〈**Article**〉

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

11. On the Histological Differences Between the Roots of Salt, Land and Water Bed Seedlings of Rice and their Rooting in Saline Soil.

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干拓地에서 水稻 및 其他作物의 耐鹽性에 關한 硏究

11. 水稻의 鹽分苗, 陸苗 및 水苗根의 組織學的 差異와 鹽分地에서의 發根에 關하여

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ABSTRACT

The rice variety, Kwanok, was reared in the water, land and salt seed beds and transplanted to the reclaimed soil area having an average of 0.48% salt content (0.67% at the end of April). The plant height of land bed seedlings at transplanting stage was short but the dry-weight/plant-height ratio was large and the rooting ability was vigorous remarkably after transplantation in the salty area.

The central cylinder, vessels, sclerenchyma, endodermis and other mechanical tissues of the root of land bed seedlings were well developed while the size of cortical cell layers were small. The cytoplasm of the cortical parenchyma at the root tips seemed to be most abundant in the land bed seedlings. The formation of the aerial cavity in the cortex of primary root was rapid and it seemed that the developmental mechanism of the aerial cavity in the rice plant roots was related to the development of the lateral roots.

INTRODUCTION

The culture of salt tolerant varieties, proper fertilizer dressing, soil desalinization by means of irrigation and transplantion of strong seedlings are considred to be the most important factors to reduce salt damage in salty area. However, most of the reclaimed areas in Korea are composed of sea alluvium and located away from the estuary of the rivers. Even if the reclaimed areas are located near the estuary of rivers, even if the reclaimed areas are located near the estuary of rivers, desalinization is very difficult due to the narrow fresh water collecting areas and unavailability of good irrigation facilities.

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Consequently, an extreme withering of the rice plants is usually caused at the rooting stage. Therefore one of the most important factors is to transplant strong salt tolerant seedlings in order to reduce the unfavorable effects of the conditions described above.

Previous experiment[14] (1967), the withering and growth disturbances which result from an excessive salt concentration were considered to be attributable to a high osmotic pressure rather than from the specific toxicity of the ions. Particularly, it is considered to be more clear that a high osmotic pressue is the very cause of the withering at the rooting stage. The environment of the seedlings on the salty seed-bed and land seed-bed different from each other. As they were hardened by a water shortage and some salt possibly, they will live in the reclaimed area where water absorption is very difficult but the roots are well developed.

MATERIALS AND METHODS

The sample variety of Kwanok was sown on the upland, salty (0.67% of salt content) and ordinary water irrigated beds on April 27. Nurseling was cultured with ordinary dressing and managements, respectively. Transplantation was done in 7 plants per hill at space intervals of 15cm×21cm on June 18.

The dressing was N 15 kg, P_2O_5 8 kg and K_2O 8 kg with the dressing proportion of N for base, tiller and head applications as 3:4:3. The standard method of the paddy field was used in the maintenance and management of the plots.

The anatomical observation of the roots of seedlings was made with Heidenhein's hematoxylin for microscopic examination.

EXPERIMENTAL RESULTS

1) Characteristics of seedlings at the transplanting stage

The highest plant heights were observed to be the water seedlings and the salty seedlings followed, while the shortest were those grown on the non-salty land seed-beds. The average numbers of stems were 3.1 and 1.6, respectively, for the saty and land prodced seedlings. In comparison with the water seedlings which averaged 1 stem per seedling, the number of stems of the salty seedling was increased surprisingly because of widened space by withering at the germination and early growing stages. The tillering capacity of the land seedlings was apparan-

Table 1. Characteristics of Seedlings at Transplanting Stage.

Characteristics	Water seedling	Land seedling	Salty seedling
Plant height (cm)	43.0	28.0	32.3
Number of stems	1.0	1.55	3.05
Number of leaves	5.8	5.4	5.1
Dry weight per plant (gr.)			
Shoot system	1.02	0.74	0.60
Root system	0.35	0.36	0.31
Total dry weight	1.37	1.10	0.91
T/R ratio	2.9	2.1	1.9
Dry weight/plant height	0.032	0.042	0.028

tely very vigorous compared with that of the water seedlings. The water seedlings grown in good environment produced the largest number of leaves (leaf age) and the salty seedlings showed the smallest. The leaf differentiation is inhibited evidently and the growth is thereby retarded under salty conditions.

