Reaction of Three Strawberry Cultivars to the Salinity: Vegetative Parameters

Ante BIŠKO [1(✉)]
Tomislav ĆOSIĆ [2]
Sibila JELASKA [3]

Summary

The study aimed at analysing the reaction of three strawberry *Fragaria x ananassa* Duch. cultivars to the salinity (0-control, 0.5, 1.0, 2.0, 3.0 and 4.0 g of NaCl L^{-1}) in the irrigation water: equivalent of the following EC values: (0.73, 1.65, 2.66, 4.37, 5.93 and 7.81 mS cm^{-1}). Vegetative trial was carried out at the Faculty of Agriculture in Zagreb during 1997 and 1998. Following parameters were tested: degrees of damage of shoots, number of leaves, number of runners (stolons), yield of fresh biomass and dry matter of shoots and roots, and percentage of dry matter of shoots and roots. Tested cultivars showed significant differences of the level of damage (necrosis and decay of plants due to high NaCl concentration). The highest degree of damage was shown by 'Elsanta' in both trial years, followed by 'Marmolada' and 'Miranda' respectively. The analysis of the number of leaves and stolons confirmed the same trend. The yield of fresh biomass and dry matter of shoots and roots was significantly reduced with the application of NaCl. 'Miranda' was characterised by the highest fresh biomass and dry matter yield, followed by 'Marmolada' and 'Elsanta'. Average decrease of fresh biomass yield of shoots in comparison to the control was 45, 33 and 22% in 'Elsanta', 'Marmolada' and 'Miranda'. Dry matter yield of shoots decreased correspondingly for 34, 28 and 18%. Total dry matter yield (shoots + roots) of 'Elsanta' was significantly reduced at 0.5 g NaCl L^{-1} and of 'Marmolada' and 'Miranda' at 1.0 and 2.0 g L^{-1} respectively.

Key words

strawberry, NaCl, root, shoot, fresh biomass, dry matter

[1] Croatian Centre for Agriculture, Food and Rural Affairs,
Hondlova 2/11, 10000 Zagreb, Croatia
✉ e-mail: ante.bisko@hcphs.hr
[2] University of Zagreb, Faculty of Agriculture Zagreb, Department of Plant Nutrition,
Svetošimunska 25, 10000 Zagreb, Croatia
[3] University of Zagreb, Faculty of Science, Department for Molecular Biology,
Horvatovac 102a, 10000 Zagreb, Croatia

Received: November 12, 2007 | Accepted: March 15, 2009

Introduction

Excessive salts in soil often are limiting factor in cultivation of agricultural crops in arid and semiarid areas (Marschner, 1995). These areas are significant for high temperatures and evapotraspiration as well as for low precipitation rate, which would rinse excess salts to lower soil layers. One third of world areas that are irrigated have high salt content (Epstein et al., 1980). When it comes to high salt content in soil (growing substrate), three main factors are influencing plants unfavourably: 1) water deficiency, induced lower (or more negative) water potential, 2) ion toxicity – excessive receipt of Cl^- and Na^+, and 3) disturbance in balance of nutrient receipt and transport (Greenway and Munns, 1980; Ream and Furr, 1976; Zekri and Parsons, 1992; Peres-Alfocea et al., 1993), which impacts negatively on growth and yield of majority of agricultural crops (Maas, 1986).

Few measures can be used for correction and usage of salted soils, although each of them has limited possibilities. Sibbett (1995) quotes *salts leaching* as the only correct measure, but only in cases when proper drainage system is put in place and sufficient level of quality water needed for salt leaching is available. Liu et al. (1997) recommend long-term cultivation of tolerant crops with high capacity for salts removal. Marschner et al. (1981b) recommend cultivation of tolerant genotypes. Soils with high sodium content are '*repaired*' best if fertilized profusely with NPK fertilizer before planting (Finck, 1982). Positive impact of calcium on decreasing of adverse salts effect, and on growth and yield were recognized by: Cramer et al. (1986); Rengel (1992) and Lopez and Satti, (1996). Importance of balanced fertilization in management of soil salinity was implied by other authors as well (Garg et al., 1993; Alarcon et al., 1994; Adler et al., 1995; Bar et al., 1997; Lei et al., 1997). Plant species react differently to high salts content (Greenway and Munns, 1980; Bergmann, 1992). Salinity tolerance, also, varies depending on growth stage of plant development (Mass, 1986; Zekri, 1993; Ashraf and McNeily, 1988). Significant differences to salts tolerance were determined within the same species (Heimler et al., 1995; Cornillon and Palloix, 1997; Serraj et al., 1998; Shannon and Noble, 1995; Marschner et al., 1981a). Tolerant genotypes are used for cultivation on salted soils, and as a basis in breeding. Previous research on strawberry has shown its strong susceptibility to salts (Maas, 1986; Maroto and Lopez-Galarza, 1989; Ehlig and Bernstain, 1958; Ehlig, 1961; Martinez Baroso and Alvarez, 1997; Awang et al., 1993, Ondrašek et al., 2006). In addition to the research executed in vegetative or field trial, Badawi et al. (1990) and Biško et al. (1997a) were studying NaCl impact on regeneration and shoot growth of strawberry in *in vitro* conditions.

Regardless of research conditions (*in vitro, ex vitro* – field or vegetative trial), significant differences to salinity tolerance of certain genotypes were determined. The main objectives of this research were to study NaCl impact on growth and development of strawberries in vegetative trial, to establish the best parameter as selection criteria, and to establish reactions conditioned by a cultivar.

