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Reaction of Three Strawberry Cultivars to the Salinity of Growing Substrate: Generative Parameters

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Abstract – **The study aimed at analysing the reaction of three strawberry (FragariaananassaDuch.) 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_{iw} values: 0.73, 1.65, 2.66, 4.37, 5.93 and 7.81 mS cm^{-1}). Vegetation trial was carried out at the Faculty of Agriculture in Zagreb during two years. Following parameters were tested: yield of fruit (g/plant), number of fruits per plant, average mass of fruits, number of floral shoots, number of fruits per floral shoot and percentage of dry matter of fruits.**

Sodium chloride had a significant impact on the fruit yield: yield reduction was observed in cvs. 'Elsanta' and 'Marmolada' at 0,5 g of NaCl L^{-1}, while in cv. 'Miranda' at 2,0 g of NaCl L^{-1}. Average reduction of yield under the influence of salinity was the highest in cv. 'Elsanta' followed by cvs. 'Marmolada' and 'Miranda' (reduced number of fruits and average of fruit mass). Dry matter percentage of fruits was increased in all three cultivars when nutrient solution contained 1.0 - 3.0 g NaCl L^{-1}. However, there was a significant reduction of dry matter percentage of fruits at the highest concentration of NaCl (4.0 g NaCl L^{-1}) in cvs. 'Elsanta' and 'Marmolada', but not in cv. 'Miranda'. Dry-matter percentage of fruits was significantly higher in cv. 'Miranda' then in cvs. 'Elsanta' and 'Marmolada'.

Keywords – **Dry-Matter Percentage of Fruits, Mass of Fruit, Number of Fruits, Nacl, Salinity, Strawberry, Yield.**

I. Introduction

Sodium (Na^+) is one of the most intensely researched ions in plant biology and has attained a reputation for its toxic qualities [24]. Excessive salts in soil often are limiting factor in cultivation of agricultural crops in arid and semiarid areas [29]. These areas are significant for high temperatures and evapotrasnpiration 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 [17]. 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 [20], [35], [46], [33] which impacts negatively on growth and yield of majority of agricultural crops [27]. Few measures can be used for correction and usage of salted soils, although each of them has limited possibilities. Marschner et al. [31] recommend cultivation of tolerant genotypes. Soils with high sodium content are 'repaired' best if fertilized profusely with NPK fertilizer before planting [18]. Positive impact of calcium on decreasing of adverse salts effect, and on growth and yield were recognized by: Rengel [36], Lopez and Satti, [26] and Joshi et al. [23]. Importance of balanced fertilization in management of soil salinity was implied by other authors as well ([19], [2], [1], [8], [25], [44]). Plant species react differently to high salts content ([20], [10]). Salinity tolerance, also, varies depending on growth stage of plant development ([27], [47], [4]). Significant differences to salts tolerance were determined within the same species ([21], [14], [39], [40], [30], [25], [43], [45]). Tolerant genotypes are used for cultivation on salted soils/substrates, and as a basis in breeding. Previous research on strawberry has shown its strong susceptibility to salts ([27], [28], [15], [32], [5], [12]). In addition tothe research executed in vegetative or field trial, Badawi et al. [7], and Biško et al. [11], were studying NaCl impact on regeneration and shoot growth of strawberry in in vitro conditions.

II. Materials 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. 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, 'frigoplants'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 ECiw: 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. For more informations, please see: Biško et al. (2010) Reaction of Three Strawberry Cultivars to the Salinity: Vegetative Parameters. Agriculturae Conspectus Scientificus Vol. 75, No 2.(83-90).

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), [34]. LSD (last significant different) was calculated in case when F-test was significant at levels $\alpha = 0.05$. Computer program EXCEL 7.0. was used to calculate Linear regression ([38], [9]) and for graphic design.

III. Results and Discussion

The number of floral shoots per plant in both trial years did not differ significantly in respect to salt treatment (Table 1). The variety Marmolada had a significantly higher number of floral shoots per plant in both years, followed by Elsanta and Miranda, with the least significant number. Floral shoots emerge in a period of ten to fifteen days after planting. In that period only two saline water treatments were carried out. Differentiation of floral shoots ended before exposure to stress, and a short period between salt treatment and floral shoots regeneration is the reason why there was no effect of salt on the number of floral shoots per plant.

