THE EFFECT OF NaCl SALINITY AND SODIUM PYRUVAT ON GROWTH OF CUCUMBER PLANT

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ABSTRACT

Salinity affected growth, the contents of chlorophyll, carotenoids, saccharides, nitrogen content and some minerals (Na, K, Ca, Mg, P) in cucumber plants (*Cucumis sativus*). Spraying the shoot system with sodium pyruvate greatly ameliorated the adverse effects of NaCl salinity. This counteraction was associated with an increase in the contents of saccharides, amino acids, proteins, Ca and P.

KEY WORDS: cucumber, salinity, sodium pyruvate.

INTRODUCTION

Salinity affects the growth of plants by decreasing the rate of water uptake due to osmoeffects (Garvis and Hopper 1982), through ion-specific toxic effects (Sharma, 1990) or through a nutritional imbalance (Alva and Syvertsen 1991) caused by antagonism (Levitt, 1980) and/or organic acid metabolism (Fougere et al., 1991). Saline irrigation water affects germination, growth and yield of greenhouse cucumber (Chartzoulakis, 1991).

The present work was undertaken to study the osmotic and ionic effects of NaCl on cucumber plants and to alleviate the toxic effects of salinity by spraying the vegetative parts of plants with sodium pyruvate as a fertilizing agent.

MATERIALS AND METHODS

Cucumber (*Cucumis sativus*) plants were grown in plastic pots containing air-dried soil (Sand/clay 1:2), NaCl salinization levels (three pots per each corresponding to osmotic potentials -300, -600, -900 and -1200 kPa). Saline solutions were added to the soil in such a way that the soil solution acquired the assigned salinization levels at field capacity. Treatment of plants with saline solutions began when seedlings were two weeks old. The salinized and non-salinized plants were irrigated every other day with 1000 m⁻³ Pfeffer's nutrient solution for two weeks. Then CH₃COCOONa (1 g kg⁻¹) solutions were applied three times (5 d intervals) by spraying the shoot system of the growing plants (each pot with 20 cm³ of CH₃COCOONa solution). The control plants were sprayed with distilled water, a week after the plants were used for analysis.

Dry matter was determined after drying plants in an aerated oven at 70 °C to constant mass. The contents of chlorophylls a and b and carotenoids were determined spectrophotometrically (Metzner et al., 1965). The amount of saccharides was

determined with the anthrone-sulphuric acid method (Fales, 1951). Free amino acids were determined according to Moore and Stein (1948). Free proline was determined according to the method of Bates et al. (1973) and 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).

RESULTS

Salinity induced a non-significant effect on fresh and dry matter of shoots and roots of cucumber plants up to the level of -600 kPa, above which they were reduced sharply (Table 1). So water content of the two organs went parallel to that of fresh and dry matter where it remained more or less unchanged up to the level of -600 kPa, above which it increased sharply specially in shoots.

Spraying with CH₃COCOONa not only alleviated the inhibitory effect of salinity, but also resulted in a distinctly increased yields in fresh and dry matter of shoots and roots, as compared with control plants. Water content rises in shoots and roots as treated with sodium pyruvate (1 g kg⁻¹), and this promotion is more marked in roots than in shoots. The content of photosynthetically active pigments (chlorophylls a, b and carotenoids) mostly remained more or less unaffected at all salinity levels (Table 1). However, there is a general tendency for reduction, especially at higher salinity levels. Treatment with CH₃COCOONa as a fertilizing agent rises these contents as compared with the corresponding salinized plants. Salinity caused a progressive reduction in soluble saccharides in shoots of cucumber plants (Table 2). On the other hand, salinization promotes accumulation of soluble saccharides in roots until -600 kPa and the insoluble and total fractions up to -600 kPa in shoots and roots, as compared with control

TABLE 1. The effect of NaCl salinity and sodium pyruvate (1 g kg⁻¹) on pigment content [g kg⁻¹ (d.m.)], fresh and dry matter (g plant⁻¹) and water content (g plant⁻¹) of cucumber plants.

Spraying	NaCl [-kpa]	Chlorophyll		Carotenoids	Shoot		Root		% Water content	
		a	b		f.m.	d.m.	f.m.	d.m.	Shoot	Root
0	0	5.28	2.22	2.28	10.63	1.34	1.36	0.186	6.93	6.31
	300	5.92	2.10	2.46	10.60	1.32	1.53	0.190	7.03	7.05
	600	5.82	2.82	2.16	10.20	1.29	1.35	0.140**	6.91	8.64
	900	5.00	2.21	2.05	7.96*	0.769**	0.766	0.109**	9.35	6.03
	1200	5.00	2.05	2.00	3.86**	0.345**	0.637	0.093**	10.19	5.85
CH ₃ COCOONa	0	7.86*	2.73	3.57**	17.19**	2.26**	3.78**	0.360**	6.61	9.50*
	300	6.85	2.48	2.71	15.41**	1.65**	2.59	0.218**	8.34	10.88**
	600	6.11	2.13	2.70	17.23**	1.73**	1.88	0.161**	8.96	10.68**
	900	7.21	2.68	2.41	16.68**	1.68**	1.88	0.177*	8.93	9.62*
	1200	6.11	2.43	2.16	8.60	0.843**	1.41	0.128**	9.20	10.02*
L.S.D. 5	%	2.57	2.46	0.676	2.04	0.149	1.31	0.009	4.29	2.79
L.S.D. 1	%	3.47	3.31	0.912	2.75	0.201	1.77	0.010	5.79	3.76

