J. Japan. Soc. Hort. Sci. 52(3) : 286—293. 1983.

Salt Tolerance of Muskmelons at Different Growth Stages as Affected by Diluted Sea Water

Akira NUKAYA, Masao MASUI and Akira ISHIDA
College of Agriculture, Shizuoka University, Ohya, Shizuoka 422

Summary

Muskmelons (*Cucumis melo* L.) were grown in diluted sea water from transplanting to harvest in order to determine the salt tolerance at 3 growth stages-stage I (transplanting to pollination), stage II (pollination to fruit net development) and stage III (fruit net development to harvest). Treatment solutions contained 0, 250, 500, 750 and 1,000 ppm Cl in sand and soil cultures, and 0, 1,000, 2,000, 3,000 and 4,000 ppm Cl in nutrient solution culture. Whole plant dry weight and fruit fresh weight at harvest decreased with increasing sea water concentrations in all cultures. The increment in growth at stages II and III was less at higher sea water concentrations. Growth was reduced more in sand than in soil culture. Slightly visible salt injury symptoms appeared at stages II and III at 1,000 ppm Cl in sand culture and at the beginning of stage I at 3,000 and 4,000 ppm Cl in solution culture. Cl and Na increased, while SO_4 and osmotic potential decreased in leaves at the end of stage III in all cultures as sea water concentrations increased. Cl and Na in leaves tended to be higher in sand than in soil culture at all stages. Cl was especially high at stage I. More accumulation of Cl and/or Na in leaves at stage I in sand than in soil culture may be one of the causes for greater growth suppression in sand culture.

Introduction

When well water contaminated with sea water is used for irrigating crops in initially non-saline soils, yield might be reduced not only by the salt concentration of the diluted sea water(8, 9), the amount of salt accumulated in the soil by contaminated well water(8), and the poor salt tolerance of the plant(6), but also by the stage at which salinization occurs (3, 5, 12). Previous studies (9, 10, 11) showed more severe salt injury and less growth in muskmelons in sand than in soil culture, in spite of higher osmotic potential and lower ion concentration in soil solution (SS, pF=0 to 3.8) in sand culture. It might have been due to poor buffering of sand. In sand and soil cultures, salts accumulated gradually in the media throughout the growth period, whereas in solution culture salt concentrations were relatively constant. Therefore, this experiment was conducted to clarify the relationship between growth stages and salt accumulation, especially that of Cl and Na, in sand, soil and nutrient solution cultures.

Materials and Methods

Treatments consisted of 5 levels of diluted sea water and 3 media. Thus, there were 15 treatments. The plant growth from transplanting to harvest was divided into 3 stages as follows: stage I (transplanting to pollination-April 11 or 12 to May 3), stage II (pollination to fruit net development-May 4 to June 1) and stage III (fruit net development to harvest-June 1 to late June). Samples were taken at the end of stages I and II in 2 replications and at the end of stage III in 4 replications. Thus, the total number of single plant plots was 120. Sea water taken from Shimizu (Miho) area was diluted with base nutrient solution to make 5 treatment solutions of 0, 250, 500, 750 and 1,000 ppm Cl in sand and soil cultures, and of 0, 1,000, 2,000, 3,000 and 4,000 ppm Cl in nutrient solution culture, as shown in Table 1. The madia were Tenryu River sand,

Table 1. Composition of treatment solution.

Treatment solution[z]			
Cl concn (ppm)	Osmotic potential (bars)	Rate of %[y] sea water	EC (mS/cm)
0	−0.70	0	2.43
250	−1.02	1.25	3.03
500	−1.35	2.50	3.87
750	−1.69	3.75	4.70
1,000	−2.02	5.00	5.29
2,000	−3.33	10.0	7.74
3,000	−4.66	15.0	10.75
4,000	−5.99	20.0	13.20

[z] Composition of base nutrient solution : $Na_2HPO_4\cdot 12H_2O$=1mM, K_2SO_4=3mM, $Ca(NO_3)_2\cdot 4H_2O$=4mM, $MgSO_4\cdot 7H_2O$=2mM, and minor elements (Mn, Fe, Zn, Cu, B and Mo). pH=6.0. Treatment solutions were diluted with 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.