The addition of salt had a significant impact on the yield of strawberries in both trial years (Tables 1 and 2, Fig. 1). A significant reduction of yield of Elsanta fruit was determined at 0.5 and 1.0 g NaCl L^{-1} (depending on the year), of Marmolada at 0.5 g NaCl L^{-1} (both years), and of Miranda only at 2.0 g NaCl L^{-1} (both years). Average reduction of yield in relation to the control group (taking into account both years) was the following: 34.7% in Elsanta, 28.8% in Marmolada and 17.6% in Miranda (Table 2). Reduction of the overall yield per plant is the result of the reduction of the number of fruits per floral shoot (Fig. 2), of the number of fruits per plant (Fig. 3) and the average fruit weight (Fig. 4).

Significant differences in the fruit yield established between varieties are the result of differences in the regeneration of the number of floral shoots in the year planting and the degree of tolerance to salt. The variety Miranda regenerated one floral shoot in both trial years, while Elsanta and Marmolada regenerated two or three floral shoots per plant. For this reason, the yield per plant in Miranda was lower than in Elsanta and Marmolada. However, the analysis of the effect of NaCl on the yield shows the difference in the tolerance degree. Miranda had a significantly lower average reduction of yield for a unit of increase in NaCl: in 1997 and 1998 ($y = - 6.91x + 55.58$ and $y = - 7.13x + 60.22$) than Marmolada ($y = - 16.19 x + 99.00$ and $y= - 14.99 x + 96.25$) and Elsanta ($y = -15.64x +80.8x$ and $y= -13.00x + 81.89$), with highly significant coefficients of determination for all varieties and for both trial years (data not shown).

Yield reduction of 50% or more in comparison to control plants was found at high salt concentrations (3.0 and 4.0 g NaCl L^{-1}) in varieties Elsanta and Marmolada, but not in Miranda (Table 2 and Fig. 6). The negative impact of salt on the yield of strawberry and specific reaction of genotype have been determined by other authors [3], [41]. Regression analysis of the effect of salt on the yield per plant is shown in Fig. 7. The negative impact of salt on reproductive parameters of peppers was determined by Rubio et al. [37]. Number of fruits per floral shoots is decreasing with the increase of salt concentration in the irrigation water (Tables 1 and 2, Fig. 2). There are differences in the sensitivity of certain varieties: Elsanta> Marmolada > Miranda. The average reduction in respect to control was 21.5%, 14.3 % and 10.0% . Significantly highest number of fruits per floral shoots had Miranda, followed by Elsanta and Marmolada. Regression analysis of the effect of salt on the number of fruits per floral shoot is shown in Fig. 8.

The number of fruits per plant decreased with the increase of salt concentration (Tables 1 and 2, Fig. 3). Significant differences were found among the tested varieties: Elsanta reacted at 1.0, Marmolada at 2.0 and Miranda at 3.0 g NaCl L^{-1} in the irrigation water. Marmolada had the highest number of fruits per plant (due to a larger number of floral shoots per plant), followed by Elsanta and Miranda, with the lowest number of fruits. Regression analysis of the effect of salt on the number of fruits per plant is shown in Fig. 9.

The average mass fruit has been decreasing with the increase of salt concentration in the irrigation water (Tables 1 and 2, Fig. 4). The least effect of salt on the average mass of fruit was observed in Miranda. Average mass of fruit reduction compared to the control group (taking into consideration both trial years) was 15.0 % in Elsanta, 18.5 % in Marmolada and 2.6 % in Miranda. Regression analysis of the effect of salt on the average mass of fruit is shown in Fig.10.

The percentage of dry matter of the fruit increased under the influence of salt (Table 1, Fig. 5) . Significant differences were determined at 0.5 and 1.0 g NaCl L^{-1} of irrigation water, depending on the year of the study. The increase of salt concentration resulted in the increase of the dry matter content of fruit, but not at 4.0 g NaCl L^{-1} in sensitive varieties (Elsanta and Marmolada). Significantly the highest fruit dry matter percentage was observed in Miranda in both years. Impact of salt on the increase in fruit dry matter was also determined by Awang et al. [6]. The increase in fruit dry matter authors attributed to the impact of reduced water content, rather to a physiological effect of photosynthesis. Bruyn and Voogt [13] had the best results in the preservation of fruits of strawberries irrigated with slightly salted water (3 mS cm^{-1}). Other authors [22], [16], [42] also refer to a significant role of a particular (low) amount of salt that has a positive effect on the taste and dry matter of tomato fruit.

