ANALYSIS OF QUALITY PARAMETERS IN EGGPLANT GROWN UNDER SALINE WATER IRRIGATION

M.I. Sifola, S. De Pascale
Department of Agronomy
and Plant Breeding
University of Naples
Portici (Naples)
Italy

R. Romano
Department of
Food Science
University of Naples
Portici (Naples)
Italy

Abstract

In 1993 the effects of increasing water salinity (0%, 0.125%, 0.25%, 0.5% and 1% commercial NaCl) and three irrigation frequencies (irrigation applied every 2, 5 and 10 days) on the quality of eggplant fruit were studied. The 1% salt concentration reduced the weight of marketable fruit (142 g vs. 165 g in the control). Irrigation with saline water resulted in round-shaped fruit due to a reduction in fruit length as compared to the control (11.7 cm vs. 14.6 cm).

An increase in mesocarp firmness was induced by salinity (26.0 N in the 1% treatment vs. 24.7 in the control) which was associated to reduced water content in fruits of plants irrigated with 1% salt as compared to those from the control. Mesocarp firmness and dry matter content increased as the irrigation frequencies decreased. Titratable acidity, reducing sugars and mineral ash increased with salinity, while pH, total polyphenols and ascorbic acid contents were reduced by saline water irrigation. Changes in mineral composition of eggplant fruit occurred in accordance with increased salinity. Irrigation with 1% salt concentration gave the highest Na^+ and Cl^- content in the fruit.

Key words: *Solanum melongena* L., water salinity, fruit quality, ion concentration, mesocarp firmness.

1. Introduction

The effects of salinity on yield processes of many crops have been studied extensively over a long period of time (Maas and Hoffmann, 1977; Shalhevet et al., 1983; Francois, 1985; Graifenberg et al., 1993; Barbieri et al., 1994) and at present a large number of crops may be classified as having a certain degree of tolerance. However, comparatively little research has been done on the effect of increasing salt concentrations on either yield or quality.

Francois and Clark (1980) reported salt as being responsible for some morphological and structural modifications (e.g. a rind thickness reduction of "Valencia" orange irrigated with saline water) while other authors (Fernandez et al., 1977; Mizrahi and Pasternak, 1985) have indicated variations in the chemical composition of fruits of plants grown under saline conditions, such as an increase of TSS (total soluble solids), titratable acidity, reducing sugars and pigments as the salt concentration of irrigation water increased. The improvement of quality by salt that commonly occurs when considering internal and, sometimes, external characteristics (high scores for taste and appearance) seems to be accompanied by a shortening of shelf life (Mizrahi, 1982; Mizrahi and Pasternak, 1985).

The following trial was carried out in order to evaluate the effect of increased salinity of irrigation water on some quality parameters of eggplant, a vegetable crop widely grown for fresh consumption.

2. Materials and methods

The experiment was carried out on eggplant (*Solanum melongena* L.) at "Torre Lama", the experimental farm of the University of Naples. Three irrigation frequencies (every 2, 5 and 10 days) were factorially combined with five salt concentrations in the irrigation water. Commercial sea salt (Na^{+} 23.8%, K^{+} 14.8%, Ca^{2+} 0.102%, Mg^{2+} 0.1%, Cl^{-} 51.2%, SO_4^{2-} 0.28%) was added to fresh water at concentrations of 0.125%, 0.25%, 0.5% and 1% (ECw of 2.30, 4.43, 8.46 and 15.73 dS m^{-1}, respectively). Irrigation with fresh water (0% NaCl) containing 79 mg l^{-1} of Ca^{2+} was included as control (ECw of 0.54 dS m^{-1}).

The experimental design was a split-plot with three replicates (blocks), with salt treatment as the main plots and the irrigation frequencies as the sub-plots.

Eggplant cv. Mirabelle seedlings were transplanted in rows 0.9 m apart with an in-row spacing of 0.4 m on May 3. Before transplanting, fertilizers were applied at the rate of 120 kg ha^{-1} N, 150 kg ha^{-1} P_2O_5, 100 kg ha^{-1} K_2O. Side dressing was nitrogen fertilized at the rate of 100 kg ha^{-1} distributed 3 and 6 weeks after seedlings transplanting. Weeds were controlled throughout the life of the crops by a combination of pre-emergence herbicide (trifluralin) and cultivation. Diseases and insects were regularly controlled with a range of commercial chemicals. Differential saline irrigations began on June 6. The irrigation volume supplied between the beginning of the treatment and the end of the harvest was 5400 m^3 ha^{-1} (30 waterings of 180 m^3 ha^{-1}, 18 of 300 m^3 ha^{-1} and 9 of 600 m^3 ha^{-1} were supplied for, respectively, the 2, 5 and 10 days irrigation frequencies). Fruits were harvested weekly (9 times) from July 15 to September 13. During this period, a 22 mm rainfall was registered.