Takamatsu light clay paddy soil taken at Shizuoka, and nutrient solution in sand, soil and nutrient solution cultures, respectively. Sixteen liters of soil mixed with 5 liters of decomposed rice straw, or 18 liters of sand were filled in each wooden box (40×40×20 cm). Uniform muskmelon seedlings, cv. Spring No. 3 of Earl's Favourite at the 2.5 leaf stage were transplanted in the boxes and placed in a greenhouse on April 11, 1978. Treatment solutions were applied to sand or soil 1 to 3 times (0.5 to 1.0 liters/plant/time) a day depending on the weather, from April 13 to harvest. No solution was applied on rainy days. In nutrient solution culture, 13 liters of each treatment solution were filled in Wagner pots (1/2,000 a), and 3-leaved seedlings were transferred to the pots and placed in the greenhouse on April 12, 1978. The solution was replaced every 2 weeks at stage I and every week at stages II and III, and aerated continuously. Tap water was added every morning to keep the solution volume in pots at 13 liters. Temperature inside the greenhouse was above 18°C. Plants were topped at the 20th node and allowed to bear only one fruit per plant around the 10th node. All other lateral shoots and flower buds were removed. At the end of each stage, plant growth, osmotic potential and major mineral elements in leaves, and chemical properties of SS were recorded. SS at pF 0 to 3.8 was extracted as follows: sand or soil was put in a plastic tube (44 mm in diameter and 55 mm high) and then saturated with distilled water. After 24 hours the tube was centrifuged at 4,570 rpm for 30 min in Marusan 9B-2 rotor. The other analytical methods were the same as described previously (7).

Results

Growth and fruit quality (Tables 2 and 3, Figs. 1 to 4) Whole plant and leaf+stem dry weights, and fruit fresh weight were always higher at lower sea water concentrations. In sand culture, they increased rapidly throughout stages II and III and varied greatly with sea water concentrations at the end of stage III. While in soil culture, they increased rapidly at stage II but little or less rapidly at stage III and the difference among sea water concentrations at the end of stage III was less than that in sand culture. These tendencies were reflected clearly in

Table 2. Effect of diluted sea water concentration on fruit soluble solids and salty taste at the end of stage III in sand and soil cultures.

Sea water concn	Soluble solids (%)		Salty taste[z]	
(ppm Cl)	Sand	Soil	Sand	Soil
0	13.4a[y]	13.7a	0	0
250	13.5a	13.4a	0	0
500	14.3a	14.4a	0.25	0.25
750	13.6a	13.6a	0.50	0.50
1,000	14.2a	14.5a	1.00	0.75

[z] Salty taste was evaluated from 0(none) to 1(salty).

[y] Mean separation in columns by Duncan's multiple range test, 5% level.

Table 3. Effect of diluted sea water concentration on fruit soluble solids and salty taste at the end of stage III in nutrient solution culture.

Sea water concn (ppm Cl)	Soluble solids (%)	Salty taste[z]
0	11.8b[y]	0
1,000	12.7ab	0∼0.5
2,000	13.7a	1∼2
3,000	14.0a	2∼3
4,000	13.5a	4

[z] Salty taste was evaluated from 0 (none) to 4 (very salty).

[y] Mean separation in columns by Duncan's multiple range test, 5% level.

leaf+stem dry weight. In solution culture, fruit fresh weight was relatively great at 0, 1,000 and 2,000 ppm Cl at the end of stage II, while the increment at stage III was smaller at 1,000 and 2,000 ppm Cl than at 0 ppm Cl. Whole plant and leaf+stem dry weights at the end of stage II was greater at 250 ppm Cl than at 0 ppm Cl in sand and soil cultures. The higher the concentration of diluted sea water, the poorer was the external appearance of fruit. Fruit taste became

