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Effect of different irrigation water salinities on some yield and quality components of two field-grown *Cucurbit species*

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Abstract: Using irrigation water with a salinity level of 0.8, 2, and 5 g L^{-1}, the impact of saline water irrigation on the yield and quality of 2 Chinese Cucurbit species, melon (Cucumis melo cv. Huanghe) and watermelon (Citrullus lanatus. convar megulaspemus) were studied in Minqin Oasis, northwestern China. Our results show that melon yields decreased as water salinity increased, just as concentrations of glutamic acid content rose, although the concentration of most amino acids did not differ significantly. In contrast, watermelon yields decreased significantly as water salinity rose, and fruit number, fruit firmness, fruit crude protein, and essential amino acid (EAA) levels of the watermelon showed a significant increase as water salinity rose. Salt stress on both Cucurbit species resulted in an increase in total soluble solids (TSS) and Na^+ concentrations, while Ca^{2+} and Cl^- concentrations were not affected significantly. In conclusion, our results showed that, although melon and watermelon yields were restrained by saline water irrigation, fruit quality was not influenced, such as for the fruit's amino acids. The fact that saline water irrigation is feasible for melon and watermelon species shows that saline water is a potential irrigation water resource in arid areas of northwest China.

Key words: Melon, watermelon, saline water, fruit quality

Introduction

Irrigation with saline water has some effects on the growth, production and quality of crop plants throughout the world (Mizrahp and Pasternak 1985). In northwest China, salinity levels in the groundwater are a concern (Ma et al. 2005) and in some areas this salinity has already reached levels that can negatively affect horticultural crops. The question of the quality of agricultural products irrigated with saline water is crucial for the future of local agriculture development and farmers' incomes. Melons are major economic fruits in the arid areas of northwest China. Salinity has to be managed to ensure that yield and quality are maintained, while minimizing the proportion

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of nutrient solution discharged. To achieve this, detailed knowledge of a crop's response to salinity is required. Based on this issue, the present experiment was designed to use saline water for the irrigation of 2 *Cucurbit* species and to examine its effects on yield and fruit quality.

Melon salinity tolerance has been studied by several researchers (Shannon and Francois 1978; Meiri et al. 1981; Mangal et al. 1988; Mendlinger and Pasternak 1992a, 1992b; Shani and Dudley 2001). The results showed that melons can moderately tolerate water salinity, and that soluble solid content rose as water salinity increased. However, fruit size and yield were reduced by saline water (Shannon and Francois 1978). Some attempts have been made to develop appropriate management practices for saline water irrigation, so as to minimize fruit yield losses and maintain soluble solid content (Botía et al. 2005). Sato et al. (2006) suggested that the evaluation of tomato fruit quality should include the analysis of individual sugars, amino acids, and other chemicals, rather than just the Brix measurement. Several studies have been conducted to determine the concentration of bioactive compounds of tomato fruits under saline water irrigation (Cramer et al. 2001; Maggio et al. 2004; Yurtseven et al. 2005). However, only a few researchers have paid attention to the nutritional value of melon fruit in respect to salinity, such as protein, neutral detergent fiber (NDF), titratable acidity, and free amino acid (FAA) contents, although changes in the amino acid content have been shown to be correlated with the nutritional value and taste of other fruits (Awang and Atherton 1995; Cramer et al. 2001; Yurtseven et al. 2005; Keutgen and Pawelzik 2007, 2008a, 2008b). To the best of our knowledge, the effect of saline irrigation on the quality of melon (*Cucumis melo cv. Huanghe*) and watermelon (*Citrullus lanatus. convar megulaspemus*) fruit has not been previously reported.

The aim of the work was to assess the effects of increasing salinity on fruit yield, yield components, several quality parameters, and the economic value of the yield of a melon and a watermelon species from the northwest of China.

Materials and methods

Description of the experimental site and meteorological trends

The research was carried out at the Xuebai Experimental Station in Minqin (Gansu province, latitude 38°35′N, longitude 103°03′E, altitude 1340 m) with a sandy silt soil. The research area is a typical continental temperate arid zone, with a mean annual precipitation of 110 mm (mainly concentrated from July to September), a mean annual evaporation from a free water surface of 2644 mm, and an annual accumulated temperature (higher than 10 °C) of more than 3148 °C.

