J. Japan. Soc. Hort. Sci. 53(2) : 168—175. 1984.

Salt Tolerance of Muskmelons as Affected by Diluted Sea Water Applied at Different Growth Stages in Nutrient Solution Culture[1]

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

Summary

Muskmelons (*Cucumis melo* L.) were grown with nutrient solutions to examine the effect of stage and duration of exposure to diluted sea water treatments at stage I (transplanting to pollination), stage II (pollination to fruit net development) and/or stage III (fruit net development to harvest) on the growth at harvest in experiment I and the growth at the end of three stages in experiment II.

Experiment I Whole plant dry weight and fruit fresh weight tended to increase with reduced exposure to diluted sea water and to decrease with increased sea water concentrations. Fruit fresh weight increased and Cl and Na contents in leaves remained unaffected when plants grown in diluted sea water at stage I were grown in base nutrient solution at stages II and III. The shorter the duration of the treatments the lower the Cl and Na contents in leaves.

Experiment II The deleterious effect of treatment solution on growth generally decreased with plant age and reduced exposure to treatment solution. The exposure to treatment solution at stage III reduced whole plant dry weight and fruit fresh weight, but did not affect leaf+stem+root dry weight. Saltiness in fruit increased with longer exposure. Cl and Na contents in leaves at harvest were significantly higher when exposed to treatment solution at stage III. Osmotic potential of leaves was proportional to that of the nutrient solution at each stage.

As a result, early stage till pollination and fruit development stages were most sensitive to saline conditions when whole plant dry weight, and fruit fresh weight and quality of muskmelons were used as index of salt tolerance, respectively.

Introduction

Previous study(11) determined salt tolerance of muskmelons (*Cucumis melo* L.) at three growth stages as affected by 5 levels of sea water diluted with a base nutrient solution at 0, 1,000, 2,000, 3,000 and 4,000 ppm Cl, in nutrient solution culture.

Growth increased throughout the experiment at all concentrations, but the rate of increment decreased with increasing sea water concentration of diluted sea water throughout the experiment. The effect of salinity on plants may vary depending on their stages (4,5,8). Generally salt content in the wells contaminated by sea water varies every month (9). So, it sometimes happens that crops receive well water with different salt content throughout the growth period. Therefore, muskmelon growth from seedling to harvest was divided into three stages (I, II and III) to obtain the basic data on the relationship between salt tolerance and growth stages in nutrient solution culture. Experiment I was conducted to determine the effect of diluted sea water treated at stages I, II and III on the growth at harvest. In experiment II the effect of stage and duration of exposure to diluted sea water (4,000 ppm Cl) on muskmelon growth was determined.

Materials and Methods

Experiment I

Treatments consisted of 5 levels of sea water diluted with a base nutrient solution, as

[1] Received for publication July 23, 1983.

Table 1. Composition of treatment solution[z].

Cl concn. (ppm)	Osmotic potential (bars)	Rate of sea water[y] (%)	EC (mS/cm)
0	−0.70	0	2.43
1,000	−2.02	5.0	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 : $Na_2HPO_4 \cdot 12 H_2O$ = 1 mM, K_2SO_4 = 3 mM, $Ca(NO_3)_2 \cdot 4 H_2O$ = 4 mM, $MgSO_4 \cdot 7 H_2O$ = 2 mM, 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.

shown in Table 1, to make treatment solutions at 0, 1,000, 2,000, 3,000 and 4,000 ppm Cl. Sea water was taken from Shimizu (Miho) area. Uniform muskmelon seedlings, cv. Spring No. 3 of Earl's Favourite in the 3 leaf stage were transferred to Wagner pots (1/2,000 a) containing 13 liters of treatment solution and placed in the greenhouse on April 12, 1978. 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. Lateral shoots and other flower buds were removed. The growth period from transplanting to harvest was divided into three stages as follows : stage I (transplanting to pollination—April 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 2 to late June). Muskmelons were subjected to treatment solutions at stage I (treatment A), stages I and II (treatment B) and stages I, II and III (treatment C). Thereafter, they were transferred to base nutrient solution exclusive of treatment C.

The solution was replaced every two weeks at stage I and every week at stages II and III, and aerated continuously. Tap water was added every morning to keep the volume in pots at 13 liters. Four replicate samplings were made at the end of the experiment. Plant growth, osmotic potential and major elements in leaves were recorded. The analytical methods were the same as described previously(10).