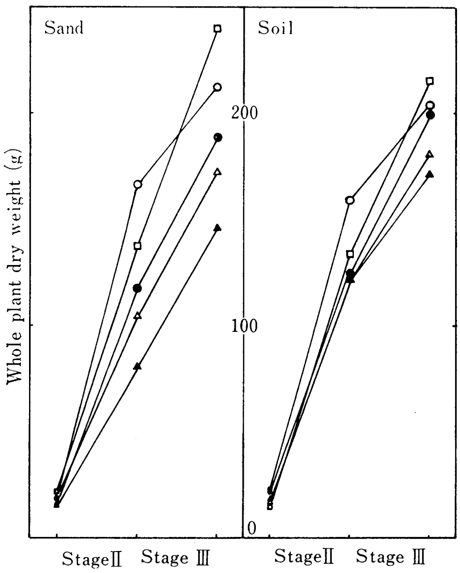

Fig. 1. Changes of whole plant dry weight in sand and soil cultures. Symbols □, ○, ●, △ and ▲ indicate 0, 250, 500, 750 and 1,000 ppm Cl, respectively. Stage II : pollination to fruit net development. Stage III : fruit net development to harvest.

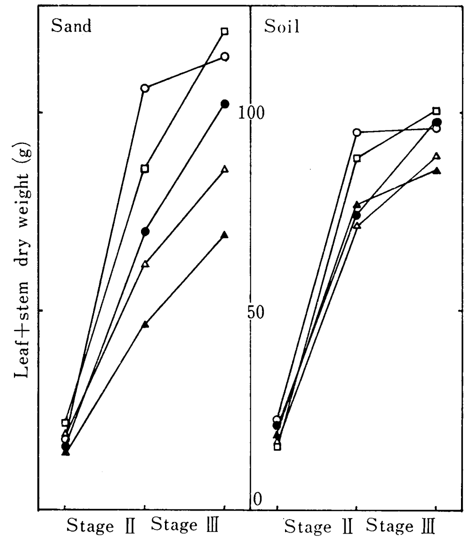

Fig. 2. Changes of leaf+stem dry weight in sand and soil cultures. As to symbols, refer to Fig. 1.

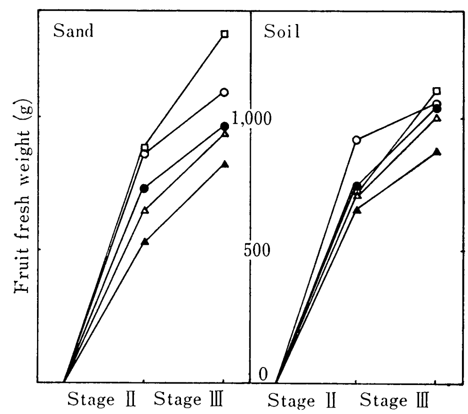

Fig. 3. Changes of fruit fresh weight in sand and soil cultures. As to symbols, refer to Fig. 1.

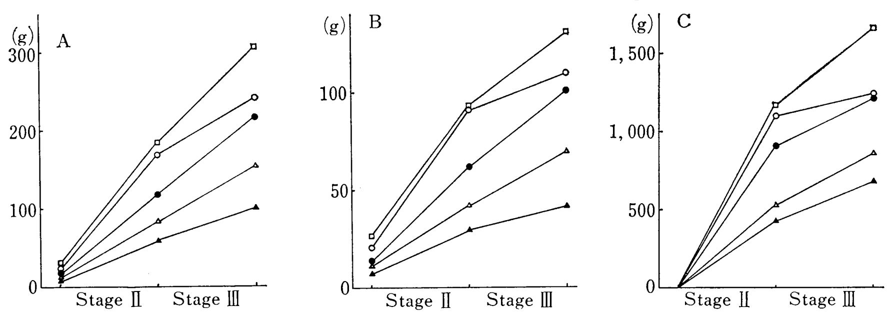

Fig. 4. Changes of whole plant dry weight (A), leaf+stem dry weight (B) and fruit fresh weight (C) in nutrient solution culture. Symbols □, ○, ●, △ and ▲ indicate 0, 1,000, 2,000, 3,000 and 4,000 ppm Cl, respectively. Stage II : pollination to fruit net development. Stage III : fruit net development to harvest.

saltier in all cultures with increasing sea water concentrations at more than 500 ppm Cl. There was no significant difference in fruit soluble solids within each medium except at 0 ppm Cl in solution culture. Visible symptoms appeared as chlorosis and marginal necrosis on lower leaves at stage II and progressed acropetally at stage III at 1,000 ppm Cl in sand culture. Salt injury was slightly found as marginal necrosis on lower leaves at the beginning of stage I at 3,000 and 4,000 ppm Cl in solution culture, but this necrosis did not advance further.

