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Study on the Salt Tolerance of Rice and Other Crops in Reclaimed Soil Areas

2. On the Salt Tolerance of Chinese Cabbage and Cabbage in Various Salty Conditions*.

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干拓地에서 水稻 및 其他作物의 耐鹽性에 關한 研究.

2. 여러가지 鹽分條件에서 배추와 양배추의 耐鹽性에 關하여

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ABSTRACT

Salt tolerances of Chinese cabbage and cabbage were observed by means of the sand culture and field experiment. The point of 50% yield reduction of Chinese Cabbage was 1 % of salt concentration in sand culture. The Na absorption in the salty upland conditions was increased but the absorption of Ca, Mg were interrupted as the salt concentration was raised and there were no differences in the absorption of N and P. The Si absorption was increased at low salty conditions, but the salt concentration was raised, the absorption was interrupted drastically.

The cabbage was more stronger salt tolerance than Chinese cabbage, and it was possible to prevent the salt damage significantly by planting on sloping beds instead of planting on the double-row beds in field condition.

INTRODUCTION

The interruption of plant growth by the over-abundance of NaCl in the soil is reported in both theories of the osmotic (Eaton 1942, Ehrler 1960, Gauch & Wadleigh 1944, Hayward 1955, Iwaki 1956) and specific ion effects. (Bernstein & Hayward 1958, Eaton 1927, Lagerwerff & Eagle 1961, 1962, Tagawa & Ishizaka 1963, 1965) The latter is futher divided into the nutritional effects on the absorption of the essential plant elements and the direct toxicity effects of excessive ions.

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Few reports on the culture of Chinese cabbage in the reclaimed salty soil area have been published. According to the research results on the salt tolerance of vegetables obtained by the Salinity Research Laboratory of U.S.D.A., (Bernstein 1964) 50 percent of the beets, the strongest salt tolerance vegetable, was produced at 12 mmhos/cm at 25°C (salt content, 0.77%) and 60 percent of cabbage was produced at 7 mmhos/cm at 25°C (salt content, 0.45%). Osawa (1965) reported that 50 percent of the Chinese cabbage by fresh weight is produced in 0.9 percent NaCl solution in sand cultures.

The present research data were obtained from two experiments; (1) Experiment with Chinese cabbage grown by sand culture in various salt concentrations, and (2) Experiment on the salt tolerance of Chinese cabbage and cabbage under field conditions.

MATERIALS AND METHODS

Sand of approximately 0.2 to 2 mm in diameter was washed and placed in 1/50,000 Wagner pots. The seeds of Kaipung No. 2, variety of Chinese cabbage were also washed thoroughly and seeded after 3 minutes disinfection in 1,000 X Uspulun solution. The seeding was grown on Hoagland No. 2 solution for one month after seeding until 4 or 5 leaves had developed. One plant per hill was placed in each pot. One month later sufficient table salt was added to each pot by subirrigation to give the compositions shown in Table 1.

Table 1. Composition of Nutrient Solutions.

Salt treatment	Nutrient solution	Osmotic concen.(atm**)	Elect. conduc. (mmhos/cm, 25°C)
0 %	Hoaglanand No. 2*	0.6	2.1
0.2 〃	〃	2.0	5.6
0.4 〃	〃	3.4	9.1
0.8 〃	〃	6.1	15.8
1.6 〃	〃	11.7	28.0

* Water was added every four days to wash the salt into the sand so that an excessive accumulation of salt was prevented.

** Micro-elements were added to the Hoagland's solution.

The cabbage was harvested one month after the salt treatment. The fresh weight and the maximum length and width of the leaves were measured. Dry samples were taken for analysis to obtain the relationship of NaCl to the absorption of N, P and K and other mineral nutrients in the plants.

