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Salt Tolerance of Tomatoes

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Summary

Experiments were conducted to determine the effect of diluted sea water on the germination, growth and yield of tomatoes.

1) The germination percentage of tomato seeds decreased even at 100 ppm Cl 2 days after the test was started. The germination percentage in 6 days was not significantly different among 0 to 1000 ppm Cl. Yet, germination at 2000 and 3000 ppm Cl was 80.5 and 21.5%, respectively, and was significantly lower than among 0 to 1000 ppm Cl.

2) Transpiration rate of tomatoes transferred to diluted sea water with Hoagland's soln decreased with increasing sea water concns.

3) Tomato seedlings were grown in water culture with sea water diluted with Hoagland's soln for 40 days from the 2 leaf stage. The fresh wt of leaves was greater at 250 and 500 ppm Cl than that at 0 and 100 ppm Cl. The fruit wt was greatest at 0 ppm Cl. One plant died at 6000 ppm Cl. The osmotic potential of leaves decreased with increasing sea water concns.

4) Tomatoes were grown in sand culture with sea water diluted with Hoagland's soln. Chlorosis and necrosis occurred on the lower leaves at 2000 ppm Cl. These symptoms were markedly severe at 3000 ppm Cl and developed from lower to upper leaves. One plant died during the growing period at 3000 ppm Cl. Fresh wt of leaves and fruit yields decreased with increasing sea water concns. The leaf content of Cl and Na increased with increasing sea water concns.

5) Tomatoes were grown in soil culture with sea water diluted with tap water. The marginal necrosis in lower leaves was found at the higher concn of sea water. However, plants did not wither even at 3000 ppm Cl. Fresh wt of leaves and fruit yields decreased as sea water concns increased. The content of N, P, K, Na, Mg and Cl in the leaves tended to increase with increasing sea water concns. The content of Cl, exchangeable Na and Mg, and EC value of the soil increased as sea water concns increased.

Introduction

High salt content in well water is one of the problems of greenhouse and plastichouse growers in Shizuoka Prefecture. It is obvious that high salt content in well water is caused by sea water contamination (14). Crops appear affected by the use of salty well water for irrigation. There are many studies on salt injury or salt tolerance in which inorganic salts were used as a source of excess soluble salt. However, few studies reported have used sea water containing NaCl and other salts.

Tomatoes were studied because it is one of the main crops at Miho, Shimizu, where the highest salinity was detected (14). A 50% reduction in yield was observed at 3500 ppm Cl by Osawa (17). It was desirable to know how much salinity would affect the fruit production of tomatoes or how much salinity tomatoes could tolerate.

Bernstein and Hayward (4) stated that the effect of salinity on plant growth may vary depending on the stage of plant development. Therefore, this study was carried out to determine the effect of various concns of diluted sea water on the germination, transpiration rate, and growth and yield of tomatoes in water, sand and soil cultures.

Materials and Methods

The experimental methods in this study

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Table 1. Cation concns and EC in relation to sea water diluted with nutrient soln used in water or sand culture.

Sea water concns			Cations (ppm)				EC(m℧/cm)
Cl	Osmotic potential	%	K	Na	Ca	Mg	
0 ppm	−0.69 bars	0	235	44	232	46	2.425
100	−0.83	0.50	237	94	234	52	2.605
250	−1.02	1.25	241	170	237	61	3.030
500	−1.35	2.50	246	296	242	78	3.865
1000	−2.02	5.00	257	548	252	109	4.960
2000	−3.33	10.0	280	1052	271	172	7.735
3000	−4.66	15.0	302	1556	291	235	10.75
4000	−5.99	20.0	324	2060	311	298	13.20
5000	−7.30	25.0	346	2565	331	362	15.20
6000	−8.63	30.0	369	3069	350	425	17.45
Sea water 20500 ppm Cl			445	10082	393	1262	33.40

pH≒6.0

Table 2. Cation concns, pH and EC in relation to sea water diluted with tap water used in soil culture.