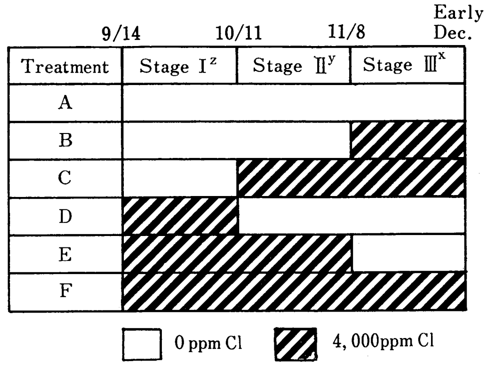

Fig. 1. Duration of exposure to diluted sea water (4,000 ppm Cl) in experiment II.

[z] Stage I : transplanting to pollination.

[y] Stage II : pollination to fruit net development.

[x] Stage III : fruit net development to harvest.

Experiment II

This experiment included 6 treatments, as shown in Fig. 1, with different duration of exposure of muskmelons to diluted sea water (4,000 ppm Cl). Sea water from Shimizu (Miho) was diluted with a base nutrient solution to make a treatment solution at 4,000 ppm Cl as shown in Table 1. The growth period was divided into three stages as in experiment I. Uniform muskmelon seedlings, cv. Fall No. 1 of Earl's Favourite in the 2.5 leaf stage were transferred to Wagner pots (1/2,000 a) containing 13 liters of treatment solution on Sept. 14, 1978. At the end of each stage (Oct. 11, Nov. 8 and early Dec. corresponding to stages I, II and III), samples were taken and plant growth, osmotic potential of leaves and major elements in leaves were measured. Each treatment had 4 replications. The other experimental procedures and analytical methods were the same as in experiment I.

Results

Experiment I

Growth at harvest (**Figs. 2 to 4**) Whole plant dry weight and fruit fresh weight tended to increase with the reduced duration of exposure, and to decrease with increased sea water concentrations. Whole plant dry weight was almost the same in all treatments at 1,000 ppm Cl, but was relatively greater in treatment

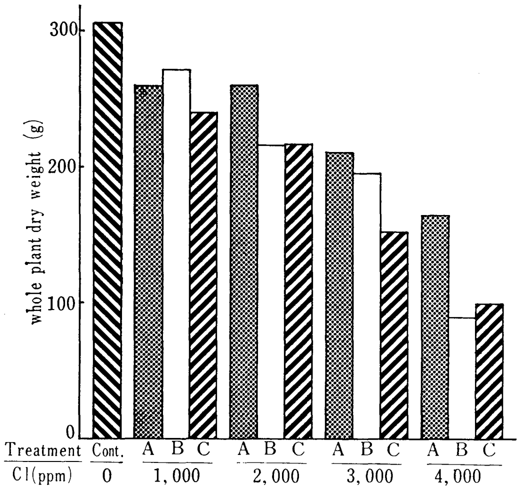

Fig.2. Effect of duration of exposure to diluted sea water on whole plant dry weight at harvest in experiment I. Treatments A, B and C below columns indicate that plants were exposed to treatment solution at stage I, stages I and II and stages I, II and III, respectively, in Figs 2 to 7.

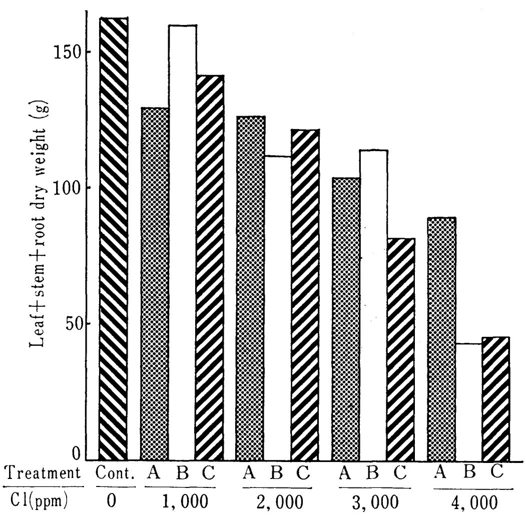

Fig.3. Effect of duration of exposure to diluted sea water on leaf+stem+root dry weight (g) at harvest in experiment I.

