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Salt Tolerance of Green Soybeans

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Summary

Experiments were conducted to determine the effect of diluted sea water on the germination, growth and yield of green soybeans. The germination rate was not significantly different at 0 to 3,000 ppm Cl 2 days after starting the germination test. Seedlings were grown in sand culture for 20 days after seeding. The top dry weight was greatest at 250 and 500 ppm Cl. Green soybeans were grown in sand and soil cultures. Salt injury in sand culture was not found at 0 and 100 ppm Cl. However, it was slight at 250 ppm Cl, and became much more severe with increasing sea water concentrations. The seed fresh weight was greatest at 0 to 250 ppm Cl in sand culture and at 0 to 500 ppm Cl in soil culture. There was an increase in Na and Cl content in the leaves in sand and soil cultures when sea water concentrations were at high Cl levels. The content of Cl and exchangeable Na, and EC value of the soil increased with increasing sea water concentrations.

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 (13) indicate 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 wells being contaminated by sea water. Crops appear affected by the use of salt contaminated well water for irrigation.

Many studies in relation to salt injury to plants have been reported. However, inorganic salts, for example NaCl or Na_2SO_4, were used as a source of excess soluble salts in most studies. Few studies reported have used sea water or river water containing NaCl and other salts. Moreover, leguminous plants seem to be one of the most sensitive plants to excess soluble salts (4, 15). Green soybeans (*Glycine max* Merr.) are one of the main crops at Miho, Shimizu, where the highest salinity was detected in well water. Chlorine during one year averaged 549.8 ppm. The salt tolerance of green soybeans has not yet been reported. Because it was desirable to know how much salinity green soybeans could tolerate, these experiments were conducted to determine the effect of various concentrations of sea water on the germination, growth of seedlings in sand culture, and growth and yield in sand and soil cultures of green soybeans.

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Materials and Methods

Treatments were made by diluting sea water with tap water or Hoagland's solution (Table 1). Sea water concentrations were based on a survey of the Cl content of well water (13). The sea water diluted with Hoagland's solution was used in sand culture and with tap water in soil culture. Each treatment solution contained 0, 50, 100, 250, 500, 1,000, 2,000 and 3,000 ppm Cl diluted from sea water. Tables 2 and 3 show cation concentrations, EC, pH and osmotic pressure in relation to diluted sea

Table 1. Composition of nutrient solution.

1	$Na_2HPO_4 \cdot 12H_2O$	0.5 mM
2	K_2SO_4	3 mM
3	$Ca(NO_3)_2 \cdot 4H_2O$	4 mM
4	$MgSO_4 \cdot 7H_2O$	2 mM
5	Mn	0.5 ppm ($MnSO_4$)
6	Fe	1 ppm ($FeC_6H_5O_7 \cdot 5H_2O$)
7	Zn	0.05 ppm ($ZnSO_4 \cdot 7H_2O$)
8	Cu	0.02 ppm ($CuSO_4 \cdot 5H_2O$)
9	B	0.5 ppm (H_3BO_3)
10	Mo	0.05 ppm ($Na_2MoO_4 \cdot 2H_2O$)
11	pH=5.7~5.8	

Table 2. Cation concentrations, EC and pH in relation to sea water diluted with nutrient solution used in water or sand culture.

Sea water concentrations			Cations (ppm)				EC m℧/cm
Cl	Osmotic pressure	%	K	Na	Ca	Mg	
ppm	atm						
0	0.68	0	117	44	232	46	2.425
50	0.75	0.25	118	69	233	49	2.435
100	0.82	0.50	119	94	234	52	2.605
250	1.01	1.25	123	170	237	61	3.030
500	1.33	2.50	128	296	242	78	3.865
1,000	1.99	5.00	139	548	252	109	4.960
2,000	3.29	10.00	162	1,052	271	172	7.735
3,000	4.60	15.00	184	1,556	291	235	10.750
Sea water 20,500 ppm Cl			445	10,082	393	1,262	—

Table 3. Cation concentrations, pH and EC in relation to sea water diluted with tap water used in soil culture.