The dry weights of the top system were in the order of the water, land and salty seedlings. The land seedlings were the heaviest in dry weight of the root systems. Therefore the land and salty seedlings were remarkably lower in the ratio of T/R than the water seedlings which suggests that substantial growth of the root system versus the top system of the two types of seedlings grown under the difficult conditions of water absorption. The coefficient of dry-weight /plant-height was remarkably greater for the land seedlings than the other two types of seedlings.

Table 2. Size of the Primary Roots and Central Cylinder of Each Seedling ($\pi \times 1,000\mu^2$).

Type of seedling	(Distance from tip)	Central cylinder	Primary root	Central cylinder/ Primary root ratio(%)
W	(5 mm)	4.0	93.0	4.3
L	(〃)	5.5	63.2	8.6
S	(〃)	3.2	100.2	3.6
W	(10mm)	4.2	107.5	3.9
L	(〃)	5.0	73.2	6.8
S	(〃)	4.2	124.0	3.5
W	(20mm)	4.5	110.2	4.1
L	(〃)	7.5	97.2	7.8
S	(〃)	5.8	144.0	3.9
W	(30mm)	5.5	172.0	3.4
L	(〃)	7.5	107.0	7.1
S	(〃)	4.5	159.2	2.9

W: Water bed seedlings, L: Land bed seedlings, S: Salty bed seedlings.

2) Histological differences in the primary root of each kind of seedlings

5mm, 10mm, 20mm and 30mm plant regions fom the primary root tip were studied after being cross and longitudinal sectioned for the comparison of histological differences. The fundamental structure of the primary root in cross section of rice seedlings is illustrated in Photograph 3 and 5.

As shown in Table 2, the microscopic measurement of the size of the primary root tip region showed that the salty bed seedlings were markedly thicker than the water bed seedlings and the land bed seedlings were the thinnest. On the contrary, the land bed seedlings are the thickest in size of the central cylinder and the other two seedlings were practically the same size. Accordingly the central cylinder/total root thickness ratio was the largest in the land bed seedlings and the water bed seedlings seemed to be slightly larger than the salty bed seedlings.

In the differentiation of vascular bundle, the land bed seedlings were well developed in the cell walls compared with other seedlings (Photographs 3, 4 and 6). The development of sclerenchyma also seemed to be rapid in order of the land, salty and water bed seedlings at the same distance from the root tip as seen from the thickness of cell wall, the degree of staining and the relative difference in cortical parenchyma.

The crown root of the rice plant proceeds to from intercellular space at the root elongation stage. It was felt that such intercellular space was formed lysigenously and schizogenously (Photographs 2, 6 and 8). It appeared at 5mm from the root tip in the land bed seedlings (Photograph 3) and developed greatly at 20mm. Living cortical cell ramained only in the region surrounding the primrodium lateral root, central cylinder and other regions. The cortical region was almost occupied by intercellulary lacunae. The lacunae developed from the intercellular space began to appear from near the parenchymatous cell of 1—3 layers of the cortical sclernechyma and proceeded inward (Photograph 4). As shown in Photograph 7, the radial septum of the developed lacunae appeared commonly as a Y-type on the outside of the cortex.

Yamasaki[40] (1952) states that this root structure is formed as the shrinking and separation of the neighboring cells of dichotomic cell division proceed. The intercellular space appeared at 10mm and 20mm from the root tip in the land and water bed seedlings, respectively. The lacunae formation of the land bed seedlings was rapidly differentiated.

The water bed seedlings were the longest lengthwise in its cortical parenchyma, salty bed seedlings followed and the land bed seedlings were the shortest. The ratio of the vertical length and that of root lenght of each seedling, as shown in Table 1, were similar to each other. It was considered that the degree of elongation of the vertical length of each root cell was one of the important factors that affect the crown root which is the longest in the water bed seedlings, medium in the salty bed seedlings and the shortest in the land bed seedlings.

The root of the salty bed seedlings was thicker in diameter than any other seedlings and the growth of cells in the radial direction was also remarkable when compared with other seedlings.

The cytoplasm of cortical parenchma of the root tip was most solid in the land bed seedlings and the vacuole was developed in the cells of other seedling. It was apparent that this was greatly correlated to the living activity of the crown root.