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Table 1: Impact of salinity on generative parameters of strawberry

	Number of floral shoots per plant		Yield of fruit (g/plant)		Number of fruits per plant		Average mass of fruit (g)		Number of fruits per floral shoot		Percentage of dry matter of fruits	
Year	97	98	97	98	97	98	97	98	97	98	97	98
gNaCl L-1						*Elsanta*						
0.0	2,10	2,00	84,32	87,90	11,60	11,60	7,30	7,70	5,62	5,80	8,19	8,31
0.5	2,10	2,10	72,93	83,44	11,40	10,90	6,51	7,85	5,50	5,32	8,28	8,55
1.0	2,10	1,90	62,36	56,74	9,70	8,10	6,46	7,35	4,68	4,40	8,89	8,52
2.0	2,00	2,00	45,62	49,63	8,40	7,80	5,44	6,65	4,20	3,90	8,49	8,46
3.0	2,00	1,90	36,10	39,73	7,90	7,10	4,58	6,07	3,95	3,90	8,36	8,60
4.0	2,00	1,80	19,20	37,45	4,70	6,10	4,14	6,43	2,60	3,60	7,83	8,06
Average	2,05	1,95	53,42	59,15	8,95	8,60	5,74	7,01	4,43	4,49	8,34	8,41
gNaCl L-1						*Marmolada*						
0.0	2,50	2,60	99,61	97,96	11,60	11,30	8,61	8,84	4,83	4,52	8,37	7,46
0.5	2,50	2,70	88,42	83,88	11,70	10,70	7,57	8,03	4,87	4,07	8,83	7,56
1.0	2,50	2,70	86,42	86,67	11,40	11,40	7,59	7,84	4,75	4,37	8,71	7,66
2.0	2,60	2,60	63,87	65,03	9,90	10,00	6,47	6,65	3,95	4,08	8,65	7,61
3.0	2,50	2,50	51,32	47,78	8,70	7,80	5,93	6,31	3,65	3,32	8,63	7,81
4.0	2,50	2,40	34,34	38,81	6,80	6,40	5,12	6,41	2,87	2,83	7,96	7,11
Average	2,52	2,58	70,66	70,02	10,02	9,60	6,88	7,35	4,15	3,68	8,53	7,53
gNaCl L-1						*Miranda*						
0.0	1,00	1,20	51,53	59,29	6,60	7,90	7,70	7,65	6,60	6,95	8,98	9,15
0.5	1,00	1,00	51,14	53,64	6,40	6,40	8,04	8,55	6,40	6,40	9,10	9,17
1.0	1,00	1,20	52,02	58,04	6,50	8,40	8,06	7,01	6,50	4,45	9,77	9,89
2.0	1,00	1,10	48,46	46,60	6,30	7,00	7,73	6,85	6,30	6,80	10,00	9,51
3.0	1,00	1,00	31,08	36,99	4,20	5,40	7,64	7,06	4,20	5,40	10,50	10,08
4.0	1,00	1,00	26,73	31,89	3,70	5,50	7,30	6,12	4,10	6,00	9,98	9,04
Average	1,00	1,08	43,49	47,74	5,62	6,77	7,75	7,21	5,68	6,50	9,72	9,47
LSD (5%)												
Tretman	N.S.	N.S.	2,34	6,12	0,35	1,14	0,45	0,71	0,36	0,81	0,10	0,11
Cultivar	0,12	0,13	1,65	4,32	0,25	0,8	0,32	N.S.	0,26	0,57	0,07	0,07
Tre. x cv.	N.S.	N.S.	4,05	10,59	0,61	1,97	0,79	N.S.	0,63	N.S.	0,18	0,18

Table 2: Relative values of the fruit yield, number of fruits per plant, average mass of fruit, number of fruits per floral shoot and the dry matter percentage of strawberries grown in a saline substrate (% in respect to control)

