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Salt Tolerance of Muskmelons as Affected by Various Salinities in Nutrient Solution Culture[1]

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Summary

Muskmelons (*Cucumis melo* L.) were grown in nutrient solution to determine the salt tolerance as affected by salinization of sea water (−2.20 and −4.20 bars), NaCl and Na_2SO_4 (−2.20, −3.20 and −4.20 bars), and $MgCl_2$ and $MgSO_4$ (−1.20, −1.70 and −2.20 bars) compared with a control of −0.70 bars of base nutrient solution. Fruit fresh weight and whole plant dry weight were greatest in the control and tended to decrease in each salinity with decreasing osmotic potential of treatment solutions. At −2.20 bars fruit fresh weight was 89.9, 94.5, 81.3, 67.8 and 13.9% compared with the control in the sea water, NaCl, Na_2SO_4, $MgCl_2$ and $MgSO_4$ series, respectively. Growth was much greater in the sodium- than magnesium-salinity and, to a less extent, in the chloride- than in the sulfate-salinity. Fruit taste varied with the salt added to the base nutrient solution. Visible salt injury was proportional to the growth reduction. No plants died at −2.20 bars before harvest in the sodium-salinity. Most plants died in the $MgCl_2$ series and all plants died in the $MgSO_4$ series at −2.20 bars before harvest. Addition of single salts or sea water to the base nutrient solution tended to increase the content of the respective added ions in leaves and fruit. Ca and K in leaves were less at −2.20 bars in all salinities than in the control.

Introduction

Salt tolerance of muskmelons (*Cucumis melo* L.) and green soybeans (*Glycine max* Merr.) to various salinities in both sand and soil cultures has been reported(9, 10, 11, 12). Green soybean growth was markedly suppressed in the chloride-salinity compared with sulfate-salinity and some plants died at lower osmotic potential (−2.70 bars). Visible salt injuries also differed with salinities. In muskmelons, growth was greatly reduced in the $MgSO_4$ and Na_2SO_4 series in sand culture and only in the $MgSO_4$ series in soil culture. No differential response to chloride- vs. sulfate-salinities, or sodium- vs. magnesium-salinities was evident in muskmelons. Therefore, the present experiment was conducted to study the growth, salt injury and leaf major elements in muskmelons as affected by various salinities of isosmotic potentials in nutrient solution culture.

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Materials and Methods

Uniform muskmelon seedlings, cv. Earl's Favourite Spring No. 3 in the 3.5 leaf stage were transplanted in Wagner pots (1/2,000 a) filled with 13 liters of base nutrient or treatment solutions, as shown in Table 1, and placed in the greenhouse on May 7, 1979. Plants were topped at the 20th node and allowed to bear only one fruit per plant around the 10th node. Lateral shoots and other flower buds were removed. Five sources of salinity were sea water, NaCl, Na_2SO_4, $MgCl_2$ and $MgSO_4$. Sea water from Shimizu (Miho) was diluted with the base nutrient solution and the others were dissolved in the solution. Osmotic potential of treatment solutions, including −0.70 bars of the base nutrient solution, were −2.20 and −4.20 bars in the sea water series, −2.20, −3.20 and −4.20 bars in the NaCl and Na_2SO_4 series and −1.20, −1.70 and −2.20 bars in the $MgCl_2$ and $MgSO_4$ series. Therefore,

Table 1. Composition of treatment and base nutrient solutions.

Treatment No.	Treatment salinities	π^z (bars)	Added salt concentration	EC (m℧/cm)
1	Base nutr. soln.	−0.70	none	2.43
2	sea water[y]	−2.20	5.7%	5.60
3		−4.20	13.2%	10.04
4	NaCl	−2.20	2,042 mgNaCl/liter	6.19
5		−3.20	3,403	8.62
6		−4.20	4,763	11.15
7	Na_2SO_4	−2.20	3,745 mgNa_2SO_4/liter	6.89
8		−3.20	6,242	9.88
9		−4.20	8,737	12.47
10	$MgCl_2$	−1.20	1,711 mg$MgCl_2\cdot 6H_2O$/liter	3.66
11		−1.70	3,422	5.24
12		−2.20	5,133	7.16
13	$MgSO_4$	−1.20	3,843 mg$MgSO_4\cdot 7H_2O$/liter	3.94
14		−1.70	7,686	5.52
15		−2.20	11,529	7.32