Sea water concentrations			Cations (ppm)				pH	EC m℧/cm
Cl	Osmotic pressure	%	K	Na	Ca	Mg		
ppm	atm							
0	0	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	0.65	2.50	11	252	10	32	7.62	1.655
1,000	1.31	5.00	22	504	20	63	7.52	2.990
2,000	2.61	10.00	45	1,008	39	126	7.62	5.470
3,000	3.92	15.00	67	1,512	59	189	7.68	7.730
Sea water 20,500 ppm Cl			445	10,082	393	1,262	—	—

water solutions. Osmotic pressure was determined by the cryoscopic method. The variety used was cv. 'Hakucho' which is grown by the commercial growers in Miho, Shimizu.

Experiment I-Seed Germination : The purpose of the experiment was to determine the effect of diluted sea water on germination. The diluted sea water treatments were replicated 4 times. Forty seeds were placed on filter paper in a petri dish. The filter paper was moistened with sea water diluted with distilled water. Seeds were incubated at 25°C. The sea water used was autoclaved to prevent seeds from rotting.

Experiment II-Salt Tolerance of the Seedlings : The objective of this experiment was to evaluate the effect of diluted sea water on seedlings grown in sand culture for 20 days. Eight sea water solutions of 0, 50, 100, 250, 500, 1,000, 2,000 and 3,000 ppm Cl diluted with 1/5 Hoagland's solution applied to seedlings resulted in osmotic pressure of 0.17, 0.21, 0.28, 0.47, 0.79, 1.45, 2.75 and 4.06 atm, respectively (Table 5). Seeds were planted directly in black plastic containers (43×35×10cm) filled with sand and placed in a plastic house on September 22, 1973. After germination seedlings were thinned to 20 uniform plants per container. Treatment was carried out beginning on the date seeded and continued for 20 days.

Experiment III-Sand Culture : The study of salt tolerance of green soybeans was made in a sand like that of the Miho, Shimizu area. Twenty-seven seeds were planted directly in a wooden container (40×40×12cm) filled with sand and placed in a plastic house on March 9, 1974. Seedlings were thinned to 9 uniform plants per container after germination. Diluted sea water solutions were applied to the sand medium from March 29, when the soybean plants were in the 3 to 4 leaf stage, to May.

31, at which time the entire plant was sampled. These treatments were made twice on clear days and once on cloudy days. There was no treatment on rainy days. The seven sea water solutions diluted with Hoagland's solution were replicated 7 times.

Symptoms of salt injury and growth were evaluated on May 1, 1974 and at harvest time, respectively. The main elements in the leaves were analyzed. Plant salt injury symptoms were evaluated as follows: 0-no marked symptoms of injury developed; 0.5-chlorosis was shown at lower leaves; 1-chlorosis at lower leaves advanced to necrosis; 2-middle leaves showed chlorosis accompanied with degree of '1'; and 3-lower leaves were dead. Middle and upper leaves showed necrosis and some plants were dead (see Table 6).

Experiment IV-Soil Culture; To determine the effect of diluted sea water, green soybeans were cultured in soil. Twenty-seven seeds were planted directly into a wooden container (40×40×12 cm) filled with paddy soil, and placed in a plastic house on September 25, 1973. All soils were mixed with the following fertilizers-2 g N, 4g P_2O_5, 3 g K_2O, and 25 g CaO. After germination, seedlings were thinned to 9 uniform plants per container. Treatments were applied from October 15 to December 11, 1973 at the same growth stage as in sand culture. Treatments consisting of 8 sea water solutions were diluted with tap water. Each was replicated 8 times. At harvest the dry weight of leaves, stems, roots and pods, and the fresh and dry weights of seed were measured. The main elements in the leaves and chemical properties of the soil were determined at the end of the experiment.

Methods of Plant Analysis: An aliquot of dry sample was ashed at 550°C and extracted with HCl, for determining K, Na, Ca, and Mg by an Atomic absorption spectrophotometer and P by the Molybdenum blue colorimetric method. N was determined by the Kjeldahl method. Cl was determined by the mercuric thiocyanate colorimetric method, after ashing the dry sample at 550°C and extraction with hot water.