A than in B and C at 4,000 ppm Cl. Fruit fresh weight increased when plants were transferred to base nutrient solution at stages II and III (treatments A and B) at 1,000, 2,000 and 3,000 ppm Cl compared with treatment C. Fruit fresh weight at 4,000 ppm Cl declined in treatments B and C. Leaf+stem+root dry weight also decreased with increasing sea water concentrations, but was not significant-

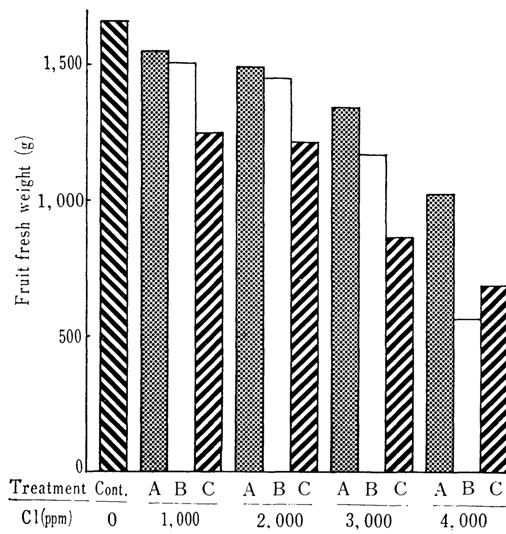

Fig.4. Effect of duration of exposure to diluted sea water on fruit fresh weight (g) at harvest in experiment I.

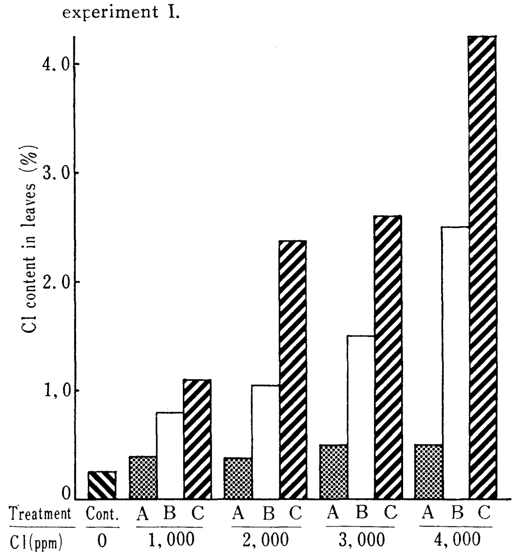

Fig.5. Effect of duration of exposure to diluted sea water on Cl content in leaves (% of dry matter) at harvest in experiment I.

ly different among treatments A, B and C at each sea water concentration except for 4,000 ppm Cl. Fruit soluble solids were less affected by the duration of exposure and sea water concentrations of treatment solution, although fruit taste was saltier in treatments B and C at 4,000 ppm Cl (data not shown).

Cl and Na content, and osmotic potential of leaves (Figs. 5 to 7) Cl and Na in treatments B and C increased with increasing sea water

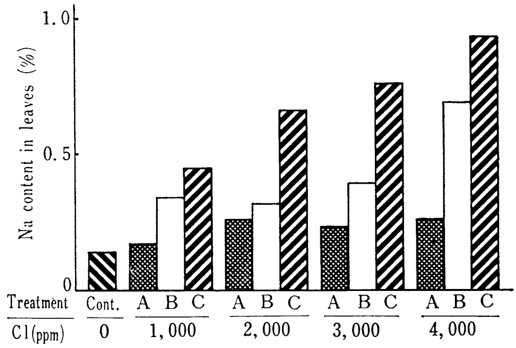

Fig. 6. Effect of duration of exposure to diluted sea water on Na content in leaves (% of dry matter) at harvest in experiment I.