Major mineral elements and osmotic potential in leaves (Tables 4 to 6, Figs. 5 to 8)

Table 4. Effect of diluted sea water concentration on SO_4, Mg and K content in leaves at the end of stage III in sand and soil cultures (% of dry matter).

Sea water concn (ppm Cl)	SO_4 Sand	SO_4 Soil	Mg Sand	Mg Soil	K Sand	K Soil
0	3.71a[z]	2.10a	2.30b	2.04a	1.64a	1.88a
250	3.23a	2.10a	2.29b	2.13a	1.50a	1.65ab
500	2.35b	1.18b	2.29b	2.19a	1.46a	1.45ab
750	1.49c	1.12b	2.24b	2.21a	1.40a	1.40b
1,000	1.88bc	0.65b	2.52a	2.25a	1.24a	1.20b

[z] Mean separation in columns by Duncan's multiple range test, 5% level.

Table 5. Effect of diluted sea water concentration on SO_4, Mg and K content in leaves at the end of stage III in nutrient solution culture (% of dry matter).

Sea water concn (ppm Cl)	SO_4	Mg	K
0	2.71a[z]	2.17c	2.82a
1,000	2.16ab	2.78b	1.66b
2,000	1.82bc	3.14b	1.48b
3,000	1.14cd	3.07b	1.26b
4,000	0.95d	3.76a	0.75c

[z] Mean separation in columns by Duncan's multiple range test, 5% level.

Table 6. Effect of diluted sea water concentration on the ratio of leaf Cl in sand/soil culture.

Sea water concn (ppm Cl)	Ratio of leaf Cl in sand/soil Stage I	Stage II	Stage III
0	0.71	0.67	0.62
250	1.02	0.88	0.56
500	1.57	1.17	1.04
750	1.77	1.09	1.26
1,000	3.11	2.97	1.02

At the end of the experiment (stage III), Cl and Na increased and SO_4 and osmotic potential decreased in sand, soil and solution cultures as sea water concentrations increased.

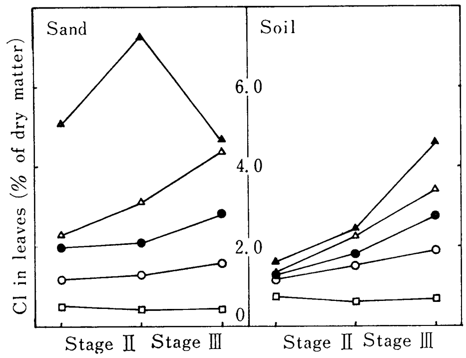

Fig. 5. Changes of Cl in leaves in sand and soil cultures. As to symbols, refet to Fig. 1.

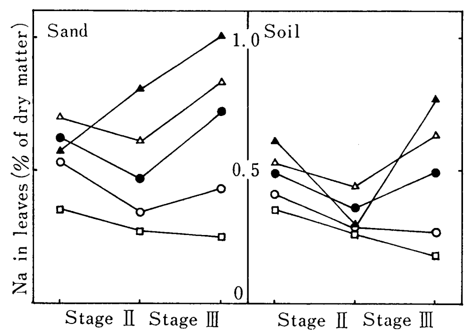

Fig. 6. Changes of Na in leaves in sand and soil cultures. As to symbols, refer to Fig. 1.

