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Consequences of NaCl Salinity on Growth and Ion Accumulation in Selected Strawberry Cultivars

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Summary

Salt-tolerance of some strawberry cultivars was examined using frigo plants grown in hydroponics. The cultivars 'Tioga' and 'Rapella' were more salt-tolerant than strawberry cultivars 'Camarosa', 'Sweet Charlie', 'Dermarvel', 'Tudla', 'Northester' and 'Douglas'. Vegetative growth in these cultivars was better compared to strawberry cultivars 'Elvira', 'Aiko', 'Camarosa', 'Sweet Charlie', 'Dermarvel', 'Tudla', 'Northester' and 'Douglas' under 100 mM NaCI treatment. Considering vegetative growth parameters, cvs 'Dermarvel', 'Douglas' and 'Camarosa'. Generally, Na accumulation caused by NaCl was higher in sensitive cultivars than in tolerant cultivars. The Ca/Na and K/Na ratios were larger in tolerant cultivars. Malondialdehyde contents of all cultivars increased due to NaCl. Nevertheless, no relationship between malondialdehyde content and salt tolerance of cultivars could be determined.

Key words. salt – ion accumulation – strawberry – malondialdehyde – active oxygen species

Introduction

Salinity is a factor that influences the entire metabolism of a plant as well as its morphology and anatomy (Lewitt 1980). Some nutritional disturbances are expected under saline conditions. In the presence of excess NaCl in the growing medium, Na and Cl are accumulated in plant organs, and these saline ions can affect the uptake of other mineral elements by competitive interactions or by affecting the ion selectivity of membranes, thereby causing nutrient deficiencies in plants (Bohra and Döffling 1993). For example, Na competes with K and induces K deficiency (Lewitt 1980). High salt concentrations may restrict Ca uptake and cause Ca deficiency (Cramer et al. 1986). K^+ and Ca^{2+} play key roles in several physiological processes, and thus the substitution of K^+ by Na^+ and decrease in Ca^{2+} content may lead to nutritional imbalances. As a result of salinity, increases in Na content but decreases in K and Ca contents, and the K/Na, Ca/Na ratios in plants have widely been reported in the literature (Ruiz et al. 1999; Yaşar 2003). Dasgan et al. (2002) suggested that the control of Na^+ accumulation by exclusion strategy, and high K^+/Na^+ and Ca^{2+}/Na^+ ratios in shoot may enhance salt tolerance or resistance in tomato crops.

The generations of active oxygen species is a common response to environmental stress conditions (Luna et al. 1994; Gossett et al. 1994). Active oxygen species may cause lipid peroxidation of membranes, reducing membrane fluidity and selectivity. Lipid peroxidation measured as malondialdehyde content, a product of lipid peroxidation, is considered to be indicative of oxidative damage (Wise and Naylor 1987).

Strawberry is considered a NaCl sensitive species, but differences between cultivars exist (Martinez Barroso and Alvarez 1997; Saied et al. 2005). Ulrich et al. (1980) suggest that the injuries are due to the accumulation of Na^+ in the leaf. It has already been shown that for strawberry, toxicities have been observed with concentrations greater than 0.1 % Na 0.5 % Cl in leaf (Ulrich et al. 1980).

In the present study, it was aimed to determine salinity tolerance of selected strawberry cultivars and identify relationships between ion contents or their ratios and vegetative growth. For this purpose, selected vegetative growth parameters such as total plant weight, root weight, leaf weight and the number of leaves, were used as criteria. In addition, accumulation of Na, K and Ca in leaves, and malondialdehyde contents were determined.

Material and Methods

Plant material and growth conditions

The 10 strawberry cultivars 'Camarosa', 'Rapella', 'Sweet Charlie', 'Dermarvel', 'Tudla', 'Northester', 'Tioga', 'Aiko', 'Douglas' and 'Elvira' were grown in aquatic culture under 280 μmol m^{-2} s^{-1} of cool white fluorescent light of 16 photoperiod in a controlled climatic room at 22/18 °C day/night temperature, and 70 % relative humidity. Fifty cold-treated plantlets (frigo) of each cultivar were planted in plastic vessels filled with 5 L half-strength Hoagland's solution (Hoagland and Arnon 1950). For each cultivar, 30 plants similar in growth were finally used for the experiment. The solution in the vessels was replaced every week. Two weeks later, salt-treatment started, and the NaCl concentration was increased by increments of

25 mM d^{-1} until a final concentration of 100 mM was achieved. Non-treated plants were kept as controls. Salt-stressed plants were subjected to 100 mM NaCl for 15 d, and all plants, including controls, were sampled thereafter. The experiment was a completely randomized design with three replications per treatment, with five plants each.