Crop information

Two *Cucurbit* species, a melon (cv Huanghe melon-3) and watermelon (cv Seed melon-1), were used as experimental materials. The experimental area was ploughed on April 27 and salt from the root zone was leached by irrigating with 1500 m^3 ha^{-1} of fresh water according to the Rhoades equation to calculate the leaching requirement:

LR = ECw/5 ECe – ECw

where LR = the minimum leaching requirement needed to control salts within the tolerance (ECe) of the crop with ordinary surface methods of irrigation

ECw = salinity of the applied irrigation water in mS cm^{-1}

ECe = average soil salinity tolerated by the crop as measured on a soil saturation extract.

The area was divided into 2 plots. One was for melons with 1.3 m bed width, and the other for watermelons with 1.2 m bed width. The beds were mulched by 0.012 mm-thick PVC. Two rows of plants 100 cm apart and 40 cm in between the plants were set over the bed in the melons and 90 cm between the rows and 25 cm in between the plants in the case of the watermelons. The melons and watermelons were sown on May 6, 2007. Furrow irrigation was applied after sowing. The harvest time of the melons was August 20, 2007, and for the watermelon crop it was on September 3, 2007. Urea was provided as a nitrogen source after irrigation at flowering (150 kg ha^{-1}) and at fruit setting (90 kg ha^{-1}).

Saline water irrigation

Three levels of salinity were used in this experiment: 0.8 g L^{-1} (C) with an electrical conductivity (EC) of 1.17 mS cm^{-1}; 2 g L^{-1} (S1) with an EC of 2.41 mS cm^{-1}; and 5 g L^{-1} (S2) with an EC of 6.12 mS cm^{-1}. The salinity of 0.8 g L^{-1} is the natural groundwater salinity at Minqin station, and it was used as the control (C). The salinities of 2 g L^{-1} (S1) and 5 g L^{-1} (S2) were used according to the groundwater salinity of other areas in Minqin county. The ionic compositions of the 3 groundwater samples, collected in April 2007, are presented in Table 1. The naturally ionic water composition was used as a reference to produce irrigation water of different salinity levels (2 g L^{-1}, 5 g L^{-1}) for the experiment through the addition of chemical compounds, $CaCl_2$, $MgCl_2$, Na_2SO_4, $NaHCO_3$, and $NaNO_3$ to local groundwater (0.8 g L^{-1}) in molar proportions of 1:1.8:1:0.2:0.2:2.5 (2 g L^{-1}) and 5:6:14.7:1:10.7 (5 g L^{-1}), respectively. In S2 salinity treatment, another 4.27 mmol L^{-1} of $MgSO_4$ was added.

Saline water irrigation at different salinity levels began 35 days after sowing. The aims of the agronomic aspects of the experiment will be evaluated via the post-delivery correspondence between the irrigation volumes applied, the water retained by the soil and water consumption in relation to ET_0. Irrigation was applied at 35 days, 54 days, 69 days, 83 days, and 100 days after sowing at the following volumes: 510 m^3 ha^{-1}, 390 m^3 ha^{-1}, 390 m^3 ha^{-1}, 338 m^3 ha^{-1}, and 338 m^3 ha^{-1}.

The experiment utilized a randomized block design with 4 replicates. The plot size was of 100 m^2 (10 m × 10 m). An area of 25 m^2 was used to measure the yields at harvest.

Physical and chemical analysis of the fruit

The fruits were harvested at the optimum ripening stage. The number of fruit and the weight of each fruit were determined to evaluate mean fruit weight and total crop yield. Ten fruits were selected from each treatment in the harvest period to measure fruit shape index (FSI), flesh hardness, total soluble solids (TSS), and fruit seeds. The equatorial and longitudinal diameters of the fruit were measured and their ratio was defined by the FSI. The fruit were split with a knife along the equatorial diameter to measure flesh hardness with a penetrometer (Fruit Pressure Tester FT-327) in the middle of the flesh and TSS with a digital refractometer (Atago) and expressed as °Brix. The fresh seeds of the fruit were weighed. Extracted juice from the fruit was placed in small bottles and immediately frozen at –20 °C in a refrigerator for further analysis. Another 3 fruit were selected randomly from each treatment plot and weighed before and after drying in an oven at 65 °C, until they reached constant weight, to determine fruit water content. The dried fruit material was milled to a fine powder and retained for ion analysis.