Significance of differences * – p = 0.01; ** – p = 0.05

TABLE 2. The effect of NaCl salinity and sodium pyruvate (1 g kg⁻¹) on content of saccharides [g kg⁻¹ (d.m.)], of shoots and roots of cucumber plants.

Spraying	NaCl [-kpa]	Saccharides					
		soluble		insoluble		total	
		shoot	root	shoot	root	shoot	root
0	0	55.36	37.74	154.9	153.6	210.3	191.3
	300	49.79*	45.93**	185.8**	138.9**	235.6**	184.8**
	600	45.35**	46.21**	206.9**	168.0**	252.3**	214.2**
	900	39.21**	31.41*	118.4**	103.6**	157.6**	135.0**
	1200	32.91**	30.75*	102.3**	69.8**	135.2**	100.6**
CH ₃ COCOONa	0	49.92**	49.92**	241.9**	148.1	291.8**	198.0**
	300	75.78**	95.37**	88.42**	54.43**	164.2**	149.8**
	600	77.06**	113.0**	99.78**	58.39**	176.8**	171.4**
	900	44.59**	77.8**	93.21**	71.69**	137.8**	149.5**
	1200	31.15**	70.9**	99.45**	55.66**	130.6**	126.6**
L.S.D. 5	%	5.31	5.62	4.85	9.85	7.46	4.39
L.S.D. 1	%	7.16	7.57	6.53	13.28	10.05	5.91

Significance of differences * – p = 0.01; ** – p = 0.05

plants. Spraying with sodium pyruvate accumulates the soluble contents at all levels; this was more obvious in roots than in shoots. While it inhibits the contents of insoluble and total saccharides with rise of NaCl levels, except of this trend, in roots the total saccharides showed a slightly increased content at -900 kpa, and -1200 kpa, as compared with control plants.

Salinity increased the contents of amino acids in shoots; in roots it decreased the accumulation of amino acids (Table 3). Treatment with CH₃COCOONa (1g kg⁻¹) rises considerably the amino acids contents about 6-fold in shoots, as compared with control plants. In roots, it showed mostly no significant change except at -1200 kpa level, where spraying treatments caused an increase in amino acids content than in non treated plants. The accumulation of free proline increased with in-

creasing level of soil salinity in shoots and roots (Table 3). Proline markedly retarded in spraying with CH₃COCOONa in both the two organs of cucumber, as compared with the corresponding salinized plants. Soluble protein decreases, with increasing salts in the soil, in shoots and roots (Table 3). Spraying with sodium pyruvate decreases the soluble protein content in, shoots, while in roots it resulted in a pronounced accumulation in the soluble protein, as compared with those of the salinized plants. While salinity induced a marked increase in Na⁺ contents, it inhibits the accumulation of K⁺ in the two organs of cucumber plants (Table 4). NaCl markedly increases Ca²⁺ and P contents in shoots and causes a significant reduction in these contents in roots. Mg²⁺ contents generally remained more or less unchanged in shoots and roots. Spraying with sodium pyruvate resulted, in most cases,

TABLE 3. The effect of NaCl salinity and sodium pyruvate (1 g kg^{-1}) on content of amino acids [g kg^{-1} (d.m.)], proline [g kg^{-1} (d.m.)] and protein [g kg^{-1} (d.m.)] of shoots and roots of cucumber plants.

Spraying	NaCl [–kpa]	Amino acids		Proline		Soluble protein	
		shoot	root	shoot	root	shoot	root
0	0	5.26	6.52	8.01	5.51	35.0	24.3
	300	5.21	6.42	11.68	6.49	22.40**	24.2
	600	9.03	4.50	10.74	8.85**	21.73**	8.7**
	900	7.99	4.96	14.15**	10.62**	15.37**	8.9**
	1200	6.87	2.66**	17.81**	10.07**	14.5**	9.5**
CH ₃ COCOONa	0	22.15**	5.42	7.82	8.40**	11.63**	28.97*
	300	22.61**	4.06*	8.95	6.45	12.33**	25.23
	600	26.96**	5.10	9.25	8.69**	12.30**	13.43**
	900	36.22**	4.26*	11.07	7.85*	14.7**	13.53**
	1200	35.98**	4.85	13.35*	8.05*	12.7**	12.20**
L.S.D. 5	%	5.87	2.20	5.00	2.01	2.43	3.83
L.S.D. 1	%	7.91	2.97	6.74	2.72	3.28	5.16

Significance of differences * – $p = 0.01$; ** – $p = 0.05$ TABLE 4. Effect of NaCl salinization and sodium pyruvate (1 g kg^{-1}) fertilization on minerals content [g kg^{-1} (d.m.)], of shoots and roots of cucumber plants.