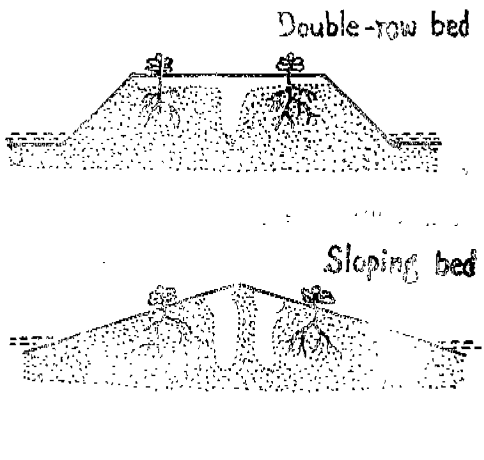
In the field experiment Chongbung-kogun variety of Chinese cabbage and the Simu cabbage, variety were grown. The soil was sterilized with Hepta and placed in vinyl bags which were then placed in the cold bed. On August 1, 3 to 4 seeds of each variety were seeded but only one plant was left after others were removed on September 6. Each seeding with four or five leaves were transplanted to the reclaimed salty farm plots containing 0.45% of salt. Two dfferent methods of transplanting were employed. The first one was, as shown 1, was transplanted in double-row beds. The other method was to plant the seedlings on sloping beds. Each plot consisted of 25 square meters. The experiment was a split plot design with four replications. On Ocotober 24, the plants were harvested and the fresh weight obtained.

RESULTS

1) Growth in Salty Conditions

As shown in Table 2, the production of fresh weight and dry weight of the top system decreases as the salt concentration rises. The point of 50 percent production in fresh weight is about 1 percent salt content. At the low salt concentrations of 0.2 to 0.4 percent the decreased of on fresh weight, was slightly greater than decrease of dry weight, and the decrease of fresh weight was well over the dry weight at 1.6 percent salt concentration. This suggests that the plants are starved for water in the high salt concentrations but not severe in the 0.2 to 1.4 percent solutions. It was observed that this phenomenon was similar to that in the case of the rice plants in the previous experiment. (Im. 1967)

The growth of the root system showed a greater decreasing trend in comparison with that of the top system. This trend is similar to the growth of rice plants in the salty areas. It can expected that high-salt concentration will accumulated in the root system due to the higher content of salt solutions in contacts with the root system. Such defective growth of the root system may result from the toxic effects of Na^+ and Cl^- ions. The maxium length is almost a simliar trend from each other as the salt condition rises but it was observed that the decrease of the leaf width by different salt concentrations was greater than that of the leaf length. Therefore, the leaf of Chinese cabbage is suffering in the development of morphogenesis.



[ ] : Zones of high-salt content

Fig. 1. Double-row bed and Sloping bed.

The Chinese cabbage grown in the sat solutions have less number of leaves. The salt effect on the growth of Chinese cabbage caused the decrease in the differentiation of leaves. The ratio of dead leaves due to the withering against the total number of leaf (number of withered leaves to total number of leaves) shows a small increasing trend in proportion to the salt concentration treatments. (Table 2)

2) Symptoms of salt Damage

Table 2. Growth of Chinese Cabbage by Sand Culture with Hoagland's Solution in the Various Salt Concentrations.

	Top system (Gr)		Root system (Gr)		Max. leaf (Cm)		No. of leaf		
	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.	Length	Width	Fresh	Withered	Total
T_1 (Control)	475.5 (100)	27.7 (100)	19.9 (100)	2.4 (100)	36.0 (100)	20.9 (100)	32.5 (100)	4.3 (100)	36.8 (100)
T_2 (0.2%)	(92.1)	(81.6)	(88.9)	(81.2)	(107.6)	(100)	(84.1)	(88.2)	(88.0)
T_3 (0.4 〃)	(77.9)	(75.2)	(68.4)	(65.2)	(97.4)	(91.0)	(87.7)	(94.1)	(88.4)
T_4 (0.8 〃)	(61.3)	(61.4)	(59.3)	(59.0)	(95.1)	(86.8)	(80.0)	(74.1)	(87.1)
T_5 (1.6 〃)	(27.7)	(34.0)	(34.2)	(40.2)	(92.4)	(85.6)	(54.4)	(76.5)	(67.1)

* The figures in parenthesis are the ratios versus control plot.

