岡大資生研報（Bull. Res. Inst. Bioresour. Okayama Univ.）1：113-129（1993）

Selection for High Salt Tolerant Cultivars in Barley

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In order to select higher salt tolerant cultivars of barley, solution culture experiments were carried out with 500 barley cultivars, which were preliminarily selected from 4581 cultivars by exposure to 1-2 % of sodium chloride (NaCl) during the germinating stage. The concentrations of NaCl used in the experiments were 2 (control), 150 and 300 mM in nutrient solution.

From the results of five solution culture experiments, each of which was carried out with about 100 cultivars, 105 cultivars of barley were selected as relatively high salt tolerant cultivars. Then the final selection was carried out on those 105 cultivars, and it was found that more than 10 cultivars were highly salt tolerant, mainly based on the comparison of shoot yields under the supply of 300 mM of NaCl. High salt tolerant barley cultivars mentioned above showed 42-86 % and 17-30 % of the control in shoot yield under the condition of 150 and 300 mM of NaCl, respectively.

On three groups of barley, each having more than 10 cultivars, which are high, moderate and low in salt tolerance, ion contents of the plants were analyzed. The results suggest that potassium (K) uptake was comparatively larger in the high salt tolerant group of barley cultivars, though there was a big variation in sodium (Na) and K contents even within the same group.

Key words: Barley, Ion content, Salt tolerance, Sodium chloride, Yield

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Received December 22, 1992
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INTRODUCTION

Recently, the requirement to produce crops having higher salt tolerance is increasing considerably. However, the poor understanding of the mechanism of salt tolerance in higher plants has led to the situation that no optimum breeding strategy has yet been developed. Barley (*Hordeum vulgare* L.) seems to be a useful crop, since this plant is a higher salt tolerant grain crop which is cultivated in a large scale around the world. The characteristics of salt tolerance of this species has been recognized for centuries[6], but it has a great variability of salt tolerance even within species[5].

The approach towards the development of salt tolerant plants by selection has been taken by a number of workers. Epstein et al.[6] selected barley by culturing the plants in media salinized with synthetic sea salts. The other technique, such as tissue culture, has been developed to select citrus[1-3], alfalfa[4], and tomato[9].

The present study investigates the salt tolerance of about 500 cultivars of barley which were collected all over the world. The seeds were supplied from the Barley Germplasm Center, Research Institute for Bioresources, Okayama University, Japan.

MATERIALS AND METHODS

All the cultivars tested in this study were the selected-cultivars, which originated from the selection on 4581 cultivars by exposure to 1-2 % of NaCl during the germinating stage[12]. They are each given in identification code and registration number. The first letter shows the geographical region where the variety was originated from or collected in, and following three numerals represent the registration number. The geographical region is classified according to the description presented in the "Catalogue" (Barley Germplasm Center Okayama University 1983)[11], as follows.

J : Japan, K : Korea, C : China, N : Nepal,
I : Southwest Asia including India, T : Turkey,
U : Europe, B : North Africa, E : Ethiopia,
A : America and others

In this investigation, the cultivars of Akashinriki and Kikaihadaka (cultivars from Japan) were used as standard varieties.

The seeds were germinated in moist washed sand for 7 days, then the seedlings were transplanted into 56 holes of a plastic board floating in a plastic box (34.3 l) containing nutrient solution. The composition of the nutrient solution used in the present experiments was as follows: N 5.0 mM (as KNO_3 4.0 mM plus $NaNO_3$ 1.0 mM), P 1.0 mM (as NaH_2PO_4), K 4.0 mM (as KNO_3), Ca 2.0 mM (as $CaCl_2$), Mg 1.0 mM (as $MgSO_4$), S 1.0 mM (as $MgSO_4$), Fe 17.7 μM (as $FeC_6H_5O_7$), B 46.2 μM (as H_3BO_3), Mn 9.1 μM (as $MnCl_2$), Zn 0.8 μM (as $ZnSO_4$), Cu 0.3 μM (as $CuSO_4$) and Mo 0.1 μM (as $(NH_4)_6Mo_7O_{24}$). The concentrations of NaCl used were 150 and 300 mM. The control treatment contained 2 mM of Na.

During the first 2-3 days, all salts except the micronutrient were given at 1/5 strength of concentration of nutrient solution, whilst NaCl at 1/4 strength of concentration. Then, full strength nutrient solution including NaCl treatment was given. The medium pH was adjusted to 5.5 and Fe was supplied every other day. The nutrient solution was aerated continuously throughout the experiment, and renewed once a week.

After about 3 weeks, the plants were harvested, and separated into shoots and roots. The parts were washed with tap and deionized water, blotted dry, weighed, and dried in an oven at 100℃ over 20 hours before measuring dry weight.

In this investigation, 5 series of experiments with two replications of each were carried out to select 500 cultivars of barley, in which about 110 cultivars were grown in each experiment. From each experiment, the most tolerant plants in both 150 mM and 300 mM NaCl were selected. These successful entries obtained from 5 series of experiments were then grown altogether in the final experiment to select the most tolerant plants from about 500 cultivars.

In order to know the distribution pattern of ions in plants, about 11 % of 500 entries, which represent the most tolerant, moderate, and the most sensitive cultivars, were analyzed by an atomic absorption spectrophotometry for Na, K, Ca and Mg, and by a molybdovanadophosphate method for P.

RESULTS

The criteria of selection used in determining the salt tolerance of plants were: (1) the yield of shoots which are expressed as a percentage of the control plants, (2) the distribution pattern of the yield of shoots grown in 150 and 300 mM NaCl, and (3) the correlation between the yield of shoots in 150 and 300 mM NaCl, which represents the tolerance stability of plants to NaCl exposure. Since high concentrations of NaCl decreased more the growth of shoots, the cultivars will be selected by comparing the yield of shoots grown in 300 mM NaCl.

Table 1. The sequence of salt tolerance of barley based on the comparison on shoot dry matter of plants grown in 300 mM NaCl (Experiment 1)