Composition of base nutrient solution

1.	$Na_2HPO_4\cdot 12H_2O$	1 mM	
2.	K_2SO_4	3 mM	
3.	$MgSO_4\cdot 7H_2O$	2 mM	
4.	$Ca(NO_3)_2\cdot 4H_2O$	4 mM	
5.	Fe	1 ppm	(Fe-EDTA)
6.	Zn	0.05 ppm	($ZnSO_4\cdot 7H_2O$)
7.	Cu	0.02 ppm	($CuSO_4\cdot 5H_2O$)
8.	B	0.5 ppm	(H_3BO_3)
9.	Mo	0.05 ppm	($Na_2MoO_4\cdot 2H_2O$)
10.	Mn	0.5 ppm	($MnSO_4$)
	pH≒6.0		

[z] Osmotic potential. The π of treatment solutions includes −0.70 bars of base nutrient solution.

[y] Sea water contains 20,500 ppm Cl, 10,082 ppm Na, 2,632 ppm SO_4, 1,262 ppm Mg, 445 ppm K and 393 ppm Ca.

there were 15 treatments including control (base nutrient solution), as shown in Table 1, with 4 replications. The osmotic potential was chosen to compare the effect of salinities at isosmotic potentials. In a preliminary experiment with $MgSO_4$ all plants died within two weeks at −2.70 and −5.70 bars. Treatment solutions were replaced every two weeks for the first one month and every week thereafter, and aerated continuously. Tap water was added every morning to keep the volume in pots at 13 liters. Observations on visible salt injury were made several times throughout the experiment. At the end of the experiment, leaves, stem, roots and fruit were separated and the fresh and dry weights recorded. The analytical methods were the same as described in a previous paper(8).

Results

Growth and fruit quality (*Table 2, Fig. 1*) At the end of the experiment, plant height, fruit fresh weight, and whole plant, leaf, stem and root dry weights were greatest in the control and tended to decrease with decreasing osmotic potential of treatment solutions in each salinity. At −2.20 bars, in all salinities, growth was much greater in the sodium-salinity than in the magnesium-salinity (Fig. 1). For example, whole plant dry weight and fruit fresh weight were 79.5 and 89.9%, 82.1 and 94.5%, and 72.1 and 81.3% compared with the control in the sea water, NaCl and Na_2SO_4 series, respectively, whereas they were 41.7 and 67.8% in the $MgCl_2$ series, and only 9.6 and 13.9% in the $MgSO_4$ series. In the magnesium-salinity, the $MgSO_4$ series reduced the growth more than the $MgCl_2$ series. In the sodium-salinity, growth at −4.20 bars was more suppressed in the Na_2SO_4 series than in the other series. Whole plant dry weight and fruit fresh weight at −4.20 bars were 51.9 and 69.1%, 38.9 and 55.2%, and 18.3 and 31.0% compared with the control in the sea water, NaCl and Na_2SO_4 series, respectively. Fruit soluble solids in the sodium-salinity were not significantly different from the control, but were higher than those in the magnesium-salinity. This is due to death of the plants in the magnesium-salinity at lower osmotic potential before fruit maturation. Fruit taste varied with the salt added to the

Table 2. Effect of various salinities on growth of muskmelons in nutrient solution culture.