Material and methods

The study was carried out in a plastic tunnel at the Faculty of Agriculture, University of Zagreb in the course of two vegetation years (1997 and 1998). In a study, growing substrate 'FLORATERA' was used, distinguished by suitable nutrient concentration and very low salt content [pH in water (10/100, g/vol) in naturally moist sample=7.05; E.C. mS cm^{-1} (1:2 vol./vol.) in naturally moist sample = 1.40; Na = 43.00 mg L^{-1}, Cl = 78.90 mg L^{-1}]. Prior to filling, entire substrate mass was mixed and in each container (6 litres vol) perforated pvc bag was inserted, filled with 3.6 kg of substrate. Prior to planting, 'frigo plants' were prepared by washing in water; roots were shortened to 8 cm and 60 uniform plants of each cultivar were planted individually in vegetative containers. Strawberry frigo plants (medium early, homogeneous cultivars: '*Elsanta*', '*Marmolada*' and '*Miranda*') were planted in the middle of April. Containers were arranged in completely randomized design (CRD) – a trial of six treatments in 10 repetitions for each cultivar was formed, followed by irrigation of 1.0 litre of water per pot. Afterwards, in each container 400 mL of substrate and 0.5 cm layer of sand (Ø 2- 4 mm) were added, previously rinsed in 2.5% of HCl and water for several times. Trial was carried out in partially controlled conditions (quantity and quality of water for irrigation). Irrigation with salted water started week after planting. The trial variants (options) were determined by adding NaCl into irrigation water in concentration of: 0.0 (control); 0.5; 1.0; 2.0; 3.0 and 4.0 g L^{-1}, equivalent to following EC_w: 0.73; 1.65; 2.66; 4.37; 5.93 and 7.81 mS cm^{-1} and pH values: 7.23; 7.26; 7.28; 7.30, 7.30 and 7.32. Plants were irrigated every 5 - 6 days with 500 ml/pot (in April, May, and June – 14 times per year in total). Underneath containers, plastic pads were placed in which strained water was collected. Potable water was used in control and for variants preparation. EC water value during treatment was 0.71 - 0.75 mS cm^{-1}. Top dressing was done four times per year; during irrigation (1% v/v: at irrigation 3 and 7 with Fertina G - composition in %: N=8, K_2O=7, MgO=2, B=0.5, Fe=0.2 , and at irrigation 5 and 9 with Fertina C – composition in %: N=4, P_2O_5=6, K_2O=8, B=0.01, Cu=0.002, Fe=0.02, Zn=0.005). Plants in a trial were observed regularly and biological changes in growth and development were recorded, as well as occurrence of chlorosis and necrosis. Moment of occurrence of runners (stolons) and their number was determined. Immediately before plants were taken to determine the growth parameters, degree of damage caused by salts – 'damage ranking' was determined:

1 – completely healthy plants, no sign of chlorosis or necrosis,
2 – chlorosis of marginal parts of older leaves (zone < ½ cm),
3 – necrosis of marginal parts of older leaves (zone < ½ cm),
4 – necrosis of marginal parts of older leaves (zone up to 1 cm),
5 – complete necrosis of older leaves,
6 – complete necrosis of older and partly of younger leaves,
7 – complete necrosis of older and younger leaves (only terminal bud left green),
8 – dead plants.

With ending of vegetative trial (1 decade in July), plant material of strawberries was taken to determine the growth parameters. Plants were taken out of the substrate, and with light shaking at the beginning followed by manual cleaning, the substrate was completely removed from roots. Subsequently, plants were washed twice in potable, distilled and redistilled water and dried out on a filter paper (see photo 1). Flower shoots were removed from the runner; plants were divided to roots and shoots.

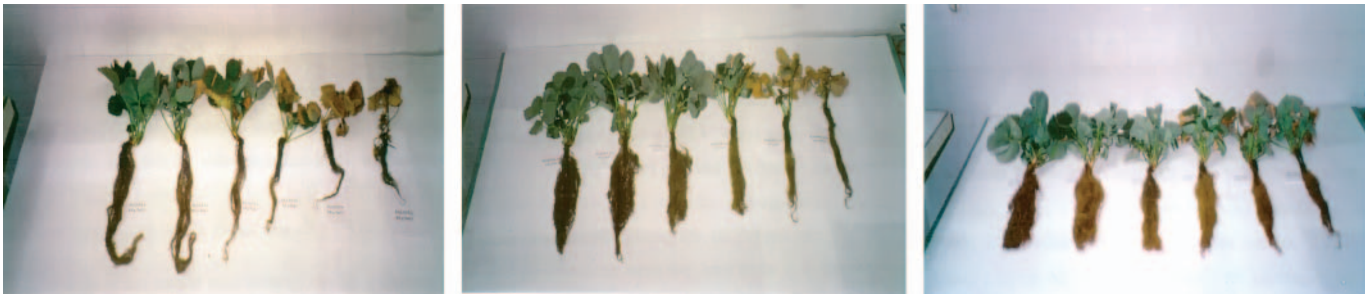


Photo 1. Plant material of strawberries (left - Elsanta, midle - Marmolada, right - Miranda; from left to right: 0; 0.5; 1.0; 2.0; 3.0 and 4.0 g NaCl L^{-1} water for irrigation)

Yield of fresh biomass (FB), dry matter (DM), and percentage of dry matter (%DM) were determined.

Once plants were divided to roots and shoots, fresh biomass yield was determined by weighing on analytical scale. Dry matter yield was determined (weighing on analytical scale) subsequent to drying of a sample until constant mass at 105°C was reached. Dry matter percentage was calculated: (DM/FB)x100.