Spraying	NaCl [–kpa]	Shoot					Root				
		Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	P	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	P
0	0	1	7.76	5.13	3.60	4.38	1	3.03	4.38	3.08	3.46
	300	1	6.03**	8.83**	2.60	4.43	2	3.50	1.25**	2.40	2.85
	600	2	3.45**	8.62**	3.83	5.99	2	1.72**	1.92**	2.80	4.41
	900	2	4.31**	7.42	3.68	6.25	2	1.72**	2.75**	3.23	2.97
	1200	3*	2.59**	4.75*	3.60	5.19	3*	1.45**	1.92**	3.70	2.22
CH ₃ COCOONa	0	1	5.17**	9.42**	3.23	7.69	1	3.45	2.25**	2.95**	4.03
	300	2	5.17**	9.32**	3.38	7.91	2	2.59	1.70**	2.14**	3.99
	600	4**	3.45**	9.42**	4.23	8.36*	2	1.72**	2.08**	2.65	5.21
	900	3*	3.45**	9.50**	3.80	5.24	2	2.95	1.83**	3.42	3.96
	1200	4**	4.31**	6.00	4.13	5.44	3*	1.72**	1.83**	2.30	4.74
L.S.D. 5	%	1.75	0.930	2.50	1.53	3.62	2.07	0.73	0.782	0.828	2.07
L.S.D. 1	%	2.38	1.26	3.37	2.06	4.88	2.82	1.01	1.05	1.12	2.79

Significance of differences * – $p = 0.01$; ** – $p = 0.05$

in a pronounced increase in the contents of Na⁺, K⁺, Ca²⁺, Mg²⁺ in shoots and P contents of both the organs of cucumber plants, while in roots K⁺, Ca²⁺ and Mg²⁺ mostly remained more or less unchanged, as compared with those of the corresponding salinized plants.

DISCUSSION

The results obtained in the present work clearly demonstrate that the fresh and dry matter of cucumber plants remained more or less unchanged up to -600 kpa NaCl, above which they decreased sharply. This decreasing effect is closely associated with a relatively stable water content.

With cucumber plants, salinity induced a progressive increase in soluble saccharides and proline in roots, and in amino acids, including proline in shoots. This increase in so-

luble components may, in turn, play an important role in increasing the osmotic pressure of the cytoplasm, a conclusion which is in accordance with the results obtained by Hellebust (1976) and Flowers et al. (1977) and Munnus et al. (1979) and Drossopoulos (1987), working with some halophytic plants. Similarly, Handa et al. (1983), using cultured tomato cells adapted to water stress, found that the concentration of reducing sugars in the cells increased with the degree of adaptation to salinity concentration. In our study, the other organic solutes (soluble saccharides in shoots, roots' amino acid and soluble protein in the two organs) decreased with increasing salinity in the soil.

This leads to the conclusion that salt tolerance seems to be linked with an equilibrium and interconversion between saccharides and nitrogen metabolism, whereas saline injury leads to metabolic disturbances in both components. The pattern of changes in roots' amino acids was opposite to that of proline,

indicating that the increase in proline is at the expense of other amino acids through an effect of salinity in promoting their conversion (Boggess et al. 1976; Morris et al. 1969). This observation confirms the osmoregulatory role of organic solutes in increasing the ability of these plants to absorb water. The strategy of osmotic adjustment of cucumber plants was mediated by soluble saccharides, and proline in roots, and by aminoacids including proline in shoots. This would confirm that the strategy of adaptation not only depends upon plant species, but also differs in the different organs of the same plants.

The present results showed also that spraying with sodium pyruvate counteracted the suppressive effect of the relatively higher salinity levels in fresh, and dry matter pigments and water content, as compared with those of control plants. The stimulatory effect was accompanied by the observed increases in some osmoregulatory components (soluble saccharides, and water soluble protein in roots, amino acids and Ca^{2+} of shoots, and P of the two organs).

This suggests that the depressive effects of salts stress on growth and other relevant physiological activities can be alleviated and/or modified to some extent, by spraying the shoot system with an appropriate concentration of sodium pyruvate.

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WPLYW ZASOLENIA NaCl I PIROGRONIANU SODU NA WZROST OGÓRKA

STRESZCZENIE

Wykazano wpływ zasolenia na wzrost, zawartość chlorofilu, karotenoidów, cukrów, azotu i niektórych pierwiastków (Na, K, Ca, Mg, P) u ogórka. Zraszanie pędów pirogronianem sodu znacznie ograniczyło szkodliwe działanie zasolenia. Przeciwdziałanie to związane było z wzrostem zawartości cukrów, aminokwasów, białek oraz Ca i P.

SŁOWA KLUCZOWE: ogórek, zasolenie, pirogronian sodu.