BIOLOGIA PLANTARUM 35 (4): 555-560, 1993

Counteraction of NaCl with $CaCl_2$ or KCl on pigment, saccharide and mineral contents in wheat

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Abstract

NaCl salinity affected growth, the contents of chlorophyll, carotenoids, saccharides and some minerals (Na, K, Ca, Mg, P) in wheat (*Triticum vulgaris* L.) plants. Irrigation of soil with $CaCl_2$ or KCl greatly ameliorated the adverse effects of NaCl salinity. This counteraction was associated with an increase in contents of saccharides, proteins and Ca, Mg and P which might explain their role in osmotic adjustment.

Introduction

A disturbance in Ca (Wilson *et al.* 1970) uptake due to salinity in peanut was evident in the experiments of Ramana and Rao (1970). Low levels of Ca can accentuate inhibitory effects of NaCl on growth (Hyder and Greenway 1965). Marchner and Possingham (1975), Helal and Mengel (1979) and Muhammed *et al.* (1987) found that addition of KCl to the culture media diminished the negative effect of NaCl salinization on some crops. Also the addition of Ca to the germination medium increased the germination percentage (Marcar 1986).

In view of the role played by Ca and K in counteracting the inhibitory effect of NaCl salinization on glycophytic plants, the present investigation was undertaken to study the interactive effect of NaCl salinity and $CaCl_2$ or KCl (200 mg kg^{-1}) on growth and some metabolic pools of wheat plants.

Materials and methods

Wheat (*Triticum vulgaris* L.) plants were grown in plastic pots containing air-dried soil (sand/clay 1:2). NaCl salinization levels (three pots per each) corrresponded to

Received 29 September 1992, *accepted* 1 February 1993.
Acknowledgement: The author wishes to express her deep gratitude to Prof. M.M.K. Shaddad for his supervision, guidance and constructive criticism. Without his help this work would not have been fulfiled.

osmotic potentials -300, -600, -900 and -1200 kPa, in addition to the control (no NaCl). Treatments of plants with saline solutions began when seedlings were two weeks old. In order to adjust the osmotic potential of the soil solutions as possible near to the desired level, plants were irrigated with the experimental solution every other day for three weeks and the soil moisture content was kept near the field capacity. Thereafter, the salinized and non-salinized plants were irrigated every other day with 1/10 Pfeffer's nutrient solution for two weeks. The plants were allowed to be adjusted to the above treatment for a period of one week before treatment with 200 mg kg^{-1} of $CaCl_2$ or KCl. Each pot was irrigated with 200 cm^3 of $CaCl_2$ or KCl solution over one week for four intervals. A week later after the last $CaCl_2$ or KCl applications plants were harvested. Dry matter was determined after drying plants in an aerated oven at 70 °C to constant mass. Leaf area was measured by the disk method (Watson and Watson 1953). The contents of chlorophyll *a* and *b* and carotenoids were determined using the spectrophotometric method of Metzner *et al.* (1965). Saccharides were determined by the anthronesulphuric acid method (Fales 1951), amino acids according to Moore and Stein (1948), soluble protein according to Lowry *et al.* (1951). Sodium and potassium were determined by the flame photometer method (Williams and Twine 1960), calcium and magnesium by the versene titration method (Schwarzenbach and Biedermann 1948), and phosphorus colorimetrically (Woods and Mellon 1985).

Table 1. The effect of NaCl salinization and treatment with $CaCl_2$ or KCl (200 mg kg^{-1}) on pigment content [g kg^{-1}(d.m.)], fresh and dry matter [g $plant^{-1}$] and leaf area [cm^2 $plant^{-1}$] of wheat plants.

