J. Japan. Soc. Hort. Sci. 48 (4) : 468—474. 1980.

Salt Tolerance of Muskmelons Grown in Different Salinity Soils

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Summary

Experiments were conducted to determine the effect of diluted sea water on the growth and fruit quality of muskmelons grown in different salinity soils. Two kinds of soil were used as a soil medium, one, a new soil, which was a virgin paddy soil, and the other, a used soil, salinized at different levels in which tomatoes had been cultured. The plant height, leaf dry weight, fruit fresh weight, and soluble solids were markedly decreased at 1,000 ppm Cl in new soil, whereas they gradually decreased in used soil as sea water concentrations were increased from 0 to 1,000 ppm Cl. The visual salt injury, such as necrosis on the leaves and wilting of leaf margins, appeared at 1,000ppm Cl in new soil, and from 250 to 1,000ppm Cl in used soil. The Na, Ca, Mg and Cl content in leaves tended to increase in both new and used soils with increasing sea water concentrations. The Cl in fruit increased from 250 to 1,000ppm Cl in new soil, and from 0 to 1,000ppm Cl in used soil with increasing sea water concentrations. The Cl, exchangeable Na, K and Mg, and EC value in the soil increased as sea water concentrations increased, although Cl and exchangeable K content in the new soil from 0 to 250ppm Cl was not significantly different.

Introduction

Data from the survey of ions in soluble salts causing salinity (Cl^-, Na^+, SO_4^{2-}, K^+, Mg^{2+} and Ca^{2+}) in well water (10) indicates that much which is available for irrigation in the coastal greenhouse crop area in the Shizuoka Prefecture is high in salt content. Also, these data show that these salts result from sea water contamination. Muskmelons (*Cucumis melo* L. cv. 'Earl's Favourite'), one of the main crops in the Shizuoka Prefecture, appear affected by the use of salt contaminated well water for irrigation. Relative to its economic importance, there is only a modicum of information on salt tolerance of muskmelon, cv. 'Earl's Favourite' (9, 17). In the current experiments sea water was used as a source of excess soluble salts to determine how much salinity muskmelons could tolerate and the effect on fruit quality in soil culture. Moreover, salts in well water accumulate in the soil bed as muskmelons have been succesively grown using the same steam-sterilized soil. Therefore, another purpose of this study was to evaluate the effect of diluted sea water on the growth of muskmelons grown in different salinity soils.

Materials and Methods

Planting.

Experiment I (New soil experiment). Four-leaf seedlings 'Summer No.2, strain of Earl's Favourite' grafted on 'Barnett Hill Favourite' rootstock, were planted in wooden boxes (40 ×40×20cm) filled with new Iwata paddy soil and placed in the greenhouse on June 20, 1974. The volume of the soil was 14 liters to which 7 liters of semi-decomposed rice straw were added. Seven g N from rape-seed cake, 10g P_2O_5 from calcium superphosphate and rape-seed cake, 10g K_2O from K_2SO_4 and rape-seed cake, and 40g CaO from $Ca(OH)_2$ were applied to the soil as total amounts of a basal fertilizer and 3 top dressings.

Experiment II (Used soil experiment). Four-leaf seedlings comparable to those in Experiment I were planted in wooden boxes filled with used Iwata paddy soil in which tomatoes had been grown and had received applications of diluted sea water solutions for 4 months prior to starting this experiment (13). Five g

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Received for publication June 4, 1979.

Table 1. Cation concentrations, pH and EC in relation to sea water diluted with tap water.