Sequence No.	Cultivars	Shoot dry matters (g)			% of control	
		Control	150 mM	300 mM	150 mM	300 mM
1	T 629	0.135	0.103	0.033	76.2	24.6
2	T 424	0.164	0.085	0.039	51.8	23.8
3	T 489	0.097	0.062	0.022	63.9	23.0
4	K 162	0.128	0.079	0.027	61.8	21.4
5	J 787	0.145	0.091	0.031	62.9	21.4
6	K 128	0.144	0.105	0.030	73.2	20.6
7	T 146	0.195	0.095	0.040	48.7	20.4
8	T 441	0.155	0.080	0.030	51.8	19.5
9	K 156	0.143	0.083	0.028	58.3	19.3
10	J 726	0.136	0.093	0.026	68.1	18.8
11	T 442	0.141	0.083	0.024	59.3	17.0
12	K 127	0.125	0.083	0.021	66.6	16.6
13	T 458	0.150	0.073	0.025	48.9	16.4
14	T 118	0.175	0.074	0.028	42.4	16.1
15	T 540	0.189	0.082	0.030	43.2	15.9
16	T 358	0.174	0.080	0.027	46.0	15.7
17	T 504	0.150	0.065	0.023	43.5	15.6
18	T 723	0.117	0.085	0.018	72.8	15.5
19	K 138	0.137	0.068	0.021	50.1	15.3
20	K 111	0.107	0.058	0.016	54.0	15.2
21	J 724	0.184	0.090	0.028	48.9	15.0
22	T 191	0.186	0.080	0.028	43.0	14.8
23	T 407	0.174	0.081	0.025	46.6	14.6
24	K 058	0.135	0.087	0.020	64.2	14.6
25	K 110	0.128	0.060	0.018	47.1	14.5
26	K 059	0.132	0.092	0.019	70.1	14.4
27	K 322	0.154	0.085	0.022	55.2	14.3
28	K 029	0.165	0.093	0.023	56.1	14.2
29	K 153	0.150	0.073	0.021	48.3	14.2
30	T 099	0.234	0.098	0.033	41.7	14.1
31	J 740	0.221	0.098	0.031	44.5	13.8
32	T 065	0.200	0.098	0.027	49.2	13.7
33	T 664	0.147	0.098	0.020	66.6	13.7
34	T 449	0.139	0.072	0.019	51.5	13.6
35	K 108	0.141	0.073	0.019	51.4	13.4
36	K 107	0.123	0.073	0.016	59.6	13.1
37	T 491	0.139	0.075	0.018	54.2	13.1
38	T 365	0.134	0.083	0.017	61.6	13.0
39	K 131	0.171	0.085	0.022	49.9	12.8
40	K 319	0.132	0.077	0.017	58.1	12.8
41	K 314	0.179	0.090	0.023	50.3	12.7
42	K 033	0.170	0.087	0.021	51.0	12.5
43	K 323	0.166	0.065	0.020	39.2	12.0
44	K 112	0.148	0.060	0.017	40.7	11.8
45	T 662	0.200	0.080	0.024	40.0	11.8
46	K 096	0.207	0.082	0.024	39.5	11.6
47	K 123	0.165	0.093	0.019	56.6	11.5
48	T 119	0.282	0.108	0.032	38.2	11.4
49	T 397	0.204	0.112	0.023	54.8	11.3
50	K 124	0.132	0.080	0.015	60.8	11.3
51	K 060	0.147	0.083	0.016	56.9	11.2
52	K 035	0.165	0.068	0.019	41.4	11.2
53	T 474	0.160	0.076	0.018	47.7	11.2
54	K 689	0.171	0.070	0.019	41.1	11.2
55	K 140	0.140	0.070	0.016	50.0	11.1
56	T 188	0.193	0.105	0.021	54.5	11.0
57	T 109	0.212	0.107	0.023	50.3	11.0
58	J 792	0.157	0.083	0.017	53.2	10.8
59	K 020	0.132	0.075	0.017	46.4	10.5
60	J 739	0.270	0.098	0.028	36.1	10.5
61	K 021	0.090	0.055	0.009	61.2	10.4
62	K 302	0.147	0.092	0.015	62.6	10.3
63	K 346	0.233	0.110	0.023	47.2	10.1
64	J 788	0.217	0.097	0.022	44.7	10.0
65	K 091	0.120	0.093	0.012	77.1	10.0
66	K 301	0.182	0.097	0.018	53.1	10.0
67	K 311	0.213	0.080	0.021	37.6	10.0
68	K 022	0.140	0.065	0.014	46.4	9.9
69	K 031	0.231	0.088	0.022	37.9	9.7
70	T 327	0.188	0.085	0.018	45.3	9.5
71	T 323	0.194	0.097	0.018	49.8	9.4
72	K 331	0.268	0.105	0.025	39.2	9.3
73	J 733	0.162	0.072	0.015	44.4	9.2
74	J 767	0.140	0.053	0.013	38.1	9.2
75	T 395	0.225	0.095	0.021	42.2	9.2
76	T 478	0.161	0.075	0.015	46.6	9.2
77	T 346	0.221	0.113	0.020	51.0	8.9
78	K 332	0.163	0.052	0.014	31.8	8.9
79	T 422	0.157	0.077	0.014	49.0	8.7
80	J 730	0.168	0.070	0.015	41.7	8.7
81	K 001	0.209	0.107	0.018	51.0	8.7
82	K 141	0.187	0.060	0.016	32.2	8.5
83	T 364	0.207	0.090	0.018	43.6	8.5
84	J 790	0.232	0.098	0.019	42.5	8.3
85	K 072	0.214	0.073	0.018	34.4	8.3
86	K 048	0.170	0.050	0.014	29.5	8.2
87	T 130	0.235	0.093	0.019	39.4	8.1
88	J 757	0.222	0.103	0.018	46.6	8.1
89	K 336	0.183	0.082	0.015	44.8	8.0
90	K 007	0.162	0.066	0.013	40.8	7.9
91	T 340	0.222	0.103	0.017	46.7	7.9
92	K 090	0.193	0.087	0.015	44.9	7.8
93	K 023	0.148	0.079	0.011	53.5	7.7
94	T 347	0.161	0.063	0.012	38.9	7.7
95	K 089	0.174	0.063	0.013	36.5	7.5
96	T 239	0.266	0.116	0.020	43.7	7.4
97	T 417	0.155	0.120	0.011	77.4	7.3
98	K 028	0.158	0.063	0.011	40.1	7.0
99	K 098	0.173	0.073	0.012	42.4	6.8
100	K	0.147	0.055	0.010	37.5	6.8
101	J 754	0.240	0.094	0.016	39.3	6.8
102	T 396	0.263	0.080	0.017	30.5	6.6
103	K 130	0.198	0.075	0.013	37.9	6.6
104	K 329	0.210	0.070	0.014	33.3	6.5
105	K 037	0.155	0.048	0.010	31.1	6.4
106	K 012	0.193	0.070	0.012	36.3	6.1
107	A	0.105	0.040	0.006	38.1	6.0
108	T 457	0.228	0.097	0.014	42.4	5.9
109	K 034	0.148	0.058	0.008	39.0	5.6
110	K 330	0.240	0.112	0.013	46.5	5.6
111	K 335	0.208	0.078	0.010	37.8	4.9
112	K 116	0.242	0.082	0.010	33.7	4.2

A : Akashinriki, K : Kikaihadaka

1. *Experiment 1*

The cultivars of barley used in Experiment 1 were mainly from Turkey and Korea, and few cultivars from Japan. This experiment was conducted during winter to early spring (February 24 to March 17, 1986). Table 1 shows the results as average of shoot yields, with the percentage of the control plants. In the table, the sequence of tolerance, which reveals consecutively the most tolerant to most sensitive cultivars, is also presented. This sequence was judged by comparing the shoot yields of all cultivars tested in 300 mM NaCl. The date of root yield are not shown.

The results indicated that the yields of shoots grown in 150 mM NaCl were in the range of 29.5-77.4 % of control plants, whilst a range of 4.2-24.6 % was found in 300 mM NaCl (Table 1). The sequence of tolerance revealed that the highly tolerant cultivars grown in 300 mM NaCl in Experiment 1 were T 629, T 424, T 489, K 162, J 787, K 128, T 146, T 441, K 156 and J 726. The highly sensitive cultivars were K 116, K 335, K 330, K 034, T 457, Akashinriki, K 012, K 037, K 329, and K 130.