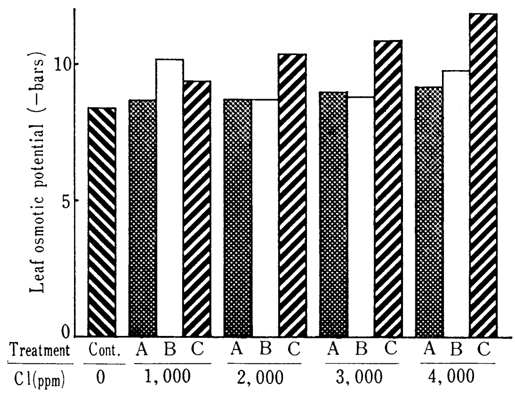

Fig. 7. Effect of duration of exposure to diluted sea water on osmotic potential of leaves (−bars) at harvest in experiment I.

concentrations, but those in treatment A were not different and were almost the same as the control. Cl and Na in decreasing order were C>B>A at each sea water concentration. Osmotic potential decreased in treatment C as sea water concentrations increased, but were not affected by sea water concentrations and duration in treatments A and B.

Experiment II

Growth and fruit quality (Figs. 8 to 11) Whole plant and leaf+stem+root dry weights, and fruit fresh weight at harvest were reduced by exposure to the treatment solution at all stages during this experiment as compared with treatment A. These deleterious effects of treatment solution on the growth generally decreased with time and shorter exposure to treatment solution. Whole plant dry weight and fruit fresh weight, compared with treatment A, were 65.8 and 69.0%, 65.1 and 61.8%,

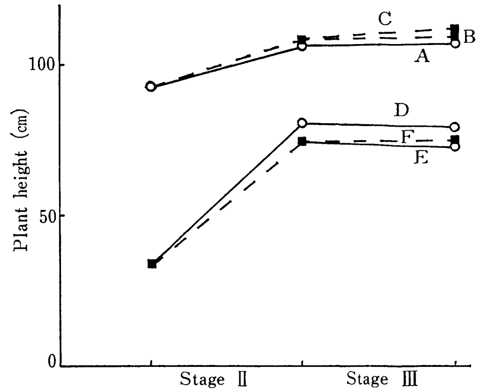

Fig. 8. Effect of stage and duration of exposure to treatment solution on plant height (cm) in experiment II. Symbols (○ and ■) in Figs. 8 to 14 indicate that plants were treated with base nutrient solution (0 ppm Cl) and treatment solution (4,000 ppm Cl), respectively, at each stage.

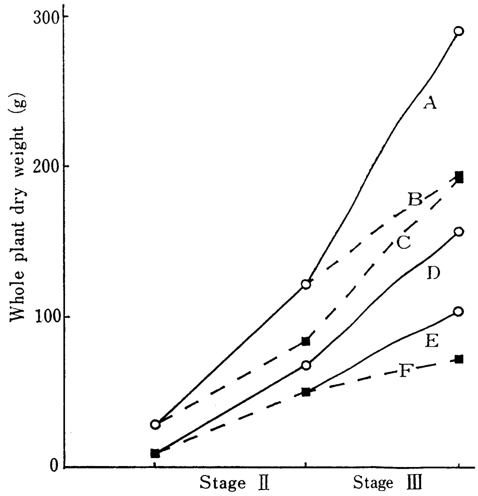

Fig. 9. Effect of stage and duration of exposure to treatment solution on whole plant dry weight (g) in experiment II.

53.2 and 64.1%, 35.3 and 41.1%, and 24.4 and 31.3% in treatments B, C, D, E and F, respectively. Plant height, and whole plant and leaf+stem+root dry weights were greater when plants were grown in base nutrient solution than in treatment solution at stage I in spite of the treatment at stages II and III. Exposure to treatment solution at stage III (treatment B) reduced whole plant dry weight and fruit fresh weight when compared with treatment A, but did not affect leaf+stem+root dry weight. Marked reduction in

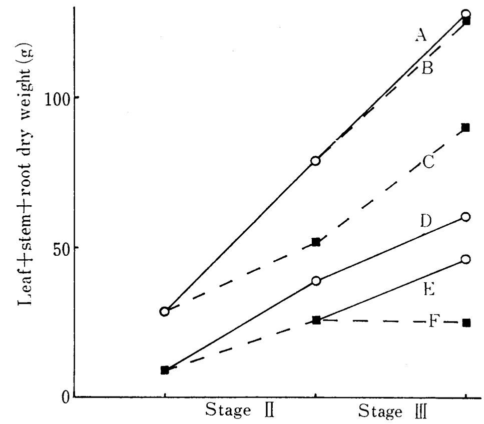

Fig. 10. Effect of stage and duration of exposure to treatment solution on leaf+stem+root dry weight (g) in experiment II.