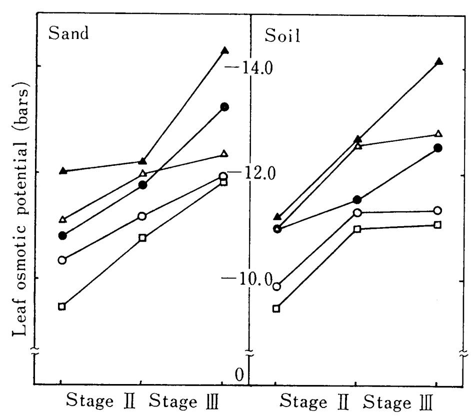

Fig. 7. Changes of leaf osmotic potential in sand and soil cultures. As to symbols, refer to Fig. 1.

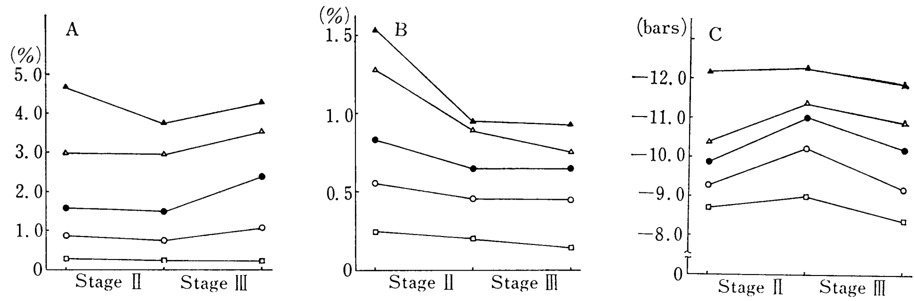

Fig. 8. Changes of Cl (A), Na (B) and osmotic potential (C) in leaves (dry wt basis) in nutrient solution culture. As to symbols, refer to Fig. 4.

K in soil and solution cultures decreased with increasing sea water concentrations. However, in sea water treatments there was little difference in Ca, Mg, K, P and total-N in sand culture, in Ca, Mg, P and total-N in soil culture, and in Ca and total-N in solution culture at each stage (data not shown). Cl increased at stages II and III at all concentrations in sand and soil cultures except at 1,000 ppm Cl in sand culture and at 0 ppm Cl in the both cultures. In solution culture, Cl was relatively stable at 1,000 to 3,000 ppm Cl at stage II, and increased at 1,000 to 4,000 ppm Cl at stage III. Cl at 0 ppm Cl was kept constant at all stages in all cultures. Na tended to decrease at stage II and to increase at stage III at 250, 500 and 750 ppm Cl in sand and soil cultures. At 1,000 ppm Cl, Na in sand culture increased continuously through stages II and III. Na tended to decrease at stage II in solution culture, and the rate of decrease increased with increasing sea water concentrations. Osmotic potential tended to decrease at stage II and to increase at stage III, at all concentrations, except at 4,000 ppm Cl, in solution culture. Osmotic potential, and Cl and Na content fluctuated erratically at higher sea water concentrations, especially at 1,000 ppm Cl in sand culture and at 4,000 ppm Cl in solution culture. Cl, Na and Mg tended to be higher in sand than in soil culture at all stages, especially Cl at the beginning of stage II. Osmotic potential was lower in sand than in soil culture at the beginning of stage II. The ratio of Cl in sand culture to that in soil culture increased with increasing sea water concetrations. The proportion of Cl and Na to 0 ppm Cl increased at each stage with increasing sea water concentrations, but was much greater in sand than in soil culture. The percentages were greater in Cl than in Na at all stages.

Chemical properties of SS (Table 7, Figs. 9 to 11) Soil solutions were extracted from sand (SSa) and soil (SSo) at the end of each stage. Cl, Na and Mg concentrations, and EC values of SSa and SSo increased, while the osmotic potential decreased at stage III with increasing sea water concentrations. Ca in SSa decreased, while that in SSo increased at stage III as sea water concentra-

Table 7. Chemical properties of soil solution (pF=0 to 3.8) at the end of stage III in sand and soil cultures.