Fig. 1 (a) and (b) show the distribution pattern of shoot dry matter at 150 and 300 mM NaCl, respectively, in which a slight difference was observed

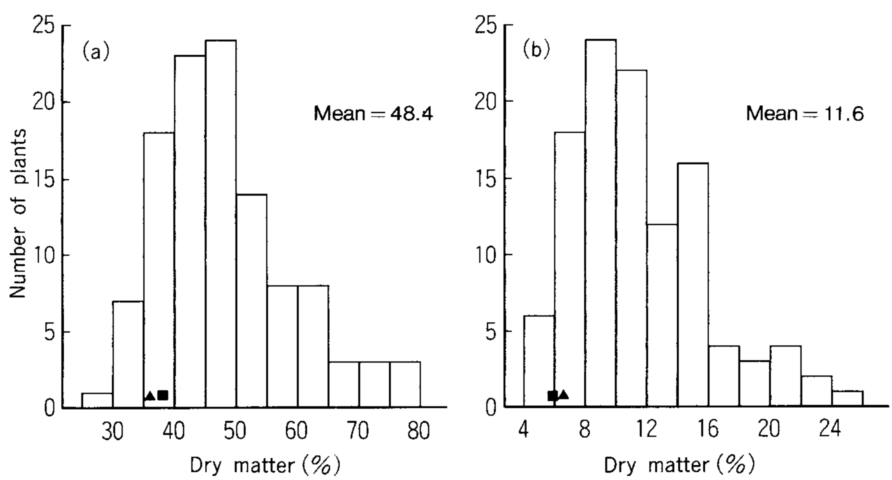

Fig. 1. Distribution pattern of shoot dry matter of barley cultivars exposed to 150 mM (a) and 300 mM (b) of NaCl (Experiment 1)
▲ Kikaihadaka ■ Akashinriki

between plants grown in 150 mM and those grown in 300 mM. The yield of the plants grown in 150 mM NaCl was 48.4 % of the mean yield, calculated from all cultivars tested, and that of those grown in 300 mM NaCl was 11.6 %.

Fig. 2 shows the correlation between the yield of shoots grown at 150 mM and those grown at 300 mM. The coefficient of correlation obtained in Fig. 2 was r= 0.557** (significant at 1 %). The coefficient of correlation obtained in Fig. 2 and the distribution pattern of plants described in Fig. 1(a) and (b) indicated that some cultivars were not consistent in the tolerance

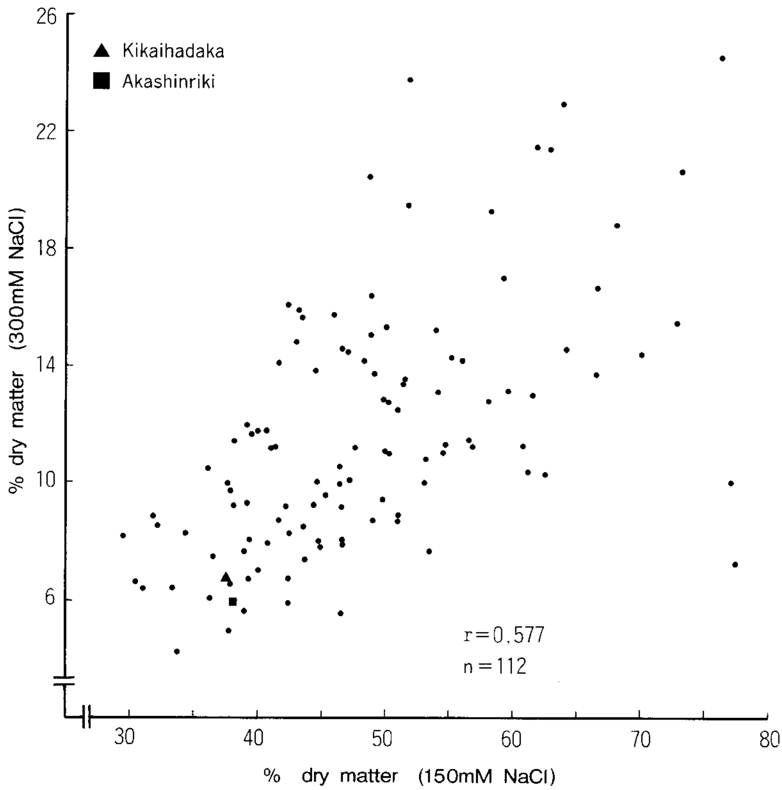

Fig. 2. Correlation between shoot dry matter of barley cultivars grown in 150 mM and 300 mM of NaCl (Experiment 1)

when the plants were grown at 150 mM and 300 mM NaCl. However, the most tolerant cultivars obtained in 300 mM NaCl could survive excellently at both NaCl concentrations.

2. *Experiment 2*

In this experiment, barley cultivars collected from China, Nepal, Southwest Asia including India were selected during the late spring season (April 16 to May 6, 1986).

The ranges of shoot yields in this experiment at both 150 and 300 mM NaCl were resembled those in Experiment 1, the range of 14.4-87.7 % being observed at 150 mM NaCl, and 5.1-27.7 % at 300 mM NaCl (data not shown).

The highly tolerant cultivars grown at 300 mM NaCl were C 641, I 031, I 078, C 640, I 079, N 346, I 381, N 635, N 686, and N 629, whilst the most sensitive cultivars were Akashinriki, C 625, C 328, C 338, C 612, C 604, C 333, I 119, C 634 and I 090. Responses of some cultivars to 150 mM and 300 mM of NaCl were found to be inconsistent.

3. *Experiment 3*

This experiment was carried out during early summer (May 7 to 26, 1986). The cultivars of barley tested were from Ethiopia, Europe, North Africa, Turkey and Southwest Asia including India.

The results show that the successful cultivars obtained in 300 mM NaCl were mostly from Ethiopia; i.e., E 428, E 574, I 400, E 580, E 059, E 390, E 446, I 685, E 143 and E 563. The most sensitive cultivars were E 496, I 437, I 653, U 324, B 345, I 719, E 552, E 591, Akasinriki, and I 717. The range of shoot yield was 13.6-109.9 % in 150 mM, and 12.0-26.2 % in 300 mM NaCl (date not shown).

4. *Experiment 4*

During early summer (May 27 to June 15, 1986), this experiment was carried out by using the cultivars collected from many countries; i.e. Ethiopia, Korea, China, Japan, Nepal, Europe, North Africa, Southwest Asia including India.

The results show that the most tolerant cultivars were mainly from Ethiopia and Korea ; i.e. E 683, E 681, E 750, C 641, B 338, E 788, E 758, K 682, K 687 and E 581. The most sensitive cultivars were K 688, K 357, K 379, E 752, A 305, K 666, K 156, C 646, K 402 and J 118. The range of shoot yield was observed to be 44.2-92.1 % in plants exposed to 150 mM NaCl, and to be 4.7-29.8 % in 300 mM NaCl (data not shown).

5. *Experiment 5*

The barley cultivars selected in this experiment were mainly from Korea, and a few cultivars from China. This experiment was conducted during the autumn (October 6 to 27, 1986).

The percentage of shoot dry matter of plants grown at 150 mM NaCl was found to be 49.3-120 % of the control, and a range of 18.1-80.2 % was obtained in 300 mM NaCl (data not shown). These ranges, especially in 300 mM NaCl, were much higher than those found in other experiments (Experiment 1, 2, 3 and 4).