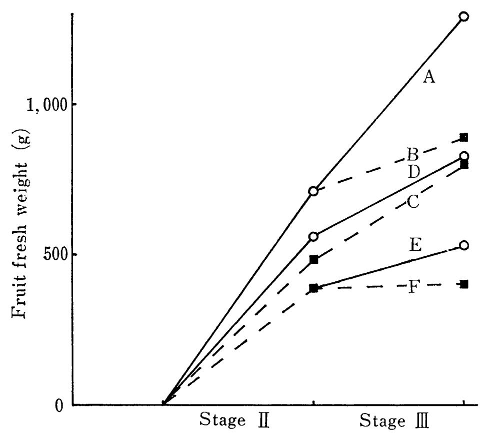

Fig. 11. Effcet of stage and duration of exposure to treatment solution on fresh weight (g) in experiment II.

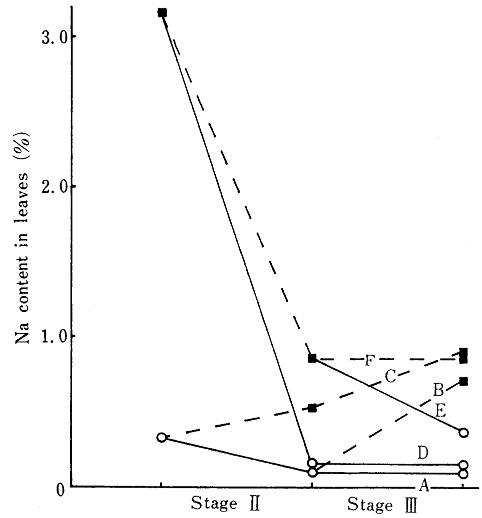

Fig. 12. Effect of stage and duration of exposure to treatment solution on Cl content in leaves (% of dry matter) in experiment II.

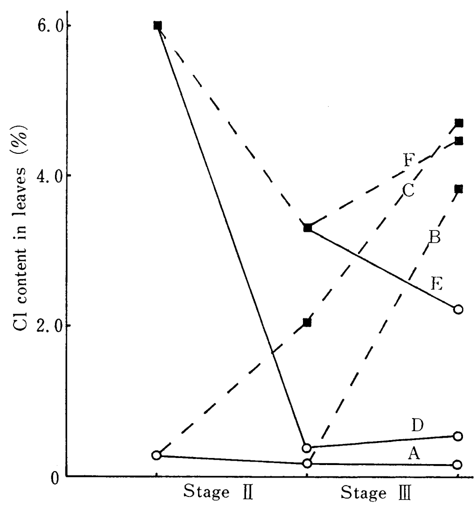

Fig. 13. Effect of stage and duration of exposure to solution on Na content in leaves (% of dry matter) in experiment II.

fruit fresh weight was observed when plants 53.2 and 64.1%, 35.3 and 41.1%, and 24.4 were exposed to treatment solution at stages I and II (treatments E and F), although the weight increased slightly when trasferred to the base nutrient solution at stage III (treatment E). Fruit fresh weight in treatments B, C and D was not significantly different each other in spite of the duration and stage of exposure. Fruit soluble solids at harvest (14.1 to 15.7%) were not affected by treatments except in treatment B where the value was very low (9.8%) (data not shown). Fruit taste, evaluated by panel tests, was best in treatments A and D, and worst in treatment B. Saltiness in fruit increased with increasing duration of exposure to treatment solution. All panelists reported saltiness in treatment F.

Major elements and osmotic potential in leaves (Table 2, Figs. 12 to 14) Cl and Na at harvest were significantly higher when exposed to treatment solution at stage III (treatments B, C and F) and lower when grown in base nutrient

Table 2. Effect of stage and duration of exposure to treatment solution on major elements in muskmelon leaves and Cl in the fruit at harvest in experiment II (% of dry matter).