Treatment			Plant height (cm)	Dry weight (g)					Fruit		
No.	Salinities	π^z (bars)		Leaves	Stem	Roots	Whole plant		Fresh wt (g)		Soluble solids (%)
1	Base nutr. soln.	−0.70	133a[y]	110.7a	27.8a	26.3a	328.4a	(100.0)[x]	1,698a	(100.0)	13.5abc
2	Sea water	−2.20	124ab	90.7b	23.3bc	19.8b	261.1cd	(79.5)	1,526ab	(89.9)	13.9ab
3		−4.20	104de	46.7ef	14.6fg	6.8ef	170.6fg	(51.9)	1,174cde	(69.1)	14.1ab
4	NaCl	−2.20	118bc	82.1bc	23.1bc	15.9bc	269.7bc	(82.1)	1,604ab	(94.5)	14.7a
5		−3.20	102de	62.4de	18.0def	9.9de	203.3ef	(61.9)	1,249cd	(73.6)	14.5ab
6		−4.20	91ef	34.3f	11.7g	4.8fg	127.8g	(38.9)	938ef	(55.2)	13.6abc
7	Na_2SO_4	−2.20	107cd	70.4cd	18.9de	15.4bc	236.9cde	(72.1)	1,381bc	(81.3)	13.8ab
8		−3.20	96de	45.7ef	15.2efg	7.8ef	170.1fg	(51.8)	1,062def	(62.5)	13.7ab
9		−4.20	83fg	12.6g	6.4hi	1.6g	60.2hi	(18.3)	526g	(31.0)	13.1abcd
10	$MgCl_2$	−1.20	126ab	111.8a	26.9ab	29.5a	307.7ab	(93.7)	1,576ab	(92.8)	12.1cde
11		−1.70	131ab	79.7bcd	21.0cd	12.9cd	249.8cd	(76.0)	1,586ab	(93.4)	12.9bcd
12		−2.20	119bc	43.8f	11.8g	6.5ef	136.9g	(41.7)	1,151cde	(67.8)	11.0e
13	$MgSO_4$	−1.20	128ab	84.9bc	19.6cd	16.1bc	225.3de	(68.6)	1,278cd	(75.3)	11.7de
14		−1.70	101de	34.5f	7.8h	4.0fg	86.5h	(26.3)	859f	(50.6)	5.5f
15		−2.20	77g	17.1g	3.9i	1.3g	31.5i	(9.6)	236h	(13.9)	4.0g

[z] Same as Table 1. [y] Mean separation in columns by Duncan's multiple range test, 5% level.
[x] Figures in parentheses show percentage to control (base nutrient solution).

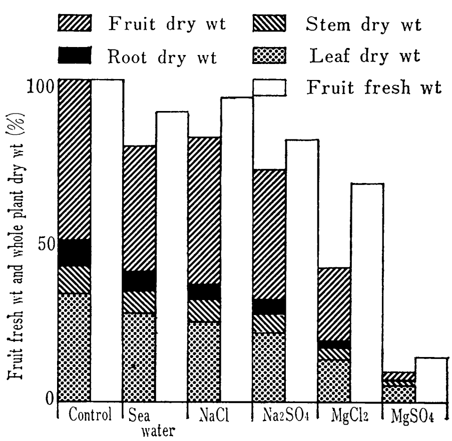

Fig. 1. Effect of various salinities on fruit fresh weight and whole plant (leaves+stem+roots+fruit) dry weight relative to the control at −2.20 bars in nutrient solution culture.

base nutrient solution: salty in the sea water and NaCl series; salty, bitter and astringent in the Na_2SO_4 series; and bitter and astringent in the $MgCl_2$ and $MgSO_4$ series. The intensity of taste increased with decreasing osmotic potential of treatment solutions, and were greater in the inner rind (outer mesocarp) than in the inner flesh (inner mesocarp).

Visible salt injury was proportional to the growth reduction. In the sea water series, visible symptoms were absent. Chlorosis on the lower and middle leaves, and marginal necrosis on the lower leaves were observed in the NaCl series to a lesser degree than in the Na_2SO_4, $MgCl_2$ and $MgSO_4$ series. During early growth marginal necrosis and chlorosis, and interveinal chlorosis appeared on the leaves at lower osmotic potentials in the Na_2SO_4 series, but disappeared in due course. Chlorosis or interveinal chlorosis reappeared on the middle and upper leaves after the middle stage, and advanced to necrosis in some leaves at −4.20 bars in the Na_2SO_4 series. No plants died before harvest in the sodium-salinity. In the $MgCl_2$ series interveinal chlorosis appeared on the lower leaves at lower osmotic potentials and advanced to necrosis after the middle stage. Necrotic spots, which expanded to necrosis in some leaves, were found in many middle leaves and some upper leaves at later stage at −2.20 bars. Some plants at −1.70 bars and most plants at −2.20 bars died before harvest. In the $MgSO_4$ series, at −2.20 bars chlorosis on lower leaves at the early stage progressed acropetally and advanced to necrosis in due course. At −1.20 and −1.70 bars chlorosis appeared on lower leaves at the early or middle stage, and necrotic spots, which expanded to necrosis of the leaf, appeared in the upper leaves at later stage. Plants died before harvest at all $MgSO_4$ concentrations.

