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Effects of Nitrogen Form on Growth of Muskmelons

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Summary

Muskmelons (*Cucumis melo* L.) were grown in sand with 7 N form treatments ($NO_3 : NH_4$; 10 : 0, 8 : 2, 6 : 4, 5 : 5, 4 : 6, 2 : 8 and 0 : 10) supplied daily at a concentration of 90 ppm. A total of 78 liters of treatment solution was applied per plant throughout the experiment. The higher NH_4 ratios caused plant growth and fruit fresh weight to decrease, while fruit soluble solids remained slightly higher. With increasing NH_4 ratios N in leaves increased. NO_3-N and NH_4-N in the plant parts and medium (sand) reflected the form of N that was supplied. N uptake by plants at all NH_4 ratios was greatest at 5,137 mg per plant. With increasing NH_4 ratios NH_4-N in soil solution increased, while NO_3-N and Na, and pH and EC values tended to decrease.

Introduction

Greenhouse muskmelon growers in Shizuoka Prefecture use mainly rapeseed cake and fish cake to supply nitrogen (N) fertilizer in a slowly available form for the production of high quality fruit. In general, rapidly available N in large amounts tends to produce poor quality fruit(8, 9). However, when analized for NO_3-N and NH_4-N in soils producing high quality fruit, amounts of these N forms tended to vary with the kind of soils, the number of crops per year, fertilization, cultural practices etc. (8, 9, 10). Thus a question arises as to which muskmelons prefer NO_3-N or NH_4-N *per se*. The objective of this study was to determine the growth of muskmelons grown in sand applied with nutrient solution containing different ratios of $NO_3 : NH_4$.

Materials and Methods

Thirty-two uniform seedlings of muskmelons (*Cucumis melo* L. cv. Earl's Favourite Fall No. 1) were used. Treatments consisted of 7 plots receiving $NO_3 : NH_4$ ratios as 10 : 0, 8 : 2, 6 : 4, 5 : 5, 4 : 6, 2 : 8 and 0 : 10. Control plants were grown in soil fertilized with 7 g N per plant from rapeseed cake. Thus there were 8 plots, each having 4 replications. On Sept. 14, 1978, seedlings with 2.5 to 3 leaves were planted in 40×40 ×20 cm boxes filled with 19 liters of Tenryu River sand which was classified into Loamy coarse sand (LS). This LS refers to sand for short thereafter. The bottom of boxes was filled with 2 kg rice straw to maintain good aeration. The muskmelons were grown in a three-quarter greenhouse kept at 20°C to 30°C during the day and 18°C to 20°C at night. The N source of NO_3 and NH_4 was $NaNO_3$ and $(NH_4)_2SO_4$, respectively. The composition of the nutrient solution except for N was as follows : $Na_2HPO_4 \cdot 12 H_2O$ (1 mM), K_2SO_4 (3 mM), $CaCl_2 \cdot 2 H_2O$ (4 mM), $MgSO_4 \cdot 7 H_2O$ (2 mM), Fe from Fe-EDTA (1 ppm), Mn from $MnSO_4$ (0.5 ppm), B from H_3BO_3 (0.5 ppm), Zn from $ZnSO_4 \cdot 7 H_2O$ (0.05 ppm), Cu from $CuSO_4 \cdot 5 H_2O$ (0.02 ppm) and Mo from $Na_2MoO_4 \cdot 2 H_2O$ (0.05 ppm). Nutrient solutions containing 90 ppm N (NO_3+NH_4) at pH 6.0 were applied 1 or 2 times each day in equal quantities of 0.75 liters to each box whether it was cloudy or sunny. No solutions were applied on rainy days. A total of 78 liters of solution was applied per plant throughout the experiment. The control plot was basically fertilized with 4 g N from rapeseed cake, 10 g P_2O_5 from calcium superphosphate, 8 g K_2O from K_2SO_4

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and 20 g CaO from $Ca(OH)_2$. In addition, 1.5 g N from rapeseed cake were applied on Oct. 4 and Oct. 27, 1978. Control plants were watered at the same time the treated plants received nutrient solutions. Total tissue N determination followed the method used by Peterson and Chesters(13). Tissue NO_3-N and NH_4-N were determined electrometically, using a distilled water extract of dried, ground plant tissue. Tissue K, Na, Ca and Mg were determined by an atomic absorption photometer, and P by an ammonium molybdate procedure. Samples of sand mediums were taken on the 29 th, 57 th and 83 rd day after planting, and air-dried, and NH_4-N and NO_3-N were determined. Also the chemical properties of the soil solution were determined at the end of the experiment on the extract centrifugally taken at pF 0 to 3.8. The resulting data were subjected to the analysis of variance, and differences among means were tested by Duncan's method.