	Treatment			Leaves						Fruit
	Cl concn. (ppm)									
	Stage I	Stage II	Stage III	Total-N[z]	P	K	Ca	Mg	SO_4	Cl
A	0	0	0	2.95[a]	1.39[b]	3.23[b]	6.45[ab]	1.76[e]	1.15[ab]	0.28[d]
B	0	0	4,000	2.75[a]	1.73[a]	3.83[a]	5.39[cd]	2.05[d]	1.13[ab]	0.81[c]
C	0	4,000	4,000	3.33[a]	1.26[bc]	1.95[cd]	4.58[d]	2.82[b]	0.47[c]	1.59[b]
D	4,000	0	0	3.04[a]	1.10[cd]	3.22[b]	7.16[a]	1.75[e]	1.18[a]	0.39[d]
E	4,000	4,000	0	2.49[a]	0.92[d]	2.31[c]	5.93[bc]	2.34[c]	0.91[b]	1.36[b]
F	4,000	4,000	4,000	2.47[a]	0.46[e]	1.56[d]	5.09[cd]	3.27[a]	0.49[c]	2.43[a]

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

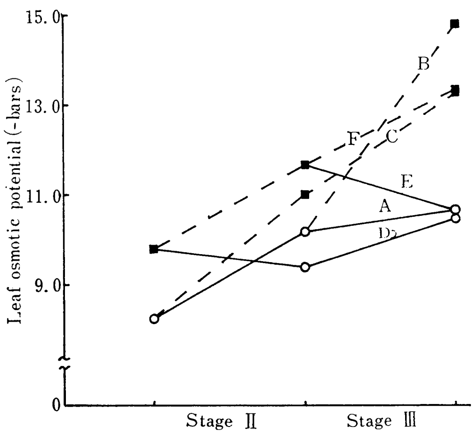

Fig. 14. Effect of stage and duration of exposure to treatment solution on osmotic potential of leaves (−bars) in experiment II.

solution at stages II and III (treatments A and D). When plants were exposed to treatment solution at stage I, Cl and Na decreased at stage II regardless of treatments. The decrease was greater when grown in base nutrient solution (treatment D) than when exposed to treatment solution (treatments E and F) at stage II. Cl and Na increased continuously at stages II and III in treatment C and at stage III in treatments B and F. Osmotic potential of leaves was proportional to that of the nutrient solution in which plants were grown at each stage. Therefore, that at harvest was lower when exposed to treatment solution at stage III (treatments B, C and F) and was higher when grown in base nutrient solution at stage III (treatments A, D and E). SO_4 tended to be high when grown in base nutrient solution and low when exposed to treatment solution. P and Ca tended to increase and total-N decreased in all treatments with time. Ca became lower when expose to treatment solution than when grown in base nutrient solution. Mg increased and K decreased with time when exposed to treatment solution.

Cl content in fruit (Table 2) Cl in fruit at harvest was proportional to the duration of exposure to treatment solution, and especially high when exposed to treatment solution at stages II and III. It was highest in treatment F and lowest in treatments A and D.

Discussion

Barley, wheat and corn were more sensitive to salinity during seedling growth than during germination and later stages of growth and grain development(2, 3, 7). Soybean tolerance might increase or decrease from germination to a later growth stage depending upon variety(1). Deleterious effects of salt stress on vegetative growth of tomatoes were most pronounced when plants were exposed to saline conditions during the early seedling stage(5). Therefore, the effect of salinity on plant growth may vary depending on the stage of the plant(4) and the most sensitive stage seems to differ with crops(8).

In experiment II, whole plant dry weight at stages II and III were greater when plants were grown at stage I in base nutrient solution (treatments A, B and C) than in treatment solution with 4,000 ppm Cl (treatments D, E and F). Whole plant dry weight transferred from base nutrient solution to treatment solution at both stages II and III (treatment C) was still greater than that transferred from treatment solution to base nutrient solution at the same stages (treatment D). These results suggest that whole plant dry weight of muskmelons was most severely reduced when plants were exposed to treatment solution during the early seedling stage as is true with tomatoes(5). However, the most sensitive stage may also differ with the plant portion used as an index of salt tolerance. Sepaskhah(12) observed that, in soybeans, water stress was more critical in the pod-filling stage and reduced seed yield and 100-seed weight at all salinity levels. In experiment II, leaf+stem+root dry weight was not significantly different between treatments A and B, but fruit fresh weight was significantly smaller in treatment B than in A. Between treatments C and D, leaf+stem+root dry weight was greater in treatment C, but fruit fresh weight was not significantly different. The taste of fruit was better in treatments A and D grown in base nutrient solution at stages II and III than in treatment B exposed to treatment solution at stage III alone. Therefore, early stage till pollination (stage I) and fruit development stage (stages II and III) were most sensitive to saline conditions when whole plant dry weight (vegetative growth) and fruit fresh weight and quality (reproductive growth) of muskmelons were used as index of salt tolerance, respectively.