The dried plant tissues were rinsed in a solution of HNO_3:$HClO_4$ (2:1, v/v), and the concentrations of Na^+, K^+, Ca^{2+}, and Mg^{2+} were determined by atomic absorption spectrometry (PerkinElmer 5500). The solid plant material was extracted with 0.1 N HNO_3 in 10% acetic acid (v/v) to determine Cl^- content in the extracts by Buchler-Cotlove chloridometer.

The juice was used to analyze the titratable acids (TA), crude protein, neutral detergent fiber (NDF), FAA and essential amino acids (EAA), and carbohydrates. TA, protein and carbohydrate content were determined according to AOAC (1990).

Table 1. Ionic composition of the local groundwater present in the study area and artificially reproduced at the experimental station according to the local groundwater. C is the fresh water at 0.8 g L^{-1}; S1 = 2 g L^{-1} and S2 = 5 g L^{-1}.

Irrigation water	Ion content (mg L^{-1})									ECw (mS cm^{-1})
	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}	Ca^{2+}	Mg^{2+}	NO_3^-	K^+	Na^+	
C	119.9	224.5	296.2	0	86.9	44.2	19.02	4.65	52.4	1.17
S1	322.7	738.5	307.0	14	125.9	191.7	0	0	228.6	2.41
S2	890.0	1640.0	360.0	0	280.0	190.0	0	0	1000.0	6.12

The NDF of the solids in the juice samples was determined according to Van Soest et al. (1991). The defatted samples were hydrolyzed in 10 mL 6 M HCl at 110 °C for 24 h under constant flowing nitrogen. The cooled and filtered hydrolyzate was then dried in a vacuum desiccator at 45 °C and re-dissolved in citrate buffer (pH 2.2). Aliquots of the solution were injected directly into a Sycom S-433 D automatic amino acid analyzer (Sykam, Eresing, Germany) to determine FAA and EAA content. Because of the small quantity of the melon sample, FAA and EAA analyses for the S1 samples were not done.

Statistical analysis

Data were analyzed with the SPSS 13.0 statistical program (SPSS Inc.). Analysis of variance (ANOVA) was performed to determine treatment effects. When significant treatment effects ($P < 0.05$) were found, the treatment means were separated by the least significant difference (LSD) test. Correlation and multiple regression procedures between normally distributed quality parameters were performed using Pearson-correlation coefficients.

Results

The fruit yield and some key quality parameters of both crops grown under different water salinities are shown in Tables 2 and 3. Irrigation at the S2 salinity level produced a significant decrease in yield (27% in melon and 52% in watermelon). No significant differences of mean fruit weight in both crops (melon and watermelon) were observed among the C, S1 and S2 treatments ($P > 0.05$). The application of saline water resulted in a significant decrease in fruit number of 19.55% and 27.69% in the melon and watermelon crops, respectively, at 5 g L^{-1} salinity.

The melon and watermelon crops varied significantly in their response to salt stress. The water content of melon pulp was significantly reduced by irrigation salinity in S2 when compared to S1 ($P < 0.05$). There was no significant difference in pulp water content among the treatments in the watermelon crop ($P > 0.05$). The 3 saline water treatments did not significantly differ in fruit firmness and fresh seed weight per fruit in the melon crop ($P > 0.05$). Fruit firmness in the watermelon crop at the S1 salinity level was significantly reduced compared with the control ($P < 0.05$), but no significant difference was found between the S2 and C treatments ($P > 0.05$). The high salinity of irrigation water significantly reduced fresh seed weight per fruit in the watermelons (5 g L^{-1} vs. 0.8 g L^{-1}) ($P < 0.05$). The shape index for melon fruit in the S1 treatment was significantly lower than the C treatment ($P < 0.05$). However, no significant difference was found in the watermelon shape index under the 3 treatments ($P > 0.05$). Saline water irrigation had no significant effect on the 100 fresh seed weight of either *Cucurbit* species ($P > 0.05$).