	Yield of fruit (g/plant)		Number of fruits per plant		Average mass of fruit (g)		Number of fruits per floral shoot		Percentage of dry matter of fruits	
Year	97	98	97	98	97	98	97	98	97	98
gNaCl L-1				*Elsanta*						
0.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100,00	100,00
0.5	86.50	94.90	98.30	94.00	89.20	101.90	97.90	91.70	101,10	102,89
1.0	74.00	64.60	83.60	69.80	88.50	95.50	83.30	75.90	108,55	102,53
2.0	54.10	56.50	72.40	67.20	74.50	86.40	74.70	67.20	103,66	101,81
3.0	42.80	45.20	68.10	61.20	62.70	78.80	70.30	67.20	102,08	103,49
4.0	22.80	42.60	40.50	52.60	56.70	83.50	46.30	62.10	95,60	96,99
Average	63.40	67.30	77.20	74.10	78.60	91.00	78.70	77.40	101,83	101,28
gNaCl L-1				*Marmolada*						
0.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100,00	100,00
0.5	88.80	85.60	100.90	94.70	87.90	90.80	100.80	90.00	105,50	101,34
1.0	86.80	88.50	98.30	100.90	88.20	88.70	98.30	96.70	104,06	102,68
2.0	64.10	66.40	85.30	88.50	75.10	75.20	81.80	90.30	103,35	102,01
3.0	51.50	48.80	75.00	69.00	68.90	71.40	75.60	73.50	103,11	104,69
4.0	34.50	39.60	58.60	56.60	59.50	72.50	59.40	62.60	95,10	95,31
Average	70.90	71.50	86.40	85.00	79.90	83.10	86.00	85.50	101,85	101,01
gNaCl L-1				*Miranda*						
0.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100,00	100,00
0.5	99.20	90.50	97.00	81.00	104.40	111.80	97.00	92.10	101,34	100,22
1.0	101.00	97.90	98.50	106.30	104.70	91.60	98.50	107.20	108,80	108,09
2.0	94.00	78.60	95.50	88.60	100.40	89.50	95.50	97.80	111,36	103,93
3.0	60.30	62.40	63.30	68.40	99.20	92.30	63.60	77.70	116,93	110,16
4.0	51.90	53.80	56.10	69.60	94.80	80.00	62.10	86.30	111,14	98,80
Average	84.40	80.50	85.10	85.70	100.60	94.20	86.10	93.50	108,26	103,53

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Picture 1. Impact of salinity on strawberry (top:Elsanta, center:Marmolada, under:Miranda)Left to right: 0-control, 0.5, 1.0, 2.0, 3.0, 4.0 g NaCl L^{-1}

