found that increased K application rates on coastal bermuda grass decreased the amount of Ca and Mg in the forage tissue. In a work with cotton, increased K application rates, which consistently increased leaf K content , generally also reduced leaf Mg levels (Lombin and Mustafa, 1981).It was also reported that cotton yield was increased with increasing K fertilization rate.

The interaction effects between cultivar and K fertilizaion rate on leaf elemental content of Mg and Ca were significant in both seasons (Table 3). Correlation between tissue Mg and tuber yield of all cultivars were negatively significant in summer season 1995. Similar results were obtained in fall 1994 with all cultivars except King Edward. (Table 3 and 4).

In summary, potassium additions increased K tissue levels in plants and had a fairly consistent effect on lowering tissue concentrtion of Ca and Mg in all potato cultivars studied. Undoubtedly some of the decreases were due to a dilution effect because yield responses to added K were significant in all cultivars. Such an evidence indicated that there was definite antagonistic effect related to cation balance involved among these nutrients. Future improvements in potato cultivars and water utilization will require better understanding of interaction effects.

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