Ion contents

N, K and Ca were determined by flame photometry in samples from the youngest two leaves on top of shoots. Leaf samples of 250 mg were rinsed in deionised double-distilled water and placed in 0.1 N HNO_3 for at least a week. Ion concentration in HNO_3 was determined (Taleisnik et al. 1997).

Lipid peroxidation

Lipid peroxidation was determined by estimating the malondialdehyde content in 250 mg leaf fresh weight according to Lutts et al. (1996). Malondialdehyde is a product of lipid peroxidation by thiobarbituric acid reaction. The concentration of malondialdehyde was calculated from the absorbance at 532 nm using extinction coefficient of 155 mM^{-1} cm^{-1}. Corrections were done by subtracting the absorbance at 600 nm for unspecific turbidity.

Results

The number of leaves and fresh weight of different organs are presented in Table 1. No significant differences were found between NaCl treatment and control for the number of leaves in all cultivars, except for 'Dermarvel' and 'Douglas'. Similarly, differences in crown weights of salt treatment and control were not statistically significant. Fresh leaf weight, root weight and total plant weight were significantly lower at 100 mM NaCl compared to control plant in six cultivars. However, salt treatment did not cause any significant change in fresh mass of cvs 'Rapella', 'Tioga', 'Elvira' and 'Aiko'.

When compared to controls, NaCl did not cause a significant change in K contents of cultivars with the exception of 'Dermarvel', 'Tudla' and 'Douglas', where NaCl-salinity resulted in an increase of K content. In all strawber-

Table 1. Effect of NaCl salinity on number of leaves and fresh masses (g) of different plant organs in selected strawberry cultivars.

Cultivars	Treatment	Number of leaves	Leaf weight	Root weight	Crown weight	Total plant weight
'Dermarvel'	Control	3.44 fgh	3.46 bc	4.98 b–f	1.63 c–f	10.07 b–e
	NaCl	2.05 i	0.61 h	1.66 i	1.09 f	3.36 j
'Douglas'	Control	3.67 efg	3.80 ab	5.72 a–d	2.40 bcd	11.92 a–d
	NaCl	2.38 hi	1.28 fgh	3.33 f–i	1.59 c–f	4.20 ij
'Camarosa'	Control	3.93 c–g	2.44 c–f	5.41 a–e	2.29 b–e	10.14 b–e
	NaCl	3.13 ghi	0.89 gh	3.48 fgh	2.59 abc	6.96 f–i
'Northester'	Control	4.00 b–g	3.90 ab	4.82 b–f	2.00 b–f	10.72 bcd
	NaCl	3.99 b–g	2.04 d–g	2.70 hi	1.22 ef	5.96 hij
'Sweet Charlie'	Control	5.00 abc	3.33 bcd	7.03 a	3.67 a	14.03 a
	NaCl	4.08 a–g	1.62 fgh	4.48 b–g	2.89 ab	8.99 d–g
'Tudla'	Control	4.83 a–d	3.48 bc	5.10 b–f	1.97 b–f	10.55 bcd
	NaCl	3.72 d–g	1.88 e–h	2.93 ghi	1.22 ef	6.03 g–j
'Aiko'	Control	4.33 a–f	3.36 bcd	4.10 d–h	1.80 b–f	9.26 def
	NaCl	3.55 fg	2.15 c–g	3.73 e–h	1.33 def	7.21 e–h
'Elvira'	Control	5.05 abc	2.98 b–e	4.63 b–g	1.91 b–f	9.52 c–f
	NaCl	5.10 ab	2.03 d–g	3.44 fgh	1.78 b–f	7.25 e–h
'Tioga'	Control	4.17 a–g	3.90 ab	4.28 c–h	1.15 f	9.33 c–f
	NaCl	4.72 a–e	3.88 ab	4.28 c–h	1.69 c–f	9.95 cde
'Rapella'	Control	4.94 abc	4.06 ab	6.13 ab	2.10 b–f	12.29 abc
	NaCl	5.18 a	5.06 a	5.95 abc	1.94 b–f	12.95 ab
LSD		1.127	1.345	1.773	1.124	2.979

Differences between means followed by the same letter within a column are not significant by Duncan's multiple range test at 0.05.

ry cultivars examined, except for 'Aiko' and 'Tioga', a pronounced increase in Na content of plants grown under NaCl salinity was detected. The highest Na accumulation was observed in 'Dermarvel' followed by 'Douglas', the lowest Na contents showed ' Tioga' and 'Aiko' followed by 'Northester' and 'Rapella'. While the Ca content was reduced by the NaCl treatments in 'Camarosa' and 'Northester', it was increased in 'Tioga' cultivars. In the other cultivars, Ca content did not differ significantly as a consequence of salt treatment. Generally, the ratio of K/Na and that of Ca/Na were decreased because of the salt treatment in all cultivars, with the exception of 'Tioga', where the Ca/Na ratio increased.