At each harvest, size (weight, length and diameter), dry matter content and specific gravity were determined on a three fruit sample per plot. Mesocarp firmness was also measured by using a penetrometer with a round tip of 5 mm. Concurrently, at the first harvest (July 15), a compression test was made on the mesocarp of three fruits per each plot sampled from 0 and 1% treatment and irrigation frequency of 2 days, using an Instron machine (model 4301). The instrument was equipped with a 50 kg-load cell and a parallel plate moving downward at a speed of 5 mm min^{-1}. Force/Deformation curves were recorded.

In addition, three fruits per treatment were sampled and stored over a period of three weeks. The storage regimes were: T=25± 2°C and

RH=66±7% (ambient conditions). Fruit were weighted to measure water loss and shelf life was also evaluated.

Analyses of ions contents were performed twice (July 15 and August 3) during the harvest period on fruit pulp from 0, 0.5 and 1% treatment and from the irrigation frequencies (every 2, 5 and 10 days) by ionic chromatography (Dionex Eluant Degas Module, Dionex Gradient Pump).

Chemical analyses on fruit pulp from the 0 and 1% treatment were also carried out. Fruit samples were homogenized to obtain the pH and titratable acidity values; pH was measured with a common pH meter and titratable acidity was determined with 0.1N NaOH up to pH 7.0. Reducing sugars were determined according to the Fehling method using methylene blue as indicator (AOAC, 1975). Total nitrogen was obtained by micro-Kjeldahl digestion and nitrates were detected by colorimetric measurement (Spectrophotometer Hatch DR2000) by the cadmium method. Lipids were obtained by weight after solvent extraction (diethyl ether) (Soxtec System HT2, Tecator) and ascorbic acid was measured using an HPLC (Hewlett Packard 1050) equipped with UV detector (245 nm). Total polyphenols and starch were determined by colorimetric measurement following the enzymatic methodology (AOAC, 1975). Both ionic and chemical analyses were carried out on three fruits per each plot.

Data were subjected to analysis of variance and means separated by LSD test at P=0.05. Fruit weight changes vs. storage time were analyzed by linear regression and differences of slopes were compared by t test.

3. Results and discussion

Water salinity reduced significantly the marketable yield (MY) by 57% (table 1). Yield quality was also significantly affected by treatments. The mean weight of marketable fruits (MFW) decreased with salt (165 g of the control vs. 142 g of 1% treatment) while irrigation frequencies gave no significant differences.

Irrigation with saline water resulted in round-shaped fruits, due to a reduction in fruit length, as compared to the control (11.7 cm vs. 14.6). Concurrently, the L/D ratio decreased. Such structural modifications usually occur under saline conditions and can be explained by a reduction of cell extension and/or division (Greenway and Munns, 1980)

Dry matter content (DM) increased with salinity, which may be due to an increase in TSS (total soluble solids) as reported by Mizrahi and Pasternak (1985) on processing tomato fruits. An increase in mesocarp firmness (MF) was also induced by the highest salinity water and this effect was associated with the highest dry matter content. High dry matter, as in the 1% treatment, is usually associated to an increase in the force required to cause compression failure and to a decrease in the incidence of impact damage (Patten and Patterson, 1985).

On the other hand, the highest irrigation frequency resulted in a significant reduction in both DM and MF. No differences were found between 0 and 1% treatment on the specific gravity of fruit (SG).

Fruits from plants irrigated with 1% salt concentration had the lowest pH, total polyphenols and ascorbic acid contents but the highest titratable acidity, ash and reducing sugars (table 2).

Changes in the mineral composition of fruit pulp occurred according to salinity. Irrigation with 1% salt concentration gave the highest Na^+ (+30% as compared to the control) and Cl^- (+23% as compared to the control) content in eggplant fruits. According to Shalhevet et al. (1983), a higher Na^+ content did not reduce K^+ concentration, which slightly increased in fruits from plants irrigated with 1% salt concentration (+6% as compared to the control). As a result the K^+/Na^+ ratio decreased from 5.270 (0%) to 4.280 (1%).