Statistical data analysis: Both years, trial was set according to completely randomized design (CRD): three cultivars x six treatments x 10 repetitions. Collected parameters that were measured were analyzed by using variance analysis (ANOVA test), Petz (1985). LSD (last significant different) was calculated in case when F-test was significant at levels α = 0.05. Computer program EXCEL 7.0. was used to calculate Linear regression (Serdar, 1977; Bender et al., 1989) and for graphic design.

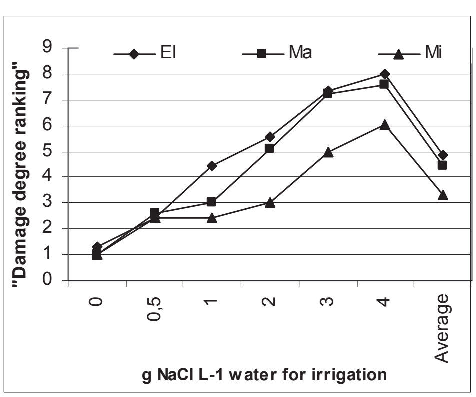
Results

First signs of salts impact appeared in older leaves 15 days after trial started. It manifested as marginal chlorosis that was transferring gradually to marginal necrosis of older leaves, their total decay followed by marginal and total necrosis of younger leaves, and finally decay of plants on substrate with higher salts concentration.

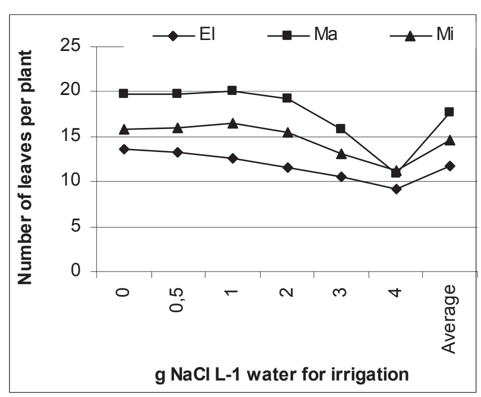
"Damage ranking of shoots" shows that in both trial years, salts application significantly influenced the degree of strawberry damage (graph 1). Marginal leaf chlorosis was caused by concentration of 0.5 g NaCl L^{-1}, and necrosis (different degree) was caused by higher concentration. Every increase of salts concentration in irrigation water above 0.5 g NaCl L^{-1}, was influencing significantly to the degree of strawberry damage (with the exception of damage degree values of 'Miranda' in variants with 0.5 and 1.0 g NaCl L^{-1}, where there were no significant differences). The impact of salts on growth and development of shoots of three cultivars, as well as damage degree during salts application is shown in graph 1. In both trial years the highest degree of damage occurred in 'Elsanta', followed by 'Marmolada', and then 'Miranda'. Differences established are statistically justified (regression analysis).

Statistical data analysis (graphs 2 and 3) demonstrates the impact of salts on number of strawberry leaves and stolons (runners). For both researched characteristics, significant cultivar characteristic was established, where 'Marmolada' had significantly more leaves, while 'Miranda' had most of the stolons. The application and increase of salts concentration in a nutritive base had stronger impact on regeneration and number of stolons then on number of leaves. For both characteristics, 'Elsanta' demonstrated higher sensitivity then 'Marmolada', and 'Mirnada' especially. Application of two the highest dosages (3.0 and 4.0 g NaCl L^{-1}) very significantly influenced both observed parameters in all three tested cultivars.

The salts impact on fresh biomass yield of shoots is shown in graph 4 and table 1. Adding of salts in concentration of 0.5 g of NaCl L^{-1} significantly impacted decrease of fresh biomass yield of 'Elsanta' in both trial years. By studying both trial years, re-



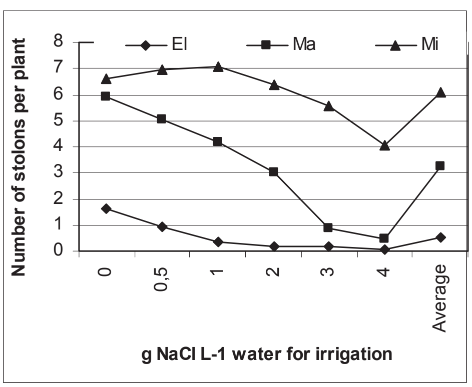
Graph 1. Impact of NaCl in irrigation water on degree of damage: chlorosis, necrosis, decay (two-year average)



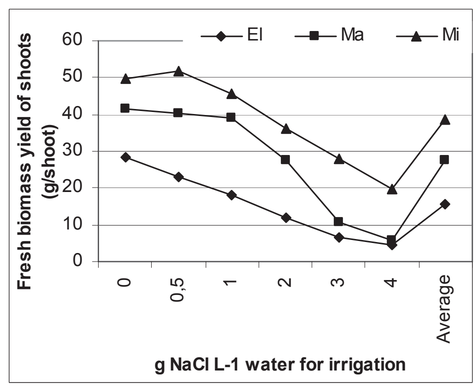
Graph 2. Impact of NaCl in irrigation water on number of leaves per plant (two-year average)

Table 1. Relative yield of: fresh biomass (FB) and dry matter (DM) of shoots, fresh biomass (FB) and dry matter (DM) of roots, total (roots+shoots) fresh biomass (FB) and dry matter (DM), mass ratio of fresh biomass of shoots and roots, and mass ratio of dry matter of shoots and roots (two-year average)