The decrease in K/Na ratio was statistically significant in all cultivars, except for 'Rapella' and 'Tioga'. While the salt treatments gave the highest K/Na and Ca/Na ratio in 'Tioga', 'Dermarvel' and 'Douglas' showed the lowest K/Na and Ca/Na ratios (Table 2)

Membrane lipid peroxidation, measured as malondialdehyde, was significantly increased by NaCl treatment in all cultivars. While the highest malondialdehyde content was determined in 'Tudla', the least malondialdehyde content was obtained from 'Camarosa' (Table 2).

Discussion

Vegetative growth parameters such as total plant weight, root weight, leaf weight and number of leaves, have been reported to be the most commonly used criteria in order to identify salinity tolerance (Lewitt 1980; Kepenek and Koyuncu 2000). Considering these vegetative growth parameters, 'Rapella', 'Tioga' and 'Elvira' appeared to be more tolerant to NaCl-salinity in the root medium than the other seven cultivars tested in the present study. In these three cultivars, a significant difference was not found between NaCl-treated and control plants for fresh weights of leaves, roots and total plants. Fresh mass of the other cultivars was significantly reduced by the NaCl treatment. The decreases of fresh weights in 'Dermarvel', 'Douglas' and 'Camarosa' were higher than in other cultivars studied. Similar results of fresh weight loss were reported by Kaya et al. (2002) for 'Camarosa' and by Martinez Borosso and Alavez (1997) for 'Douglas' cultivars.

Further proposed indices of tolerance to NaCl treatments have been proposed that are based on physiological characteristics, for example, accumulation of specific ions in shoots or leaves or production of specific metabolites (Noble and Shannon 1988). Salt-tolerant genotypes are able to regulate

Table 2. Ion (mg g^{-1} FW) and malondialdehyde (μmol g^{-1} FW) content of selected strawberry cultivars exposed to NaCl stress in the root medium.

Cultivars	Treatment	K	Na	Ca	K/Na	Ca/Na	MDA
'Dermarvel'	Control	4.85 bc	4.71 fgh	1.80 a–d	1.04 abc	0.38 abc	30.80 k
	NaCl	6.19 a	21.84 a	2.19 abc	0.29 g	0.09 c	56.47 de
'Douglas'	Control	4.53 bcd	5.42 fg	1.57 a–d	0.83 a–f	0.29 bc	41.99 i
	NaCl	6.08 a	18.06 b	1.63 a–d	0.33 g	0.09 c	62.25 bc
'Camarosa'	Control	4.43 bcd	4.15 gh	2.58 ab	1.13 a	0.68 ab	35.11jk
	NaCl	4.76 bc	10.90 c	1.49 a–d	0.43 fg	0.13 c	45.67 ghi
'Northester'	Control	4.38 bcd	4.17 gh	2.96 a	1.11 a	0.86 a	46.55 gh
	NaCl	4.72 bc	7.01 e	0.63 d	0.68 b–g	0.09 c	50.12 fg
'Sweet Charlie'	Control	4.55 bcd	3.94 h	1.33 bcd	1.16 a	0.33 abc	36.38 j
	NaCl	4.67 bc	9.06 d	1.65 a–d	0.52 efg	0.18 bc	66.21 ab
'Tudla'	Control	4.14 cd	3.63 h	1.24 bcd	1.15 a	0.34 abc	42.75 hi
	NaCl	5.31 ab	10.52 c	1.40 bcd	0.50 efg	0.14 c	70.49 a
'Aiko'	Control	4.09 cd	3.97 h	1.07 cd	1.07 ab	0.27 bc	47.15 gh
	NaCl	3.92 cd	5.93 ef	0.54 d	0.66 c–g	0.09 c	59.94 cd
'Elvira'	Control	4.27 bcd	4.75 fgh	1.08 cd	0.90 a–e	0.23 bc	37.26 j
	NaCl	4.53 bcd	10.34 cd	1.69 a–d	0.43 fg	0.16 bc	53.98 ef
'Tioga'	Control	4.26 bcd	4.69 fgh	0.47 d	1.01 abc	0.11 c	34.36 jk
	NaCl	4.20 bcd	4.51 gh	1.72 a–d	0.96 a–d	0.40 abc	63.02 bc
'Rapella'	Control	3.47 d	3.66 h	1.55 a–d	0.95 a–d	0.42 abc	30.64 k
	NaCl	4.11 cd	7.24 e	1.57 a–d	0.57 d–g	0.22 bc	55.40 e
LSD		1.124	1.387	1.476	0.4051	0.5352	4.490