There was no effect from the treatment on the TA content in the melons, but irrigation with saline water at both concentrations (S1 and S2) in the watermelon group increased TA content. With increasing salinity TSS rose about 10.59% and 18.59% in the melons and about 27.13% and 42.68% in the watermelons under the S1 and S2 treatments, respectively. A comparison of TSS data and carbohydrate content revealed that for the control watermelons the TSS consisted of 50.3% total soluble carbohydrates. With increasing levels of salt stress, the relative contents of soluble carbohydrates increased to 3.64% and 12.73% for S1 and S2, respectively. In the control melons, the percentage of soluble carbohydrates in TSS was more than in the watermelons (57.53%), but in contrast to this cultivar the stepwise increase of salinity soluble carbohydrates did not change. Salt stress caused an increase of crude protein content in both *Cucurbit* species, which was more pronounced in the watermelon. The content was up to 40% higher than that in the control fruit for the watermelon crop, while it was up to 27.8% in the melon crop. Salinity had no effect on the neutral detergent fiber content of the watermelon fruit, but it was 8.55% lower (S2) for the melon fruit.

The Na^+, Cl^-, and Ca^{2+} concentrations in the fruit of the 2 *Cucurbit* species under different saline water irrigation treatments are shown in Figure 1. The Na^+ concentration of the melons and watermelons in S2 was significantly higher than in C and S1 ($P < 0.05$). As irrigation water salinity rose, the Cl^- concentration of the 2 *Cucurbit* species showed a decreasing trend, but it was not significant in statistical analysis terms ($P > 0.05$). There were also no significant differences in Ca^{2+} for the *Cucurbit* species in the S1, S2, and C groups ($P > 0.05$).

Table 2. Effect of water salinity on yield and on some quality parameters of melon fruit (mean±S.E.) .

Tre.	Fruit yield	Mean fruit weight	Fruit number	Water content of pulp	Firmness	Shape index	Seed amount	100 seed weight	TA	TSS	Carbohydrates	Crude protein	NDF
	(t ha^{-1})	(kg)	(×10^{3} ha^{-1})	(%)	(N cm^{-2})		(g fruit^{-1})	(g)	(% FM)	°brix	(% FM)	(% FM)	(% FM)
C	39.0 ± 1.5 a	2.49 ± 0.08	22.0 ± 2.30 a	91.66 ± 0.52 a	24.97 ± 0.49	0.94 ± 0.02 a	21.8 ± 1.25	3.9 ± 0.35	0.15 ± 0.01	9.6 ± 0.65 b	5.5 ± 0.37	0.58 ± 0.03 b	0.234 ± 0.004 a
S1	37.3 ± 0.4 a	2.17 ± 0.15	24.5 ± 0.21 a	90.09 ± 0.45 ab	24.65 ± 0.37	0.84 ± 0.03 b	23.7 ± 1.04	3.6 ± 0.22	0.13 ± 0.02	10.7 ± 0.40 ab	5.2 ± 0.88	0.73 ± 0.02 a	0.229 ± 0.003 a
S2	28.5 ± 1.7 b	2.29 ± 0.12	17.7 ± 1.43 b	89.63 ± 0.67 b	24.69 ± 0.26	0.89 ± 0.02 ab	24.8 ± 1.36	3.6 ± 0.19	0.17 ± 0.03	11.4 ± 0.45 a	6.4 ± 0.82	0.74 ± 0.06 a	0.214 ± 0.003b

values followed by the same letter within a row are not significantly different at the 5% level of probability according to Duncan's test (FM = fresh mass, TA = titratable acids, TSS = total soluble solids, NDF = neutral detergent fiber).

Table 3. Effect of water salinity on yield and on some quality parameters of watermelon fruit (mean±S.E.)