The leaf of Chinese cabbage grown in the salt areas showed a trend of being tinged with dark blue-green which is similar to the coloring of the rice plants in salty areas. The phenomena of deepening of this color tinge is not attributable only to a higher content of salt but occurs also in the culture with other kind of higher salt concentrations. From this point of view, it may be considered that the appearance of such tinge is a symptom of water shortage due to high osmotic pressure of the culturing medum. In addition, the edges of the leaves were rolled up over the surface to form shallow cup-shape depressions or troughs.

The leaf tip of rice plants grown in salty soil areas withers and rolls. Similarily the tip edge of the outer leaf of Chinese cabbage was also withered to show the so-called leaf burn phenomenon and also necrosis of the tissue around the end of leaf was observed on the inner leaf.

The growth of the root was retarded as the salt concentrations increased in comparison with that of the top system which was tinged with brown colorations.

3) Absorption of Mineral Nutrients

Table 3 shows that the results from an analysis of cabbage plants grown in sand culture.

The contents of N and P expressed on a dry weight basis did not change when grown on different salt concentrations. It appeared that absorption of K was decreased as the salt concentrations increased. Ca absorption was decreased as the salt concentrations increased.

Table 3. Analysis of Chemical Components in Inorganic Substances, Chinese Cabbage in Sand Culture.

No. of treat.	Salt cont. treated	Chemical constituents						
		N	P_2O_5	K_2O	CaO	MgO	Na_2O	SiO_2
T_1	0 %	3.83	1,278	5.75	2.88	0.75	1.69	0.82
T_2	0.2 〃	3.56	1.367	5.65	2.96	0.69	3.14	1.27
T_3	0.4 〃	3.34	1.300	5.38	2.23	0.48	4.60	2.00
T_4	0.8 〃	3.72	1.355	5.52	2.30	0.51	5.50	0.97
T_5	1.6 〃	3.74	1.175	5.50	1.59	0.56	7.05	0.64

* Figuresent the percentage of unit dry weight.

As the salt concentrations increased the absorption of Mg was decrease, and Na increased. Si absorption increased to 0.4 percent salt concentrations.

4) Culturing in Salty Field

In the salty plots the Chinese cabbage began to suffer from salt damage seven days after they were transplanted. The growth was far worse on the salty plots. After 10 days, all plants, had died. In other words, Chinese cabbage has a very weak salt tolerance compared with head cabbage.

Table 4. Yield of Cabbage in Fresh Weight.
(Average in Gr/stock)

Salty and treatment	Average (4 Replications)
Non-salty, double-row bed	1,105.0
Non-salty, sloping bed	993.0
Salty, double-row bed	138.5
Salty, Sloping bed	186.0

No Chinese cabbage was availabe forvest in the salty plots as the salt content was 0.45 percent or more. Table 4 shows only the yield of cabbage. As shown in Table 4 there was great difference between the harvested yields of cabbage on the non-salty plots in this experimental farm of salty area.

It was found that double-row bed in the non-salty plots resulted in securing significant difference but on sloping beds better results in the salty plot were obtained (See Figure 1).

DISCUSSION

Hayward (1955) maintained that salt tolerance of crops should be determined by (1) survival data on salty soils, (2) productivity in salty soils, and (3) comparison between yields of the varieties on non-salty plots and that in salty plots.

The Salinity Research Institute of the U.S. Department of Agriculture showed from their researchs that production of spinach, which has the strongest one in salt tolerance, is reduced 25 to 50 percent of normal at 10 to 12 mmhos (salt content 0.64 to 0.7 percent), cabbage 25 to 50 percent at 4 to 7 mmhos and lettuce 50 percent at 6 mmhos (Hayward 1955).

According to Osawa (1961 a,b,c, 1965) cabbage, spinach and Chinese cabbage have the strong salt tolerance. He maintained that the maximum limit of salt content of soil to harvest 50 percent of fresh weight in the the non-salty sand culture is 0.9 percent, and below 0.65 percent salt content produces 50 percent of head cabbage. In the case of spinach and Chinese cabbage, adequate content to produce 50 percent is 0.65 percent.