Major elements in leaves (Table 3) Na, Mg, Cl and SO_4 increased with decreasing osmotic potential of treatment solutions in sodium (except the sea water)-, magnesium-, chloride- and sulfate-salinities, respectively. Na was higher at −2.20 bars in the NaCl and Na_2SO_4 series than in the control, but non-significant in the sea water series. Na was higher in the Na_2SO_4 series than in the others. Mg was higher in the $MgSO_4$ series than in the $MgCl_2$ series at −1.20 and −1.70 bars, but was lower in the $MgSO_4$ series at −2.20 bars. Mg in the sea water series was higher than in the control and increased with decreasing osmotic potential of treatment solutions. At −2.20 bars in the chloride-salinity Cl was highest in the $MgCl_2$ series, followed by the NaCl series and least in the sea water series. SO_4 was higher at −2.20 bars in the $MgSO_4$ series and −3.20 and −4.20 bars in the Na_2SO_4 series than in the control. Ca and K were lower at −2.20 bars in all series. They were markedly low and tended to decrease with decreasing osmotic potential of treatment solutuions in the magnesium-salinity.

Major elements in fruit (Table 4) Na, Mg, Cl and SO_4 tended to increase with decreasing osmotic potential of treatment solutions in the sodium-, magnesium- and chloride-salinities, and in the $MgSO_4$ series, respectively. Ca tended to be lower and K at lower osmotic potentials was higher in the magnesium-salinity than in the control. Except for K the content of other elements was lower in fruit than in leaves.

Discussion

It has been considered that the primary cause of growth reduction by high salinity was the low osmotic potential of the medium (1, 13). However, differential responses were observed in the plants, according to the kind of salts in the medium(14, 15, 16, 17).

In the present experiment, the osmotic potential of treatment solutions which caused a 50% loss in fruit fresh weight was calculated by graphic interpolation and was −6,

Table 3. Effect of various salinities on major elements in muskmelon leaves in nutrient solution culture (% of dry matter).

Treatment			Total-N	P	K	Na	Ca	Mg	Cl	SO_4
No.	Salinities	π^z (bars)								
1	Base nutr. soln.	−0.70	3.32de[y]	0.99cd	3.07a	0.21fg	4.70ab	1.38f	0.25h	3.55d
2	Sea water	−2.20	3.90bc	1.42ab	1.42bcd	0.42fg	3.51de	1.93e	0.90f	2.01ef
3		−4.20	3.64cd	0.75de	1.13d	0.48ef	3.86cd	2.26d	2.61b	0.70hi
4	NaCl	−2.20	4.20b	1.18abc	1.90bc	0.83d	3.92cd	1.14g	1.27e	1.82efg
5		−3.20	3.97bc	1.04cd	1.38cd	0.73de	4.84a	1.24fg	2.18c	1.21gh
6		−4.20	4.03bc	0.59e	1.46bcd	1.12c	5.05a	1.10g	3.00a	0.35i
7	Na_2SO_4	−2.20	4.92a	1.31abc	2.02b	1.35c	3.60de	1.09g	0.29h	3.78d
8		−3.20	3.95bc	1.15bc	1.85bc	2.16b	4.29bc	1.29fg	0.33gh	4.71bc
9		−4.20	2.72g	0.52e	1.11d	4.36a	3.21e	1.07g	0.46gh	8.75a
10	$MgCl_2$	−1.20	3.34de	1.26abc	1.84bc	0.19fg	2.47f	2.74c	0.71fg	2.50e
11		−1.70	3.07efg	1.15bc	1.64bcd	0.14g	1.98g	3.83b	1.66d	1.47fgh
12		−2.20	2.80fg	1.06c	1.11d	0.14g	1.53h	4.22a	2.86ab	1.13gh
13	$MgSO_4$	−1.20	3.57cd	1.49a	1.96bc	0.21fg	1.53h	3.74b	0.15h	3.74d
14		−1.70	3.17defg	1.49a	1.01d	0.11g	1.06i	4.19a	0.18h	4.07cd
15		−2.20	3.25def	1.24abc	1.10d	0.20fg	0.65j	3.78b	0.08h	5.22b