Tre.	Fruit yield	Mean fruit weight	Fruit number	Water content of pulp	Firmness	Shape index	Seed amount	100 seed weight	TA	TSS	Carbohydrates	Crude protein	NDF
	(t ha^{-1})	(kg)	(×10^{3} ha^{-1})	(%)	(N cm^{-2})		(g fruit^{-1})	(g)	(% FM)	°brix	(% FM)	(% FM)	(% FM)
C	26.0 ± 3.4 a	1.1 ± 0.06	31.0 ± 1.9 a	96.4 ± 0.81	21.0 ± 0.06 a	1.00 ± 0.01	80.2 ± 4.4 a	61.9 ± 1.3	0.090 ± 0.003 b	3.28 ± 0.28 b	1.65 ± 0.01	0.42 ± 0.01 b	0.099 ± 0.001
S1	21.1 ± 4.5 ab	1.2 ± 0.08	29.2 ± 1.1 a	95.8 ± 0.59	20.4 ± 0.08 b	1.01 ± 0.01	69.4 ± 4.1 ab	61.3 ± 1.8	0.115 ± 0.01 a	4.17 ± 0.22 a	1.71 ± 0.01	0.55 ± 0.06 a	0.093 ± 0.02
S2	12.6 ± 1.2 b	1.1 ± 0.09	22.4 ± 1.5 b	95.6 ± 0.36	20.9 ± 0.09 ab	1.04 ± 0.01	67.2 ± 3.5 b	61.2 ± 2.1	0.120 ± 0.001 a	4.68 ± 0.17 a	1.86 ± 0.02	0.59 ± 0.03 a	0.090 ± 0.001

values followed by the same letter within a row are not significantly different at the 5% level of probability according to Duncan's test (FM = fresh mass, TA = titratable acids, TSS = total soluble solids, NDF = neutral detergent fiber).

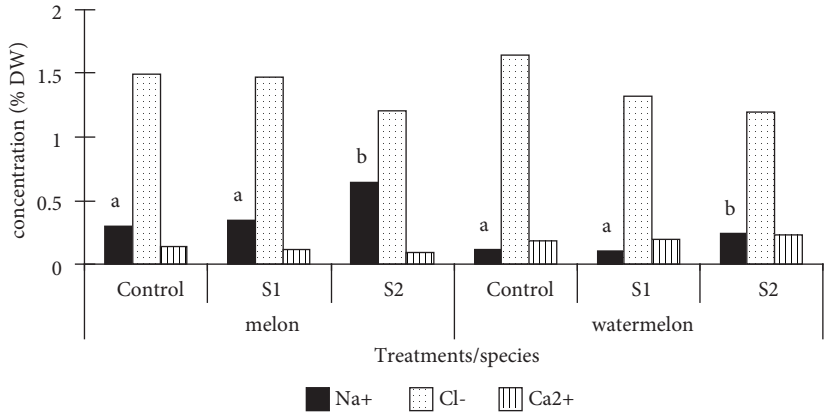

Figure 1. Effects of saline irrigation water on Ca^{2+}; Na^{+} and Cl^{-} concentrations in melon and watermelon fruit. (Bars identified with the same letters are not significantly different at the P = 0.05 level). C = control; S1 = treatment irrigated with saline water at 2 g L^{-1}; S2 = treatment irrigated with saline water at 5 g L^{-1}.

The amino acid profiles of the 2 crops are shown in Tables 4 and 5. Generally, salt stress caused an increase in amino acid content in both *Cucurbit* species, which was more pronounced in the watermelons. In this fruit, increases of 48.2% (S2) and 64.8% (S1) in amino acid content compared to the control fruit were observed. EAA content improved significantly (by 42%) in the watermelons at 2 g L^{-1} saline water, while in the melons it remained fairly stable. Differences in response to salinity levels between the 2 *Cucurbit* species were detected for single amino acid contents. There were no significant differences for single amino acid contents in the melons under S2 saline water irrigation treatment compared with the control group ($P > 0.05$) except for glutamic acid (Glu) (Table 4). The contents of free Glu in the fruit rose as salt stress increased in both *Cucurbits*; Glu content increased by over 49% in the melons, and by about 93% in the watermelons. Free proline (Pro) content in the fruit also rose as salt stress increased in both *Cucurbit* species, but this increase was significant only in the watermelon, where Pro content was about twice as high in S1 compared to the control fruit. Most single amino acid contents distinctly increased as salinity rose in the watermelons, except for levels of Trp, Ala, Gly, and His, which remained fairly constant.