Differences between means followed by the same letter within a column are not significant by Duncan's multiple range test at 0.05

both the absorption and the translocation of ions more effectively than sensitive genotypes (YAN et al. 1992). A generally accepted view is that the capability of a variety to maintain shoot and leaf K levels at high concentration of Na in the root zone is one of the factors influencing salt tolerance (YAŞAR 2003). Contrary to this view, in this study, K contents of sensitive 'Douglas' and 'Dermarvel' were higher than those of the tolerant 'Rapella' and 'Tioga' under NaCl salinity. Previous studies reported that salt-tolerant varieties differ from salt-sensitive ones mainly in having a low Na content (GRATTAN and GRIEVE 1992; GARCIA-SANCHEZ et al. 2006). Likewise, Na accumulation was higher in the leaves of 'Dermarvel' and 'Douglas' which appeared to be more sensitive than other cultivars. The least Na content was determined in 'Tioga' followed by 'Rapella'. These two cultivars grow best under salinity stress conditions.

In a similar study, CUARTERO et al. (1992) reported that salt tolerance in tomatoes was linked to selective uptake of potassium over sodium. DASGAN et al. (2002) suggested that the control of Na^+ accumulation by exclusion strategy, resulting in higher ratios of K^+/Na^+ and Ca^{2+}/Na^+ in shoots, may enhance salt tolerance or resistance in tomato crops. In concordance to these results, the highest K/Na ratio was obtained from the tolerant 'Tioga', whereas the smallest K/Na ratios were determined in the sensitive 'Dermarvel' followed by 'Douglas' under NaCl salinity. While the highest Ca/Na ratio was determined in 'Tioga' followed by 'Rapella', the smallest Ca/Na ratio was found in 'Douglas', 'Dermarvel', Ailo and 'Northester'.

Although 'Camarosa' may be characterized as a sensitive cultivar, Na accumulations in leaves of this cultivars was not as high as in the leaves of other sensitive cultivars, e. g. 'Dermarvel' and 'Douglas'. However, the decrease in Ca content under NaCl stress was more pronounced in cv. 'Camarosa' than in the other cultivars. The regulatory significance of calcium in plant metabolism is well known (CRAMER et al. 1986). It has been hypothesized that high calcium levels can protect the cell membrane from the adverse effects of salinity (BUSCH 1995). According to MARSCHNER (1986) Ca plays a crucial role in controlling cell membrane permeability and selectivity. In case of salinity-induced Ca deficiency, ion uptake and osmoregulation of plants is imbalanced, and ion toxicity, osmotic stress and nutritional disruption may occur.

It has been reported that lipid peroxidation measured as malondialdehyde content is considered to be the indicator in determining salt tolerance in plants. In this study, malondialdehyde contents of all cultivars increased under NaCI salinity. In consequence, a relationship between malondialdehyde production and salt tolerance of cultivars could not been determined. However, the elevated levels of malondialdehyde indicate that all of the studied cultivars were impaired by NaCl in the root medium.

The present study carried out on ten strawberry cultivars revealed that Na content and the ratios of K/Na and Ca/Na may be considered as adequate indicators of the salt tolerance potential in strawberry plants, whereas malondialdehyde content may not be an appropriate indicator for determining salt tolerance in strawberry plants.

References

BOHRA, J.S. and K. DÖFFLING 1993: Pottassium nutrition of rice (*Oryza sativa* L) varieties under NaClsalinity. Plant and Soil **152**, 229–303.

BUSCH, D.S. 1995: Calcium regulation in plant cell and his role in signaling. Ann. Rev. Plant Physiol. **46**, 95–102.

CRAMER, G.R., A. LAUCHLI and E. EPSTEIN 1986: Effects of NaCl and $CaCl_2$ on ion activities in complex nutrient solutions and root growth in cotton. Plant Physiol. **81**, 792–797.