Sea water concns			Cations (ppm)				pH	EC(m℧/cm)
Cl	Osmotic potential	%	K	Na	Ca	Mg		
0 ppm	0 bars	0	0	0	0	0	7.00	0.135
50	−0.07	0.25	1	25	1	3	7.19	0.290
100	−0.14	0.50	2	50	2	6	7.35	0.460
250	−0.33	1.25	6	126	5	16	7.58	0.910
500	−0.66	2.50	11	252	10	32	7.62	1.655
1000	−1.33	5.00	22	504	20	63	7.52	2.990
2000	−2.64	10.0	45	1008	39	126	7.62	5.470
3000	−3.97	15.0	67	1512	59	189	7.68	7.730
Sea water 20500 ppm Cl			445	10082	393	1262	8.89	33.40

were similar to those previously described (16). Table 1 and 2 show cation concns, EC, pH and osmotic potential when diluting sea water with Hoagland's soln or with tap water.

Experiment I. — Seed germination : Fifty seeds, cv. 'Tohko,' were placed on filter paper in a petri dish. The filter paper was moistened with 7 levels (0, 100, 250, 500, 1000, 2000 and 3000 ppm Cl) of sea water diluted with distilled water. Seeds were incubated at 25°C. The sea water used was autoclaved to prevent seeds from rotting. The diluted sea water treatments were replicated 4 times. The number of germinated seeds was recorded 2, 3, 4, 5, 6 and 12 days after starting the test.

Experiment II. —Transpiration rate: Tomatoes were grown in water culture with Hoagland's soln until Sept. 9, 1974, when the second cluster bloomed, in the greenhouse. Uniform tomato seedlings were transferred to containers with 10 levels of sea water diluted with Hoagland's soln as shown in Table 1 on Sept. 9, 1974. Total weight of tomato plant, nutrient soln and container was measured by a platform scale every 2 hrs from 8 : 00 am to 6 : 00 pm and the loss in weight recorded. Transpiration rates were measured on Sept. 10, 11 and 12, 1974, and calculated from the difference in the measurements.

Experiment III. — Water culture: A uniform tomato plant, cv. 'Kyoryoku-beiju,' in the 2 leaf stage (28 days old) was transferred to each 3.5 liter pot, with 10 levels of sea water diluted with Hoagland's soln as shown in Table 1. The experiment was continued in the greenhouse for 40 days, May 9 through June 19, 1974. Treatments were replicated 5 times. Diluted sea water soln was replaced every 2 weeks and aerated continuously. Tap water was added to keep the water in pots at a constant 3.5 liters. At the end of the experiment, measurements were made of plant height, and fresh wt of each plant part, and osmotic potential of leaves and roots.

Experiment IV.—Sand culture: A uniform tomato seedling, cv. 'Kyoryoku-beiju,' in the 5 leaf stage was transplanted to a wooden container (40×40×20 cm) filled with sand and placed in the greenhouse on Jan. 10, 1974. Eight levels (0, 50, 100, 250, 500, 1000, 2000 and 3000 ppm Cl) of sea water diluted with Hoagland's soln were applied to the sand medium from Jan. 11 to Apr. 30, after which all fruits were harvested. These treatments were made twice on clear days and once on cloudy days. There was no treatment on rainy days. Treatments were made 7 times. Plants were pinched at the 3rd upper leaf of the 5th fruit cluster. Each cluster had 4 fruits. After all fruits were harvested, plant height, fresh wt of leaves, stems and roots were measured. The major elements in the leaves were analyzed as described previously (16).

Experiment V.—Soil culture: A uniform tomato seedling was transplanted in each wooden container filled with paddy soil on Jan. 10, 1974. The following fertilizers —8 g N, 10g P_2O_5, 10g K_2O, 30g CaO and 2g MgO—were applied to all soils as a basal fertilizer and 4 top dressings. Treatments consisted of 8 sea water levels diluted with tap water. The main elements in the leaves and the chemical properties of thesoil were determined at the end of the experiment, using the same methods described previously (16). The other experimental methods were identical with the sand culture experiment.

Results

Germination (Table 3) : The germination percentage 2 days after starting the test was 42.5% at 0 ppm Cl and decreased with increasing sea water concns. The percentage was

Table 3. Effect of sea water concns on the germination percentage of tomato seed (%).