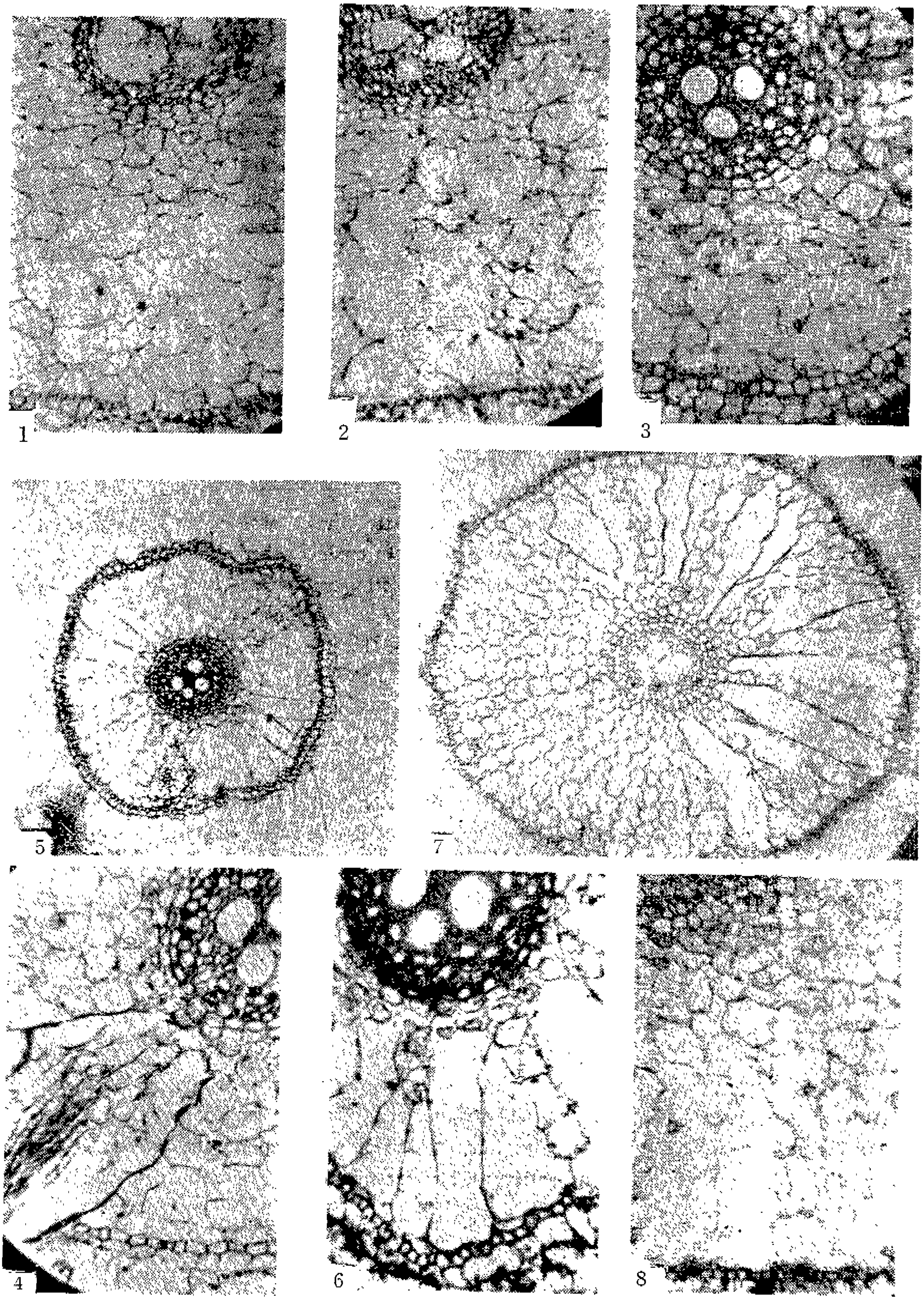
The lateral root or secondary root of the land bed seedlings proceeded to develop at 5mm from the tip and the number of lateral root was enormous. It seemed that the formation of lateral root primordium developed in the vicinity of the tip was closely related to the intercellular space.