Sea water concns			Cations (ppm)				pH	EC (m℧/cm)
Cl concns (ppm)	Osmotic potential (bars)	%	K	Na	Ca	Mg		
0	0	0	0	0	0	0	7.00	0.14
50	−0.07	0.25	1	25	1	3	7.19	0.29
100	−0.14	0.50	2	50	2	6	7.35	0 46
250	−0.33	1.25	6	126	5	16	7.58	0.91
500	−0.66	2.50	11	252	10	32	7.62	1.66
1,000	−1.32	5.00	22	504	20	63	7.52	2.99
Sea water 20,500ppm Cl			445	10,082	393	1,262	8.89	33.10

N from rape-seed cake, 2.27g P_2O_5 from calcium superphoshate and rape-seed cake, 10g K_2O from K_2SO_4 and rape-seed cake, and 8g CaO from $Ca(OH)_2$ were applied to the soil. The soil was steam-sterilized at 80° to 90°C for 30 minutes. The other experimental procedures were the same as Experiment I.

Salinity treatment and harvest in Experiment I and II.

The treatment solutions, 0, 50, 100, 250, 500 and 1,000ppm Cl, were made by diluting sea water with tap water. Each treatment solution level was based on the survey of the Cl content of well water (10) and that in the previous tomato experiment (13). Table 1 shows cation concentrations, EC, pH and osmotic potential in relation to diluted sea water solutions. Each diluted sea water solution was applied to the soil medium from June 21 to Aug. 24. The treatments were replicated 6 times. These treatments were made 2 or 3 times (approximately 1 liter/plant/time) on clear days and 1 or 2 times on cloudy days. There was no treatment on rainy days. Muskmelons were harvested on Aug. 26. Plant height, dry weight of leaves, stems and roots, and fresh weight and soluble solids of fruit were measured at harvest. Plant height was also measured on July 10. The main elements in leaves and soil chemical properties were determined at the end of the experiment. All analyses used were described in a previous paper (12).

Results

Growth.

Experiment I. Growth data are given in Table 2. Plant height at harvest was not significantly different between 0 and 250ppm Cl, but decreased at 500 and 1,000ppm Cl. Plant height on July 10 and leaf dry weight at harvest were depressed only at 1,000ppm Cl. Fruit fresh weight decreased with increasing sea water concentrations from 250 to 1,000ppm Cl. It was 100, 84.5, 73.9 and 49.3% at 0, 250, 500 and 1,000ppm Cl, respectively. Fruit soluble solids were little affected by diluted sea water concentrations. The leaf color was lightest at 0ppm Cl and became darker as sea water concentrations increased. A slight injury (necrosis) was observed on the upper leaves at 1,000ppm Cl after Aug. 1.

Experiment II. Table 3 shows the growth data. Plant height on July 10 decreased as sea water concentrations increased from 100 to

Table 2. Effect of sea water concentrations on the growth, fruit weight and soluble solids of muskmelons grown in new soil.

Sea water concns		Plant height(cm)*		Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)	Fruit	
Cl concns (ppm)	Osmotic potential (bars)	July 10	At harvest				Fresh weight (g)	Soluble solids (%)
0	0	105^{a}	108^{a}	44.4^{a}	17.2^{ab}	1.02^{a}	$1,319^{a}$	12.4^{b}
50	−0.07	97^{ab}	102^{ab}	43.1^{a}	21.3^{a}	0.96^{a}	$1,373^{a}$	13.0^{ab}
100	−0.14	99^{ab}	101^{ab}	44.4^{a}	20.4^{a}	0.96^{a}	$1,189^{ab}$	13.3^{a}
250	−0.33	88^{abc}	95^{abc}	42.7^{a}	19.2^{a}	0.92^{a}	$1,114^{bc}$	13.3^{a}
500	−0.66	82^{bc}	88^{bc}	40.1^{a}	19.3^{a}	1.00^{a}	975^{c}	13.0^{ab}
1,000	−1.32	76^{c}	82^{c}	28.6^{b}	13.0^{b}	0.92^{a}	650^{d}	12.6^{b}

* : Mean separation in columns by Duncan's multiple range test, 5% level.

Table 3. Effect of sea water concentrations on the growth, fruit weight and soluble solids of muskmelons grown in used soil.