CUARTERO, J., A.R. YEO and T.J. FLOWERS 1992: Selection of donors for salt-tolerance in tomato using physiological traits. New Phytol. **121**, 63–69.

DASGAN, Y., H. AKTAS, K. ABAK and I. CAKMAK 2002: Determination of screening techniques to salinity tolerance in tomatoes and investigation of genotype responses. Plant Science **163**, 695–703.

GARCIA-SANCHEZ, F., J.G. PEREZ-PEREZ, P. BOTIA and M. MARTINEZ 2006: The response of yang mandarin trees grown under saline conditions depends on the rootstock. Europ. J. Agronomy **24**, 129–139.

GOSSETT, D.R., E.P. MILLHOLLON and C. LUCAS 1994: Antioxidant response to NaCl stress in salt-tolerance and salt sensitive cultivars of cotton. Crop Sci. **34**, 706–714.

GRATTAN, S.R. and C.M. GRIEVE 1992: Mineral element acquisition and growth response of plants grown in saline environment. Agric. Ecosyst. Environ. **38**, 275–300.

HOAGLAND, D.R. and D.I. ARNON 1950: The water-culture method for growing plants without soil. Calif. Agric. Exp. Stn. Circ. 1–32.

KAYA, C., H. KIRNAK, D. HIGGS and K. SALTALI 2002: Supplementary calcium enhances plant and fruit yield in strawberry cultivars grown at high (NaCl) salinity. Sci. Hort. **93**, 65–74.

KEPENEK, K. and F. KOYUNCU 2000: Studies on the salt tolerance of some strawberry cultivars under glasshouse - Fruit yield and vegetative growth. Techniques to Control Salination for Horticultural Productivity. November 7-10, 2000. Antalya, Turkey.

LEWITT, J. 1980: Responses of plants to environmental stresses 2. Physiological Ecology. Academic Press. Inc. Pp.365–384.

LUNA, C., C. GONZALEZ and V. TRIPPI 1994: Oxidative damage caused by an excess of copper in oat leaves. Plant Cell Physiol. **35**, 11–15.

LUTTS, S., J.M. KINET and J. BOUHARMONT 1996: NaCl-induced senescence in leaves of rice (*Oryza sativa* L.) cultivars differing in salinity resistance. Ann. Bot. **78**, 389–398.

MARSCHNER, H. 1986: Mineral nutrition in higher plants. Academic Press, London.

MARTINEZ BARROSO, M.C. and C.E. ALVAREZ 1997: Toxicity symptoms and tolerance of strawberry to salinity in the irrigation water. Sci. Hort. **71**, 177–188.

NOBLE, C.L. and M.C. SHANNON 1988: Salt tolerance selections of forage legumes using physiological criteria. In: SINHA, S.K. (ed.): Proc. International Congress of Plant Physiology, New Delhi, India, February 1988 **2**, 989–994.

RUIZ, D., V. MARTINEZ and A. CERDA 1999: Demarcating specific ion (NaCl, Cl^-, Na^+) and osmotic effects in the response of two citrus rootstocks to salinity. Sci. Hort. **80**, 213–224.

SAIED, A.S., A.J. KEUTGEN and G. NOGA 2005: The influence of NaCl salinity on growth, yield and fruit quality of strawberry cvs. 'Elsanta' and 'Korona'. Sci. Hort. **103**, 289–303.

TALEISNIK E., G. PEYRANO and C. ARIAS 1997: Response of *Chloris gayana* cultivars to salinity. 1. Germination and early vegetative growth. Trop. Grassl. **31**, 232–240.

ULRICH, A., M.A.E. MOSTAFA and W.W. ALLEN 1980: Strawberry deficiency symptoms: A visual and plant analysis guide to fertilization. Agric. Sci. Publ. University of California.

WISE, R.R. and A. W. NAYLOR 1987: Chilling-enhanced photooxidation: evidence for the role of single oxygen and endogenous antioxidant. Plant Physiol. **83**, 278–282.

YAN, X., S. ZHENG and Y. KUANG 1992: Rice genotypes differing in salt tolerance. II. Short-term kinetics of NaCl absorption and translocation in intact plant. J. Plant Nutr. **15**, 2667–2678.

YASAR, F. 2003: *In vivo* ve *in vitro* olarak tuz stresi altinda yetiştirilen patlican genotiplerinde bazi antioksidant enzim aktivitelerinin incelenmesi. Ph. D. Thesis, Yüzüncü Yil Universitesi Fen Bilimleri Enstitüsü, Turkey.

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