In addition to the effect on growth, duration of exposure to salinization is important. Experiments I and II showed that plant responses were directly related to the duration of exposure to salinity as observed by other investigators(6, 7), although the duration of treatment was related to the stage of plant.

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-doctoral fellow (research student of the Ministry of Education in Japan) at Shizuoka Univ. for the critical review of this manuscript.

Literature Cited

1. Abel, G. H. and A. J. MacKenzie. 1964. Salt tolerance of soybean varieties (*Glycine max* L. Merr.) during germination and later growth. Crop Sci. 4 : 157—161.
2. Ayers, A. D., J. W. Brown and C. H. Wadleigh. 1952. Salt tolerance of barley and wheat in soil plots receiving several salinization regimes. Agron. J. 44 : 307—310.
3. Ayers, A. D. 1953. Germination and emergence of several varieties of barley in salinized soil cultures. Agron. J. 45 : 68—71.
4. Bernstein, L. and H. E. Hayward. 1958. Physiology of salt tolerance. Ann. Rev. Plant Physiol. 9 : 25—46.
5. 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.
6. George, L. Y. and W. A. Williams. 1964. Germination and respiration of barley, strawberry, clover and Ladino clover seeds in salt solutions. Crop. Sci. 4 : 450—452.
7. 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.
8. Maas, E. V. and G. J. Hoffman. 1977. Crop salt tolerance ——current assesment. ASCE J. Irrig. Drain. Div. 103 : 115—134.
9. Masui, M., A. Nukaya and A. Ishida. 1975. Salt content of well water of greenhouse growers in Shizuoka Prefecture. Bull. Fac. Agr., Shizuoka Univ., Japan. 25 : 15—22. (In Japanese with English summary).
10. Nukaya, A., M. Masui, A. Ishida and T. Ogura. 1977. Salt tolerance of green soybeans. J. Japan. Soc. Hort. Sci. 46 : 18—25.
11. Nukaya, A., M. Masui and A. Ishida. 1983. Salt tolerance of muskmelons at different growth stages as affected by diluted sea water. J. Japan. Soc. Hort. Sci. 52 : 286—293.
12. Sepaskhah, A. R. 1977. Effects of soil salinity levels and plant water stress at various soybean growth stages. Can. J. Plant Sci. 57 : 925—927.

養液耕における異なる生育段階の海水希釈液処理が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

メロンを養液耕で栽培し，ステージⅠ（定植時から受粉時），ステージⅡ（受粉時から果実ネット発達期），ステージⅢ（果実ネット発達期から収穫時）の全期間又はある一定期間の海水希釈液処理が，収穫時の生育（実験Ⅰ）と各ステージ終了時の生育（実験Ⅱ）に及ぼす影響を調査した．

実験Ⅰ　全植物体乾物重と果実新鮮重は，海水希釈液の処理期間が短くなるにつれて増加し，海水濃度が増すにつれて減少する傾向を示した．ステージⅠにおいて海水希釈液処理をしたメロンを，ステージⅡ及びⅢにおいて基本培養液で育てた場合，果実新鮮重は増加したが，葉中 Cl, Na 含量は海水希釈液の影響を受けなかった．処理期間が短くなるにつれて，葉中 Cl, Na 含量は低下した．

実験Ⅱ　生育に及ぼす海水希釈液の影響は，概して生育の進行及び処理期間の減少につれて小さくなった．ステージⅢにおける海水希釈液の処理は，全植物体乾物重と果実新鮮重を減少させたが，葉・茎・根の合計乾物重には影響を及ぼさなかった．果実の塩辛味は，処理期間が長くなるにつれて増加した．収穫時の葉中 Cl, Na 含量は，ステージⅢで海水希釈液の処理をした場合に高かった．葉の浸透ポテンシャルは，概してそれぞれのステージにおける培養液の浸透ポテンシャルと比例的関係にあった．

以上の結果，メロンの耐塩性の指標として全植物体乾物重を用いた場合には受粉時までの生育期（ステージⅠ）が，果実新鮮重及び品質を用いた場合には果実発達期（ステージⅡ，Ⅲ）が，塩類処理に最も敏感であった．