Sea water concns		Plant height (cm)*		Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)	Fruit	
Cl concns (ppm)	Osmotic potential (bars)	July 10	At harvest				Fresh weight (g)	Soluble solids (%)
0	0	116^{a}	120^{a}	52.7^{a}	23.2^{a}	1.47^{a}	$1,156^{a}$	13.6^{ab}
50	−0.07	105^{a}	106^{b}	51.3^{a}	22.7^{a}	1.53^{a}	$1,051^{ab}$	14.1^{a}
100	−0.14	90^{b}	99^{b}	45.7^{ab}	22.5^{a}	1.20^{b}	$1,108^{a}$	13.9^{a}
250	−0.33	74^{c}	81^{c}	38.7^{b}	19.2^{a}	0.98^{c}	947^{b}	13.1^{b}
500	−0.66	57^{d}	72^{c}	28.2^{c}	14.5^{b}	0.78^{d}	691^{c}	12.7^{c}
1,000	−1.32	45^{d}	72^{c}	18.4^{c}	9.3^{c}	0.63^{d}	465^{d}	12.0^{d}

* : The same as Table 2.

1,000 ppm Cl. However, plant height at harvest was markedly higher at 0 ppm Cl than at other treatments and decreased with increasing sea water concentrations. Leaf dry weight, and fruit fresh weight and soluble solids were greatest at 0, 50 and 100 ppm Cl and decreased with increasing sea water concentrations from 250 to 1,000 ppm Cl. Fruit fresh weight was 81.9, 59.8 and 40.2% at 250, 500 and 1,000 ppm Cl, respectively, as compared to the weight at 0 ppm Cl. Leaf color became darker as sea water concentrations increased. Salt injury, such as necrosis and wilting of leaves, became more severe with increasing sea water concentrations over 250 ppm Cl, after Aug. 1. Necrosis was observed on the upper leaves at 500 and 1,000 ppm Cl. Lower leaf peripheries wilted at 250 to 1,000 ppm Cl. The wilting became more severe with increasing sea water concentrations. At the late growing stage, in late Aug., these symptoms became more severe.

Main elements in the leaves and Cl content in the fruit in Experiment I (Table 4) and Experiment II (Table 5).

Na, Ca, Mg and Cl content in the leaves

Table 4. Effect of sea water concentrations on the main elemental content in the leaves and Cl content in the fruit of muskmelons grown in new soil (% of dry matter).

Sea water concns		Leaves							Fruit
Cl concns (ppm)	Osmotic potential (bars)	Total-N*	P	K	Na	Ca	Mg	Cl	Cl
0	0	2.34^{a}	0.44^{a}	2.18^{a}	0.14^{d}	6.88^{c}	0.87^{c}	0.62^{c}	0.66^{d}
50	−0.07	2.55^{a}	0.32^{b}	1.81^{ab}	0.16^{d}	7.50^{bc}	0.90^{c}	1.08^{c}	0.67^{d}
100	−0.14	2.50^{a}	0.33^{b}	1.89^{ab}	0.19^{cd}	7.20^{c}	0.92^{c}	1.70^{b}	0.75^{d}
250	−0.33	2.43^{a}	0.34^{b}	1.65^{bc}	0.29^{bc}	8.02^{ab}	1.04^{b}	2.05^{b}	1.07^{c}
500	−0.66	2.55^{a}	0.35^{b}	1.20^{cd}	0.39^{b}	8.38^{a}	1.03^{b}	2.21^{b}	1.62^{b}
1,000	−1.32	2.54^{a}	0.45^{a}	1.11^{d}	0.88^{a}	8.73^{a}	1.17^{a}	3.66^{a}	2.48^{a}

* : The same as Table 2.

Table 5. Effect of sea water concentrations on the main elemental content in the leaves and Cl content in the fruit of muskmelons grown in used soil (% of dry matter).