The results revealed that the most tolerant cultivars exposed to 300 mM

Table 2. The sequence of salt tolerance of barley based on the comparison on shoot dry matter of plants grown in 300 mM NaCl (Final selection)

Sequence No.	Cultivars	Shoot dry matters (g)			% of control	
		Control	150 mM	300 mM	150 mM	300 mM
1	E 428	0.195	0.145	0.059	74.4	30.3
2	B 338	0.173	0.150	0.046	87.0	26.7
3	K 156	0.165	0.091	0.041	54.9	24.8
4	E 538	0.200	0.159	0.049	79.3	24.3
5	E 574	0.207	0.130	0.049	62.8	23.6
6	E 448	0.345	0.188	0.079	54.4	22.8
7	E 758	0.309	0.158	0.070	51.0	22.5
8	E 750	0.314	0.192	0.069	61.2	22.0
9	T 458	0.222	0.111	0.046	50.1	20.6
10	K 682	0.168	0.113	0.034	67.2	20.0
11	A 019	0.268	0.209	0.053	78.1	19.7
12	K 687	0.184	0.097	0.036	52.6	19.5
13	T 424	0.185	0.111	0.036	60.0	19.4
14	E 577	0.288	0.138	0.056	47.8	19.4
15	E 779	0.235	0.153	0.045	64.9	19.2
16	E 518	0.209	0.113	0.040	54.0	18.9
17	E 449	0.350	0.270	0.066	77.1	18.8
18	K 029	0.220	0.094	0.041	42.7	18.5
19	K 698	0.160	0.080	0.030	50.0	18.4
20	T 723	0.197	0.088	0.035	44.4	17.9
21	K 454	0.167	0.085	0.030	50.9	17.7
22	E 575	0.231	0.155	0.041	67.1	17.7
23	N 635	0.255	0.140	0.045	54.9	17.5
24	K 450	0.190	0.093	0.033	49.0	17.4
25	K 418	0.192	0.069	0.033	35.8	17.3
26	E 681	0.353	0.218	0.061	61.8	17.2
27	T 664	0.225	0.092	0.038	40.7	16.7
28	E 580	0.342	0.161	0.057	47.1	16.6
29	K 435	0.155	0.060	0.026	38.7	16.5
30	U 043	0.258	0.109	0.043	42.3	16.5
31	T 146	0.220	0.190	0.036	86.4	16.4
32	K 162	0.203	0.092	0.033	45.2	16.3
33	N 346	0.270	0.107	0.044	39.4	16.2
34	T 397	0.252	0.125	0.041	49.6	16.2
35	I 381	0.270	0.165	0.044	61.1	16.2
36	E 499	0.403	0.182	0.065	45.1	16.1
37	E 739	0.288	0.175	0.046	60.9	16.1
38	E 557	0.325	0.220	0.052	67.7	16.1
39	K 128	0.215	0.099	0.034	45.8	16.0
40	K 446	0.230	0.127	0.037	55.0	15.9
41	T 629	0.284	0.149	0.045	52.4	15.7
42	K 111	0.160	0.091	0.025	56.9	15.7
43	K 400	0.250	0.132	0.039	52.6	15.6
44	I 400	0.202	0.115	0.032	56.9	15.6
45	J 726	0.270	0.089	0.042	33.0	15.6
46	K 415	0.190	0.112	0.030	58.7	15.6
47	E 683	0.373	0.183	0.058	49.0	15.6
48	K 417	0.187	0.087	0.029	46.4	15.5
49	K 438	0.210	0.088	0.032	41.7	15.4
50	E 788	0.255	0.220	0.039	86.3	15.4
51	I 388	0.198	0.095	0.031	48.0	15.4
52	K 381	0.207	0.094	0.040	45.3	15.2
53	K 447	0.190	0.100	0.029	52.6	15.2
54	K 763	0.210	0.098	0.031	46.4	14.9
55	K 138	0.200	0.088	0.030	43.8	14.9
56	K 322	0.166	0.092	0.024	55.1	14.5
57	I 420	0.322	0.145	0.046	45.1	14.4
58	K 423	0.198	0.100	0.028	50.5	14.3
59	C 353	0.250	0.114	0.035	45.4	14.2
60	K 388	0.205	0.082	0.029	39.8	13.9
61	C 645	0.210	0.137	0.029	65.2	13.8
62	K 127	0.215	0.093	0.029	43.0	13.5
63	K 440	0.192	0.102	0.026	53.0	13.5
64	T 489	0.274	0.139	0.037	50.6	13.4
65	C 357	0.249	0.120	0.033	48.3	13.3
66	A 649	0.195	0.079	0.026	40.3	13.2
67	T 441	0.267	0.126	0.035	47.3	13.2
68	K 153	0.223	0.074	0.029	33.3	13.2
69	T 188	0.229	0.114	0.030	49.9	13.2
70	K 670	0.205	0.105	0.027	51.2	13.1
71	K 059	0.225	0.134	0.029	59.6	12.8
72	J 724	0.228	0.102	0.029	44.6	12.7
73	E 563	0.300	0.153	0.038	50.8	12.7
74	T 417	0.280	0.150	0.035	53.6	12.6
75	K 606	0.227	0.117	0.028	51.4	12.4
76	N 685	0.251	0.159	0.031	63.5	12.2
77	K 706	0.263	0.118	0.032	44.8	12.2
78	T 442	0.232	0.078	0.028	33.4	12.0
79	N 636	0.284	0.144	0.034	50.6	11.9
80	J 787	0.217	0.114	0.026	52.7	11.9
81	E 581	0.285	0.118	0.034	41.2	11.8
82	N 334	0.349	0.163	0.040	46.8	11.6
83	C 642	0.282	0.122	0.031	43.2	11.1
84	K 648	0.222	0.092	0.025	41.5	11.1
85	I 698	0.237	0.100	0.026	42.2	11.0
86	C 346	0.255	0.122	0.028	47.7	10.9
87	C 650	0.250	0.113	0.027	45.0	10.8
88	K 110	0.165	0.069	0.017	41.5	10.5
89	C 641	0.230	0.095	0.024	41.3	10.4
90	C 624	0.252	0.100	0.026	39.7	10.3
91	C 319	0.268	0.096	0.028	35.9	10.3
92	K 401	0.245	0.093	0.025	38.0	10.1
93	K 728	0.280	0.109	0.028	38.8	10.1
94	K 058	0.250	0.095	0.025	38.0	10.1
95	C 639	0.257	0.157	0.026	60.9	9.9
96	K 741	0.235	0.140	0.023	59.6	9.9
97	K 091	0.199	0.079	0.020	39.6	9.9
98	C 614	0.275	0.125	0.027	45.3	9.8
99	J 441	0.205	0.085	0.020	41.5	9.7
100	C 640	0.230	0.099	0.022	42.8	9.5
101	I 685	0.328	0.150	0.031	45.8	9.3
102	A	0.190	0.085	0.017	44.7	9.1
103	K 033	0.338	0.115	0.029	34.1	8.5
104	K	0.225	0.070	0.019	31.1	8.3
105	K 653	0.209	0.070	0.017	33.6	8.2
106	A	0.218	0.083	0.017	37.8	8.0
107	C 633	0.347	0.144	0.027	41.4	7.9
108	C 348	0.360	0.110	0.025	30.6	7.0
109	K	0.279	0.109	0.019	39.1	6.8

A : Akashinriki, K : Kikaihadaka

NaCl were mostly from Korea ; i.e. K 400, K 435, K 388, K 606, K 381, K 450, K 463, K 454, K 446, and K 423. Among these, K 400, K 435, K 606 and K 381 showed very high tolerance at both NaCl concentrations. In this experiment, the cultivars C 029, C 022, K 666, C 033, Kikaihadaka, C 305, K 714, C 004, C 025 and C 050 were found to be highly sensitive ones. Generally, most cultivars, which showed a high yield of shoot, also had a better root growth (data not shown).

6. *Final Selection*

From the results of solution culture experiments (Experiment 1-5) described above, barley cultivars were selected as relatively high salt tolerant cultivars, mainly based on the comparison of shoot yields under the supply of 300 mM of NaCl. Some cultivars were added to and neglected from the entry to the final selection, based on the comparison of shoot yields under 150 mM of NaCl. One hundred and five cultivars of the successful entries were tested altogether in the final experiment, during the winter season (January 4 to 23, 1987).