Methods of Soil Analysis: Nitrate-N was determined by the phenoldisulphonic acid method. Phosphorous (Truog), Cl (soil/water =1/5), and exchangeable K, Ca, Na and Mg (1 N ammonium acetate) were determined by the same analysis used for plant. Electric conductivity (1 : 5) was measured by the Tōa Model CM-IDB meter and pH was determined by the glass electrode method.

Results

Germination:

Table 4 shows results of the germination test. The germination rate 1 day after starting was 28.0% at 2,000 ppm Cl and 25.0% at 3,000 ppm Cl. These values were about 50% less than those that germinated between 0 and 1,000 ppm Cl. However, after 2 and 3 days the germination rate was not significantly different among the treatments. Even at 3,000 ppm Cl it was 99.4% after 3 days.

Seedlings:

As shown in Table 5, leaf, stem and root

Table 4. Effect of sea water concentrations on germination rate of soybean seeds (%).

Sea water concentrations		Days after starting the germination test		
Cl	Osmotic pressure	1*	2	3
ppm 0	atm 0	43.8^{a}	96.9^{ab}	100.0^{a}
50	0.07	41.0^{a}	95.0^{b}	98.1^{b}
100	0.14	49.8^{a}	95.0^{b}	99.4^{ab}
250	0.33	50.6^{a}	99.4^{a}	99.4^{ab}
500	0.65	48.3^{a}	96.9^{ab}	100.0^{a}
1,000	1.31	46.3^{a}	97.5^{ab}	100.0^{a}
2,000	2.61	28.0^{b}	91.3^{c}	96.3^{c}
3,000	3.92	25.0^{b}	96.3^{ab}	99.4^{ab}

*: Means followed by the same letter within columns are not significantly different at the 5% level, as determined by Duncan's multiple range test.

Table 5. Effect of sea water concentrations on the growth of soybean seedlings in sand culture (g of dry wt.).

Sea water concentrations		Leaves* (*L*)	Stems (*S*)	Roots (*R*)	Whole plant (*L*+*S*+*R*)
Cl	Osmotic pressure				
ppm 0	atm 0.17	1.28^{c}	0.93^{cd}	0.95^{b}	3.16^{d}
50	0.21	1.63^{b}	1.05^{bcd}	0.98^{b}	3.66^{bc}
100	0.28	1.60^{b}	1.08^{bc}	1.05^{ab}	3.73^{b}
250	0.47	1.53^{b}	1.55^{a}	1.10^{a}	4.18^{a}
500	0.79	1.83^{a}	1.25^{b}	1.05^{ab}	4.13^{a}
1,000	1.45	1.35^{c}	0.98^{cd}	1.05^{ab}	3.38^{cd}
2,000	2.75	0.90^{d}	0.83^{cd}	0.78^{c}	2.51^{e}
3,000	4.06	0.40^{e}	0.58^{e}	0.55^{d}	1.53^{f}

*: Means followed by the same letter within columns are not significantly different at the 5% level, as determined by Duncan's multiple range test.

Table 6. Effect of sea water concentrations on the growth and salt injury symptoms of green soybeans in sand culture (g of each part for growth).

Cl concn (ppm)	Leaves* dry wt	Stems dry wt	Roots dry wt	Pods dry wt	Seeds fresh wt	Seeds dry wt	Whole plant dry wt	Salt injury symptoms
0	29.6[a]	27.6[a]	13.1[a]	24.2[a]	82.3[a]	23.4[a]	117.9[a]	0
100	28.7[ab]	23.3[b]	13.9[a]	23.0[ab]	84.0[a]	23.4[a]	112.3[a]	0
250	23.6[bc]	19.1[c]	10.0[b]	21.3[b]	80.2[a]	22.4[a]	96.4[b]	0～0.5
500	24.1[bc]	16.2[c]	8.3[bc]	18.2[c]	56.2[b]	14.3[b]	81.1[c]	1
1,000	20.1[c]	11.8[d]	6.2[cd]	12.0[d]	30.0[c]	6.6[c]	56.7[d]	2
2,000	12.1[d]	10.0[d]	3.9[de]	4.2[e]	8.3[d]	1.8[d]	32.0[e]	2～3
3,000	6.7[e]	4.5[e]	2.0[e]	1.8[f]	2.6[d]	0.3[d]	15.3[f]	3