Higher concentrations of total nitrogen (2.69% in the 1% salt treatment vs. 2.30% in the control) and nitrates occurred according to salinity (4.12 ppm in the 1% treatment vs. 3.24 in the control). Similar results were reported by other authors (Lunin et al., 1964; Frota and Ticker, 1978; Pessarakli and Tucker, 1985). On the other hand, Ca^{2+} content decreased with increasing water salinity.

In the compression test on mesocarp, ϵ (strain at yield, %) and σ (stress at yield, N) were measured. ϵ represents the sample thickness reduction (%) that occurs during the compression test and it is a measure of the sample "crushing", while σ expresses the sample force that counteracts the exerted pressure. The 1% treatment gave the highest ϵ value and the lowest σ value (table 4). By analyzing the Force/Deformation curves in the 0 and 1% treatments (figure 1), it emerged that in the 0% treatment the exerted pressure produced initially a localised compression of tissue (average thickness 6.25 mm to start with) that rapidly developed into a fracture. A yield interval in the salt treatment was also registered, suggesting that fruit mesocarp of the highest salinity level can extend more under the pressure before failing. This result indicated a greater extensibility of the cell walls of the 1% treatment as compared to the control, as was evident from σ values for the 1% salt tissue samples compared with the control samples (75.76 vs. 55.43). This suggested a better resistance to the breakage of mesocarp in salt-stressed fruit that might be due to its reduced water content as compared to the control. Damage to a fleshly commodity by physical force is reported, in part, as a function of its moisture content (Mohsenin, 1970). Most evidence from intact fruit and vegetables indicates that when a tissue is less turgid its compressive strength increases (Diehl et al., 1979), confirming a decreased impact damage as the percentage of water decreases.

Severe salinity stress resulted in the shortening of shelf life. The 1% salt concentration in the irrigation water reduced the mean weight loss of fruit at the end of the storage period (22.7 vs. 28.6% in the 0.125% salt treatment), but earlier and more pronounced tissue browning was registered. Weight loss (figure 2), as % of initial weight, was slow during the first 3 days and over the last 12-21 days in the 1%

treatment compared with the control and significant differences between slopes of 1% treatment and others were registered during the first 3 days (table 5). These different dehydration rates could be explained by differential water transfer between fruit and the storage atmosphere, which depends on the free water content of the samples at start and/or on thickness of fruit pericarp which affects the actual rate of water diffusion (Tsang and Furutani, 1989; King et al., 1989).

5. Conclusions

The incidence of salt stress by reduction of the marketable yield emerges significantly for 0.5 and 1% treatment, indicating a moderate tolerance of eggplant to irrigation with saline water up to an ECw of 4.5 dS m^{-1}. In spite of little variation in the fruit nutritive value in the 1% as compared to the control, the more consistent morphological and structural modifications that occur with increasing salinity could produce changes in consumer requirement. Other parameters of fruit quality (mesocarp firmness, dry matter content, ϵ and σ), which indicate a better from-harvest-to-sale fruit resistance to handling after the 1% treatment, suggest a positive effect of saline irrigation.

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Table 1 - Quality parameters of eggplant fruit (means followed by the same letters are not significantly different at P=0.05). MY, marketable yield; MFW, marketable fruit weight; L, length; D, diameter; MF, mesocarp firmness; SG, specific gravity.

Salt concentrations (%)	MY ($t\ ha^{-1}$)	MFW (g)	L (cm)	D (cm)	L/D	MF (N)	DM (%)	SG ($g\ cm^{-3}$)
0	43.9a	165b	14.6a	5.2a	2.8a	24.7bc	9.1a	0.61a
0.125	49.6a	170a	14.5a	5.3a	2.8a	23.9c	9.5b	0.62a
0.25	44.1a	161b	13.9b	5.2a	2.6b	25.6ab	9.4b	0.62a
0.5	32.8b	153c	13.0c	5.3a	2.4c	25.1ab	9.7b	0.63a
1	19.1c	142d	11.7d	5.4a	2.2d	26.0a	10.1c	0.62a
Irrigation intervals (days)								
2	37.5a	157a	13.3a	5.3a	2.5a	25.8a	9.7a	0.62a
5	38.0a	156a	13.4a	5.3a	2.6a	25.0ab	9.6a	0.62a
10	38.4a	160a	13.9b	5.3a	2.6a	24.0b	9.3b	0.63a

Table 2 - Chemical composition of fruits from 0 and 1% of salt (on a fresh weight basis).