Table 2 shows the results of the final experiment, with the percentage of the control in shoot dry matter at 150 and 300 mM NaCl. The sequence of tolerance was judged by comparison of the values obtained in 300 mM NaCl. The results indicated that the most tolerant cultivars were mainly from Ethiopia, Korea, Turkey, and few cultivars from USA and Egypt ; i.e. E 428, B 338, K 156, E 538, E 574, E 446, E 758, E 750, T 458, K 682, A 019, K 687,

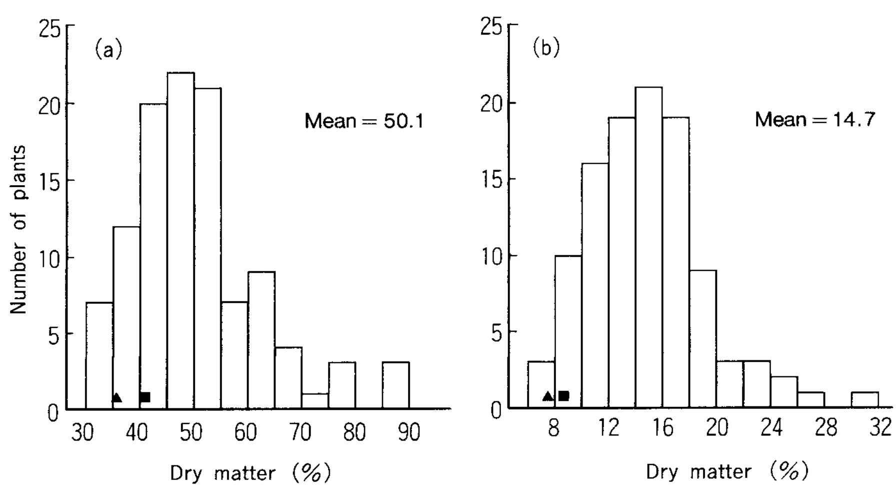

Fig. 3. Distribution pattern of shoot dry matter of barley cultivars exposed to 150 mM (a) and 300 mM (b) of NaCl (Final selection)
▲ Kikaihadaka ■ Akashinriki

T 424, E 577 and others. The results imply, therefore, that these cultivars obtained in the final selection were the most excellent plants selected from about 500 cultivars. These cultivars revealed a good growth at both 150 and 300 mM of NaCl, as evidenced by 48-87 % of the control at 150 mM NaCl and 19-30 % at 300 mM NaCl in shoot yields.

The distribution patterns of plant growth at 150 and 300 mM NaCl are presented in Fig. 3 (a) and (b), respectively. The findings revealed that cultivars were distributed frequently in a lower level (below 50 %) at 150 mM NaCl, though at 300 mM NaCl, they were distributed to have the peak shifted slightly to the right. A similar situation was also evidenced from the results in Fig. 4, in which the coefficient of correlation was r= 0.592**

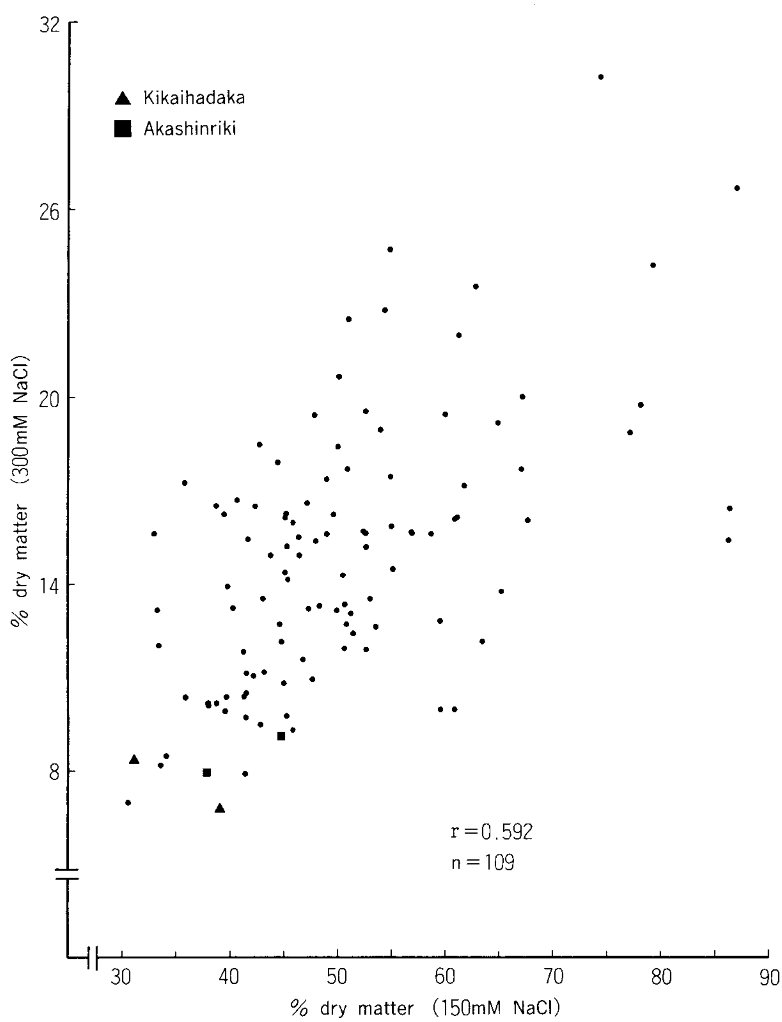

Fig. 4. Correlation between shoot dry matter of barley cultivars grown in 150 mM and 300 mM NaCl (Final selection)

(significant at 1 %).

Since these cultivars tested in the final experiment, except for Akashinriki and Kikaihadaka, were the selected plants obtained from Experiment 1 to 5, the term of "low grade" shown here should represent the moderate tolerance of 500 entries.

7. *Ion Content in Plants*

About 11 % of the 500 cultivars which represent the most tolerant, moderate and sensitive levels were chosen to determine ion distribution in plants. For analysis, the plants which represent the most tolerant and moderate cultivars were obtained from the final selection, whilst the most sensitive ones were taken from Experiment 1 to 5.

(1) *Na content in plants*

In Table 3, Na contents of shoots are given in three groups (tolerant, moderate and sensitive) of barley cultivars grown at different levels of NaCl. There was a great variability in the Na accumulation among the cultivars tested, even within a group, as shown by the value of "STD" (standard deviation), especially in the plants subjected to 300 mM NaCl. It leads to the difficulty in judging the significant difference among the groups.

Principally, there was no significant difference in the pattern of Na accumulation among the group of plants grown at 150 mM NaCl. The difference only appeared when the plants were exposed to 300 mM NaCl. The average data revealed that much less Na was accumulated in the shoots of sensitive cultivars (1.62 m mol/g DW) than in those of both tolerant (2.27 m mol/g DW) and moderate plants (2.72 m mol/g DW), when the plants were grown at 300 mM NaCl. There was an exception, however, for Akasinriki, Kikaihadaka, C 646 and I 635, which showed the Na accumulation in the shoots basically similar to that of moderate cultivars.

(2) *K content in plants*

Table 3 shows the content of K in shoots analyzed on three groups of plants grown at various concentrations of NaCl. As for Na accumulation, the K content in plants tested was found to be scattered, even within the group, especially in NaCl-treated plants.

The parameter "% of contorol" (see Table 3) revealed that the groups of sensitive and moderate cultivars had a lower K content in shoots, than did those of the tolerant cultivars. However, there was principally no significant difference in K accumulation observed at 150 mM NaCl.