Discussion

Under saline irrigation, the total yield of the *Cucurbit* species (melon and watermelon) decreased with increasing salinity (Tables 2 and 3). Mendlinger (1994) and Mavrogianopoulos et al. (1999) found that saline water irrigation caused a reduction in the total yield of 2 *Cucumis melo* cultivars (Galia and Parnon), decreased mean fruit weight, but not fruit number. However, in this experiment, mean fruit weight was not reduced by salinity, while the S2 treatment reduced the number of fruit in both *Cucurbit* species, probably by aborting flowers and/or fruits, as suggested by Del Amor et al. (1999). Similar results have been reported for other melon cultivars, including Galia and Amarillo Oro, by Botía et al. (2005). However, in S1 the number of fruit was unaffected and no yield reduction was obtained. Depending on cultural conditions, the mean fruit weight (Mendlinger and Fossen 1993; Mendlinger 1994) or both the mean fruit weight and the number of fruit (Meiri et al. 1982; Del Amor et al. 1999; Navarro et al. 1999) can be the first indication of reduced yields caused by salinity. Mavrogianopoulos et al. (1999) found that, at moderate salinity, fruit size was the first indicator of reduced yield, while at higher salinity levels the number of fruit also decreased.

In the present experiment, saline irrigation treatments led to a delay in firmness in the watermelon

Table 4. Amino acid composition (mg 100 mL^{-1}) of melon juice (mean±S.E.).

Amino acid	Treatments		*P*
	C	S2	
Sum of amino acid	530.65 ± 4.63	582.85 ± 5.14	*
Sum of essential amino acid	100.03 ± 3.15	100.85 ± 4.35	ns
Threonine (Thr)	16.30 ± 1.10	15.60 ± 0.40	ns
Valine (Val)	20.20 ± 1.40	19.65 ± 7.35	ns
Methonine (Met)	2.85 ± 0.85	3.30 ± 1.10	ns
Isoleucine (Iso)	9.10 ± 1.90	11.65 ± 0.55	ns
Leucine (Leu)	17.05 ± 0.85	16.90 ± 0.10	ns
Phenylalanine (Phe)	9.30 ± 0.40	8.75 ± 0.15	ns
Lysine (Lys)	19.60 ± 0.90	19.05 ± 0.15	ns
Tryptophane (Trp)	5.85 ± 0.45	5.85 ± 0.05	ns
Aspartic acid (Asp)	100.40 ± 10.50	104.85 ± 8.15	ns
Serine (Ser)	32.90 ± 2.80	31.95 ± 1.25	ns
Glutamic acid (Glu)	107.60 ± 7.40	160.55 ± 0.95	*
Glycine (Gly)	24.70 ± 1.60	23.20 ± 0.15	ns
Alanine (Ala)	117.65 ± 5.05	109.25 ± 5.75	ns
Histidine (His)	10.95 ± 0.05	11.35 ± 0.35	ns
Arginine (Arg)	13.80 ± 0.80	18.35 ± 0.75	ns
Proline (Pro)	12.95 ± 0.75	14.20 ± 0.40	ns
Cystine (Cys)	5.35 ± 0.75	5.90 ± 0.10	ns
Tyrosine (Tyr)	3.90 ± 0.30	3.40 + 0.004	ns

ns, no signification difference between means ($P > 0.05$); * significant at the 5% level.
The essential amino acids are shown in italics.

crop, although there was no effect on the melons. Botía et al. (2005) found that fruit firmness was increased for Amarillo Oro, but for Galia it decreased significantly after salinity irrigation. Although the total fresh seed weight of the melons per fruit and per 100 seeds was not affected by salinity treatments, there were significant positive correlations between fresh seed weight per watermelon fruit and irrigated saline water treatments ($P < 0.05$) (Table 3).

Saline water irrigation influenced some fruit quality parameters (e.g. TA and TSS protein, NDF, EAA, and carbohydrate). Salinity improved fruit quality by increasing TSS and TA concentrations. This agrees with the results found in other studies (Mendlinger 1994; Del Amor et al. 1999; Navarro et al. 1999; Botía et al. 2005). TSS increased with rising salinity (Tables 2 and 3). TA content increased in the watermelons for all salinity treatments with respect to

Table 5. Amino acid composition (mg 100 mL^{-1}) of watermelon juice (mean±S.E.).