	Salt concentrations (%)	
	0	1
pH	5.48a	5.21b
Titratable acidity (% malic acid)	0.18a	0.21b
Lipids (%)	0.31a	0.30a
Reducing sugars (%)	1.21a	1.23a
Ashes (%)	0.50a	0.55b
Starch (%)	1.50a	1.49a
Total polyphenols (mg/100 g gallic acid)	68.0a	66.6b
Ascorbic acid (mg/100 g)	7.0a	6.3b

Table 4 - Results of the compression tests: σ (N) stress at yield; ϵ (%) train at yield. (Mean ± standard deviation).

Salt concentrations (%)	(N)		(%)	
0	104.15±3.75		55.43±6.51	
1	6.9±0.92	7.8±0.14 (*)	59.52±2.44	75.76±4.61 (*)

(*) data measured at the beginning and at the end of the harvest period.

Table 5 - Linear responses of changes in fruit weight vs. storage time (*y=a+bx*, where *y* represents the changes in fruit weight as % of initial weight, and *x* stands for the days of storage) and comparisons of the slopes of the 1% salt treatment vs. the other salt treatments (*, slope difference significant at P=0.05; n.s., not significant).

Salt concentrations	0-3 days		3-12 days		12-21 days	
	a	*b*	*a*	*b*	*a*	*b*
1(%)	100	-2.39	94.69	-0.87	93.59	-0.75
Others	100	-2.83	93.31	-0.74	96.64	-0.98
		*		n.s.		n.s.

Table 3 - Mineral composition (mmol g^{-1} dry weight), total nitrogen concentration (%, dry weight basis) and nitrates (ppm) (average of the 2 harvest dates) as influenced by saline treatments (0, 0.5 and 1%) and irrigation frequencies.

Salt concentrations (%)	Na^+	K^+	Mg^{2+}	Ca^{2+}	K^+/Na^+	Cl^-	PO_4^{3-}	SO_4^{2-}	NO_3^-	Total N
0	0.200a	1.054a	0.066a	0.042a	5.270a	0.130a	0.004a	0.048a	3.24a	2.30a
0.5	0.235b	1.138b	0.070a	0.040a	4.842b	0.149b	0.004a	0.039b	4.39b	2.51b
1	0.261c	1.117c	0.070a	0.032b	4.280c	0.161c	0.005a	0.035c	4.12b	2.69c
Irrigation intervals (days)										
2	0.230a	1.117a	0.074a	0.037a	4.856a	0.166b	0.005a	0.037a	4.54a	2.47a
5	0.217a	1.087a	0.062a	0.037a	5.009ab	0.113a	0.004a	0.049b	3.96b	2.63b
10	0.252a	1.110a	0.070a	0.040a	4.405a	0.144a	0.004a	0.037a	4.54a	2.33a

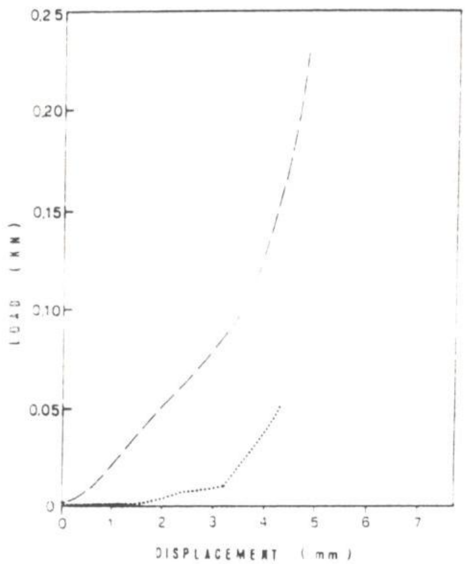

Figure 1 - Force/Deformation curves for 0 (——) and 1% (....) salt treatments.

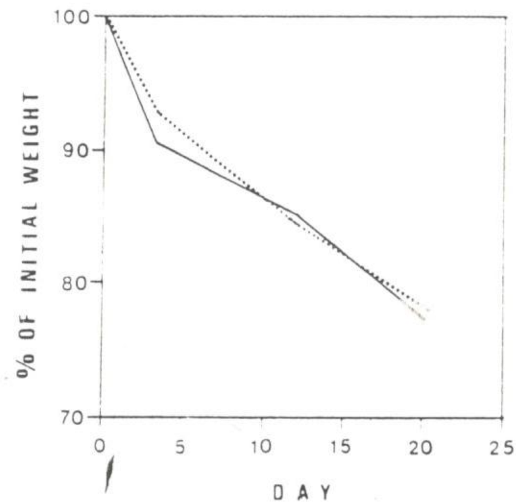

Figure 2 - Changes in fruit weight (% of initial weight) for 1% (....) and the other (——) salt treatments.