* : Means followed by the same letter within columns are not significantly different at the 5% level, as determined by Duncan's multiple range test.

weights were greatest at 500 ppm Cl, 250 ppm Cl and 250 ppm Cl, respectively. The whole plant dry weight was greatest at 250 and 500 ppm Cl. As sea water concentrations were increased from 0 to 250 ppm Cl the whole plant dry weight was increased. However, it was markedly decreased with increasing sea water concentrations from 1,000 to 3,000 ppm Cl. The growth at 0 ppm Cl was almost the same as that at 1,000 ppm Cl.

Sand Culture :

Growth–The growth data are given in Table 6. The whole plant dry weight was greatest at 0 and 100 ppm Cl and decreased with increasing sea water concentrations from 250 to 3,000 ppm Cl. The value of whole plant dry weight was 117.9 g at 0 ppm Cl and 15.3 g at 3,000 ppm Cl. There was no significant difference in the seed fresh weight between 0 and 250 ppm Cl. However, as sea water concentrations were increased from 500 to 3,000 ppm Cl the seed fresh weight markedly decreased. The seed fresh weight was 68%, 36%, 10% and 3%, at 500, 1,000, 2,000 and 3,000 ppm Cl, respectively, as compared to the weight at 0 ppm Cl. The leaf, stem, root and pod dry weights were similar to the whole plant dry weight.

The progress of visible salt injury on leaves was as follows : 1) Leaf margins showed slight chlorosis. 2) Injury was much more advanced, and necrosis and withering of leaves developed and 3) Leaves became brown and dropped. During the experiment, necrosis was observed 16 days after the beginning of the treatments (April 14 th) at 2,000 and 3,000 ppm Cl, and after 22 days (April 20 th) at 500 and 1,000 ppm Cl. Withered plants were noted after 40 days. Fifty per cent of the plants were dead at 3,000 ppm Cl 10 days before harvest (May 20 th). As shown in Table 6, salt injury was not found at 0 and 100 ppm Cl, however, chlorosis was found on lower leaves in some plants at 250 ppm Cl. Salt injury became much more severe with increasing sea water concentrations from 250 to 3,000 ppm Cl.

Mineral Composition in the Leaves–Results are summarized in Table 7. The content of Cl and Na increased almost in proportion to sea water concentrations. The content of N and P was greater at 2,000 and 3,000 ppm Cl. The content of Ca and Mg was greater from

Table 7. Effect of sea water concentrations on the main elements of green soybean leaves in sand culture (% of dry matter).

Cl concn	N*	P	K	Na	Ca	Mg	Cl
ppm 0	2.49[e]	0.13[d]	2.45[a]	0.10[d]	2.52[bc]	0.95[c]	1.90[e]
100	2.60[de]	0.12[d]	2.31[a]	0.13[d]	2.77[b]	1.08[b]	3.32[d]
250	2.60[de]	0.11[d]	2.26[ab]	0.36[c]	3.18[a]	1.18[a]	5.42[c]
500	2.90[cd]	0.13[d]	2.40[a]	0.52[b]	3.08[a]	1.14[ab]	6.46[ab]
1,000	3.18[c]	0.17[c]	2.26[ab]	0.55[b]	2.79[b]	1.11[ab]	7.21[a]
2,000	3.57[b]	0.23[b]	2.18[ab]	0.63[b]	2.33[c]	1.06[c]	7.07[a]
3,000	4.14[a]	0.30[a]	1.97[b]	0.77[a]	1.71[d]	0.86[d]	6.71[ab]

* : Means followed by the same letter within columns are not significantly different at the 5% level, as determined by Duncan's multiple range test.

Table 8. Effect of sea water concentrations on the growth of green soybeans in soil culture (g of each part).