Sea water concns		Days after starting the test					
Cl	Osmotic potential	2^{X}	3	4	5	6	12
0 ppm	0 bars	42.5^{a}	93.0^{a}	97.5^{a}	98.0^{a}	98.0^{a}	98.0^{a}
100	−0.14	33.5^{b}	92.0^{a}	96.5^{a}	97.0^{a}	97.5^{a}	98.0^{a}
250	−0.33	26.5^{c}	88.0^{a}	97.5^{a}	98.0^{a}	98.0^{a}	98.5^{a}
500	−0.66	24.0^{c}	77.0^{b}	96.0^{ab}	96.5^{a}	96.5^{a}	96.5^{a}
1000	−1.33	12.5^{d}	61.0^{c}	92.0^{b}	96.0^{a}	96.5^{a}	97.0^{a}
2000	−2.64	0.5^{e}	14.5^{d}	54.0^{c}	77.0^{b}	80.5^{b}	96.0^{a}
3000	−3.97	0^{e}	0.5^{e}	9.5^{d}	16.5^{c}	21.5^{c}	70.0^{b}

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

Table 4. Effect of sea water concns on the transpiration rate of tomatoes in water culture (g. H_2O lost/g. leaf dry wt).

Sea water concns		Transpiration rate		
Cl	Osmotic potential	Sept. 10^{X} 8 : 00-18 : 00	Sept. 11 8 : 00-18 : 00	Sept. 12 8 : 00-18 : 00
0 ppm	−0.69 bars	63.7^{a}	62.6^{a}	71.6^{a}
100	−0.83	54.0^{b}	55.8^{bc}	65.4^{ab}
250	−1.02	52.3^{b}	54.0^{bc}	64.2^{ab}
500	−1.35	57.2^{ab}	58.4^{ab}	69.5^{a}
1000	−2.02	54.9^{b}	53.4^{bc}	61.8^{ab}
2000	−3.33	51.3^{b}	51.0^{c}	58.3^{bc}
3000	−4.66	37.1^{c}	38.3^{de}	45.8^{de}
4000	−5.99	35.5^{c}	41.4^{d}	49.5^{cd}
5000	−7.30	25.4^{d}	32.4^{e}	37.8^{e}
6000	−8.63	17.4^{e}	22.0^{f}	28.4^{f}

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

0.5% at 2000 ppm Cl and 0% at 3000 ppm Cl. The differences in the germination percentage decreased with time. The germination percentage between 0 and 1000 ppm Cl 6 days after starting the test ranged from 98.0 to 96.5% and was not significantly different. Although at 2000 ppm Cl the germination percentage was 0.5% after 2 days and 80.5% after 6 days, 96% seeds germinated after 12 days and the percentage was not significantly different from 0 ppm Cl. Germination was most suppressed at 3000 ppm Cl, showing 0, 21.5 and 70.0% after 2, 6 and 12 days, respectively.

Transpiration rate : Transpiration rate measurements were expressed as g. water lost per g. dry wt of leaves and shown in Table 4 and Fig. 1. The greatest transpiration rate was observed at 0 ppm Cl followed by 500 ppm Cl. There was no significant difference from 0 to 1000 ppm Cl in measurements on Sept. 12. Transpiration rate decreased with increasing sea water concns over 2000 ppm Cl.

Water culture: As shown in Table 5, the plant height at harvest was highest at 250 ppm Cl followed by 100 and 500 ppm Cl. The plant height at 0 ppm Cl was lower than at 250 ppm Cl and the same as at 1000 ppm Cl. The leaf, stem and root fresh wt at 250 and 500 ppm Cl was greater than at 0 and 100 ppm Cl. However, the fruit fresh wt was greatest at 0 ppm Cl followed by 100, 250 and, 500 ppm Cl. The whole plant fresh wt was greater between 0 and 500 ppm Cl. The plant height, fruit fresh wt and fresh wt of each plant part decreased between 1000 and 6000 ppm Cl with increasing sea water concns. Plants grown between 0 and 4000 ppm Cl were more healthy, more vigorous and a darker green as sea water concns increased during the early growth of the experiment.