Sea water concn (ppm Cl)	Mg (me/l)		Ca (me/l)		K (me/l)		EC (mS/cm)		pH	
	Sand	Soil	Sand	Soil	Sand	Soil	Sand	Soil	Sand	Soil
0	15.54b[z]	28.44c	18.13a	26.73d	10.59ab	8.31b	4.65d	6.01c	8.08c	7.87a
250	16.91ab	38.94b	17.89a	31.83c	10.97a	10.18ab	6.39c	11.56b	8.22bc	7.69ab
500	16.05ab	45.71b	15.28b	37.18b	10.96a	10.37ab	6.89bc	14.00b	8.37ab	7.31b
750	17.47a	59.43a	13.97c	41.31a	10.86ab	12.02a	7.45ab	16.81a	8.33ab	7.54ab
1,000	17.40a	61.46a	11.62d	40.82a	9.74b	12.41a	7.69a	19.13a	8.44a	7.36b

[z] Mean separation in columns by Duncan's multiple range test, 5% level.

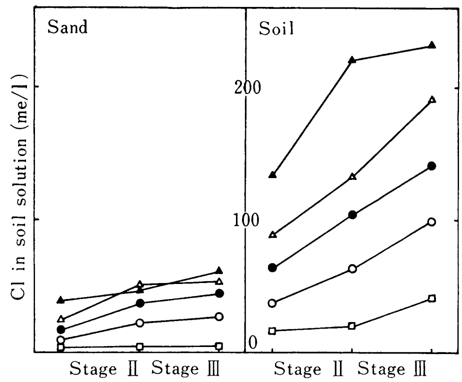

Fig. 9. Changes of Cl in soil solution (pF=0 to 3.8) in sand and soil cultures. As to symbols, refer to Fig. 1.

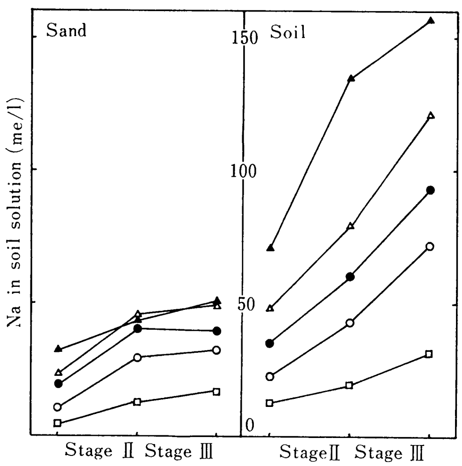

Fig. 10. Changes of Na in soil solution (pF=0 to 3.8) in sand and soil cultures. As to symbols, refer to Fig. 1.

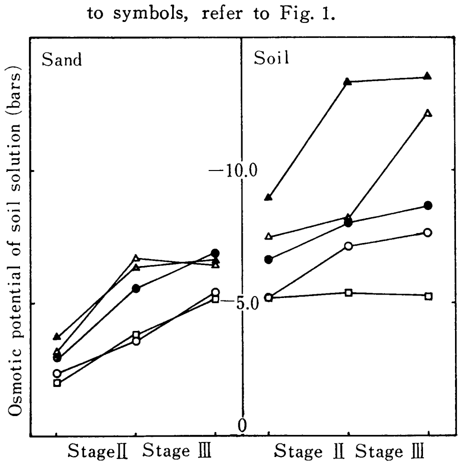

Fig. 11. Changes of osmotic potential of soil solution (pF=0 to 3.8) in sand and soil cultures. As to symbols, refer to Fig. 1.

tions increased. Cl, Na, Mg and Ca, and EC values were higher and osmotic potential was lower in SSo than in SSa at all stages. SO_4, P and NO_3-N were not markedly different between SSa and SSo. Cl, Na and EC values of both SSa and SSo tended to increase, while the osmotic potential decreased throughout the experiment.

Discussion

The effect of salinity on plant may vary depending on the growth stage(1, 3, 4, 5, 6). In many crops deleterious effect of salt stress was more promounced during the seedling stage(1, 3, 6, 12) although opinions differ in rice(13), spinach(12) and Japanese hornwort (12). Osawa(12) reported that pak-choi and chard were considerably less tolerant to salinity at the early growth stage, and in such cases Na and Cl in the plant increased proportionally to their concentrations in the treatment solutions but the increase was moderate at later stages. Difference in growth among sea water concentrations at stages II and III was more marked in sand than in soil culture. Cl and Na in leaves tended to be higher in sand than in soil culture at the end of stages I and II. Leaf osmotic potential tended to be similar in sand and soil cultures at the end of stages I and II. Therefore, one of the reasons for greater growth suppression in sand culture may be attributed to higher accumulation of Cl and/or Na in leaves at stages I and II in sand than in soil culture. In addition to Cl and Na, Mg was also higher in sand than in soil culture at all stages. However, the increase in Mg with sea water concentrations was lower than Cl or Na in sand and soil cultures. Thus, Mg accumulation in leaves does not seem to cause growth suppression in sand culture in this experiment.