Sea water concns		Leaves							Fruit
Cl concns (ppm)	Osmotic potential (bars)	Total-N*	P	K	Na	Ca	Mg	Cl	Cl
0	0	2.00^{b}	0.27^{b}	1.96^{bc}	0.14^{d}	4.78^{c}	0.85^{c}	0.89^{d}	0.78^{c}
50	−0.07	1.86^{b}	0.33^{a}	2.28^{ab}	0.21^{d}	4.73^{c}	0.86^{c}	1.70^{d}	0.98^{c}
100	−0.14	2.22^{b}	0.34^{a}	2.48^{a}	0.40^{cd}	5.48^{c}	0.98^{bc}	3.00^{c}	1.77^{b}
250	−0.33	2.78^{a}	0.35^{a}	1.57^{cd}	0.57^{c}	6.87^{b}	1.14^{b}	3.07^{c}	1.75^{b}
500	−0.66	2.28^{b}	0.32^{ab}	1.14^{d}	1.17^{b}	8.17^{a}	1.46^{a}	4.82^{b}	1.65^{b}
1,000	−1.32	2.19^{b}	0.30^{ab}	1.03^{d}	1.71^{a}	8.27^{a}	1.59^{a}	6.88^{a}	4.27^{a}

* : The same as Table 2.

Table 6. Chemical properties of the soil at the end of the new soil experiment (Air dried soil basis).

Sea water concns		NO_3-N* (ppm)	P(Truog) (ppm)	Exchangeable cations (me/100g)				Cl (ppm)	EC(1 : 5) (m℧/cm)	pH (H_2O)
Cl concns (ppm)	Osmotic potential (bars)			K	Na	Ca	Mg			
0	0	5.8^{b}	275^{a}	0.85^{c}	0.45^{f}	10.77^{ab}	1.08^{d}	79^{c}	0.72^{d}	6.61^{a}
50	−0.07	3.6^{b}	263^{a}	0.87^{c}	0.75^{e}	11.10^{a}	1.13^{cd}	153^{c}	0.89^{cd}	6.62^{a}
100	−0.14	8.0^{b}	263^{a}	0.78^{c}	1.07^{d}	10.39^{abc}	1.23^{cd}	278^{c}	0.90^{cd}	6.70^{a}
250	−0.33	6.2^{b}	287^{a}	0.94^{c}	2.25^{c}	10.39^{abc}	1.39^{c}	378^{c}	1.07^{c}	6.78^{a}
500	−0.66	9.7^{b}	278^{a}	1.26^{b}	3.80^{b}	9.84^{bc}	2.03^{b}	$1,410^{b}$	1.41^{b}	6.64^{a}
1,000	−1.32	25.3^{a}	267^{a}	1.49^{a}	5.21^{a}	9.57^{c}	2.39^{a}	$2,201^{a}$	1.68^{a}	6.70^{a}

* : The same as Table2.

Table 7. Chemical properties of the soil at the end of the used soil experiment (Air dried soil basis).

Sea water concns		NO_3-N* (ppm)	P(Truog) (ppm)	Exchangeable cations (me/100g)				Cl (ppm)	EC(1 : 5) (m℧/cm)	pH (H_2O)
Cl concns (ppm)	Osmotic potential (bars)			K	Na	Ca	Mg			
0	0	3.8^{b}	141^{b}	1.06^{c}	0.80^{e}	10.20^{a}	1.29^{c}	151^{d}	1.23^{c}	5.68^{c}
50	−0.07	3.2^{b}	139^{b}	0.78^{d}	1.38^{e}	10.44^{a}	1.32^{c}	220^{d}	1.24^{c}	5.71^{c}
100	−0.14	3.9^{b}	142^{b}	1.12^{c}	2.35^{d}	9.96^{ab}	1.66^{d}	620^{c}	1.41^{bc}	5.83^{bc}
250	−0.33	3.8^{b}	137^{b}	1.39^{b}	3.26^{c}	9.20^{bc}	2.00^{c}	$1,017^{b}$	1.60^{b}	5.98^{b}
500	−0.66	15.8^{a}	170^{a}	2.06^{a}	5.04^{b}	8.39^{c}	2.59^{b}	$1,886^{a}$	1.65^{b}	6.21^{a}
1,000	−1.32	17.2^{a}	178^{a}	1.92^{a}	6.30^{a}	8.48^{c}	3.25^{a}	$2,133^{a}$	2.10^{a}	6.32^{a}