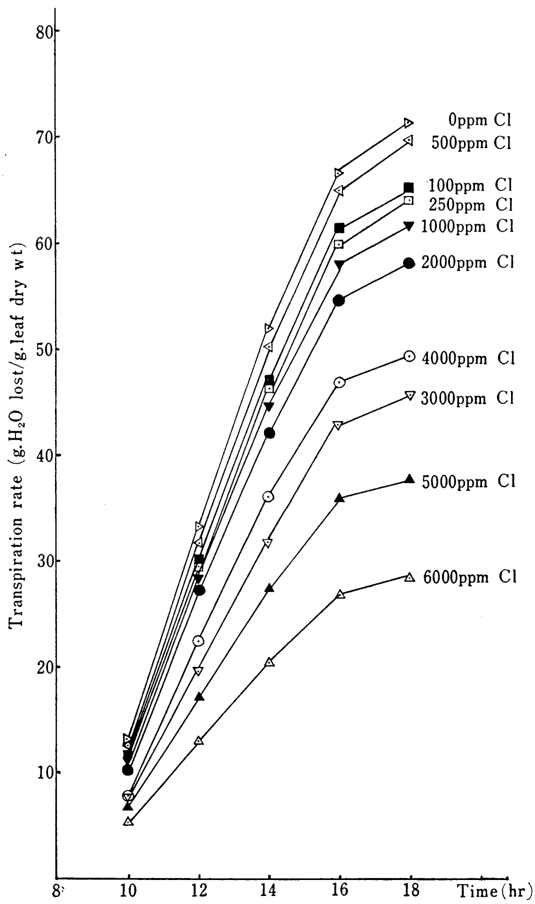

Fig. 1. Effect of sea water concns on the transpiration rate in water culture (Sept. 12).

Table 5. Effect of sea water concns on the growth of tomatoes in water culture.

Cl concn	Plant height at harvest (cm)^X	Fresh wt (g)				
		Leaves	Stems	Roots	Fruit	Whole plant
0 ppm	56^c	68^b	122^b	43^b	164^a	397^a
100	59^{bc}	65^b	125^b	41^b	112^b	343^b
250	69^a	80^a	158^a	51^a	106^b	395^a
500	63^b	80^a	149^a	52^a	110^b	391^a
1000	55^c	53^c	96^c	34^c	62^c	245^c
2000	62^b	55^c	92^c	32^c	67^c	246^c
3000	58^{bc}	44^d	77^d	26^d	46^{cd}	193^d
4000	47^d	30^e	44^e	18^e	34de	126^e
5000	41^e	26^{ef}	34^e	15^{ef}	11^{ef}	86^f
6000	35^f	24^f	24^f	12^f	2^f	62^f

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

Table 6. Effect of sea water concns on the osmotic potential of tomato leaves and roots in water culture.

Sea water concns		Osmotic potential (bars)	
Cl	Osmotic potential	Leaves	Roots
0 ppm	−0.69 bars	−9.6	−4.0
100	−0.83	−10.7	−4.0
250	−1.02	−11.4	−4.1
500	−1.35	−11.8	−4.9
1000	−2.02	−11.1	−5.3
2000	−3.33	−12.4	−6.5
3000	−4.66	−12.4	−6.6
4000	−5.99	−13.6	−7.9
5000	−7.30	−16.2	−9.3
6000	−8.63	−17.9	−11.1

However, after that the most vigorous plant growth was exhibited at relatively lower concns of sea water (0 to 1000 ppm Cl). Salt injury was observed in the lower leaves at 6000 ppm Cl. Some plants wilted immediately after transferring to 5000 and 6000 ppm Cl of diluted sea water soln. There were many more wilted plants at 6000 ppm Cl than at 5000 ppm Cl. The osmotic potential of leaves and roots decreased with increasing sea water concns (Table 6). The leaf osmotic potential at 0 ppm Cl was approx. a half that of 6000 ppm Cl, but a decreasing rate of the root osmotic potential (6000/0 ppm Cl) was approx. 3 times and greater than that of the leaf osmotic potential.