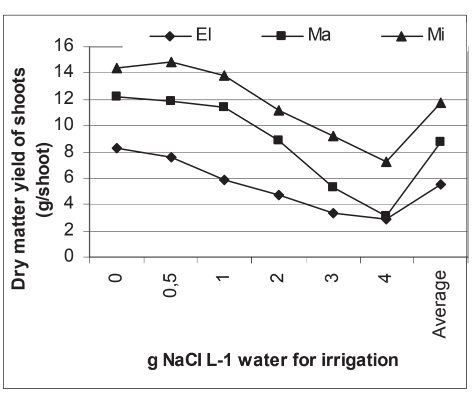
gNaCl L^{-1}	FB (shoots)	DM (shoots)	FB (roots)	DM (roots)	FB (total (r+s))	DM (total (r+s))	FB (shoot/root)	DM (shoot/root)
				'Elsanta'				
0.0	100.0	100.0	100.0	100.0	100.0	100.0	3.7	3.3
0.5	80.5	91.3	87.2	88.2	84.2	90.5	3.4	3.4
1.0	63.5	70.6	77.5	68.2	67.3	70.0	3.0	3.4
2.0	41.9	56.9	65.9	56.2	47.7	56.7	2.3	3.3
3.0	22.8	40.9	54.9	37.5	29.0	40.1	1.5	3.6
4.0	16.3	34.0	49.8	35.4	22.9	34.4	1.2	3.2
Average	54.2	65.6	72.3	64.4	58.5	65.3	2.8	3.3
				'Marmolada'				
0.0	100.0	100.0	100.0	100.0	100.0	100.0	4.1	3.6
0.5	96.8	96.3	92.2	90.8	94.8	95.1	4.4	3.8
1.0	93.7	92.9	98.2	90.0	93.6	92.3	4.0	3.7
2.0	66.9	72.2	82.5	67.8	69.8	71.2	3.4	3.8
3.0	25.1	43.3	56.8	41.2	30.1	42.8	1.8	3.8
4.0	14.1	25.1	56.4	41.3	22.7	28.6	1.0	2.3
Average	66.1	71.6	81.0	72.0	68.5	71.7	3.4	3.6
				'Miranda'				
0.0	100.0	100.0	100.0	100.0	100.0	100.0	2.3	2.8
0.5	103.7	102.9	99.7	101.8	100.9	102.7	2.4	2.8
1.0	91.1	94.7	79.6	84.4	86.2	91.9	2.7	3.1
2.0	72.6	78.2	62.1	58.4	69.6	72.9	2.7	3.7
3.0	56.7	64.9	48.5	45.1	56.8	59.6	2.7	4.0
4.0	40.1	50.4	39.0	34.5	41.9	46.1	2.5	4.2
Average	77.4	81.9	71.5	70.7	75.9	78.9	2.5	3.2



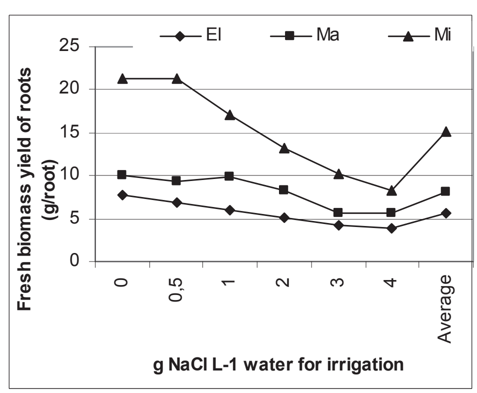
Graph 3. Impact of NaCl in irrigation water on number of stolons per plant (two-year average)



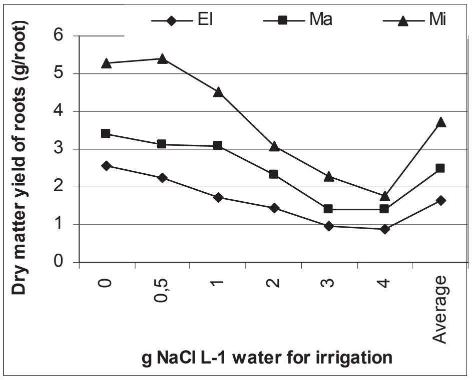
Graph 4. Impact of NaCl in irrigation water on yield of fresh biomass of shoots (two-year average)



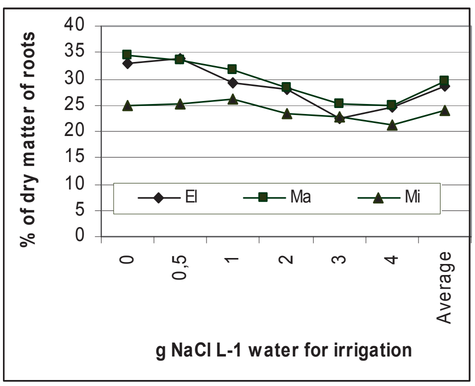
Graph 5. Impact of NaCl in irrigation water to yield of dry matter of shoots (two-year average)



Graph 6. Impact of NaCl in irrigation water on yield of fresh biomass of roots (two-year average)



Graph 7. Impact of NaCl in irrigation water on yield of dry matter of roots (two-year average)



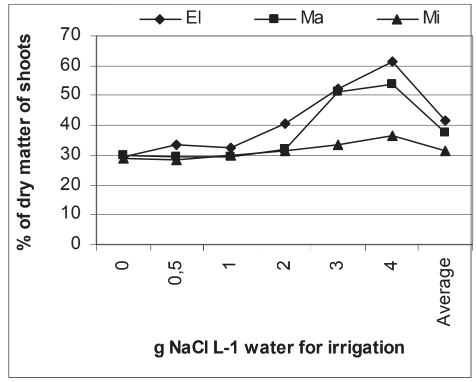
Graph 9. Impact of NaCl in irrigation water on % of dry matter of roots (two-year average)

duction of fresh biomass yield was determined in 'Marmolada' and 'Miranda' at 1.0 g NaCl L^{-1} in irrigation water in comparison to the control. For every further increase in salts concentration in both trial years the fresh biomass yield of shoots in all three strawberry cultivars was reduced significantly.