Adding	NaCl [-kPa]	Chlorophyll *a*	Chlorophyll *b*	Carotenoids	Shoot f.m.	Shoot d.m.	Root f.m.	Root d.m.	Leaf area
0	0	7.48	2.10	2.30	3.69	0.688	7.44	0.987	2899
	300	7.19	1.54	2.56	1.52**	0.338**	1.76**	0.222**	2711
	600	8.93**	2.02	3.40	1.36**	0.338**	1.70**	0.211**	2721
	900	9.59**	2.42	4.22*	1.47**	0.276**	1.44**	0.299**	2411*
	1200	5.47**	1.75	2.61	1.12**	0.234**	1.36**	0.231**	2227**
$CaCl_2$	0	1.52**	9.69**	1.62	4.33**	0.790	5.41*	0.939**	5663**
	300	1.84**	10.58**	1.38	2.81**	0.590	3.98**	0.549**	2842
	600	1.37**	11.63**	2.32	2.42**	0.411**	3.90**	0.573**	2794
	900	1.99**	11.44**	2.40	2.31**	0.366**	2.25**	0.323**	3386*
	1200	1.98**	12.64**	2.43	2.37**	0.382**	2.02**	0.267**	3458*
KCl	0	1.74**	13.47**	2.47	3.89	0.724	4.90**	0.689**	5621**
	300	2.01**	15.01**	3.48	2.78**	0.454**	4.79**	0.629**	3201
	600	2.03**	15.12**	3.59	2.59**	0.479**	2.83**	0.409**	3484*
	900	1.56**	12.79**	2.16	2.22**	0.355**	2.33**	0.312**	2759
	1200	3.37**	10.67**	1.70	1.80**	0.290**	3.36**	0.336**	2316*
L.S.D.	5 %	1.06	3.46	1.79	0.440	0.123	1.57	0.017	438
L.S.D.	1 %	1.42	4.66	2.42	0.594	0.166	2.12	0.023	590

Significance of differences to control: * - $P = 0.01$; ** - $P = 0.05$.

Results

A significant decrease in leaf area, fresh and dry matter of shoot and root and the amount of photosynthetic pigments (especially in chlorophyll *b*) was induced by increasing soil salinity. Irrigation with 200 mg kg^{-1} $CaCl_2$ or KCl solutions increased all these characteristics irrespective of the salinization level used and the plant organ tested (Table 1). High salinity level induced also a marked decrease in the contents of saccharides and soluble proteins (Table 2). On the other hand, the amino acids content in shoots and roots increased with the increase in concentration of NaCl in the soil.

Table 2. Effect of NaCl salinization and treatment with $CaCl_2$ or KCl (200 mg kg^{-1}) on contents of saccharides [g kg^{-1}(d.m.)], amino acids [g kg^{-1}(d.m.)] and soluble protein [g kg^{-1}(d.m.)] of wheat plants.

Adding	NaCl [-kPa]	Saccharides soluble		insoluble		Amino acids		Soluble proteins	
		shoot	root	shoot	root	shoot	root	shoot	root
0	0	2.30	5.80	45.22	38.13	8.09	6.69	26.10	22.40
	300	2.65	5.61	34.55**	37.12	7.94	9.09**	16.60**	12.50**
	600	2.14	3.50*	42.17*	39.08	9.32	10.81**	14.60**	12.30**
	900	2.29	3.59*	44.00	41.16	16.24**	12.89**	12.50**	13.30**
	1200	2.23	4.25	42.00*	47.91**	14.56**	18.65**	6.80**	12.80**
$CaCl_2$	0	5.39**	9.79**	58.17**	52.88**	8.85	7.74	60.4**	28.40**
	300	6.73**	6.89	61.38**	63.58**	8.59	9.09**	72.4**	28.75**
	600	6.55**	6.57	49.26**	52.73**	8.00	9.22**	50.4**	29.10**
	900	4.10	4.51	58.04**	44.76*	7.90	8.94**	38.9**	30.90**
	1200	4.15	4.75	58.04**	44.57*	8.63	8.94**	58.4**	32.70**
KCl	0	8.71**	7.36	40.31**	31.68*	25.19**	24.92**	32.40**	22.6
	300	13.46**	6.94	70.11**	47.06**	35.53**	24.79**	53.50**	18.6**
	600	16.34**	6.94	64.83**	47.45**	34.17**	32.22**	24.10**	15.7**
	900	16.03**	6.02	46.59	58.30**	26.28**	24.39**	27.50**	11.8**
	1200	17.56**	6.17	59.33**	51.98**	26.60**	19.25**	30.90**	15.0**
L.S.D.	5 %	1.92	1.79	2.86	4.96	2.90	1.63	0.250	1.04
L.S.D.	1 %	2.59	2.41	3.85	6.69	3.91	2.19	0.340	2.58

Significance of differences to control: * - $P = 0.01$; ** - $P = 0.05$.

Irrigation with $CaCl_2$ or KCl strongly increased the contents of saccharides and soluble proteins in shoots and roots of wheat plants (Table 2), while the contents of amino acids were significantly increased only in plants treated with KCl, but they were significantly lower in plants treated with $CaCl_2$, whatever the salinity level used or the plant organ tested.

There was a general increasing trend in the contents of monovalent cations (Na^+ and K^+) with increasing salinity in the culture media in shoots and roots of wheat plants (Table 3). Irrigation with $CaCl_2$ or KCl mostly retarded the accumulation of Na^+ and K^+ in shoots and roots of wheat plants whatever the salinity levels and the

plant organ analysed. The contents of Ca^{2+}, Mg^{2+} and P were significantly decreased in shoots and roots of wheat plants with increasing salinity.