Amino acid	Treatments		
	Control	S1	S2
Sum of amino acid	133.7 ± 4.27 b	220.4 ± 4.15 a	198.2 ± 6.34 a
Sum of essential amino acid	41.16 ± 0.4 b	58.45 ± 3.55 a	50.30 ± 2.20 ab
Threonine (Thr)	3.45 ± 0.15 b	6.55 ± 0.95 a	4.95 ± 0.25 ab
Valine (Val)	8.30 ± 0.20 b	11.95 ± 0.25 a	10.30 ± 0.70 ab
Methonine (Met)	1.80 + 0.002 b	2.35 ± 0.05 ab	2.60 ± 0.30 a
Isoleucine (Iso)	4.90 ± 0.20 b	7.30 ± 0.50 a	6.20 ± 0.70 ab
Leucine (Leu)	7.25 ± 0.15 b	10.35 ± 1.05 a	9.25 ± 0.75 a
Phenylalanine (Phe)	3.65 ± 0.15 b	5.80 ± 0.20 a	5.10 ± 0.60 a
Lysine (Lys)	7.90 ± 0.40 b	10.15 ± 1.15 a	8.60 ± 0.40 ab
Tryptophane (Trp)	3.85 ± 0.35 a	3.90 ± 0.10	3.10 ± 1.00
Aspartic acid (Asp)	9.05 ± 0.45 b	18.15 ± 2.75 a	15.55 ± 1.55 a
Serine (Ser)	12 ± 5.50 b	21.10 ± 4.8 a	24.60 ± 6.4 a
Glutamic acid (Glu)	24.05 ± 1.45 b	46.45 ± 4.05 a	41.15 ± 6.15 a
Glycine (Gly)	7.65 ± 1.25	7.30 ± 0.80	6.65 ± 0.55
Alanine (Ala)	5.30 ± 1.00	8.70 ± 1.10	7.65 ± 0.55
Histidine (His)	2.55 ± 0.05	3.15 ± 0.25	2.80 ± 0.20
Arginine (Arg)	3.65 ± 0.05 b	6.10 ± 0.20 a	5.30 ± 0.40 a
Proline (Pro)	18.65 ± 2.35 b	37 ± 3.10 a	32 ± 2.90 a
Cystine (Cys)	4.80 ± 0.30 b	6.90 ± 0.30 a	6.25 ± 0.55 a
Tyrosine (Tyr)	4.40 ± 0.10 b	7.25 ± 1.75 a	5.95 ± 0.55 a

Different letters within each row mean significant differences ($P < 0.05$). The essential amino acids are shown in italics.

the control. Species such as the tomato (Cramer et al. 2001) and strawberry (Keutgen and Pawelzik 2007) have also been reported to exhibit increased TSS content at higher salinity levels. This accumulation of sugars and other organic compounds in various compartments are an important plant strategy to cope with the osmotic challenges posed by drought or salt stresses (Serrano et al. 1999; Zhu 2001).

Cl^- showed a higher concentration compared with other ions, and the concentration of Cl^- showed a decreasing trend at increased irrigation water salinity levels. This phenomenon was also found by Keutgen and Pawelzik (2007, 2008a) to occur in strawberry fruit. In both *Cucurbit* species grown under long-term saline irrigation, the Na^+ accumulation of salt was higher than in the control treatment (Figure

1), although the concentration was lower in the watermelon ($P < 0.05$). The accumulation of Na^+ and/or Cl^- is a major cause of the detrimental effect of salinity, namely reduced growth and ion imbalance. In conclusion, the results of the present study resemble those shown by De Pascale et al. (2005) that plants delay the accumulation of toxic ions in reproductive organs such as fruit. In addition, studies indicate that an increase in Ca^{2+} concentration in melon plants challenged with salinity stress could ameliorate the inhibitory effects of salinity on growth (Carvajal et al. 2000; Navarro et al. 2000; Kaya et al. 2003). Our results showed that fruit Ca^{2+} was unaffected by salinity. This agrees with data reported by Walker et al. (1980) for Capsicum fruit under different NaCl treatments. The different behavior between the fruit, leaves and stems in melons could be explained by the ability of different tissues to compartmentalize ions, which results in an effective dilution of the salt (Yeo 1983).