Cl concn (ppm)	Leaves* dry wt	Stems dry wt	Roots dry wt	Pods dry wt	Seeds fresh wt	Seeds dry wt	Whole plant dry wt
0	11.7^{ab}	7.7^{ab}	3.3^{a}	13.9^{a}	24.6^{a}	7.5^{abc}	44.1^{a}
50	10.7^{b}	7.0^{bc}	3.2^{a}	11.5^{b}	26.5^{a}	7.9^{ab}	40.3^{a}
100	11.9^{ab}	7.7^{ab}	3.3^{a}	12.9^{ab}	28.0^{a}	8.6^{a}	44.3^{a}
250	13.4^{a}	8.3^{a}	3.6^{a}	12.8^{ab}	25.7^{a}	7.0^{bc}	45.0^{a}
500	11.6^{ab}	7.1^{ab}	3.1^{ab}	12.4^{ab}	24.6^{a}	7.2^{bc}	41.5^{a}
1,000	10.7^{b}	5.8^{c}	2.5^{bc}	8.8^{c}	19.5^{b}	5.8^{d}	33.6^{b}
2,000	8.4^{c}	4.5^{d}	1.9^{cd}	3.9^{d}	8.6^{c}	2.2^{e}	20.8^{c}
3,000	9.6^{bc}	4.0^{d}	1.7^{d}	2.1^{d}	4.0^{d}	1.0^{e}	18.4^{c}

* : Means followed by the same letter within columns are not significantly different at the 5% level, as determined by Duncan's multiple range test.

Table 9. Effect of sea water concentrations on the main elements of green soybean leaves in soil culture (% of dry matter).

Cl concn	N*	P	K	Na	Ca	Mg	Cl
ppm 0	2.03^{c}	0.042^{c}	1.46^{c}	0.082^{d}	3.74^{d}	0.68^{d}	0.58^{d}
50	2.08^{bc}	0.041^{c}	1.46^{c}	0.083^{d}	4.05^{cd}	0.68^{d}	0.56^{d}
100	2.01^{c}	0.043^{c}	1.26^{c}	0.105^{d}	4.27^{bc}	0.70^{d}	0.56^{d}
250	2.06^{bc}	0.050^{c}	1.25^{c}	0.090^{d}	4.03^{cd}	0.68^{d}	0.75^{d}
500	1.99^{c}	0.050^{c}	1.28^{c}	0.098^{d}	5.19^{a}	0.80^{c}	1.30^{d}
1,000	2.38^{b}	0.074^{b}	1.46^{c}	0.176^{c}	5.05^{a}	0.88^{ab}	4.76^{c}
2,000	3.31^{a}	0.113^{a}	1.86^{b}	0.345^{b}	4.62^{b}	0.94^{a}	5.90^{b}
3,000	3.59^{a}	0.121^{a}	2.11^{a}	0.450^{a}	3.92^{cd}	0.86^{bc}	7.80^{a}

* : Means followed by the same letter within columns are not significantly different at the 5% level, as determined by Duncan's multiple range test.

250 to 1,000 ppm Cl. There was no significant difference in K content.

Soil Culture :

Growth-Table 8 shows the effect of sea water concentrations on growth. The seed fresh weight was not significantly different between 0 and 500 ppm Cl, but it was markedly decreased with increasing sea water concentrations from 1,000 to 3,000 ppm Cl. The percentage of the seed fresh weight compared to 0 ppm Cl was 79%, 35% and 16% at 1,000, 2,000 and 3,000 ppm Cl, respectively.

Sea water concentrations above 1,000 ppm Cl caused a decrease in the top, leaf, stem, root and pod dry weights. These conditions were similar to that of the seed fresh weight. Although the salt injury in soil culture was almost the same as that in sand culture, the degree of injury and number of dead plants were less in soil culture than in sand culture.

Mineral Composition in the Leaves-Table 9 shows the effect of sea water concentrations on the main elements in the leaves. Cl and Na were increased when sea water concentrations increased. However, they were not significantly different between 0 to 500 ppm Cl. The content of N, P, K and Mg was considerably higher at 2,000 and 3,000 ppm Cl. Ca accumulated to a much greater degree at 500 and 1,000 ppm Cl than at other concentrations.