* : The same as Table2.

tended to be higher with increasing sea water concentrations in both Experiment I and II. The content of Cl in the fruit was not significantly different from 0 to 100ppm Cl, but increasd as sea water concentrations increased from 250 to 1,000ppm Cl in Experiment I. In Experiment II Cl increased with increasing sea water concentrations and concentrated approximately 2.5 times at 1,000ppm Cl, as compared to 100, 250 and 500ppm Cl. The content of K decreased as sea water concentrations increased. There were little significant differences in N and P content.

Soil chemical properties in Experiment I (Table 6) and Experiment II (Table 7).

The amount of Cl, exchangeable Na, K and Mg, and EC value increased with increasing sea water concentrations, although Cl and K content between 0 and 250ppm Cl was not significantly different in Experiment I. The content of NO_3-N accumulated at relatively high sea water concentrations as compared to 0ppm Cl. The pH value in Experiment II increased and Ca content decreased with increasing sea water concentrations. There was no significant difference in available P and pH in Experiment II.

Discussion

Similar trends in the plant growth and the main elements in leaves were observed between Experiment I and II. For example, plant height, leaf dry weight and fruit fresh weight decreased at relatively higher sea water concentrations, and Na, Ca, Mg and Cl in the leaves tended to increase with increasing sea water concentrations. However, the growth was much more depressed in Experiment II than in Experiment I. The relative fruit fresh weight in order of increasing sea water concentrations from 0 to 1,000ppm Cl was 100, 104.0, 90.1, 84.5, 73.9 and 49.3% in Experiment I, and 100, 90.9, 95.8, 81.9, 59.8 and 40.2% in Experiment II, respectively. Also leaf dry weight and plant height at 1,000ppm Cl at harvest were reduced as much as 35.6 and 24.1% in Experiment I, and 65.1 and 40.0% in Experiment II, respectively. The main elements in leaves were higher in Experiment II than in Experiment I at comparable sea water concentrations. The Na and Cl in the leaves at 0ppm Cl were almost the same between Experiment I and II. However, as compared to 0ppm Cl the increment of Na and Cl at 1,000ppm Cl was 6.3 and 5.9 times in

Experiment I, and 12.2 and 7.7 times in Experiment II, respectively. Moreover, leaf Na and Cl content at 1,000ppm Cl in Experiment I was 0.88 and 3.66%, respectively, and markedly increased as compared to 0.39% Na and 2.21% Cl at 500ppm Cl. On the contrary they gradually increased in Experiment II. Ayoub (1) reported that when the percentage of Na in bean roots exceeded about 1.2~1.4% leaf Na content increased as the root Na concentration increased. Although the root Na content was not determined in these studies, this interaction might occur due to the difference of soil exchangeable Na. Salt injury symptoms were observed at 1,000ppm Cl in Experiment I, and at 250 to 1,000ppm Cl in Experiment II. These symptoms appeared to be induced by the excess Na and Cl accumulation in the leaves. The Na and Cl concentration levels were more than 0.5 and 3.0%, respectively, and the degree of injury increased as they increased.

At the beginning of the experiment, the EC value, Cl, and exchangeable Na and Mg in the soil used in Experiment II were already higher than in Experiment I and increased with increasing sea water concentrations due to an application of corresponding diluted sea water solutions to the soils. They were also higher at the comparable sea water concentrations at the end of the experiment. Therefore, the main elements in the leaves and the growth response might reflect the chemical property differences between the two soils similar to that reported by many investigators (2, 7, 8, 12, 13, 14).