[z] Same as Table 1. [y] Same as Table 2.

Table 4. Effect of various salinities on some elements in muskmelon fruit in nutrient solution culture (% of dry matter).

Treatment			K	Ca	Mg	Na	Cl	SO_4
No.	Salinities	π^z(bars)						
1	Base nutr. soln.	−0.70	3.61c[y]	0.15a	0.22ef	0.21e	0.20e	0.75de
2	Sea water	−2.20	3.53c	0.15a	0.25e	0.65d	1.01cd	0.64def
3		−4.20	3.11cd	0.12abc	0.23ef	1.02bc	2.12a	0.53fg
4	NaCl	−2.20	3.16cd	0.15a	0.20efg	0.96c	1.31bc	0.57efg
5		−3.20	2.54de	0.14ab	0.16fgh	1.02bc	1.43b	0.44gh
6		−4.20	2.13ef	0.12abc	0.15gh	1.24b	2.01a	0.33h
7	Na_2SO_4	−2.20	2.51de	0.15a	0.21efg	1.09bc	0.16e	0.71def
8		−3.20	2.12ef	0.09bcd	0.17fgh	1.17bc	0.17e	0.60defg
9		−4.20	1.34f	0.09bcd	0.13h	1.94a	0.19e	0.79d
10	$MgCl_2$	−1.20	3.89c	0.12abc	0.34d	0.24e	0.79d	0.74de
11		−1.70	3.54c	0.08cd	0.35d	0.27e	0.91d	0.61defg
12		−2.20	4.80b	0.06d	0.44c	0.23e	1.83a	0.73def
13	$MgSO_4$	−1.20	3.92c	0.09bcd	0.39cd	0.23e	0.34e	1.04c
14		−1.70	6.46a	0.10bcd	0.51b	0.24e	0.42e	1.40b
15		−2.20	6.41a	0.09bcd	0.59a	0.25e	0.39e	1.77a

[z] Same as Table 1. [y] Same as Table 2.

−5, −3.7, −3.0 and −1.5 bars in the sea water, NaCl, Na_2SO_4 and $MgCl_2$ series, respectively. According to the above results and other observations, the growth in decreasing order was control > sea water ≧ NaCl > Na_2SO_4 > $MgCl_2$ > $MgSO_4$ series. Therefore, it is concluded that muskmelons were more sensitive to Mg than Na and, to a lesser extent, to SO_4 than Cl. The growth of kidney bean (4), corn(7), spinach, celery, turnip, Welsh onion, chard and kidney bean (13) and cucumber(14) were more suppressed in the magnesium- than sodium-salinity. Shimada (14) examined the reducing activity of cucumber roots to TTC (2, 3, 5-triphenyl tetrabenzolium chloride). The inhibition oe the activity was greatest in the magnesium-salinity. It was observed (9, 10) that the growth of green soybeans was most suppressed in the chloride-salinity, but not severly suppressed in the sulfate-, sodium- and magnesium-salinities. The reduced growth was mainly due to the specific ion effect of Cl in the sea water and NaCl series, as reported in honeylocust which was considered to be a Cl sensitive plant(2). The growth of muskmelons was also suppressed even in the sea water and NaCl series. However, the specific ion effect of Cl and Na on muskmelons was not apparent in sand (11), soil(12) and nutrient solution culture experiments. Further studies will be needed to clarify this point.

The addition of single salts or sea water to the base nutrient solution tended to increase the content of the respective cations and anions in leaves and fruit. Similar responses were observed with other crops, such as grape (5), sugarcane (6), corn (7) and onion, spinach, cucumber and kidney bean (15).