Chemical Composition in the Soil-Chemical properties of the soil at the termination of the experiment are shown in Table 10. The amount of Cl, exchangeable Na, K and Mg, and EC value were increased with increasing sea water concentrations. The Ca content was greater at 500 and 1,000 ppm Cl. There was no significant difference in pH, NO_3-N and P levels.

Discussion

It is well known that the delay in emergence and also the decreased germination percentages in many crops are aggravated by higher levels of salinity (2, 3, 4, 5, 16). However, Lunin et al (11) reported that the effect of three highest salt levels (ECe values of 8, 12, 16 mmho/cm) applied prior to germination (Contender green

Table 10. Soil chemical properties at the termination of the green soybean experiment.

Cl concn (ppm)	NO_3-N* (ppm)	P (Truog) (ppm)	Exchangeable cations (me/100 g) K	Na	Ca	Mg	Cl (ppm)	EC m℧/cm (1:5)	pH (H_2O)
0	79[a]	105[a]	0.66[e]	0.48[f]	6.52[b]	0.86[e]	89[f]	0.62[e]	5.84[a]
50	89[a]	100[a]	0.65[e]	0.60[f]	6.52[b]	0.88[e]	182[ef]	0.67[e]	5.50[d]
100	81[a]	98[a]	0.63[e]	0.74[ef]	6.29[b]	0.93[de]	259[ef]	0.67[e]	5.67[bc]
250	72[a]	94[a]	0.67[e]	1.15[e]	6.60[b]	1.03[de]	451[e]	0.78[de]	5.79[ab]
500	84[a]	97[a]	0.75[d]	2.22[d]	7.09[a]	1.21[d]	867[d]	0.96[d]	5.59[cd]
1,000	74[a]	103[a]	0.81[c]	3.69[c]	6.81[a]	1.55[c]	1,498[c]	1.21[c]	5.56[cd]
2,000	85[a]	104[a]	0.90[b]	6.30[b]	6.64[b]	2.39[b]	2,876[b]	1.85[b]	5.44[d]
3,000	72[a]	99[a]	0.97[a]	8.77[a]	6.48[b]	3.01[a]	3,794[a]	2.28[a]	5.16[e]

*: Means followed by the same letter within columns are not significantly different at the 5% level, as determined by Duncan's multiple range test.

beans) was evident in delayed germination but with no significant difference in per cent germination. Similar results for green beans were noted by Bernstein and Pearson (4). According to other investigators (7, 9) it seems the effect of high salt solution applied to the seed is not due to the kind of salt or osmotic pressure, but rather is due to certain enzymatic or hormonal activities which take place within the seed due to salinity or osmotic pressure during treatment.

It is noteworthy that the growth at 250 and 500 ppm Cl was superior to that at 0 ppm Cl during the first 20 days after seeding. However, the seed fresh weight at 500 ppm Cl in sand culture was not only less than that at 0 ppm Cl, but also the top dry weight at 500 ppm Cl was significantly lower than that at 0 ppm Cl. The content of Cl, Na and Mg in the diluted sea water solution was markedly increased with increasing amounts of sea water, as shown in Tables 2 and 3. It appeared that these ions stimulated growth at 250 and 500 ppm Cl in the early growing stage. Lunin et al (11) found that there was no difference in the growth of bean seedlings at the two lower levels (ECe values of 2 and 4 mmhos/cm) of salinization. Osawa (15) stated that stimulative effects of 1,000 or 2,000 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. Weddin and Struckmeyer (18) also reported that tobacco grown at low Cl levels exhibited no marked growth responses but increases in Cl to 280 ppm caused moderate increases in average length and weight of leaves. However, it appeared that an excess of Na and Cl, cationic unbalance, high osmotic pressure or a combination of these factors (5) reduced the growth and yield at higher sea water concentrations in the later growth stage.

