Studies on the Saline Injury to Crops (V)
Sodium and chloride accumulation and moisture in leaves associated with leaf-burn symptoms in rice

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作物の塩害に関する研究 (V)
水稲被害葉の塩分集積量及び水分含量について

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The responses of a growing plant to the excessive accumulation of sodium chloride in the rhizosphere have been discussed by many research workers (1) (2) (3) (6) (8) (9) (10). It can be concluded that the effects of salt on plant growth are concerned with the following three factors :

1) Water deficit induced by osmotic inhibiton.
2) Specific ionic effects involved in direct toxicity and nutritional unbalance.
3) Combination of the above two.

The author has tried to demonstrate the effects of these factors on plant growth, but, since the causal relationship of ion accumulation to saline injury is still in the stage of mere presumption, special attention was, in this paper, focused on various levels of the ion accumulation with reference to leaf-burn symptoms. As a result of this research he has come to consider that the ion accumulation is a more predominant factor for the development of saline injury than water deficit.

Materials and Methods

With the object of throwing more light on the correlation between the observed symptoms and the accumulation of ions (sodium and chloride), experimental rice seeds (var. Nōrin No. 44) were selected and sown on May 6, '58, in such a manner that the most uniform crops possible would be obtained. All cultures were grown in pots (1/2000 ares) with sand in them, some of which were supplied with the special solution (sodium chloride was added so that the solution might hold the concentration of 0.4% or 0.8% NaCl during the course of experiments). Saline treatments of cultures were not initiated until June 3, '58. The base nutrient solution had the composition described in the previous report (10).

The saline treatments resulted not only in the reduced growth but also in the leaf injury. The first effect observed after the treatments was a slight burniug at the tip of the leaf-blade, showing a "tip burn" pattern. The severity of the symptoms increased with time and salinity, as follows :

Degree	Index
Normal	0
Tip burn (slight)	1/4
〃 (moderate-A)	2/4
〃 (〃 -B)	3/4
〃 (severe)	4/4

The chemical analyses were made on the affected leaves clipped 25 days after the saline treatments (tillering stage) and again just before heading (boot stage). Chloride content was determined by a modification of the method of Clark et al (11), and the flame photometer was used to determine sodium content.

Results and Discussion

The effect of salinity on the leaf-moisture content of rice plant associated with leaf-burn symptoms is shown in Fig. 1.

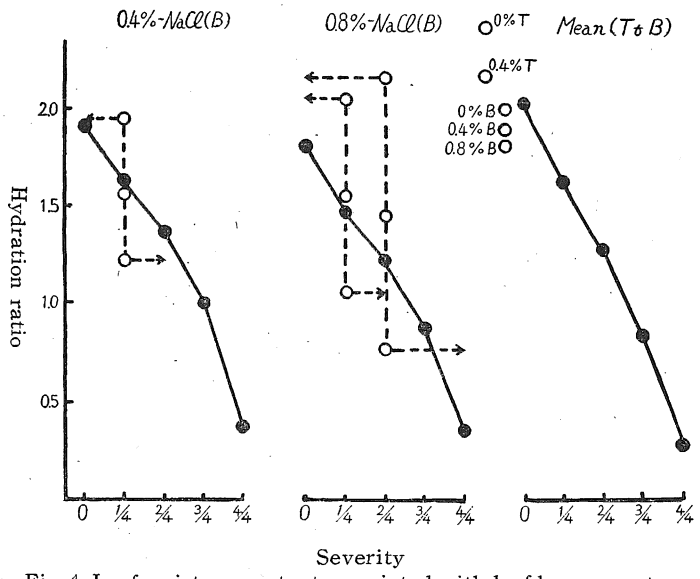

Fig. 1 Leaf-moisture content associated with leaf-burn symptoms.