The highest fresh biomass yield of shoots, in both trial years had 'Miranda', followed by 'Marmolada', and 'Elsanta' respectively. The differences are statistically justified.

As expected, the dry matter yield of shoots was under salts influence, of which results are shown on Graph 5 and Table 1. Upon analyzing two-year results, the dry mater yield of 'Elsanta' shoots was significantly reduced at 1.0 g NaCl L^{-1} application and of 'Marmolada' and 'Miranda' at 2.0 g NaCl L^{-1}. 'Miranda' had increase of dry matter yield at 0.5 g NaCl L^{-1}, however, this difference was not statistically significant in comparison to the control. In both trial years 'Miranda' had higher dry matter yield of shoots, followed by 'Marmolada', and 'Elsanta'; differences are statistically justified.

The fresh biomass yield of roots was decreasing with the increase of salts (Graph 6 and Table 1). Slightly higher fresh biomass yield of roots was established in 'Marmolada' and 'Miranda' (as well as of shoots) in variants with lower salts concentration (0.5 and 1.0 g NaCl L^{-1}). The highest fresh biomass yield of roots in both trial years had 'Miranda', followed by 'Marmolada', and 'Elsanta' respectively; differences are statistically justified.



Graph 8. Impact of NaCl in irrigation water on % of dry matter of shoots (two-year average)

The impact of salts on dry matter yield of roots is shown in graph 7 and table 1. In both trial years, the highest dry matter yield of roots had 'Miranda', followed by 'Marmolada', and 'Elsanta' respectively; differences are statistically justified. Two-year average of dry matter yield of roots demonstrates that application of higher salts concentration in irrigation water (2.0, 3.0 and 4.0 g NaCl L^{-1}) strongly influenced reduction of dry mater yield of roots in all three strawberry cultivars.

Salts impact on percentage of dry matter of shoots is shown in graph 8. Increase in salts concentration significantly impacted increase of percentage of dry matter of shoots. The highest percentage of dry matter of shoots in the first trial year had 'Elsanta', followed by 'Marmolada' and 'Miranda', respectively; differences are statistically justified. In the second trial year, the highest percentage of dry matter of shoots was established in 'Elsanta', followed by 'Marmolada' (difference was not statistically justified). Yet again, significantly lower percentage of dry matter of shoots was established in 'Miranda'.

The salts impact on percentage of dry matter of roots demonstrates the reduction in percentage of dry matter as a consequence of salts application (graph 9). The highest percentage of dry matter of roots, in the first trial year had 'Elsanta', followed by 'Marmolada' and 'Miranda' respectively. In the second trial year, the highest percentage of dry matter of roots was established in 'Marmolada', followed by 'Elsanta' and again by 'Miranda'; differences are statistically justified.

Discussion

The impact of NaCl on strawberry growth, in both vegetation trial years, was shown in first sign of necrosis of older leaves; in both years differences between cultivars were established. Necrosis was developing further with time; however, it was the fastest and in higher degree in 'Elsanta'. Established results are consistent with other authors that were studying salts impact on strawberry (Ehlig and Bernstein, 1958; Ehlig, 1961; Bruyn and Voogt, 1989; Martinez Baroso and Alvarez Gonzalez, 1990; Keutgen and Keutgen, 2003; Ondrašek et al., 2006; Saied et al., 2003; Iapichino and D'Anna, 2003; Wahome, 2003; Kurunc and Cekic, 2005) Authors established as well significant differences between genotypes in degree of leaves damage, or decaying at higher concentrations. Most of authors reference that necrosis of leaves was influenced by chlorine and (in lesser degree) sodium in leaves. Significance of establishing the intensity and degree of necrosis caused by salts is quoted by other authors as well (Shannon, 1979; Ream and Furr, 1976; Huang et al., 1995).

Regression analysis of salts impact on damage degree of strawberry in vegetative first year cycle indicated significant differences between characteristics: ‘Elsanta’ (y = 1.67x + 1.98), ‘Marmolada’ (y = 1.67x + 1.42), and ‘Miranda’ (y = 1.14 +1.22), in all cases at high and significant determination coefficient (0.95). While there were no significant differences in second year either in values of damage degree in comparison to previous year, it can be said with certainty that cultivars are significantly different when it comes to salinity tolerance. Zaither and Mahfouz (1993) emphasize that specific reaction of genotype, i.e. damage degree of leaves can be used as the best indicator in initial selection of tolerant (or more tolerant) genotypes.