There was an increase in Na and Cl content in the leaves in both sand and soil cultures when sea water concentrations were increased to high Cl levels. The value of the Na and Cl content was lower in soil culture than in sand culture. The Na and Cl content at 500 ppm was significantly higher than at 250 ppm or less of Cl in sand culture. There was no significant difference in the Na and Cl content below 250 ppm Cl in soil culture. Also, as compared to sand culture less injury was observed in soil culture. In this experiment it appears to be relationships between the Na and Cl content in the leaves and the degree of injury. However, it is not evident whether or not Na and Cl accumulation in the leaves resulted directly in injuries. Ehlig and Bernstein (6) reported that high concentrations of chloride in the substrate caused marginal burn on mature strawberry leaves and sodium also produced some marginal burn. But Osawa (15) stated that direct toxicity from excessive accumulation of Na or Cl in plants could not be considered as the primary cause of salt injury in most crops, except strawberry which is sensitive to salt injury. Bernstein and Ayers (1) found that there is no relationship between chloride content in bean plants and salt tolerance.

Osmotic pressure in a medium is also considered one of the causes of salt injury (5). The osmotic pressure in the diluted sea water solution and EC value in the soil at the end of the experiment were increased with increasing sea water concentrations. The increments of osmotic pressure and EC value might reduce the growth and yield. Gauch and Wadleigh (8) reported that there was a linear relationship between osmotic concentration of the substrate and reduction in dry weight of the bean plants. Meiri and Kamburoff (14) pointed out that although growth of beans was suppressed similarly by the two types of salinity (NaCl and Na_2SO_4) when expressed on an osmotic basis, other parameters showed different responses according to salinity type. Masui (12), Smith and Warren (17), Osawa (15) and Yoneda (19) reported that the high EC value was relative to the reduction in yield. High EC values appeared to result in the depression of root development, especially the activity of root hairs, and the absorption of nutrients and water.

LaHaye and Epstein (10) demonstrated that although beans treated with 50mM NaCl (which is comparable to about 2,000 ppm Cl) were severely damaged in the absence of Ca, the growth at 1 mM Ca was damaged only slightly and at 3mM Ca growth was not noticeably affected. As the Ca concentration increased in diluted sea water solutions, the content of Ca in the leaves decreased between 500 and 3,000 ppm Cl in sand and soil cultures as the content of Na in the leaves increased. In sand and soil cultures of 0 to 500 ppm Cl soybean leaf analyses showed an increase in Ca content, but no interaction between Ca and Na was found.

The seed fresh weight and the top dry weight at 0 ppm Cl were not significantly different with these measurements at 500 ppm Cl in soil culture. However, they were significantly higher at 500 ppm Cl in sand culture. In soil culture salt injury was observed to be slight as compared to sand culture. Therefore, it was calculated that Cl content in diluted sea water at 711 ppm Cl in sand culture and at 1,339 ppm Cl in soil culture as compared to 0 ppm Cl caused a 50% loss in seed fresh weight. The buffer action in soil may account for the reduction of salt injury in soil as compared to sand culture.

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エダマメの耐塩性

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摘　要

希釈した海水が，エダマメの発芽，生育，収量に及ぼす影響を明らかにするため実験を行なつた．発芽率は，発芽試験開始 2 日後には海水の Cl 濃度 0 から 3,000 ppm の間で有意な差がみられなかつた．エダマメを発芽後 20 日間砂耕栽培した．地上部の乾物重は，250 と 500 ppm Cl で最も大であつた．エダマメを土耕と砂耕で栽培した．塩害は，砂耕では 0 と 100ppm Cl でみられなかつたが，250 ppm Cl ではわずかにみられ，それ以上では，海水の Cl 濃度が高くなるにつれて塩害は激しくなつた．エダマメの種子の新鮮重は，砂耕では 0 から 250 ppm Cl，土耕では 0 から 500 ppm Cl で最も大であつた．砂耕，土耕とも海水の Cl 濃度が高い場合，葉の Na，Cl 含量は増加した．土壌の Cl，置換性 Na 含量及び EC は，海水の Cl 濃度が高くなるにつれて増加した．