It was found that the decrease of moisture in the leaf-blades was proportional to the progress of the visible symptoms, in spite of the traditional view supported by many research workers that water deficit induced by high osmotic pressure of the root medium is a factor inhibiting plant growth. Moreover, this proportionality was the same in the leaf-blades that were treated with salinity at different stages of growth or with different concentrations of salinity. Even in a leaf where the burn symptom began to develop, the moisture content in the green portion (the basal portion obviously uninjured) was the same with that of an unburned leaf, and the moisture content of the injured portion bore a resemblance to that of another wholly burned leaf showing the corresponding severity. Accordingly, it seems that the decrease of all moisture content of a leaf induced by salinization follows, and not precedes, the severity of the tip burn as a result of the decrease of moisture in the burned portion itself. It is not difficult, of course, to suppose that the moisture content is gradually reducing at the border part between the injured and the uninjured portion of a leaf.

If water deficit in a plant were induced by salinity in root medium, the moisture

content in the uninjured portion of a burned leaf would be less than in an unburned leaf.

Table 1. Sodium and chloride accumulation in leaves associated with leaf-burn symptoms (meq. /100 g)

Leaf-order \ Injurious degree	0		1/4		2/4		3/4		4/4	
	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na
9	27	7								
8	39	16	49	23						
7	49	12	53	19	103	37				
6	57		83		123	92	170		177	
5			97		133	110	177		170	
4									177	125
3									177	

Sodium and chloride accumulation in affected leaves classified according to the leaf-order is shown in Table 1. It was found that the levels of sodium and chloride accumulation required to develop visible symptoms varied with the leaf-order, and that the minimum levels of the accumulation to exhibit the same degree of injury were higher in the lower (older) leaves. Unlike the case of the moisture described above, the relation between the chloride or sodium accumulation and the severity of the tip burn was not linear, though it was clear that chloride and sodium content in leaves increased with the development of the saline injury (Fig. 2).

These results may play an important role in studying the saline injury to crops, and yet it seems that these problems were not too well determined and were still in the stage of mere presumption for all reports of many research workers.

It was also found that chloride accumulation in the green portion (the basal portion of a burned leaf) was lower than in the burned leaf or the injured portion of a burned leaf and was higher than in the unburned leaf,

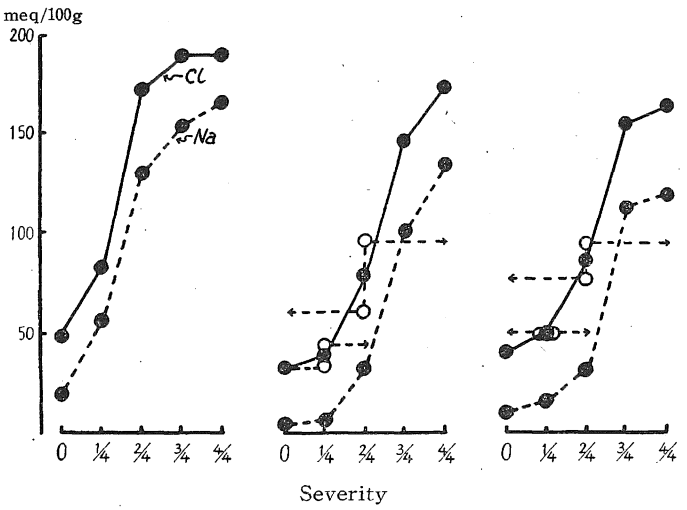

Fig. 2 Na or Cl accumulation in leaves associated with leaf-burn symptoms

and moreover, that the chloride content in the burned portion was lower than in another wholly burned leaf showing the corresponding severity ; especially that the differences of the accumulation between the injured and the uninjured portion decreased with the salinity increase. Therefore, it seems that the severity of symptom follows the chloride or sodium accumulation and that the accumulation plays a great role in the development of the saline injury, for chloride is found to be accumulated especially in the uninjured portion.