In the present research, it was found that the salt content needed to obtain a 50 percent harvest of Chinese cabbage in the nonsalty plots was about 1 percent. This is a higher concentration than that found by Osawa (1965).

An experimental farm was set up on silt clay in the reclaimed salty land containing 0.45 percent of salt. The soils were found to be too salty for the cultivation of vegetables. It was further found that the salt content increased following transplanting. Dry soils in autumn accelerated the extent of salt damage and resulted in a 15 percent harvest. According to the report of Israel on salt water agriculture (Scientific American 1967, March), roots can maintain contact with air instead of salty water thanks to the large sand particles present. Because of this, roots have less contacts with salt and obtain more oxygen, which enables the crops to cope with high salt concentrations. In view of this fact, salt content in sand culture and salt tolerance in actual farm are different. In the present research, Chinese cabbage which appeared to have very strong salt tolerance in the sand culture, but in the field experiment almost all the cabbage plants died 10 days after transplanting. Only cabbage survived. It seemed that there are many factors which affect the cultivation of vegetables in reclaimed salty soil areas.

According to Ayers et al. (1943), Schwalen and Wharton (1930), soils have less salt damage to crops when they are comparatively wet. It was found that the salt content is higher when the soils are dried. In many cases, the salt content becomes so higher that crops are damaged.

According to Magistad, Ayers and Wadleigh (1943) a decrease in the harvest of crops due to salt damage is due primarily to the total salt content rather than to specifically harmful effects of ions. All factors considered make the cultivation of crops in salty field quite complicated. Thus the utilization of the reclaimed land of Korea requires more extensive research.

The cabbage grown in sand culture was chemical analyzed. As the rice experiment, Na was accumuated as the salt content increased. Ca and Mg absorption were decreased. There were indications that the absorption of K was reduced. More Si was absorbed under low-salty conditions.

According to Osawa(1965), cabbage had no definite trend in the absorption of N and P when various concentrations of salt were applied. The current research substantiates the results of Osawa (1965) regarding the absorption of Ca and Mg ions. He further showed that Ca, Mg and K are definitely antagonistic to Na ions. Except for Mg ions, this phenomenon was noticeable in the rice paddy field experiments. In the present sand cultures with Chinese cabbage there was a certain antagonism of K but the amount was not as extensive as was expected.

Bernstein(1957, 1957, 1960, 1963, 1964) showed that in salty fields, ridges should be made in such a way as to enable farmers to seed on both sides of the slopes in sloping beds. The vegetative growth of the plants growing on the broad ridges so called double-row beds contained a high-content of salt while those growing on both sides of the sloping beds as seen in Figure 1, contained less salt. He maintained that planting on the slope is one planting method to avoid salt damage.

In the present research involving two different types of ridges both was used in salty and non-salty areas. The results were similar to those obtained and reported by Bernstein. In salty plots plant growth was significantly better on the sloping bed. In non-salty plot, double-row on the ridge gave better results.

摘　　要

鹽分 條件下에서의 砂耕에 依한 폿트實驗 및 鹽分圃 移植實驗을 하였던 바 砂耕栽培에서 新鮮重 生產은 鹽分濃度 0.4%에서는 約 20%程度 減收되었고 白菜 新鮮重 50% 生產點은 鹽分濃度 1% 程度이였다.

田狀態의 鹽分地에서는 栽培地의 鹽分濃度가 높을 수록 Na의 吸收는 많았으며, N와 P의 吸收는 變動이 없었으나, Ca, Mg의 吸收는 抑制되었다. K의 吸收도 鹽分條件에서는 그 吸收가 阻害되는 傾向이었다. Si는 低鹽分條件에서 吸收가 活潑하였으나 高鹽分條件에서는 急激히 그 吸收가 떨어졌다.

苗移植에 依한 鹽分地의(0.45% 干拓地)栽培에 있어서 白菜의 栽培는 어려우나 양배추 栽培는 可能할 것으로 생각되며, 鹽分地에서는 넓은 두럭의 方法보다 뾰죽한 고기목型 두럭의 兩側斜面에 심는 것이 有意하게 鹽害를 적게 받았다.

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