Sand culture:

Growth (Table 7)—Salt injury was not found at 0 to 1000 ppm Cl. However, chlorosis and necrosis occurred on the lower leaves at 2000 ppm Cl. These symptoms were markedly severe at 3000 ppm Cl, and developed from lower to upper leaves. One plant died during experiment at 3000 ppm Cl. The fresh wt of leaves and stems was not significantly different between 0 and 250 ppm Cl. However, over 500 ppm Cl they decreased with increasing sea water concns. The fresh wt of roots decreased with increasing sea water concns over 250 ppm Cl. The incidence of blossom-end rot of fruit was relatively higher at 0 to 500 ppm Cl (31.0 to 45.0%) than at 1000 to 3000 ppm Cl (6.2 to 29.0%). The fruit yield was greatest at 0 to 100 ppm Cl and decreased with increasing sea water concns from 250 to 3000 ppm Cl. The fruit yield was 57.4 and 32.6% less at 2000 and 3000 ppm Cl, respectively, as compared to the yield at 0 ppm Cl.

Major elements in the leaves and fruit (Table 8)—The content of Na and Cl in the leaves increased as sea water concns increased from 0 to 250 ppm Cl, but there were no significant differences over 500 ppm Cl. The K content in the leaves decreased with increasing sea water concns. The content of P and Mg in the leaves was relatively higher at 1000 to 3000 ppm Cl. The content of Cl in the fruit was not significantly different at 0 to 500 ppm Cl, but was higher at 1000 to 3000 ppm Cl than at 0 to 500 ppm Cl.

Soil culture:

Growth (Table 9) — The plant height on Feb. 28 and at harvest, and the fresh wt of leaves, stems and roots were not significantly different at 0 to 250 ppm Cl, but they decreased with increasing sea water concns over 500 ppm Cl. The fruit yield was greatest at 0 ppm Cl. Even at 100 ppm Cl it was less

Table 7. Effect of sea water concns on the growth and incidence of blossom-end rot fruit of tomatoes in sand culture.

Cl concn	Plant height (cm)^X		Fresh wt (g)				Blossom-end rot of fruit (%)
	Feb. 28	At harvest	Leaves	Stems	Roots	Fruit	
0 ppm	107^a	127^a	686^a	219^a	117^a	1832^{ab}	45.0^a
50	107^a	128^a	682^a	218^a	115^a	1846^{ab}	41.1^{ab}
100	105^{ab}	128^a	659^a	215^a	115^a	1886^a	31.0^{ab}
250	102^{ab}	128^a	656^a	206^a	95^b	1716^{bc}	37.0^{ab}
500	99^b	124^{ab}	570^b	172^b	63^c	1641^c	32.8^{ab}
1000	93^c	118^{bc}	477^c	143^c	43^d	1404^d	29.0^{bc}
2000	81^{cd}	111^{cd}	297^d	93^d	28de	1051^e	16.2^{cd}
3000	70^d	104^d	157^e	58^e	14^e	597^f	6.2^d

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

Table 8. Effect of sea water concns on the major elements of tomato leaves and Cl content in the fruit in sand culture (% of dry matter).

Cl concn	Leaves[X]							Fruit
	N	P	K	Na	Ca	Mg	Cl	Cl
0 ppm	3.27[a]	0.09[d]	2.62[a]	0.62[c]	3.06[c]	1.45[c]	2.49[c]	0.69[bc]
50	3.47[a]	0.11[c]	2.39[a]	0.66[c]	3.19[bc]	1.40[c]	2.11[c]	0.60[c]
100	2.81[b]	0.11[c]	2.12[b]	0.74[c]	3.41[ab]	1.49[c]	1.88[c]	0.71[bc]
250	2.80[b]	0.10[cd]	2.06[b]	1.51[b]	3.43[ab]	1.43[c]	3.47[bc]	0.81[b]
500	2.55[b]	0.10[cd]	1.78[c]	2.14[a]	3.70[a]	1.68[b]	5.62[ab]	0.83[b]
1000	2.54[b]	0.13[b]	1.19[d]	2.39[a]	3.68[a]	1.83[a]	6.15[a]	1.07[a]
2000	2.53[b]	0.17[a]	1.06[de]	2.28[a]	3.52[a]	1.94[a]	6.10[a]	1.04[a]
3000	2.70[b]	0.18[a]	0.88[e]	2.23[a]	3.16[bc]	1.80[ab]	6.85[a]	1.16[a]

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

Table 9. Effect of sea water concns on the growth and incidence of blossom-end rot fruit of tomatoes in soil culture.