Cl in leaves tended to increase throughout the experiment in sand and soil cultures, while it tended to remain relatively constant in solution culture. Na in leaves tended to decrease at stage II and to increase at stage III in sand and soil cultures, while it tended to decrease gradually throughout the experiment in solution culture. These differences are due to gradual accumulation of Cl and Na in the media throughout the experiment in sand and soil cultures and relatively constant level in solution culture. Thus, Cl and Na content in leaves was lower in soil (0.76 to 1.63% Cl and 0.35 to 0.61% Na) than in solution (0.28 to 4.07% Cl and 0.24 to 1.66% Na) culture at the end of stage I, and was almost the same in soil (0.66 to 4.57% Cl and 0.18 to 0.77% Na) and solution (0.24 to 4.26% Cl and 0.14 to 0.93% Na) cultures at the end of stage III, although sea water concentrations used differed in both. Growth suppression was more marked in solution than in soil culture, in spite of almost the same Cl and Na in leaves, at the end of stage III. Compared with 0 ppm Cl whole plant dry weight was 78.4, 70.9, 50.0 and 32.7% at 1,000, 2,000, 3,000 and 4,000 ppm Cl, respectively, in solution culture, while it was 95.1, 94.4, 90.9 and 79.5% at 250, 500, 750 and 1,000 ppm Cl, respectively, in soil culture. One of the causes for this greater growth suppression in solution culture might be high Cl and Na content in leaves at the early growth stage (stage I) in solution than in soil culture. As for growth suppression, the tendency was similar in sand and solution cultures as in soil and solution cultures. However, Cl in leaves at the beginning of stage II was higher in sand (0.50 to 5.08%) than in soil (0.76 to 1.63%) culture.

Osmotic potential of SS at the end of stage III ranged from −5.3 to −13.6 bars in soil culture and from −5.1 to −6.5 bars in sand culture at 0 to 1,000 ppm Cl. That of treatment solutions in solution culture was −0.70, −2.0, −3.3, −4.7 and −6.0 bars, being higher than that of SS in sand and soil cultures. Considering these points, Cl and Na in leaves seemed to be more deleterious to muskmelons than osmotic potential of the media. However, accurate sampling of SS which reflects the real osmotic potential at the field condition should be investigated in order to compare the osmotic potential of SS in sand and soil cultures with that of treatment solutions in solution culture.

In the current experiment, growth was more suppressed in sand than in soil culture. Cordukes and MacLean (2) observed greater salt tolerance in turfgrass in sand than in clay loam and sandy loam soils, and Cl content in turfgrass tended to be lower in sand than in soil. The relationship between greater salt tolerance and lower Cl in grasses was similar to that found in muskmelons in the present experiment, although salt tolerance was greater in soil than in sand culture. They also stated that the tolerance might be related to soil moisture content at field capacity which was 26.1% in the clay loam, 22.0% in the sandy loam and 10.0% in the sand. Therefore, further studies using SS at field capacity are needed in muskmelons to clarify the difference in growth suppresion between sand and soil cultures.

Acknowledgement

Recognition is given Dr. T. Asahira, Professor at Kyoto Univ., Dr. W. J. Clore, Horticulturist Emeritus and Dr. E. L. Proebsting, Horticulturist at IAREC, WSU, U. S. A. and Dr. M. F. R. Mallick, post-doctral fellow (research student of Monbusho) at shizuoka Univ. for the critical review of this manuscript.