The amino acid profile in the melons (Table 4) was dominated by Glu (107.6-160.55 mg 100 mL^{-1}) and Ala (117.65-109.25 mg 100 mL^{-1}). The other important amino acid was Asp (100.4-104.85 mg 100 mL^{-1}). While the watermelons (Table 5) were rich in Glu (24.05- 46.45 mg 100 mL^{-1}), and Arg (3.65-6.1 mg 100 mL^{-1}), EAA were rich in Val (8.3-11.95 mg 100 mL^{-1}), Lys (7.9-10.15 mg 100 mL^{-1}), and Leu (7.25-10.35 mg 100 mL^{-1}). Total FAAs play an important role in maintaining the osmotic balance in plant tissue (Zushi et al. 2005). FAAs participate in several metabolic processes involved in salinity stress response, like turnover, synthesis and the incorporation of N into proteins, or in the accumulation of Pro (Ashraf and Harris 2004). In the present experiment, elevated levels of FAA, as well as of protein, were found in both *Cucurbit* species. Sato et al. (2006) regarded that the increase of FAA could represent an active physiological response to cope with drought or salt stress. In order to relate the modification of amino acid pools of *Cucurbit* fruit grown under saline conditions to nutritional quality, EAA were further investigated. Higher amounts of EAA were found in the watermelons at 2 g L^{-1}, while in the melons the increased tendency was less distinct.

One of the main roles of Pro accumulation is to adjust plant water potential to cope with the difficulty of water availability and transport under stress (Hare et al. 1999). It is, however, important to note that Pro accumulates under various stress conditions, for example drought, temperature and starvation, while in many salt-stressed plants its level decreases or remains more or less constant (Yamaya and Matsumoto 1989). Keutgen and Pawelzik (2008b) observed an increase of Pro in 2 strawberry cvs (Korona and Elsanta) under salinity stress. Sato et al. (2006), consider that Pro does not need to accumulate much more in tomato fruit under salt treatment because the contents of other soluble solids were already high and some increased significantly after the treatment. In this experiment the results showed that concentrations of Pro in watermelon and melon were increased under salt treatment. However the concentration of Pro in melon showed no significant effect with saline water irrigation. Thus, it is difficult to prescribe the precise role of Pro as an osmotic regulator (Sato et al. 2006; Keutgen and Pawelzik 2008b).

Also worthy of note is that Asn and Gln were not detected during TAA analyses. These amino acids were probably converted to Asp and Glu during sample preparation.

Amides accumulate in salinity stressed plants (Mansour 2000). Nevertheless, the concentrations of Asn may rise in response to salt stress and even to higher levels than those of Pro (Sato et al. 2006). In the present experiment with *Cucurbit* species, in the case of the watermelon fruit, Asp levels rose more than 100% at S1 compared to the control fruit. In addition to Asp, the concentrations of the other amides (Glu or Gln) may be elevated under salt stress. For example, an accumulation of Gln has been reported in strawberry fruit (Keutgen and Pawelzik 2008b) and in the roots and leaf blades of barley (Yamaya and Matsumoto 1989). In *Cucurbit* species salt stress led to a considerable increase in Glu, especially in the watermelon. This sharp increase occurred already at a moderate salt stress level, though additional increases in salinity did not result in a further rise of fruit Glu content.

The study revealed that salt stress-induced changes of the amino acids pool is a significant response of melon to salinity levels, because they reflect the impairment of the plant metabolism and

the investment of nitrogen into stress-related proteins and enzymes (Keutgen and Pawelzik 2008b). The accumulation of nitrogen compounds in melon fruit presumably is a protective response to salt stress. The enrichment in essential amino acids may be rated as an advantage for human nutrition. However, this enrichment is accompanied by a significant degradation in fruit yield. From an economic point of view, reduced yield under salinity stress can be at least partly compensated for by improved fruit quality, as indicated by the higher concentrations of antioxidants and soluble solids. Further investigation into this phenomenon is needed in the future.

Conclusion

In the scarce water conditions found in these regions, saline water utilization (brackish water with a salt content ranging from 2 to 5 g L^{-1}) offers a potential new perspective for local agricultural development. Although saline water irrigation cannot provide for high crop production, the nutritional value and quality of the fruit are highly improved. This will provide a major level of support for local economic development. Therefore, the use of saline water for irrigation can be introduced even if further studies are needed to confirm the preliminary results obtained. However, the long-term effects of saline water irrigation on crop yield and soil characteristics need to be further evaluated to ensure the sustainability of the system.

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