Table 3. Sodium and potassim contents in shoots of selected cultivars grown under different concentrations of NaCl

Cultivars	Na (m mol/g DW)			% of Control		K (m mol/g DW)			% of Control		K/Na ratio		
	control	150mM	300mM	150mM	300mM	control	150mM	300mM	150mM	300mM	control	150mM	300mM
Tolerant													
E 428	0.16	1.46	1.86	9.2	11.7	1.92	1.13	1.01	58.8	52.4	12.1	0.77	0.54
B 338	0.15	1.99	2.90	13.0	19.0	2.25	0.74	0.59	32.7	26.2	14.7	0.37	0.20
K 156	0.13	1.10	1.55	8.6	12.2	2.16	1.42	0.92	65.5	42.7	17.0	1.29	0.60
E 538	0.13	1.36	2.57	10.2	19.3	1.90	1.07	0.66	56.4	34.8	14.3	0.79	0.26
E 574	0.13	1.29	1.47	9.7	11.0	1.88	0.72	0.35	38.2	18.8	14.1	0.56	0.24
E 446	0.14	1.42	1.98	10.2	14.3	1.96	0.68	0.37	34.6	19.0	14.1	0.48	0.19
E 758	0.12	1.05	1.18	8.5	9.5	1.86	0.72	0.50	38.7	27.0	15.0	0.68	0.43
E 750	0.12	1.49	2.37	12.8	20.4	1.91	0.65	0.42	33.7	21.8	16.4	0.43	0.18
T 458	0.14	1.85	3.58	13.1	25.2	2.17	0.66	0.29	30.5	13.2	15.3	0.36	0.08
K 682	0.11	1.15	2.06	10.0	18.0	2.33	1.09	0.44	46.9	19.0	20.3	0.95	0.21
A 019	0.10	1.04	2.09	10.4	20.9	2.17	1.11	0.34	51.3	15.7	21.7	1.07	0.16
K 687	0.12	1.35	2.60	11.2	21.6	2.27	1.01	0.35	44.7	15.2	18.8	0.75	0.13
T 424	0.15	1.31	2.87	8.7	19.0	1.83	0.90	0.22	49.0	12.2	12.1	0.68	0.08
E 577	0.12	1.51	1.92	12.4	15.8	1.99	0.70	0.34	35.3	17.1	16.4	0.47	0.18
E 779	0.13	1.14	2.17	8.9	17.0	2.05	1.09	0.34	53.1	16.4	16.0	0.96	0.15
E 518	0.12	1.30	3.19	10.4	25.6	2.16	0.80	0.29	37.0	13.4	17.3	0.61	0.09
E 449	0.14	1.47	1.81	10.8	13.3	2.02	0.61	0.35	30.3	17.4	14.9	0.42	0.19
K 029	0.12	1.20	1.04	9.9	8.6	2.27	0.84	0.52	36.9	23.0	18.7	0.70	0.50
K 698	0.13	1.54	2.77	11.9	21.4	2.27	0.86	0.24	37.7	10.5	17.5	0.56	0.09
T 723	0.13	1.16	3.41	8.7	25.6	1.91	0.95	0.33	49.4	17.1	14.3	0.82	0.10
Average	0.13	1.36	2.27	10.4	17.5	2.06	0.89	0.44	43.0	21.7	16.1	0.69	0.23
STD	0.01	0.25	0.71	1.5	5.3	0.16	0.21	0.21	10.2	10.6	2.52	0.25	0.16
Moderate													
C 348	0.11	1.61	4.61	14.1	40.4	2.52	1.16	0.59	46.1	23.3	22.1	0.72	0.13
C 641	0.14	1.26	3.67	9.1	26.5	2.16	1.04	0.21	48.4	9.7	15.6	0.83	0.06
C 624	0.11	1.36	3.88	12.4	35.3	2.25	1.03	0.16	45.6	7.3	20.5	0.76	0.04
C 319	0.12	1.30	1.62	11.0	13.6	2.14	0.82	0.28	38.1	13.0	18.1	0.63	0.17
K 401	0.13	1.34	2.67	10.7	21.2	1.98	0.82	0.15	41.2	7.4	15.7	0.61	0.05
K 728	0.12	1.29	2.13	10.8	17.8	2.05	0.96	0.18	46.6	8.7	17.2	0.74	0.08
K 058	0.11	1.34	1.69	11.9	15.1	2.04	0.89	0.21	43.6	10.3	18.2	0.67	0.12
C 639	0.13	1.52	3.03	11.7	23.5	2.19	0.80	0.20	36.4	9.2	16.9	0.52	0.07
K 741	0.13	1.22	2.39	9.8	19.1	2.33	0.94	0.22	40.5	9.3	18.6	0.77	0.09
K 091	0.12	1.11	2.24	9.5	19.2	2.07	1.02	0.16	49.5	7.8	17.8	0.92	0.07
C 614	0.14	1.63	2.76	11.7	19.7	2.10	0.73	0.18	34.7	8.8	15.0	0.45	0.07
J 441	0.11	1.27	2.18	11.8	20.2	2.25	0.93	0.18	41.3	8.0	20.9	0.73	0.08
C 640	0.13	1.11	2.73	8.7	21.3	2.17	1.12	0.16	51.6	7.3	17.0	1.01	0.06
I 685	0.14	1.50	4.05	10.9	29.6	2.12	0.79	0.21	37.2	9.9	15.5	0.52	0.05
K 033	0.11	1.21	1.55	10.9	14.0	2.10	0.77	0.23	36.8	11.1	19.0	0.64	0.15
K 653	0.16	1.74	2.36	10.7	14.4	2.05	0.71	0.21	34.4	10.1	12.6	0.41	0.09
Average	0.12	1.36	2.72	11.0	21.9	2.16	0.91	0.22	42.0	10.1	17.5	0.68	0.09
STD	0.01	0.19	0.91	1.3	7.7	0.13	0.14	0.10	5.5	3.8	2.42	0.16	0.04
Sensitive													
A	0.12	1.37	3.77	11.8	32.5	2.34	1.19	0.53	50.9	22.8	20.1	0.87	0.14
K	0.11	1.35	3.95	12.4	36.2	2.43	1.25	0.47	51.6	19.5	22.3	0.93	0.12
C 646	0.12	1.68	2.59	13.9	21.4	2.29	1.05	0.45	45.7	19.7	18.9	0.62	0.17
C 625	0.12	1.15	1.96	9.9	16.9	2.19	0.94	0.56	42.9	25.5	18.8	0.81	0.28
I 437	0.10	1.03	1.58	10.0	15.3	1.97	1.16	0.33	58.7	16.6	19.1	1.12	0.21
C 604	0.11	1.24	1.21	11.3	11.1	1.83	0.32	0.43	17.3	23.4	16.7	0.26	0.35
C 612	0.11	0.85	1.15	7.4	10.0	1.94	0.84	0.32	43.4	16.6	16.9	0.99	0.28
C 338	0.12	0.85	1.05	7.1	8.8	2.03	0.78	0.28	38.7	14.0	17.0	0.92	0.27
C 328	0.13	1.05	1.16	8.0	8.8	2.16	0.70	0.24	32.7	11.2	16.4	0.67	0.21
I 719	0.14	1.42	1.32	10.0	9.3	1.96	0.32	0.21	16.4	10.8	13.8	0.23	0.16
B 345	0.11	0.94	1.15	8.3	10.1	1.59	0.63	0.25	39.5	15.6	14.0	0.67	0.22
U 324	0.14	1.11	0.98	7.9	7.0	1.99	0.70	0.24	35.3	12.3	14.2	0.63	0.25
I 653	0.12	1.04	2.18	8.4	17.6	1.70	0.61	0.31	35.8	18.2	13.8	0.59	0.14
E 496	0.10	1.03	0.92	10.1	9.0	1.81	0.54	0.20	30.1	11.0	17.6	0.53	0.21
K 666	0.11	1.09	0.98	9.9	8.9	1.72	0.42	0.22	24.5	12.9	15.7	0.39	0.23
E 752	0.14	1.34	1.39	9.8	10.2	1.79	0.41	0.24	23.1	13.4	13.2	0.31	0.17
A 305	0.11	1.32	0.91	12.3	8.5	2.25	0.67	0.25	29.9	10.9	21.0	0.51	0.27
J 118	0.13	1.41	0.95	11.1	7.5	2.08	0.57	0.21	27.3	10.2	16.3	0.40	0.22
Average	0.12	1.18	1.62	10.0	13.8	2.00	0.73	0.32	35.8	15.8	17.0	0.64	0.22
STD	0.01	0.22	0.94	1.9	8.5	0.24	0.29	0.12	11.9	4.8	2.66	0.26	0.06