Results

1. *Plant and fruit growth (Table 1).*

Dry weight of the leaves, stem and whole plant was greatest at $NO_3 : NH_4 = 8 : 2$, and that of leaves, stem and roots was less at 2 : 8, and 0 : 10. Dry weight of the roots was greater at $NO_3 : NH_4 = 6 : 4$, 5 : 5, and 4 : 6, while less at 10 : 0, and 2 : 8. Fruit fresh weight tended to decrease with decreasing ratios of $NO_3 : NH_4$ except for $NO_3 : NH_4 = 8 : 2$. Fruit soluble solids were slightly greater at higher NH_4 ratios. Fruit external appearance such as shape, net and rind color, and internal quality such as flesh texture and color, except for soluble solids, were not affected by treatments. The control fruit fresh weight was slightly greater, while soluble solids were slightly lower.

2. *Elemental content in leaves (Table 2).*

With decreasing ratios of $NO_3 : NH_4$, N tended to increase, while P, Na, Ca and Mg tended to decrease. The control Ca was greatest, while N, K and Na was least.

3. *NO_3-N and NH_4-N content in plant parts, and N plant uptake (Table 3).*

NO_3-N in plant parts decreased with decreasing ratios of $NO_3 : NH_4$. At the $NO_3 : NH_4 = 10 : 0$ NO_3-N was highest in the stem followed by the roots and then the leaves. The control NO_3-N was lower in the stem. In leaves NH_4-N was lower than NO_3-N, but was higher at $NO_3 : NH_4 = 4 : 6$, 2 : 8, and 0 : 10 than the others. NH_4-N in the roots tended to increase with decreasing ratios of $NO_3 : NH_4$. The N plant uptake (total of leaves, stem, roots and fruit) was greatest at all NH_4 ratios showing 5,137 mg per plant.

4. *NO_3-N and NH_4-N content in sand during growing period (Table 4).*

NO_3-N in sand tended to increase with increasing ratios of $NO_3 : NH_4$, and tended to increase with time at each ratio of $NO_3 : NH_4$. NH_4-N in sand tended to increase with decreasing ratios of $NO_3 : NH_4$ with increasing time. The control NH_4-N was as low as 4.2 ppm on Dec. 6.

5. *Chemical properties of soil solution*

Table 1. Effect of nitrogen form on the growth of muskmelons in sand culture.

$NO_3 : NH_4$	Plant height at harvest(cm)	Leaf dry wt (g)	Stem dry wt (g)	Root dry wt (g)	Whole plant dry wt (g)	Fruit	
						Fresh wt (g)	Soluble solids (%)
10 : 0	116^{az}	64.9^{ab}	19.0^{ab}	2.4^{b}	199^{abc}	1121^{a}	14.1^{c}
8 : 2	116^{a}	70.2^{a}	21.0^{a}	4.3^{ab}	213^{a}	936^{bc}	14.4^{bc}
6 : 4	120^{a}	58.8^{ab}	18.4^{abc}	5.5^{a}	207^{ab}	1030^{ab}	15.0^{ab}
5 : 5	118^{a}	64.5^{ab}	19.3^{ab}	5.4^{a}	205^{ab}	923^{bc}	14.9^{ab}
4 : 6	112^{a}	55.1^{ab}	16.6^{bcd}	5.6^{a}	186^{bcd}	907^{bc}	15.6^{a}
2 : 8	111^{a}	47.6^{b}	14.0^{d}	2.5^{b}	175^{cd}	910^{bc}	15.5^{a}
0 : 10	112^{a}	50.7^{ab}	14.8^{cd}	3.2^{ab}	168^{d}	832^{c}	15.7^{a}
Rs C^{y}	114	53.0	18.8	2.3	209	1195	14.3

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

Table 2. Effect of nitrogen form on the elemental content of muskmelon leaves grown in sand culture (% of dry wt).