Significant differences in salinity tolerances were determined on vegetative parts of strawberry in vegetation trial in both years. Average decrease of number of leaves in comparison to the control was between 10 and 15% (depending on genotype), with the smallest influence on ‘Miranda’. The impact of salts on growth and development, as well as on number of leaves per plant was established by other authors also (Lopez and Satti, 1996, in tomatoes; Huang et al., 1995, in pumpkin), as a result of imbalance in nutrient and water receipt (low water potential), excess sodium and chlorine build up (Greenway and Muns, 1980; Pasternak, 1987), and their unfavourable effect on photosynthesis (Cheeseman, 1988). Yield of fresh biomass and dry matter of shoots and roots was reduced significantly in both trial years. In most plants shoots adversely react on increased salts level in substrate (Greinferberg et al., 1996; Cordovilla et al., 1995; Al-Karaki, 1997; Ehlig and Bernstein, 1958), where weight ratio of shoots/roots was decreasing. However, Bar et al. (1997) quote that high chlorine concentration in irrigation water more influenced reduction of dry matter yield of roots then of shoots. In our case the stronger impact on reduction of dry matter of roots in relation to shoots was determined in ‘Miranda’, while other two cultivars (more sensitive ones) did not show significant diference between reduction of dry matter of roots and shoots. ‘Elsanta’ had higher decrease in researched parameters then ‘Marmolada’ and ‘Miranda’. The average decrease of fresh biomass yield of shoots in comparison to the control was: 43 and 48%, 32 and 35% and 21 and 24%, and of dry matter: 34 and 35%, 24 and 33% and 16 and 20% (depending on the trial year), for cultivars ‘Elsanta’, ‘Marmolada’ and ‘Miranda’; this demonstrates significant specific reactions caused by genotype. Impact of salts to decline of fresh biomass yield of roots was in lesser degree then in shoots. Results are in line with the results of Ehlig and Bernstein (1958), but only for cultivars ‘Elsanta’ and ‘Marmolada’ which demonstrated their susceptibility. Alberico and Cramer (1993) considered yield of total dry matter as a realistic indicator when it comes to tolerance assessment of maize to salts. Yield of total dry matter in strawberry for two trial years demonstrates that ‘Elsanta’ had significant decrease at 0.5 g NaCl L^{-1}, and ‘Marmolada’ and ‘Miranda’ at 1.0, or 2.0 g NaCl L^{-1} respectively (depending on the trial year). The average decrease of total dry matter yield in comparison to the control, in both trial years, was highest in ‘Elsanta’, followed by ‘Marmolada’ and ‘Miranda’, respectively. At 0.5 g NaCl L^{-1} certain increase in dry matter yield of cultivars ‘Marmolada’ and ‘Miranda’ was established. Mentioned increase was influenced by portions of dry matter of shoots, and Mamo et al. (1996) have established significant increase in dry matter of shoots at 2.0 dS m^{-1} (1.23 g NaCl L^{-1}) in lentil and chick-pea. Authors quote that it is not known why the application of smaller dosages of NaCl improves the yield of dry matter of shoots, and that other authors have obtained similar results (Marschner, 1995, in maize, Greenway and Rogers, 1963, in barley). According to Marschner (1995) possible cause for growth stimulation rests in potassium and sodium switch in vacuole. One of possibilities for better shoots growth (as well as to lower the degree of leaves damage) in cultivar ‘Miranda’ is better control of sodium and chlorine intake and transfer and/or excessive build up of essential mineral nutritive elements and adjustments to create their more favourable relations. Mentioned thesis should be methodically verified through chemical analysis (per fractions – plant parts), calculation of content and relation of essential and non-essential cations.

Conclusions

(i) Adding of NaCl into irrigation water has increased significantly all researched vegetative parameters; reaction threshold depended on researched vegetative parameter and cultivar.

(ii) Strawberry cultivars were differentiating significantly in reaction to stress (occurrence of stress signs: chlorosis and necrosis of older leaves, damage intensity: number of necrotic leaves and decay of plants at high salt concentration in substrate).

(iii) The average number of leaves per plant and especially the average number of stolons per plant were under influence of salts in substrate. Threshold reaction that was manifested in decrease of number of leaves emerged later on (at higher concentrations) in comparison to threshold reaction of reduction in number of stolons.

(iv) The fresh biomass yield and dry matter yield of shoots and roots decreased significantly during NaCl application. The yield of total dry matter of strawberry (shoots + roots) in cultivar Elsanta decreased significantly at 0.5 g NaCl L^{-1}, and in ‘Marmolada’ and ‘Miranda’ at 1.0, or 2.0 g NaCl L^{-1}. The average decrease of total dry matter yield in comparison to the control was the highest in ‘Elsanta’, followed by ‘Marmolada’ and ‘Miranda’, respectively.

(v) The percentage of dry matter of shoots was increasing significantly, and the percentage of dry matter of roots was reducing significantly with the increase in salinity of nutritive base. The most consistent cultivar for both observed characteristics (the smallest increase, i.e. the reduction of dry matter percentage) under the salts influence was Miranda.

(vi) The sequence of analyzed vegetative parameters according to the degree of selection to salinity is following: “damage degree ranking of shoots” > number of stolons > mass ratio of fresh biomass of shoots and roots > total fresh biomass > total dry matter > yield of fresh biomass of shoots > yield of dry matter of shoots > yield of fresh biomass of roots $\geq$ yield of dry matter of roots > percentage of dry matter of roots $\geq$ percentage of dry matter of shoots $\geq$ number of leaves.

(vii) According to their salts sensitivity cultivars were ranked: 'Elsanta' > 'Marmolada' > 'Miranda'.

References

Adler P.R. & Wilcox G.E. (1995) Ammonium increases the net rate of sodium influx and partitioning to the leaf of muskmelon. *Journal of Plant Nutrition*, 18(9):1951-1962.

Al-Karaki G.N. (1997) Barley response to salt stress at varied levels of phosphorus. *Journal of Plant Nutrition,* 20(11):1635-1643.

Alarcon J.J., Sanchez-Blanco M.J., Bolarin M.C. & Torrecillas A. (1994) Growth and osmotic adjustment of two tomato cultivars during and after saline stress. *Plant and Soil,* 166:75-82.