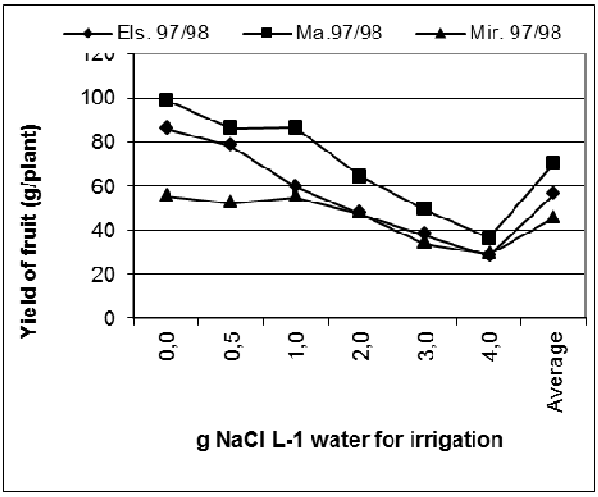

Fig.1. Impact of salinity on yield of fruit

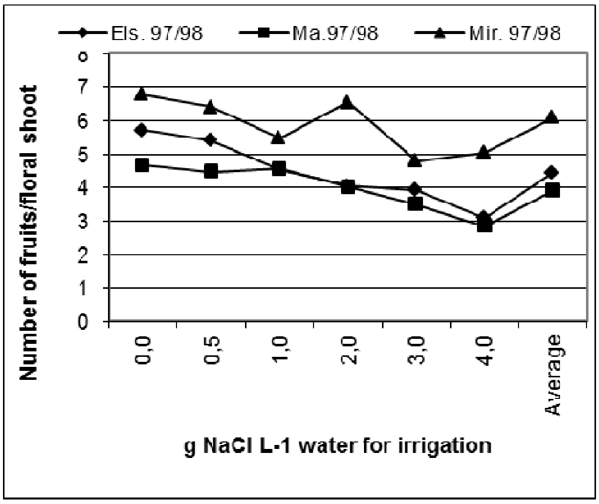

Fig.2. Impact of salinity on No. of fruits/floral shoot

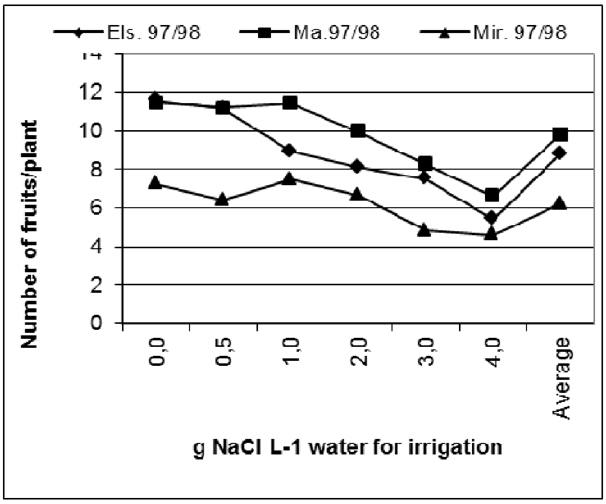

Fig.3. Impact of salinity on No. of fruits per plant

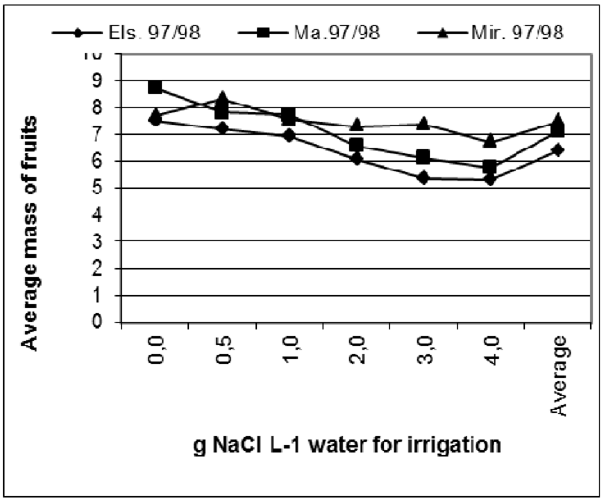

Fig.4. Impact of salinity on average mass of fruits

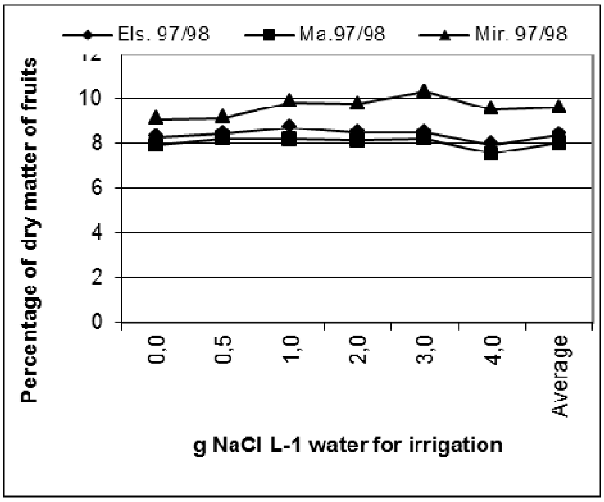

Fig.5. Impact of salinity on % of dry matter of fruits

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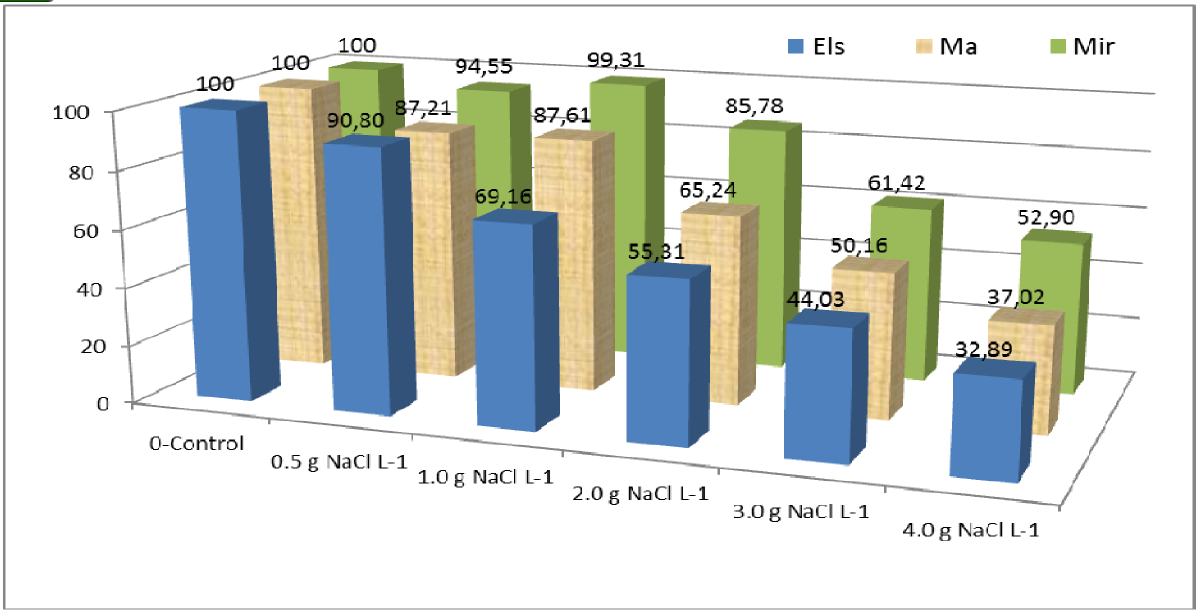