$NO_3 : NH_4$	N	P	K	Na	Ca	Mg
10 : 0	2.98[c z]	0.65[a]	2.49[b]	0.27[a]	6.75[a]	1.69[a]
8 : 2	3.11[c]	0.56[b]	2.97[ab]	0.20[b]	5.20[b]	1.26[b]
6 : 4	3.54[bc]	0.57[b]	3.02[ab]	0.20[b]	4.24[c]	1.11[c]
5 : 5	3.35[bc]	0.49[c]	3.26[a]	0.16[b]	3.86[c]	1.06[c]
4 : 6	3.33[bc]	0.49[c]	3.26[a]	0.18[b]	3.98[c]	1.11[c]
2 : 8	3.85[ab]	0.46[c]	3.08[ab]	0.11[c]	3.48[cd]	0.87[d]
0 : 10	4.48[a]	0.41[d]	3.05[ab]	0.10[c]	3.31[d]	0.88[d]
Rs C[y]	2.08	0.44	2.16	0.07	7.15	0.73

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

Table 3. Effect of nitrogen form on the nitrate and ammonium content of plant parts and N amount taken up by muskmelon plants grown in sand culture.

$NO_3 : NH_4$	NO_3-N (ppm of dry wt)			NH_4-N (ppm of dry wt)			N taken up[x] (mg/plant)
	Leaves	Stem	Roots	Leaves	Stem	Roots	
10 : 0	773[a z]	3423[a]	1061[a]	36[b]	284[a]	267[c]	4446
8 : 2	633[ab]	2755[a]	661[b]	33[b]	255[a]	275[c]	4470
6 : 4	645[ab]	1605[b]	385[c]	35[b]	371[a]	315[b]	4848
5 : 5	609[ab]	818[c]	222[d]	36[b]	308[a]	308[b]	4557
4 : 6	481[bc]	583[c]	123[e]	47[ab]	391[a]	332[ab]	4425
2 : 8	306[c]	260[c]	44[f]	55[a]	331[a]	354[a]	4412
0 : 10	337[c]	178[c]	31[f]	54[a]	306[a]	343[a]	5137
Rs C[y]	539	213	218	22	311	321	2949

[z],[y]Same as Table 1. [x]Not subjected to statistical analysis.

Table 4. Nitrate and ammonium content of sand during growing period (ppm of dry sand).

$NO_3 : NH_4$	NO_3-N			NH_4-N		
	Oct. 13	Nov. 11	Dec. 6	Oct. 13	Nov. 11	Dec. 6
10 : 0	4.4[a z]	7.5[ab]	22.0[a]	1.8[d]	1.4[e]	2.3[g]
8 : 2	2.9[b]	8.7[a]	14.4[b]	1.7[d]	1.4[e]	6.7[f]
6 : 4	3.0[ab]	6.6[b]	9.3[c]	1.5[d]	1.9[de]	12.8[e]
5 : 5	2.6[b]	4.3[c]	7.4[cd]	1.6[d]	2.1[d]	16.7[d]
4 : 6	3.2[ab]	4.4[c]	6.1[de]	3.0[c]	3.3[c]	20.0[c]
2 : 8	2.3[b]	2.8[e]	4.2[ef]	5.4[b]	5.7[b]	31.3[b]
0 : 10	1.8[b]	1.0[d]	2.0[f]	6.3[a]	7.7[a]	35.7[a]
Rs C[y]	51.7	7.6	21.8	4.5	4.0	4.2

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

(*Table 5*).

With increasing ratios of $NO_3 : NH_4$, NO_3-N and Na, and pH and EC values increased, while NH_4-N decreased. P was higher at $NO_3 : NH_4 = 10 : 0$, and K, Ca and Mg was lower at $NO_3 : NH_4 = 0 : 10$. The control pH was as high as 6.73, while NH_4-N, K, Na and Mg were markedly low.

Discussion

This experiment showed that higher NH_4 ratios reduce plant growth and fruit weight, increase fruit soluble solids, decrease Ca and Mg in leaves, and increase N in leaves of muskmelons in sand culture. Similar results were reported for some vegetable crops (1, 2, 3, 4, 5, 6, 7, 12, 15). The reason of reduced

Table 5. Chemical properties of soil solution (pF=0~3.8) at the end of experiment.