3) Rooting activities and other growing characteristics at rooting stage.

The results of the investigation of each seedling one week after transplantation revealed that the non-salty land bed seedlings produced 134 roots per hill on the average while the water and salty seedlings produced 99 and 94 roots, respectively. The root length of the salty bed seedlings

Explanation of Photographs

Phot. 1: Cross Section of the Primary Root of Water Bed Seedlings at 5mm from Root Tip.
Phot. 2: Cross Section of the Primary Root of Water Bed Seedlings at 20mm from Root Tip.
Phot. 3: Cross Section of the Primary Root of Land Bed Seedlings at 5mm fron Root Tip.
Phot. 4: Cross Section of the Primary Root of Land Bed Seedlings at 10mm from Root Tip.
Phot. 5: Cross Section of the Primary Root of Land Bed Seedlings at 20mm from Root Tip.
Phot. 6: Cross Section of the Primary Root of Land Bed Seedlings at 30mm form Root Tip.
Phot. 7: Cross Section of the Primary Root of Water Bed Seedlings at 40mm from Root Tip.
Phot. 8: Cross Section of the Primary Root of Salty Bed Seedlings at 10mm from Root Tip.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was comparatively longer than that of the other two seedlings and the diameter of newly grown roots was increased to some extent in the water seedlings when compared with that of the others.

The plant height and root length 2 weeks after transplanting were compared. Although the plant height of the land seedlings was about 5cm longer than that of other two seedlings, the land seedling showed a tendency of being somewhat short in total root length. The dry weights of top and root systems at this time were similar in both regions in the order of the salty, water and land seedlings.

DISCUSSION

A marked tendency to use the land bed seedligs for transplanting in non-salty areas is practiced recently in Japan.[32] This is because of the superior rooting activity of the land bed seedlings after transplantation than the water bed seedlings. In the present experiments the number of roots developed one week after transplantation in the salty area was larger by about 35%.

The earliest growth of the land bed seedlings after sowing was better than that of other seedlings. However, the plant height and dry weight produced thereafter were lesser than those of other seedlings. The water bed seedlings were better as indicated in Table 1.

Dakagi[5] (1969) states that the growth of the land bed seedlings was better than that of the water bed seedlings because it was greatly affected by the upland condition which is rather advantageous in nutritional absorption than water absorption in the early growth.[28] Kawada et al.[17] (1964) reported the results of the investigation on the RNA of root harirs of rice plants that the physiological life of the root hairs of crown root is short under the uplant conditions. This is due to the inactive growth in the later stage in the seedlng bed.

The land bed seedlings were weak in growth of top parts although the growth of the roots system was favorable. Accordingly the T/R ratio of the land bed seedlings was less than that of the water bed seedlings. The root system of the land bed seedlings was abundant with fine lateral roots and root hairs, severely bending and somewhat hard compared with the water bed seedlings. It seemed that root elongation was inhibited at the later growth stage of the seedlings of the land bed. The ratio of dry-weight/plant-height was also greater in land bed seedlings. The coefficent of this ratio is generally expressed by the degree of living activity of the seedlings.

As discussed above it is felt that the characteristics of the land bed seedlings are the adaptation to drought resistance due to limited water supply and development of the structure for the accumulation of stored matters and contraction of the stems and leaves as may be observed in general plants. It is presumed that drought hardening of the land bed seedlings was made probably by the vigorous rooting activity after transplanting in the salty area of high osmotic pressure.

According to the comparison of the seed root of land and water cultured rice plants by Gokura[11] (1957), the numbers of vessels, central cylinders and protoxylem of the former were larger than that of the latter and the sclerenchyma, endodermis and mechanical tissues of the central cylinders were severely thickened. The same tendency was observed in the land and water bed seedlings in the present experiments. The root structure of the salty bed seedlings was similar in many aspects to that of the water bed seedlins.

The accumulation of lignin in the cell walls is accelerated by water shortage conditions in general. Sugar and carbohydrates are not combing with NH_3 transformed to amino acid and protein to form cytoplasm in the small-grown plants is due to a water shortage. According to Hibbert[12][13] (1939, 1940), an excess carbohydrate readily becomes lignin through condensation and polymerization.