Cl concn	Plant height (cm)[X]		Fresh wt (g)				Blossom-end rot of fruit (%)
	Feb. 28	At harvest	Leaves	Stems	Roots	Fruit	
0 ppm	109[ab]	125[ab]	626[ab]	248[a]	72[ab]	3403[a]	17.4[c]
50	111[a]	131[a]	630[ab]	254[a]	66[b]	3204[a]	27.7[bc]
100	111[a]	127[ab]	647[ab]	257[a]	79[a]	2637[b]	48.0[ab]
250	109[ab]	127[ab]	651[a]	259[a]	71[ab]	2246[c]	51.6[a]
500	107[b]	122[b]	583[b]	223[b]	70[ab]	1854[d]	35.7[abc]
1000	103[c]	123[b]	456[c]	163[c]	61[b]	1262[e]	32.7[abc]
2000	92[d]	104[c]	285[d]	109[d]	34[c]	959[f]	18.3[c]
3000	77[e]	89[d]	213[e]	81[e]	24[c]	692[g]	19.7[c]

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

Table 10. Effect of sea water concns on the major elements of tomato leaves and Cl content in the fruit in soil culture (% of dry matter).

Cl concn	Leaves[X]							Fruit
	N	P	K	Na	Ca	Mg	Cl	Cl
0 ppm	1.61[c]	0.11[d]	1.51[a]	0.17[e]	3.04[b]	0.42[ef]	0.65[c]	0.62[d]
50	1.72[c]	0.10[d]	1.19[bcd]	0.19[e]	3.06[b]	0.40[f]	1.22[c]	0.70[cd]
100	1.55[c]	0.12[d]	1.06[cd]	0.27[de]	3.05[b]	0.44[ef]	1.02[c]	0.76[bcd]
250	1.58[c]	0.10[d]	0.95[d]	0.37[de]	2.73[b]	0.50[de]	1.27[c]	0.83[abcd]
500	1.60[c]	0.11[d]	1.24[bc]	0.48[d]	2.89[b]	0.59[d]	1.31[c]	0.86[abc]
1000	2.59[b]	0.14[c]	1.35[ab]	0.78[c]	2.85[b]	0.89[c]	2.67[b]	0.84[abcd]
2000	2.61[b]	0.20[b]	1.24[bc]	1.44[b]	3.65[a]	1.23[b]	2.89[b]	0.99[a]
3000	2.95[a]	0.23[a]	1.00[cd]	2.02[a]	3.91[a]	1.35[a]	4.47[a]	0.97[a]

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

than at 0 ppm Cl. The percentage of the fruit fresh wt compared to 0 ppm Cl was 37.1, 28.2 and 20.3% less at 1000, 2000 and 3000 ppm Cl, respectively. The incidence of blossom-end rot of fruit was higher at 100 to 1000 ppm Cl. The leaves showed lighter green at lower sea water concns. However, they were darker green and plants were stunted at higher sea water concns. Although lower leaves showed a marginal necrosis at higher sea water concns, plants did not die even at 3000 ppm Cl. The upper leaves wilted at 1000, 2000 and 3000 ppm Cl though soil moisture was adequate.

Major elements in the leaves and fruit (Table 10)—N, P, Mg and Cl in the leaves increased as sea water concns increased over 1000 ppm Cl, and was not significantly different between 0 and 500 ppm Cl. Na in the leaves and Cl in the fruit tended to increase

Table 11. Soil chemical propertie at the termination of the tomato experiment.