A: Akashinriki, K: Kikaihadaka, STD: Standard deviation

(3) *K/Na ratio in plants*

Table 3 also shows the K/Na ratio in the plant shoot. According to average values, there seems to be no significant difference in K/Na ratio of three groups of cultivars grown in the control and 150 mM NaCl conditions. In 300 mM NaCl, however, the shoot of both tolerant and sensitive cultivars gave a nearly similar value, whilst the moderate plants showed a lower K/Na ratio. A similar tendency was found in the roots and for the whole plant (data not shown). The descriptions presented here, however, reveal only general results, since the K/Na ratio was found to be varied considerably among the cultivars tested.

In the group of sensitive cultivars grown at 300 mM NaCl, the higher value of K/Na ratio in the shoots was due to the low Na content. By contrast, in moderate cultivars, a low content of K which was followed by a high Na accumulation resulted in a lower K/Na ratio. On the other hand, although the tolerant plants accumulated Na highly in the shoots, it was compensated by a high accumulation of K, thereby resulting in a relatively high K/Na ratio.

The standard varieties, Akashinriki and Kikaihadaka revealed a low K/Na ratio, the value of which was similar to that found in moderate cultivars. The most tolerant cultivars (E 428, K 156, E 758 and K 029) gave an excellently high K/Na ratio.

(4) *Ca, Mg and P contents in plants*

Table 4 shows the Ca, Mg and P contents in plant shoots. The exposures to salinity resulted in the decrease of Ca and Mg contents of shoots in the three groups of cultivars. However, there was no definitive pattern of P accumulation in shoots of NaCl-treated plants, as indicated. The P content appeared to increase when the plants were exposed to 150 mM NaCl, but not in the 300 mM NaCl condition.

As for Na and K accumulation, the results revealed that the accumulation of Ca, Mg and P among cultivars tested were found to be varied. The average results indicated that principally there was no significant difference in Ca and Mg accumulation in the shoots of the three groups of barley. Since there was no clear pattern of accumulation of Ca, Mg and P in plants, it was suggested that the results might not reveal any important relation between the salt tolerance and the accumulation of these ions, especially for Mg and P.

DISCUSSION

The tolerance of plants was judged by comparing the yields of shoots.

Table 4. Calcium, magnesium and phosphorus contents in shoots of selected cultivars grown under different concentrations of NaCl

Cultivars	Ca (m mol/g DW)			Mg (m mol/g DW)			P (m mol/g DW)		
	Control	150 mM	300 mM	Control	150 mM	300 mM	Control	150 mM	300 mM
Toleront									
E 428	0.260	0.095	0.067	0.143	0.064	0.053	0.352	0.435	0.463
B 338	0.186	0.054	0.058	0.118	0.054	0.053	0.316	0.519	0.380
K 156	0.190	0.074	0.077	0.129	0.097	0.076	0.394	0.627	0.570
E 538	0.212	0.075	0.070	0.128	0.078	0.062	0.263	0.425	0.420
E 574	0.203	0.069	0.079	0.126	0.075	0.069	0.243	0.382	0.319
E 446	0.273	0.085	0.077	0.126	0.067	0.057	0.265	0.377	0.265
E 758	0.225	0.072	0.073	0.110	0.058	0.063	0.233	0.362	0.297
E 750	0.183	0.054	0.060	0.108	0.067	0.060	0.262	0.388	0.288
T 458	0.178	0.058	0.089	0.121	0.069	0.060	0.270	0.333	0.204
K 682	0.194	0.070	0.106	0.120	0.059	0.077	0.375	0.517	0.285
A 019	0.149	0.045	0.087	0.106	0.063	0.074	0.315	0.462	0.266
K 687	0.199	0.096	0.109	0.116	0.092	0.077	0.333	0.521	0.249
T 424	0.247	0.067	0.090	0.143	0.077	0.059	0.338	0.499	0.176
E 577	0.176	0.062	0.079	0.110	0.064	0.066	0.221	0.317	0.275
E 779	0.200	0.063	0.077	0.112	0.066	0.061	0.287	0.458	0.278
E 518	0.181	0.066	0.091	0.117	0.084	0.066	0.272	0.435	0.228
E 449	0.190	0.063	0.072	0.117	0.081	0.068	0.250	0.387	0.358
K 029	0.170	0.059	0.057	0.110	0.061	0.062	0.294	0.481	0.431
K 698	0.190	0.095	0.135	0.123	0.090	0.079	0.306	0.471	0.212
T 723	0.201	0.056	0.102	0.136	0.081	0.071	0.289	0.367	0.173
Average	0.200	0.069	0.083	0.121	0.072	0.066	0.294	0.438	0.307
STD	0.031	0.014	0.019	0.011	0.012	0.008	0.047	0.077	0.103
Moderate									
C 348	0.192	0.064	0.140	0.110	0.065	0.072	0.427	0.771	0.244
C 641	0.182	0.085	0.100	0.117	0.090	0.080	0.359	0.528	0.172
C 624	0.172	0.077	0.090	0.114	0.081	0.072	0.417	0.626	0.190
C 319	0.221	0.089	0.051	0.112	0.055	0.056	0.374	0.553	0.293
K 401	0.192	0.098	0.099	0.109	0.085	0.069	0.311	0.455	0.171
K 728	0.314	0.124	0.131	0.106	0.071	0.082	0.374	0.515	0.234
K 058	0.165	0.085	0.092	0.099	0.084	0.089	0.341	0.517	0.292
C 639	0.213	0.077	0.081	0.109	0.059	0.066	0.347	0.577	0.259
K 741	0.246	0.090	0.041	0.132	0.082	0.075	0.397	0.567	0.204
K 091	0.166	0.086	0.105	0.106	0.081	0.087	0.334	0.458	0.200
C 614	0.301	0.108	0.082	0.139	0.084	0.068	0.309	0.454	0.199
J 441	0.156	0.081	0.066	0.108	0.090	0.068	0.304	0.489	0.196
C 640	0.181	0.091	0.085	0.112	0.089	0.077	0.348	0.550	0.201
I 685	0.180	0.072	0.113	0.115	0.075	0.081	0.360	0.587	0.173
K 033	0.161	0.085	0.059	0.107	0.084	0.093	0.332	0.451	0.288
K 653	0.300	0.128	0.098	0.137	0.094	0.092	0.360	0.486	0.242
Average	0.209	0.090	0.090	0.114	0.079	0.077	0.356	0.536	0.222
STD	0.053	0.017	0.027	0.012	0.011	0.010	0.036	0.082	0.043
Sensitive									
A	0.175	0.072	0.129	0.117	0.074	0.079	0.356	0.519	0.235
K	0.172	0.069	0.148	0.118	0.077	0.088	0.362	0.550	0.280
C 646	0.185	0.054	0.086	0.116	0.070	0.056	0.392	0.696	0.383
C 625	0.277	0.085	0.112	0.127	0.069	0.070	0.341	0.583	0.441
I 437	0.223	0.097	0.097	0.107	0.077	0.063	0.326	0.449	0.209
C 604	0.233	0.098	0.130	0.123	0.079	0.126	0.236	0.302	0.250
C 612	0.206	0.109	0.178	0.137	0.091	0.092	0.257	0.436	0.194
C 338	0.244	0.083	0.166	0.131	0.093	0.091	0.327	0.534	0.319
C 328	0.293	0.125	0.107	0.148	0.106	0.078	0.373	0.529	0.212
I 719	0.236	0.067	0.128	0.134	0.061	0.089	0.319	0.280	0.195
B 345	0.199	0.081	0.137	0.114	0.073	0.064	0.233	0.368	0.206
U 324	0.236	0.086	0.122	0.127	0.080	0.127	0.302	0.545	0.311
I 653	0.236	0.088	0.130	0.166	0.098	0.147	0.310	0.469	0.371
E 496	0.195	0.086	0.168	0.118	0.080	0.049	0.263	0.323	0.178
K 666	0.266	0.081	0.125	0.137	0.079	0.049	0.267	0.365	0.233
E 752	0.271	0.047	0.102	0.139	0.061	0.051	0.282	0.299	0.179
A 305	0.197	0.071	0.166	0.098	0.070	0.035	0.346	0.551	0.165
J 118	0.294	0.091	0.135	0.120	0.074	0.050	0.304	0.427	0.260
Average	0.230	0.083	0.131	0.126	0.079	0.078	0.311	0.457	0.257
STD	0.039	0.019	0.026	0.016	0.012	0.031	0.047	0.116	0.079