The marked histological characters of the land bed seedlings are the development of the lysygenous aerenchyma in the primary root and excellent growth of the secendary and tertiary roots compared with the other seedlings (Photograph 5).

There are many theories on the developmental process and structure of the lacunae or aerenchyma of the root systems of the rice plant and other hydrophytes.

Boeke[4] (1940) and Mori[22] (1959) indicated that intercellular space of the cortical parenchyma of the rice plant root occurs by middle lamella dissolution of the cell walls at the time of cell division and the cavity is formed by the separating of the radial cell walls of the cortical cells and that the cell walls are separated by the action of physical force resulting from the thick growth of the roots. The further stage of the ready separating of the radial cell walls is attributed to biochemical differences in the pectic compounds of the middle lamella. Although it is indicated that the cavity is formed entirely by a lygygenous process, the cavity formation seemed to be accelerated by shizogenous rupture of the cell walls as shown in Photograpsh 2 and 4.

The aerial cavity proceeded to appear from near the root tip of the land bed seedlings while the development was retarded in order of the salty and water bed seedlings. Thus the land bed seedlings were characterized by the rapid formation and development of the cavity.

Valmis[29] (1944) reported that the required oxygen content is the same in the detached roots of rice, tomato and barley plants and that the O_2 supply from the top part is probably great in such plant roots as rice plant grown in the area of low O_2 content. Many scholars[33][23][8][2] reported that the aeration is accelerated through a large aerial cavity developed under over-humid and submerged conditions. It is also supplied through a large space[33][2] producd by columnar arrangement of cortical parenchymatous cells (Photogrph 7).

A good deal of discussion[24][16][22][26][27] has been made on the formation of the aerial cavity. Arikato[2] (1965) and other scholars[33][10][19][15] indicated that due to low O_2 content in the root growing area, the aerenchyma develops secondarily from the top to the underground part under reductive conditions of low oxidative and reductive electrical potential (Eh). The necessary O_2 is supplied to the roots. On the contrary, some scholars[16][26] maintain that the aerenchyma also develops markedly even under oxidative upland conditions and development is closely related to the initiation of lateral roots which results in the reduced in aerial functions.

In the present experiments the cavity formation was rapid in the land bed seedlings grown under favorable O_2 supply conditions.[20] It seemed to be deeply correlated to the initiation of lateral roots as indicated by Kawada[16] (1956). The initiation of lateral roots proceeded at 5 to 10mm from the root tip (Photographs 3 and 4) was accompanied by the cavity formation and it was rapidly developed by the supply of energy attributed with the collapse of cortical parenchyma under the upland condition.

The lateral root is surrounded by living parenchyma and there would be sufficient nutritional supply to the lateral root with cortical living cells linked each other across the cavity.

However, a large cavity was observed at the basal of the roots, 40mm from the root tips of the water bed seedlings (*Photograph 7*). There appeared little doubt, therefore, that O_2[1,9] was supplied probably to the root tips through the aerial cavity under low Eh conditions.

The symptom of salt damage observed after transplanting the three different seedlings at the same time in the salty area was that the chlorophyll of the assimilation part of the land and salty bed seedlings were partly destroyed although grown similarly to the seedlings transplanted in the non-salty area, and the root system was good. On the contrary, severe chlorosis, leaf burn[3,7] and withering of the lower leaves were observed in the water bed seedlings. Particularly, the water bed seedlings suffered from severe salt damage[6] caused by extensive evaporation and high temperature.

摘 要

關玉을 水苗垈, 陸苗垈, 鹽分苗垈에서 길러 水稻生育期間中의 平均 鹽分濃度 0.48% (4月末 0.67%)의 干拓地畓에 移秧하였던 바 陸苗는 他苗들에 比하여 移秧期의 草長이 짧았으며 乾物重/草長이 크고 苗가 充實하였으며 鹽分地移秧後의 發根力이 顯著히 强하였다.

陸苗는 他苗에 比하여 뿌리의 中心柱, 導管, 厚膜組織, 內皮 其他 器械組織의 發達이 좋았으며 皮層細胞層의 크기는 적었으나 根端部位의 柔細胞의 細胞質은 豊富한 것 같았다.

一次根皮層에서의 通氣空洞의 發生機作은 側根發生과 關係가 있는 것 같이 보였다.

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