$NO_3 : NH_4$	NO_3-N (ppm)	NH_4-N (ppm)	P (ppm)	K (me/*l*)	Na (me/*l*)	Ca (me/*l*)	Mg (me/*l*)	pH	EC (m℧/cm)
10 : 0	108[a z]	5[g]	9.7[a]	10.3[a]	34.7[a]	14.1[ab]	13.0[ab]	6.68[a]	7.18[a]
8 : 2	86[b]	14[f]	4.3[b]	9.7[ab]	23.4[b]	13.2[abc]	11.5[ab]	6.00[b]	6.88[ab]
6 : 4	55[c]	29[e]	3.4[b]	10.3[a]	21.6[b]	14.5[ab]	13.9[a]	5.20[c]	6.96[ab]
5 : 5	37[d]	38[d]	2.8[b]	9.9[ab]	19.1[bc]	14.7[a]	13.8[ab]	5.00[cd]	6.06[bc]
4 : 6	35[de]	48[c]	2.7[b]	9.7[ab]	16.1[c]	15.1[a]	14.3[a]	4.80[de]	5.89[cd]
2 : 8	24[e]	73[b]	3.1[b]	7.5[bc]	10.5[d]	12.4[bc]	12.0[ab]	4.59[ef]	4.93[de]
0 : 10	8[e]	86[a]	3.7[b]	5.7[c]	5.6[e]	11.8[c]	10.6[b]	4.50[f]	4.32[e]
Rs C[y]	98	4	5.7	3.1	6.5	27.7	8.1	6.73	4.33

[z,y]Same as Table 1.

plant growth and fruit weight (Table 1) may be due to excess NH_4 uptake by plant, depressed Ca absorption by plants, a lowering of medium pH etc. In this experiment NH_4 injury was not found on leaves. However, NH_4-N content in sand and soil solution seemed to be high enough to reduce plant growth and fruit weight as showing 35.7 and 86 ppm at $NO_3 : NH_4 = 0 : 10$, respectively. Fruit soluble solids were slightly greater at higher NH_4 ratios. This seems to be due to fruit weight because small fruits have generally higher soluble solids under greenhouse cultivation. In general, higher NH_4 supply promotes protein synthesis in plants. However, vigorous protein synthesis often reduces plant growth due to an excess NH_4 when the carbohydrate is deficient within plants. As shown in Table 2, N content in leaves increased with increasing NH_4 ratios. In comparing these results to another study (11), more than 3.5% N in leaves seem to be high for plant growth. Thus the ratio of $NO_3 : NH_4$ for optimum plant growth seems to be 10 : 0 or 8 : 2 judging only from the N content in the leaves.

According to results by some reporters(3, 4, 12, 15,), the symptom of NH_4 injury found on leaves was rolling, and marginal and interveinal chlorosis or necrosis. In this experiment any symptom of NH_4 injury was not found on leaves although growth was reduced, and leaves became darker green at higher NH_4 ratios. The reason seems to be related to cultivation time. Iwata reported that NH_4 injury appears more rapidly on summer crops than winter crops(3). Another study of ours showed that NH_4 injury appears on leaves as marginal chlorosis and necrosis in muskmelons grown in early summer, and that NH_4-N content in leaves is much higher than that in this experiment (11).

Ca and Mg in leaves decreased with increasing NH_4 ratios (Table 2). These reductions can be explained by the electrochemical equilibrium theory that NH_4 uptake must be accompanied by either inorganic anion uptake and/or higher organic anion production, or reduced uptake of inorganic cations(14). As to Ca nutrition we have pointed out that muskmelons are luxurious consumers of this element(10). Considering this, the decreasing Ca absorption with higher NH_4 ratios is highly correlated with the poor growth of plants.

Nutrient solutions with higher NH_4 ratios became extremely acid as the plants extracted NH_4^+ ions from the soil solution (Table 5). This increased acidity seems to be associated with poor utilization of NH_4, Ca and Mg which restricted plant growth. Maynard *et al.* reports that the growth of some vegetable crops is increased by maintaining sand medium pH near neutrality by the addition of $CaCO_3$ regardless of N source(12). Similar results with muskmelons will be published separately.

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窒素の形態がメロンの生育に及ぼす影響

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摘　要

窒素（NO_3 と NH_4 の合計）濃度 90 ppm で，NO_3：NH_4 の比率 10：0, 8：2, 6：4, 5：5, 4：6, 2：8, 0：10 の7処理を設け，メロンを砂耕栽培した．全生育期間中の1株当たりの処理溶液は78 *l* であった．NH_4 の比率が高くなると生育は低下し，果重は減少したが，果実の糖度はやや増加した．NH_4 の比が増加するにつれ，葉のN含量は増加した．植物体各部及び培地（砂）の NO_3-N と NH_4-N 含量は，施用した窒素の形態をよく反映した．

1株当たりの窒素吸収量は，NH_4 のみを施用した区が 5,137 mg で最も多かった．NH_4 の比が増加するにつれ，土壌溶液中の NH_4-N 含量は増加したが，NO_3-N, Na 含量，pH, EC は減少する傾向がみられた．