BRIEF COMMUNICATION

Effects of NaCl on photosynthetic pigments, saccharides, and chloroplast ultrastructure in leaves of tomato cultivars

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Abstract

In leaves of four tomato (*Lycopersicon esculentum* Mill.) cultivars (Red Cloud, Floradade, Peto 95, and Scorpio) the contents of chlorophyll (Chl) (*a+b*), Chl *a*, and β-carotene decreased due to 100 mM NaCl treatment as compared with those of controls. The contents of soluble sugars and total saccharides were significantly increased in leaves of NaCl-treated plants, but the starch content was not significantly affected. Transmission electron microscopy indicated that in leaves of NaCl-treated plants, the chloroplasts were aggregated, the cell membranes were distorted and wrinkled, and there was no sign of grana and thylakoid structures in chloroplasts.

Additonal key words: β-carotene; chlorophyll; grana; *Lycopersicon esculentum*; saccharides; soluble sugars; starch; thylakoids.

Photosynthesis and growth of many plants are inhibited under NaCl salinity, and the sensitivity and tolerance against the NaCl concentration depend upon plant species, intracellular ionic status, and environment. Under salinity, net photosynthetic CO_2 uptake decreases mainly because NaCl treatment decreases stomatal conductance, and consequently less CO_2 is available for carboxylation reaction in the photosynthetic apparatus. Also the rate of ribulose-1,5-bisphosphate carboxylase/oxygenase activity decreases under NaCl salinity (Seemann and Sharkey 1986), and photochemical reactions are inhibited. NaCl salinity also changes thylakoid membrane structure (*e.g.*, Strogonov *et al.* 1970, Sato *et al.* 1992), and decreases the contents of Chls and carotenoids. The production and transport of saccharides in the plants are both affected by the NaCl treatment.

The plant genus *Lycopersicon* includes diverse species, with a broad range of salt tolerance. Though none are absolute halophytes, genetic resources are available for

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improving cultivated *Lycopersicon* in many aspects of stress tolerance, including salt (Rick 1978). The present work examined the effects of 100 mM NaCl salinity on some photosynthetic characteristics of four cultivars of *Lycopersicon esculentum* Mill. plants.

The four cultivars (Red Cloud, Scorpio, Peto 95, and Floradade) were supplied from the Seed and Seedling Production Centre of Iranian Ministry of Agriculture (Mardabad, Karaj, Iran). The seeds were surface sterilized in 1 % sodium hypochloride solution for 1 min, and then were germinated in plastic pots in mineral perlite at room temperature. Young seedlings were transferred into greenhouse with natural irradiance supplemented with tungsten lamps when desired. The plants were supplied with half-strength Hoagland solution without or with NaCl (its final concentration in medium was 100 mM). The field capacity of perlite was measured by a pressure plate (*Soil Moisture Equipment Co.*, Santa Barbara, CA, USA) at the beginning of experiments, and water loss was compensated by daily weighing the pots and adding the desired amount of Hoagland solution. 86 d-old plants were harvested. Detached leaves were kept in a flask containing wet muslin in the bottom, under low temperature.

Pigment and saccharide analyses were done on the 3rd pair of leaflets (counting from the top). Samples for transmission electron microscopy (TEM) were prepared from the 2nd pair, and assays for production of reducing agents were carried out on the 4th pair. The amounts of Chl and β-carotene were measured in 80 % acetone extracts according to Arnon (1949) and Hellubust and Craigie (1978), respectively. Saccharides (soluble sugars and starch) were measured using phenol sulfuric acid method according to Hellubust and Craigie (1979). Each value presented is the mean (±SE) of five replicates. Differences between means were evaluated at $p = 0.05$. The equations were based upon the formulae introduced by Bishop (1985).

Table 1. The effects of 100 mM NaCl salinity on the contents of chlorophyll (Chl) and β-carotene [g kg^{-1}(d.m.)] in the leaves of 87 d-old plants of four cultivars of tomato. Each value is the mean (±S.E.) of five replicates.

Cultivar	Chl *a*		Chl *b*		Chl (*a+b*)		β-carotene	
	Control	NaCl	Control	NaCl	Control	NaCl	Control	NaCl
Scorpio	3.42±0.96	0.91±0.13	1.43±0.67	0.55±0.17	4.85±1.62	1.46±0.25	0.16±0.05	0.06±0.02
Peto 95	1.49±0.28	1.17±0.66	0.65±0.17	0.49±0.23	2.14±0.44	1.57±0.49	0.11±0.05	0.05±0.03
Red Cloud	1.92±0.35	0.60±0.23	0.76±0.16	0.48±0.13	2.67±0.50	1.07±0.14	0.09±0.05	0.04±0.01
Floradade	1.68±0.28	0.61±0.27	0.66±0.11	0.92±0.45	2.34±0.39	1.61±0.58	0.05±0.01	0.05±0.05

Differences in the contents of Chl per unit leaf dry matter among the four tomato cultivars (Table 1) were statistically not significant. 100 mM NaCl caused a significant decrease in the contents of Chl in leaves of all cultivars. Similar results were found by Strogonov *at al.* (1970), Marschner an Possingham (1975), Baset and Arju (1989), Datta and Sharma (1990), Singh and Dubey (1995), and Jimenez *et al.* (1997). In plants sensitive to NaCl salinity, the reduction in Chl contents is largely exhibited through the decay of Chl *a*, Chl *b* being more stable (Strogonov *et al.*

1970). The content of β-carotene in all four cultivars was also significantly decreased.

Table 2. The effects of 100 mM NaCl salinity on the contents of saccharides in leaves of 87 d-old plants of four cultivars of tomato. Each value is the mean (±S.E.) of five replicates.

Cultivar	Soluble sugars		Starch		Total saccharides	
	Control	NaCl	Control	NaCl	Control	NaCl
Scorpio	35.18±12.76	31.20±6.76	17.69±4.11	14.96±3.91	52.87±16.23	46.16±10.40
Peto 95	23.50±1.74	44.32±7.38	14.10±1.56	21.14±6.20	37.60±2.21	65.46±12.19
Red Cloud	18.41±3.07	28.25±5.10	15.13±1.51	15.41±2.97	33.54±3.38	43.66±7.62
Floradade	22.74±4.28	36.66±5.22	16.14±4.58	20.37±4.17	38.88±8.42	57.03±9.02

100 mM NaCl stress increased the contents of both soluble sugars and total saccharides in three tomato cultivars, not in the cv. Scorpio (Table 2). Our results are in accord with those of Doddema *et al.* (1986). In most higher plants, the consequences of salt stress are very similar to those of drought stress. Irigoyen (1992), Amundson *et al.* (1993) and other researchers also reported an increase in soluble sugars in plants under water stress.

The 100 mM NaCl treatment caused chloroplasts to aggregate. Their lamellar system was disorganized in all four cultivars of tomato plants, and the grana structure and starch grains disappeared. Strogonov *et al.* (1970) show that prolonged treatment with high NaCl concentrations in spinach and tomato plants causes swelling within granal loculi, accumulation of lipid droplets, and complete disappearence of grana structure. De Felipe and Sanchez Conde (1984) reported that in tomato plants an increase in osmotic pressure caused breakdown of cell wall, and cell and chloroplast membranes. In plants affected by NaCl, cytorrhysis and partial aggregation of chloroplasts were evident (Strogonov 1964).

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