Cl concn	NO_3-N[X] (ppm)	P(Truog) (ppm)	Exchangeable cations (me/100g)				Cl (ppm)	EC(1 : 5) (m℧/cm)	pH (H_2O)
			K	Na	Ca	Mg			
0 ppm	1.0[d]	49[d]	0.26[c]	0.77[f]	7.73[ab]	1.03[g]	160[f]	1.48[f]	5.98[a]
50	0.9[d]	51[cd]	0.23[c]	1.23[f]	8.12[a]	1.14[fg]	279[f]	1.75[e]	6.14[a]
100	0.9[d]	53[bcd]	0.26[c]	2.07[e]	8.08[ab]	1.37[f]	643[e]	2.04[d]	6.01[a]
250	0.9[d]	53[bcd]	0.29[c]	3.16[d]	8.23[a]	1.63[e]	1128[d]	2.27[d]	5.92[a]
500	1.1[cd]	55[abcd]	0.51[b]	5.06[c]	7.81[ab]	2.08[d]	1907[c]	2.84[c]	5.94[a]
1000	2.6[c]	58[abc]	0.81[a]	7.71[b]	7.80[ab]	2.84[c]	3106[b]	3.65[b]	6.03[a]
2000	7.0[b]	59[ab]	0.91[a]	9.97[a]	7.68[ab]	3.49[b]	3847[a]	4.16[a]	6.18[a]
3000	10.7[a]	61[a]	0.89[a]	10.47[a]	7.25[b]	3.76[a]	3746[a]	4.12[a]	6.34[a]

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

with increasing sea water concns. Ca was considerably higher at 2000 and 3000 ppm Cl than at 0 to 1000 ppm Cl.

Chemical composition of the soil (Table 11) — The amount of Cl, P, exchangeable Na and Mg, and EC value increased with increasing sea water concns. NO_3-N and exchangeable K were higher at 2000 and 3000 ppm Cl and between 1000 and 3000 ppm Cl, respectively.

Discussion

The effect of salinity on the plant growth is related to the stage of plant development at which the salinity is imposed. For example, it has been reported that salinity delays germination, but does not appreciably reduce the final percentage of germination (12, 16, 19). In the present experiments diluted sea water containing 2000 ppm Cl decreased the percentage of tomato seed germination 6 days after starting the test, but did not affect the final percentage of germination 12 days after starting the test. However, at 3000 ppm Cl both final percentage and the rate of germination decreased. Diluted sea water may affect the seed germination in 2 ways: (i) by decreasing the ease with which seeds may take up water and thereby decreasing the rate of water entry; and (ii) by facilitating the intake of ions in sufficient amounts which cause changes of certain enzymatic or hormonal activities within seeds (1, 2, 8, 10). These physico-chemical effects upon the seed seem to result in a slower rate of seed emergence and a lower percentage of germination.

Dumbroff and Cooper (7) observed that with tomatoes salt tolerance does change during ontogeny, and osmotic stress (−6 bars) is most deleterious to plants when applied during early growth, particularly during the succulent seedling stage. In the water culture the growth at 250 and 500 ppm Cl was superior to that at 0 ppm Cl (Table 5), even though young seedlings were transferred to diluted sea water solns. The content of Cl, Na and Mg in the diluted sea water soln was markedly increased with increasing amounts of sea water. The osmotic potential of sea water diluted with Hoagland's soln ranged from −0.69 bars at 0 ppm Cl to −8.63 bars at 6000 ppm Cl and the osmotic potential at 250 and 500 ppm Cl was lower (−1.20 and −1.35 bars, respectively) than that employed by Dumbroff and Cooper. Therefore, it appeared that these ions stimulated growth at 250 and 500 ppm Cl in water culture. Shourbagy and Wallace (20) reported moderate levels of Na (5 and 10 me/l) increased an average of 28% in the yields of 5 varieties of barley when grown in soln culture. Osawa (18) also stated that stimulative effects of 1000 or 2000 ppm NaCl on the vegetative growth of such crops, pak-choi, cabbage, radish, chinese cabbage, celery and tomato might be due to Na in most cases. Similar results were noted by other investigators (9, 12, 21).

Salt tolerance values should also be considered in the portion of the plant to be marketed. The yield of tomato was greatest at 0 ppm Cl in water culture, below 100 ppm Cl in sand culture and at 0 and 50 ppm Cl in soil culture. These Cl concns were lower than those that resulted in maximum growth of tops in each culture. The effect of salinity on fruit yields does not always parallel vegetative growth (12, 17). Nieman (15) considered that photosynthetic activity per unit leaf area was not suppressed by NaCl and photosynthate is generally not a limiting factor in the growth of salt-stunted plants.