Fig.6. Impact of salinity on relative yield of strawberry (average of two years)

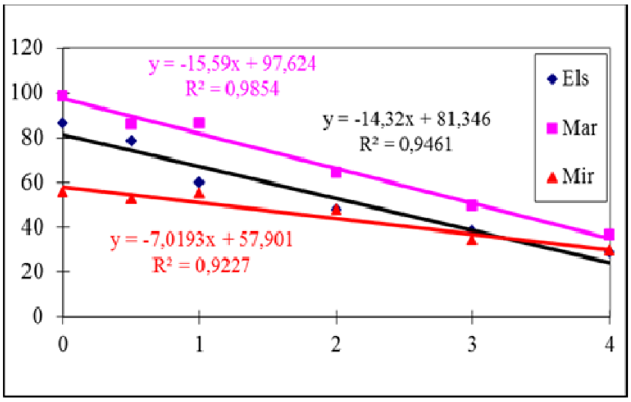

Fig.7. Impact of salinity on yield of fruit (regressioon)

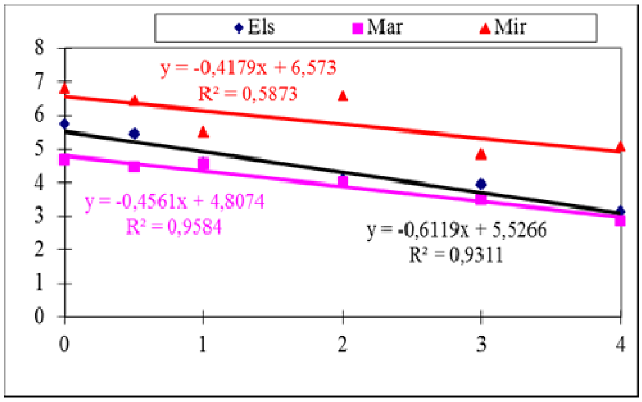

Fig.8. Impact of salinity on No. of fruits per floral shoot

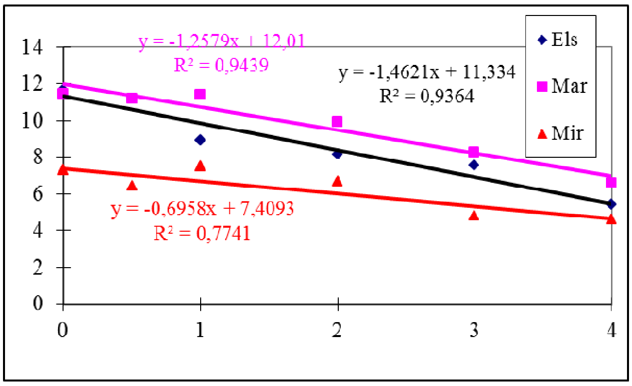

Fig. 9. Impact of salinity on No. of fruits per plant

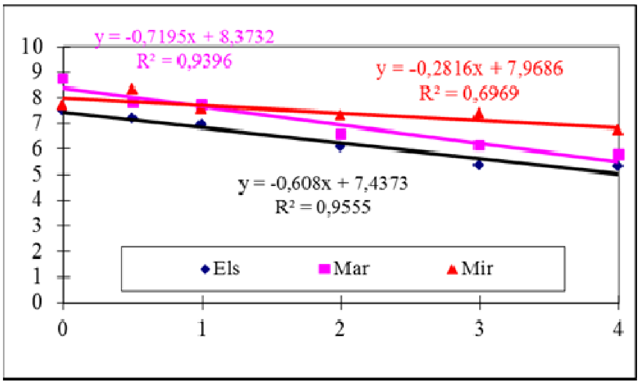

Fig. 10. Impact of salinity on average mass of fruits

IV. Conclusion

The tested varieties significantly differed in their response to the increase of salt in the irrigation water (ECiw). The impact of salt was shown to be the lowest in Miranda in respect to all analysed parameters (except the number of floral shoots where there was no effect of salt in any of the analysed varieties).

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