Literature Cited

1. BERNSTEIN, L. and H. E. HAYWARD. 1958. Physiology of salt tolerance. Ann. Rev. Plant Physiol. 9 : 25—46.
2. CORDUKES, W. E. and A. J. MACLEAN. 1973. Tolerance of some turfgrass species to different concentrations of salt in soils. Can. J. Plant Sci. 53 : 69—73.
3. DUMBROFF, E. B. and A. W. COOPER. 1974. Effects of salt stress applied in balanced nutrient solutions at several stages during growth of tomato. Bot. Gaz. 135 : 219-224.
4. KADDAH, M. T. and S. I. GHOWAIL. 1964. Salinity effects on the growth of corn at different stages of development. Agron. J. 56 : 214—217.
5. LUNIN, J., M. H. GALLATIN, and A. R. BATCHELDER. 1963. Saline irrigation of several vegetable crops at various growth stages. I. Effect on yields. Agron. J. 55 : 107—110.
6. MAAS, E. V. and G. J. HOFFMAN. 1977. Crop salt tolerance—current assesment. ASCE J. Irrig. Drain. Div. 103 : 115—134.
7. NUKAYA, A., M. MASUI, A. ISHIDA and T.

OGURA. 1977. Salt tolerance of green soybeans. J. Japan. Soc. Hort. Sci. 46 : 18—25.
8. NUKAYA, A., M. MASUI, and A. ISHIDA. 1980. Salt tolerance of muskmelons grown in different salinity soils. J. Japan. Soc. Hort. Sci. 48 : 468-474.
9. NUKAYA, A., M. MASUI, and A. ISHIDA. 1980. Salt tolerance of muskmelons grown in different media. J. Japan. Soc. Hort. Sci. 49 : 354—360.
10. NUKAYA, A., M. MASUI and A. ISHIDA. 1983. Salt tolerance of muskmelons as affected by various salinities in sand culture. J. Japan. Soc. Hort. Sci. 51 : 427—434.
11. NUKAYA, A., M. MASUI and A. ISHIDA. 1983. Salt tolerance of muskmelons as affected by various salinities in soil culture. J. Japan. Soc. Hort. Sci. 52 : In press.
12. OSAWA, T. 1966. Effect of the stage of growth on the salt tolerance of some vegetable crops. J. Japan. Soc. Hort. Sci. 35 : 291—296. (In Japanese with English summary)
13. PEARSON, G. A. and L. BERNSTEIN. 1959. Salinity effects at several growth stages of rice. Agron. J. 51 : 654—657.

希釈した海水が異なる生育段階のメロンの耐塩性に及ぼす影響

糠谷 明・増井 正夫・石田 明
静岡大学農学部 422 静岡市大谷

摘 要

基本培養液で希釈した海水の処理が，ステージⅠ（定植時から受粉時），Ⅱ（受粉時から果実ネット発達期），Ⅲ（果実ネット発達期から収穫時）の各生育段階におけるメロンの耐塩性に及ぼす影響を明らかにするため，定植時から収穫時まで栽培した．処理濃度は，砂耕および土耕で 0, 250, 500, 750, 1,000ppm Cl，養液耕で 0, 1,000, 2,000, 3000, 4,000 ppm Cl とした．実験終了時の全植物体乾物重および果実新鮮重は，砂耕，土耕，養液耕とも海水濃度が増加するにつれて減少した．ステージⅡ，Ⅲにおける生育量の増加は，海水高濃度区で減少した．生育は土耕より砂耕で抑制された．塩害症状は，砂耕では 1,000 ppm Cl のステージⅡとⅢでわずかに現れ，養液耕では 3,000, 4000 ppm Cl のステージⅠの初期にのみ現れた．砂耕，土耕，養液耕のステージⅢでは，海水濃度が増すにつれて葉中の Cl と Na は増加し，SO_4 と浸透ポテンシャルは減少した．土耕と砂耕を比べた場合，葉中 Cl と Na はどのステージでも砂耕で高い傾向にあり，特に葉中 Cl はステージⅠで著しく高かった．砂耕における生育抑制の原因の一つは，砂耕のステージⅠで葉に集積した Cl と Na，あるいは Cl, Na 単独の影響であると考えられる．