A : Akashinriki, K : Kikaihadaka, STD : Standard deviation

There was a difficulty to compare altogether the tolerance of 500 cultivars, since the range of plant yield in each experiment was found to vary considerably. Moreover, the temperature range throughout the experiment was found to be significantly different, and it was considered to be one factor which might affect the salt tolerance. The discrepancy in the yields might, to some extent, be associated with the differences in temperature ranges. These findings lead to the consideration that the comparison of the tolerance of plants should be, therefore, separately carried out in each experiment.

In all experiments of the present investigation, the correlation between the yields at 150 mM NaCl and those at 300 mM was significant at the 1 % level, though the correlation coefficient is not so high. The responses of some cultivars were found to be relatively inconsistent between different levels of salinity. Some cultivars, which well tolerated 150 mM NaCl, often failed to survive in 300 mM NaCl. The reverse situation was also found for a few cultivars, which showed a higher tolerance at 300 mM, even though at a lower concentration of NaCl they appeared to be more or less moderate. The findings showed, however, that the most tolerant plants obtained in 300 mM NaCl were able to survive well in both NaCl conditions. Shannon[10] revealed a similar situation found in the selection of muskmelon. He suggested that selection for high yield under low salinities might slightly favor the varieties which have relatively low salt tolerance, and the selection in the higher saline conditions might be suitable for the varieties with higher salt tolerance. However, it is difficult to judge if the situation found in muskmelon is also true for barley. Judging from the evidence obtained in the present study, it appears to be somewhat beneficial to select the most tolerant barley by exposing it to a higher concentration (300 mM) than to a lower concentration (150 mM) of NaCl.

The cultivars Akashinriki and Kikaihadaka revealed some variability in tolerance when they were grown in different experiments. These cultivars were found to be sensitive or moderately sensitive to 150 mM NaCl, though they appeared to be sensitive to 300 mM NaCl. Since the aim was to select the most tolerant cultivars in 300 mM NaCl, Akashinriki and Kikaihadka should be in the sensitive cultivars group.

The findings obtained in the final selection indicated that the most tolerant entries selected from about 500 cultivars were from Ethiopia, Egypt, Turkey, Korea, and USA (Table 2). It was shown by the cultivars E 428, B 338, K 156, E 538, E 574, E 446, E 758, E 750, T 458, K 682, A 019, K 687 and T 424. These cultivars could keep highly their yields (50–87 % of control plants), when the plants were exposed to 150 mM NaCl, a concentration which often kills most glycophyte plants. Moreover, these tolerant cultivars remaind alive without showing serious damage in 300 mM NaCl, a condition which is often found in the habitat of halophyte plants[7,8]. Thus, the results show that very highly tolerant barley cultivars were obtained in this investigation.

The analysis of the accumulation of ions in plants revealed principally no significant differences in the Na accumulation in the shoots of plants exposed to 150 mM NaCl, but a difference appeared in the higher concentration of NaCl (300 mM). There was a tendency that the group of sensitive cultivars accumulated much less Na, as compared to those in other groups. It is, however, difficult to draw a definitive conclusion, since tha Na accumulation among plants tested was found to be variable.

There was no significant difference in the K accumulation in plants exposed to 150 mM NaCl. The difference appeared when the plants were exposed to 300 mM NaCl, though the results in K accumulation were found to be scattered. The tendency revealed that in the sensitive and moderate plants the K content in the shoots decreased more than did the tolerant ones, as the plants were exposed to 300 mM NaCl.

The interaction between Na and K in plants showed that in the tolerant plants, a high accumulation of Na was compensated by a high accumulation of K, which led to the higher K/Na ratio, though a more complex situation was found in the sensitive and moderate groups. With a few exceptions, however, the findings suggest that the tolerant plants are more effective than the other groups in protecting the K nutrition in shoots from the adverse effect of NaCl. The mechanism underlying the salt tolerance remains to be determined.

Acknowledgements — The authors wish to thank the late Ms. Eiko Kimoto for her excellent technical assistance. Thanks are also given to Dr. Mineo Shibasaka for his helpful discussions.

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高耐塩性オオムギ品種の選抜

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耐塩性品種を選抜するため，500品種のオオムギを用い，水耕栽培実験を行った．培地の塩化ナトリウム濃度は2（対照区），150および300 mMとした．用いた500品種は，4581品種のオオムギから，発芽時の耐塩性の高い品種として選抜されたものである．

1回に約100品種を用い，5回の水耕栽培実験で耐塩性の高い105品種を選抜した．この105品種を同一時期に水耕栽培し，主として塩化ナトリウム300 mMでの地上部収量を比較することにより，最終選抜を行った．その結果，10余品種の高耐塩性オオムギが得られた．これらの高耐塩性オオムギ品種では，塩化ナトリウム150 mMの場合に，対照区の42～86%，300 mMの場合に対照区の17～30%の地上部収量が得られた．

これらの実験に用いたオオムギ品種から，耐塩性の高いもの，中程度のもの，および低いものを各々10数品種選び，それらのイオン含量を測定した．その結果，同一グループ内でもイオン含量にかなりの変動が見られるが，耐塩性の高いグループでは，オオムギのナトリウム吸収に比較し，カリウム吸収の大きい傾向を認めた．

キーワード：オオムギ，イオン含量，耐塩性，塩化ナトリウム，作物生育