Diluted sea water may reduce plant growth in 2 ways : i) low osmotic potential and ii) high concentrations of potentially toxic ions such as Na, Ca, Cl, and others. It is considered (15) that the reduction in plant growth is primarily associated with osmotic potential of the medium, but in some plants nutritional imbalance or toxicity of specific ions are also important factors (4, 16). Although the osmotic potential of the soil solution was not determined in these studies, it seemed to be decreased by applying diluted sea water as the EC value, Cl and exchangeable Na in the soil increased by the end of the experiment. The high EC value and low osmotic potential of the root medium which inhibited water absorption were factors restricting growth (3, 18). It is possible that the much greater growth reduction in Experiment II than in Experiment I might have resulted from the higher EC value of the soil.

There was no significant difference in leaf, stem and root dry weight from 0 to 500ppm Cl in Experiment I, whereas fruit fresh weight decreased significantly at 250 and 500ppm Cl rather than at 0ppm Cl. Cl, Na and Mg in the diluted sea water solution were proportional to the amounts of sea water. It appeared that these ions stimulated vegetative growth from 0 to 500ppm Cl, but decreased fruit fresh weight at 250 and 500ppm Cl. Similar results were previously reported with tomatoes (13) and green soybeans (12). In suppressing growth, salinity may decrease the rate of photosynthesis per unit leaf area and/or the utilization of photosynthate in growth (11). In the case of muskmelons, diluted sea water may affect the translocation or utilization of photosynthate rather than photosynthesis itself as stated by Gauch and Eaton (6).

Salt tolerance of crop plants should be considered in the plant portion to be marketed. It was calculated that the sea water concentration caused a 50% loss in fruit fresh weight at 986 ppm Cl in Experiment I and 750ppm Cl in Experiment II. With tomatoes (13), a 50% reduction in yield was observed at 871 ppm Cl in soil culture. The concentration which caused a 50% loss in yield of muskmelon in Experiment I was higher than the tomato concentration just mentioned. However, these concentrations were evaluated only by the fruit weight. In the case of muskmelon, the quality should be based on size, weight, fruit shape, soluble solid percentage, taste, netting, and so on. Above all, a salty taste may lower fruit quality. Moreover, only a small decrease in fruit weight and size makes the price much lower. On the other hand, the criterion for deciding the price of sound and ripe tomatoes generally depends upon the fruit weight except for economical factors. Therefore, the adverse effects of diluted sea water at 100 to 500 ppm Cl were greater in muskmelons than in tomatoes.

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異なる塩類土壌におけるメロンの耐塩性

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摘　要

塩類含量の異なる土壌を培地としてメロンを育てた場合，希釈した海水がメロンの生育と果実品質に及ぼす影響を調べるため実験を行った。培地として用いた土壌は２種類で，１つは水田新土，他の１つは異なる濃度の希釈した海水を用いてトマトを栽培した水田旧土である。草丈，葉の乾物重，果実の新鮮重と糖度は，新土では1,000 ppm Cl で著しく減少したが，旧土では海水濃度が0から1,000ppm Cl に増すにつれ，徐々に減少した。葉のネクロシスや葉縁の萎ちょうなどの塩害症状は，新土では1,000ppm Cl で，旧土では250から1,000ppm Cl で現れた。葉中の Na, Ca, Mg 及び Cl 含量は，新土及び旧土ともに，海水濃度が増すにつれ増加する傾向を示した。果実の Cl 含量は，新土では250から1,000 ppm Cl で，旧土では0から1,000ppm Cl で海水濃度が増すにつれ増加した。新土における0から250ppm Cl の土壌中 Cl と置換性K含量には明らかな差がみられなかったが，土壌中の Cl，置換性 Na, K, Mg 含量及び EC は，海水濃度が増すにつれ増加した。