Alberico G.J. & Cramer G.R. (1993) Is the salt tolerance of maize related to sodium exclusion? I. Preliminary screening of seven cultivars. *Journal of Plant Nutrition*, 16(11):2289-2303.

Ashraf M. & McNeily T. (1988) Variability in salt tolerance of nine spring wheat cultivars. *Journal of Agronomy & Crop Science , 160:14-21.*

Awang Y.B., Atherton J.G. &Taylor A.J. (1993) Salinity effects on strawberry plants grown in rockwol. I. Growth and leaf water relations. *Journal of Horticultural Science*, 68:783-790.

Badawi M.A., Alphonse M. & Bandok A.Z. (1990) Effect of some disinfectant treatments and different sodium chloride concentrations on the in vitro growth of some strawberry cultivars. *Egyptian Journal of Horticulture,*17(1):17-24.

Bar Y., Apelbaum A., Kafkafi U. & Goren R. (1997) Relationship between chloride and nitrate and its effect on growth and mineral composition of avocado and citrus plants. *Journal of Plant Nutrition,* 20(6):715-731.

Bender F., Douglass L. & Kramer A. (1989) Statistical methods for food and agriculture. Food Products Press, New York · London.

Bergmann W. (1992) Nutritional disorders of plants: development, visual and analytical diagnosis. Gustav Fischer Verlag Jena; Stuttgart; New York.

Biško A., Poljak M. & Jelaska S. (1997a) Utjecaj genotipa na umnažanje jagode in vitro. VI kongrs biologa Hrvatske, Opatija, Hrvatska, 22.-26. rujna 1997.

Bruyn J.M. & Voogt W. (1989) Strawberries. Which EC-value is the most satisfactory in autumn culture? *Groenten en Fruit,* 45(3):30.

Cheeseman J. M. (1988) Mechanisms of salinity tolerance in plants. *Plant Physiology,* 87:547-550.

Cordovilla M.P., Ocana A., Ligero F. & Lluch C. (1995) Salinity effects on growth analysis and nutrient composition in four grain legumes-*Rhizobium* symbiosis. *Journal of Plant Nutrition,*18(8):1595-1609.

Cornillon P. & Palloix A. (1997) Influence of sodium chloride on the growth and mineral nutrition of pepper cultivars. *Journal of Plant Nutrition,* 20(9):1085-1094.

Cramer G.R., Lauchli A. & Epstein E. (1986) Effects of NaCl and $CaCl_2$ on ion activities in complex nutrient solutions and root growth of cotton. *Plant Phisiol*ogy, 81:792-797.

Ehlig C.F. & Bernstein L. (1958) Salt tolerance of strawberries. *Proceedings of the American Society for Horticultural Science,* 72:198-206.

Ehlig C.F. (1961) Salt tolerance of strawberry under sprinkler irrigation. *Proceedings of the American Society for Horticultural Science,* 77:376-379.

Epstein E., Norlin D.J., Rush D.V., Kingsbury R.W., Kelly C.B., Cunningham G.A., & Wrona A. F. (1980) Saline culture of crops: A genetic approach. *Science*, 210:399-404.

Finck A. (1982) Fertilizers and fertilization: introduction and practical guide to crop fertilization. Weinheim; Deerfield Beach, Florida; Basel: Verlag Chemi.

Garg B.K., Vyas S.P., Kathju S., Lahiri A.N., Mali P.C. & Sharma P.C. (1993) Salinity-fertility interaction on growth, mineral composition and nitrogen metabolism of indian mustard. *Journal of Plant Nutrition,* 16(9):1637 - 1650.

Graifenberg A., Botrini L., Giustiniani L. & Lipucci di Paola M. (1996) Yield, growth and element content of zucchini squash grown under saline-sodic conditions. *Journal of Horticultural Science*, 71(2):305-311.

Greenway H. & Munns R.A. (1980) Mechanisms of salt tolerance in nonhalophytes. *Annual Review of Plant Physiology,* 31:149-190.

Greenway H. & Rogers A. (1963) Growth and ion uptake of *Agropyron elongatum* on saline substrates, as compared with a salt-tolerant variety of *Hordeum vulgare. Plant and Soil*, 18:21-30.

Heimler D., Tattini T., Ticci S., Coradeschi M.A. & Traversi M.L. (1995) Growth, ion accumulation, and lipid composition of two olive genotypes under salinity. *Journal of Plant Nutrition,* 18(8):1723-1734.

Huang B., Scot NeSmit D., Bridges D.C. & Johnson J.W. (1995) Responses of squash to salinity, waterlogging, and subsequent drainage: II.Root and shoot growth. *Journal of Plant Nutrition,* 18(1):141-152.

Huang J. & Redmann R.E. (1995) Salt tolerance of *Hordeum* and *Brassica* species during germination and early seedling growth. *Canadian Journal of Plant Science,* 75: 815-819.

Iapichino G. & D'Anna F. (2003) Genotype variation in *Fragaria x ananassa* Duch. seed germination under in vitro salinity stress. *Acta Hort.* (ISHS) 609:119-111.

Keutgen A.J. & Keutgen N. (2003) Influence of salinity stress on fruit quality in strawberry, International Symposium on Managing Greenhouse Crop in Saline Environment, Pisa –Italy, 30. May, *Acta Hort.,* Vol.I., No.609:155-157.

Kurunc A. & Cekic C. (2005) Response of three strawberry cultivars (*Fragaria x ananassa* Duch.) to different salinity in irrigation water. Hort. Sci. (Prague) 32(2):50-55.