Addition of any of the two fertilizers ($CaCl_2$ or KCl) induced in most cases, a significant increase in content of these ions; this effect was most pronounced in Ca^{2+} and Mg^{2+}, whatever the plant organ tested.

Table 3. Effect of NaCl salinization and treatment with $CaCl_2$ or KCl (200 mg kg^{-1}) on minerals content [g kg^{-1}(d.m.)] of shoot and root of wheat plants.

Adding	NaCl [-KPa]	Na^+	K^+	Ca^{2+}	Mg^{2+}	P	Na^+	K^+	Ca^{2+}	Mg^{2+}	P
0	0	10	11	12.50	9.17	1.13	13	16	2.50	5.50	5.40
	300	18**	13*	15.00	16.67**	0.819	19**	16	1.50	4.67	5.91
	600	34**	18**	14.17	15.00**	1.01	29**	15	1.50	4.50	4.76
	900	35**	24**	10.83	11.67	0.281**	22**	15	1.50	6.50	3.50
	1200	36**	24**	9.17	13.33*	0.460**	27**	18**	1.50	5.50	1.37**
$CaCl_2$	0	16**	22**	33.33**	10.50	4.99**	32**	18**	39.17**	14.17**	1.52**
	300	18**	18**	36.67**	15.50**	6.58**	22**	18**	22.50**	21.00**	2.09**
	600	20**	23**	42.50**	16.50**	4.22**	25**	19**	31.50**	19.67**	1.57**
	900	20**	23**	33.33**	16.00**	3.70**	26**	19**	23.33**	13.33**	2.55**
	1200	20**	23**	25.00**	14.50**	3.31**	29**	19**	29 17**	9.83**	2.21**
KCl	0	10	21**	22.33**	22.50**	1.68*	19**	15	12.67**	11.83**	4.97
	300	24**	18**	39.17**	18.33**	1.60*	24**	13**	14.17**	11.50**	3.30
	600	26**	20**	30.83**	21.67**	1.65*	24**	10**	12.00**	7.50*	2.57*
	900	32**	21**	39.00**	24.17**	0.659*	26**	10**	11.83**	5.50	4.72
	1200	32**	21**	30.83**	17.50**	0.201**	28**	17**	14.83**	5.50	8.26*
L.S.D. 5 %		0.28	1.50	3.91	3.41	0.446	2.79	1.35	1.71	1.83	2.20
L.S.D. 1 %		0.29	2.16	5.27	4.59	0.601	3.83	1.42	2.30	2.47	2.97

Significance of differences to control: * - $P = 0.01$; ** - $P = 0.05$.

Discussion

Salinity caused a great reduction in leaf area, fresh and dry matter, contents of photosynthetic pigments, saccharides, proteins, Ca^{2+}, Mg^{2+} and P. A marked and progressive increase effects of salinization were attributed to "ion excess" (Greenway and Munns 1983).

The consistent decrease in saccharides and proteins contents which was associated with concomitant increase in total amino acids indicated that salinity might stimulate the conversion of saccharides into amino acids (Stewart *et al.* 1966) and/or slowing down the rate of incorporation of free amino acids into protein chain (Devitt *et al.* 1987).

The recorded promotion in growth of salinized wheat plants after irrigation with 200 mg kg^{-1} $CaCl_2$ or KCl was linked with a great promotion in the contents of

saccharides, proteins as well as Ca^{2+}, Mg^{2+} and P contents as compared with control salinized plants.

The high soluble protein content in K-treated plants was accompanied with a significant decrease in free amino acids content that indicated the role of K in the proper utilization of amino acids in protein synthesis which may in turn play an important role in increasing the osmotic pressure of the cytoplasm (Munns *et al.* 1979) and salt tolerance of wheat plants. In accordance with this, Thakur and Rai (1982) have shown that in drought resistant maize cultivars exposed to osmotic stress, more protein was accumulated than in the susceptible ones. Similar results were also obtained by Stutte and Todd (1967) and Singh and Rai (1982) with wheat and chick pea cultivars. Hedge and Joshi (1974), Janardan *et al.* (1976) and Rana *et al.* (1976) have also reported the role of Ca and K in raising salt tolerance of rice, cotton and barley, respectively.

Conclusively, our results show that both $CaCl_2$ and KCl play a role in alleviating the adverse effects on growth and relevant metabolic processes of wheat plants.

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Communicated by Z. ŠESTÁK