Based on the observation that leaf area per unit fresh wt might vary with salinity (13), the transpiration rate in the experiment II was expressed on a leaf wt basis. In addition to the reduced leaf area, the osmotic potential of the medium was decreased and the total water stress of the medium increased with the salinity. Therefore, evapotranspirational losses by tomatoes became smaller with increasing sea water concns.

Leaf analyses revealed that Cl, Na, Mg and K content differed between sand and soil cultures. Leaf Cl and Na content in sand culture was higher than in soil culture. For example, leaf Cl content at 0 and 3000 ppm Cl in sand culture was approx. 4 and 1.5 times higher than in soil culture. However, the increment of leaf Cl and Na content was greater in soil culture than in sand culture. Leaf Na content at 3000 ppm Cl in soil culture was 12 times as compared to 0 ppm Cl, but that in sand culture was only 3.6 times. Capacities for differential uptake or translocation of Na, Ca, Mg and Cl in leaves were evident in sand and soil cultures. Leaf Cl and Na content tended to increase almost linearly with increasing salinity between 0 and 500 ppm Cl in sand culture. Leaf Cl and Na content was not significantly different among 500 to 3000 ppm Cl and did not exceed 6.85 and 2.39%, respectively. However, in soil culture the leaf Cl and Na content was highest at 3000 ppm Cl. The reduction of Na absorption by the presence of Ca was demonstrated by several investigators (3, 11). However, in the present experiments Ca content in the leaves was not reduced by the increment of leaf Na content. Therefore, no interaction between Ca and Na seemed to be found.

Accumulation of minerals in leaves may indicate how well the plant adapts to salinity stress. Plants growing under saline conditions must adjust to the osmotic potential of the soil water (5, 6). The osmotic potential of leaves in water culture decreased with the decreasing osmotic potential of increasing sea water concns. The accumulation of leaf Na and Cl content (data not shown) may account for the decreasing the osmotic potential of leaves. Visible salt injury symptoms, such as chlorosis and necrosis, were much more evident at 3000 ppm Cl in sand culture than in soil culture. The buffer action of the soil and the higher leaf Na and Cl content in sand culture seemed to be the reasons for this difference. The difference in plant response to the same salinity in sand and soil cultures may be taken into consideration as one of the experimental approaches when trying to clarify the mechanism of salt tolerance.

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トマトの耐塩性

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摘　要

希釈した海水が，トマトの発芽，生育，収量に及ぼす影響について調査した．

（1） 発芽試験開始2日後，Cl 濃度の 100 ppm により発芽率は減少した．6日後の発芽率は 0 から 1000 ppm Cl 間で有意差がなかったが，2000 ppm Cl では 80.5%，3000 ppm Cl では 21.5% で，0 から 1000 ppm Cl より低かった．

（2） ホーグランド液で希釈された海水で育てられたトマトの蒸散量は，海水濃度が増すにつれ減少した．

（3） トマトを本葉2枚のステージより 40 日間，ホーグランド液で希釈された海水で育てた．葉の新鮮重は 250，500 ppm Cl で 0，100 ppm Cl より大であったが，果実収量は 0 ppm Cl で最大であった．6000 ppm Cl で枯死株がみられた．葉の浸透ポテンシャルは海水濃度の増加により減少した．

（4） トマトを砂耕で栽培した結果，クロロシスとネクロシスは 2000 ppm Cl では下位葉にみられた．これらの症状は 3000 ppm Cl ではさらに激しく，下位葉から上位葉にまで認められた．3000 ppm Cl では枯死株もみられた．また，海水濃度の増加とともに，葉の新鮮重と果実収量は減少し，葉の Cl，Na 含量は増加した．

（5） トマトを土耕で栽培した結果，葉の周縁ネクロシスは海水の濃度が高い場合，下位葉にみられたが，3000 ppm Cl においても枯死株はなかった．また，海水濃度の増加とともに，葉の新鮮重と果実収量は減少し，葉の N，P，K，Na，Mg，Cl 含量は増加する傾向がみられた．実験終了時の土壌の Cl，置換性 Na，Mg 含量及び EC は，海水濃度が高まるにつれて増加した．