The added salts also resulted in concomitant reductions in other cations in leaves and fruit, especially in Ca and K in leaves. In the present experiment, Ca in leaves was markedly affected by the magnesium-salinity and slightly by the sodium-salinity. There were many reports that Ca uptake decreased due to salt treatments. The antagonistic relationship between Ca and Mg was observed in corn(7). Osawa(13) reported that $MgCl_2$ inhibited Ca absorption in spinach, celery, turnip, Welsh onion, chard and kidney bean, while Ca uptake of sugarcane(6) was hindered by all salts (NaCl, Na_2SO_4, $MgCl_2$ and $MgSO_4$). Inhibition of Ca uptake possibly caused severe toxicity to muskmelons in the magnesium-salinity. An antagonistic relationship was observed between K and added cations. Decreased rate of K uptake as compared with the control was greater in the magnesium- than in the sodium-salinity. The Na/K ratio was highest in the control and decreased with decreasing osmotic potential of treatment solutions. Joolka(5) reported that K content invariably increased in NaCl and Na_2SO_4 salinities, but Eaton(3) stated that K accumulation in the expressed sap was little affected by other ions.

There were several reports with respect to uptake of and response to Cl and SO_4. Joshi and Naik (6) reported a more pronounced entry of SO_4 than Cl in sugarcane, and that SO_4 was more toxic than Cl. Shimose(15) found that cucumber, celery, spinach, onion and kidney bean absorbed Cl in the chloride-salinity more readily than SO_4 in the sulfate-salinity and, except for onion, were more sensitive to Cl than SO_4. In the present experiment, the increased rate of Cl as compared with the control was more suppressed in the sulfate- than in the chloride-salinity. Sensitivity to Cl or SO_4 may vary with crops.

In this experiment, each salt was added to the base nutrient solution at isosmotic potentials. In such cases, ion concentrations in me/l varied between different salts, especially monovalent and divalent ions. The growth of muskmelons was more suppressed in the sulfate- than in the chloride-salinity. However, Na and Mg in leaves in the Na_2SO_4 and $MgSO_4$ series was higher than in the NaCl and $MgCl_2$ series, respectively, because of higher concentration of Na and Mg in the treatment solutions. Additional studies will be needed to determine the apparent sensitivity of muskmelons to Cl and SO_4.

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各種塩類が養液耕におけるメロンの耐塩性に及ぼす影響

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摘　要

メロンの耐塩性と塩の種類との関係を明らかにするため，養液耕により本実験を行った．海水(−2.20, −4.20 bar)，NaCl と Na_2SO_4 (−2.20, −3.20, −4.20 bar)，$MgCl_2$ と $MgSO_4$ (−1.20, −1.70, −2.20 bar) の塩類源を所定の浸透ポテンシャルになるように基本培養液に添加し，基本培養液で育てた対照区 (−0.70 bar) と生育を比較した．果実新鮮重と全植物体乾物重は，対照区で最大となり，浸透ポテンシャルが低下するにつれて，それぞれの塩類源で減少した．−2.20 bar 区における果実新鮮重は，対照区を 100% とした場合，海水で 89.9%，NaCl で 94.5%，Na_2SO_4 で 81.3%，$MgCl_2$ で 67.8%，$MgSO_4$ で 13.9% であった．Mg 塩処理の生育は，Na 塩処理に比較して著しく劣り，SO_4 塩処理では Cl 塩処理より劣った．果実の食味は添加塩類により異なっていた．塩害症状の程度は，生育抑制の程度とほぼ同じであった．Na 塩処理の −2.20 bar では，植物体は枯死しなかったが，$MgCl_2$ の −2.20bar ではほとんどの株が，$MgSO_4$ の −2.20 bar では全部の株が収穫前に枯死した．単一塩類または海水を基本培養液に添加した場合，添加したそれぞれのイオン (Na, Mg, Cl, SO_4) の葉及び果実中含量は増加する傾向を示した．葉の Ca とK含量は，すべての −2.20 bar で対照区より低かった．