Lei Y., Tadano T., Tian K., Ichizen N., Sun J. & Yamazaki S. (1997) Effect of soil salinity on the growth and nutritional status of crop plants and that of N and P application. pp 419-420. In: T. Ando, K. Fujita, T. Mae, H. Matsumoto, S. Mori, and J. Sekiya (eds.): *Plant Nutrition for Sustainable Food Production and Environment*. Kluwer Academic Publishers. Dordrecht, The Netherlands.

Liu M., Tian K. & Tadano T. (1997) Effects of soil salinity on the growth, nutritional status and salt-removing capacity of fodder beet. pp 421-422. In: T. Ando, K. Fujita, T. Mae, H. Matsumoto, Mori S. & Sekiya J. (eds.): *Plant Nutrition for Sustainable Food Production and Environment.* Kluwer Academic Publishers. Dordrecht, The Netherlands.

Lopez M.V. & Satti S.M.E. (1996) Calcium and potassium-enhanced growth and yield of tomato under sodium chloride stress. *Plant Science,* 114:19-27.

Maas E.V. (1986) Salt tolerance of plants. *Applied Agricultural Research, I.* 12-25.

Mamo T., Richter C. & Heiligtag B. (1996) Salinity effects on the growth and ion contents of some chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medic.) varieties. *Journal of Agronomy & Crop Science,* 176:235-247.

Maroto J.V. & Lopez-Galarza S. (1989) The spanish strawberry industry. International strawberry symposium, Cesena - Italy, 22-27 May. *Acta Horticulturae,* Vol. II, No 265:653-658.

Marschner H. (1995) Mineral Nutrition of Higher Plants, Second edition. Academic Pres, London, San Diego, New York, Boston, Sydney, Tokyo, Toronto.

Marschner H., Kylin A. & Kuiper P.J.C. (1981a) Differences in salt tolerance of three sugar beet genotypes. *Physiologia Plantarum*, 51:234-238.

Marschner H., Kylin A. & Kuiper P.J.C. (1981b) Genotypic differences in the response of sugar beet plants to replacement of potassium by sodium. *Physiologia Plantarum*, 51:239-244.

Martinez Baroso M.C. & Alvarez C.E. (1997) Toxicity symptoms and tolerance of strawberry to salinity in the irrigation water. *Scientia Horticulturae,* 71:177-188.

Martinez Baroso M.C. & Alvarez Gonzalez C.E. (1990) Balance kationico de la planta de fresa (*Fragaria x ananassa* Duch.) en condiciones de salinidad. III Simposio Nacional NUTRICION MINERAL DE LAS PLANTAS, Palma de Mallorca, 18-20 septiembre 1990.

Ondrašek G., Romić D., Romić M., Duralija B. & Mustač I. (2006) Strawberry growth and fruit yield in a saline environment, *Agriculturae Conspectus Scientificus*, Vol. 71. No.4 (155-158).

Pasternak D. (1987) Salt tolerance and crop production - a comprehensive approach. *Annual Review of Phytopathology*, 25:271-297.

Peres-Alfocea F., Estan M.T., Caro M. & Bolarin M.C. (1993) Response of tomato cultivars to salinity. *Plant and Soil,* 150:203-211.

Petz B. (1985) Osnovne statističke metode za nematemetičare. Drugo izdanje, *SNL-Zagreb.*

Ream C.L. & Furr J.R. (1976) Salt tolerance of some *Citrus* species, relatives and hibrids tested as rootstocks. *Journal of the American Society for Horticultural Sci*ence, 101(3):265-267.

Rengel Z. (1992) The role of calcium in salt toxicity. *Plant Cell Environment*, 15:625-632.

Saied A.S., Keutgen N & Noga G. (2003) Effects of NaCl stress on leaf growth, photosyntesis and ionic contents of strawberry cvs. 'Elsanta' and 'Korona'. Acta Hort. (ISHS) 609:67-73.

Serdar V. (1977) Udžbenik statistike, deseto izdanje. *Školska knjiga - Zagreb.*

Serraj R., Vasquez-Diaz H. & Drevon J.J. (1998) Effects of salt stress on nitrogen fixation, oxygen diffusion and ion distribution in soybean, common bean and alfalfa. *Journal of Plant Nutrition,* 21(3):475-488. Shannon M.C. (1979) In Quest of rapid screening techniques for plant salt tolerance. *HortScience,* 14(5):587-589.

Shannon M.C., Noble C.L. (1995) Variation in salt tolerance and ion accumulation among subterranean clover cultivars. *Crop Science,* 35(3):798-804.

Sibbett G.S. (1995) Managing high pH calcareous, saline and sodic soils of the western pecan-growing region. *HortTechnology*, 5(3):222-225.

Wahome P.K. (2003) Mechanisms of salt (NaCl) stress tolerance in horticultural crops –a mini review. Acta Hort.(ISHS) 609:127-131.

Zaiter H. Z. & Mahfouz B. (1993) Salinity effect on root and shoot characteristics of common and tepary beans evaluated under hydroponic solution and sand culture. *Journal of Plant Nutrition,* 16(8):1569-1592.

Zekri M. & Parsons L.R. (1992) Salinity tolerance of citrus rootstock: Effects of salt on root and leaf mineral concentrations. *Plant and Soil,* 147:171-181.

Zekri M. (1993) Seedling emergence, growth and mineral concentration of three citrus rootstocks under salt stress. *Journal of Plant Nutrition*, 16(8):1555-1568.

---

acs75_12