As far as this experiment went, chloride and sodium accumulated in leaves were equivalent in quantity, so it seems that chloride and sodium added to the base nutrient solution are carried in mass flow process (5) (7) (Fig. 3).

The author already found (8) (9) that with the same saline treatment, the dry-air condition more promoted the development of injury than the humid-air condition and produced the marked increase of water uptake, while under both conditions no difference was seen in the rates of water uptake decreasing with the progress of salinity. Tagawa found that water absorption in an intact plant was remarkably higher than in a dettoped plant. Therefore, it follows that the dry-air condition is a factor predominating over the salinity in root medium. This factor seems to increase chloride and sodium accumulation in leaves and consequently develop the injury. If so, it can be said that the uptaken moisture in leaves of an intact plant is replenished well and there hardly occurs a phenomenon of "water deficit resulting from the salinization in the rhizosphere".

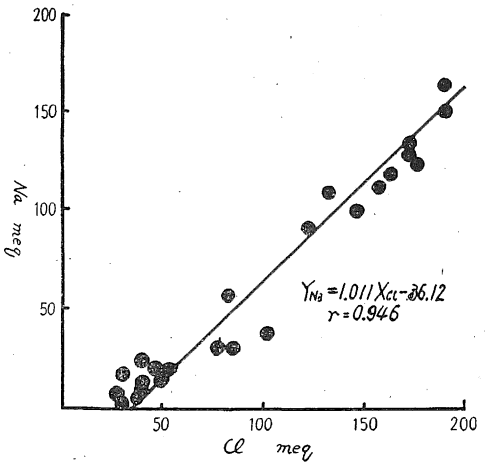

Fig. 3 Relation between sodium and chloride accumulation in leaves

Recently, as the conception of "Outer Space in plant"—which is practically a meaningful one—was introduced into the relationship of roots to the external medium, the above results may raise additional question in the developmental mechanism of the saline injury.

Accordingly, although the mechanism of chloride or sodium toxicity remains unknown, it is considered that the presence of abnormally high amount of chloride or sodium in leaves may be a more predominant factor in the developmental mechanism of the saline injury than the inhibition of water-availability in the whole plant. Moreover, the idea that a conceivable water-availability in a leaf may stem chloride and sodium accumulation resulting from mass flow process perhaps provides a new approach to the problem of the saline injury.

SUMMARY

Determinations of sodium, chloride and leaf-moisture content were made on leaves of rice plant grown on a series of artificially salinized plots. The decrease of moisture content in leaves affected was circumstanced proportionally with the progress of leaf-burn symptoms and even in a leaf where the burn symptom began to develop, the moisture content in the green portion was the same with that of an uninjured leaf (a normal leaf). And the severity of the tip burn was closely associated with the levels of sodium and chloride accumulation, but unlike the case of the moisture described above, the relationship between the accumulation and the severity was not linear and the uninjured portion of a burned leaf had higher chloride accumulation than an uninjured leaf and also it was found that the accumulation was higher on the older leaves for similar severity. Moreover, the equivalent relation between sodium and chloride accumulation in a leaf would indicate that sodium and chloride added to the base nutrient solution were carried in mass flow process.

Accordingly, it seems that the saline effect on the plant is attributed to the presence of abnormally high amount of sodium or chloride in leaves rather than the inhibition of water-availability in the whole plant.

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摘　　要

塩水被害葉の水分含量は害徴の進むに従って減少するが，既に先端から枯死し始めている葉でも比較的基部の緑色部位では水分の減少がみられない。一方枯死部の水分含量は枯死葉の水分含量に近似し，あたかも枯死部の水分のみが減じたような結果が得られた。

Na 及び Cl の集積も害徴に従っていることは明かであるが，水分消長にみられたような直線的な関係ではない。又一枚の葉においても，枯死部は緑色部よりも多く集積され，緑色部もまた，未だ害徴を現わさない葉より多く集積していた。更に同じ害徴を示しているものでも，葉位によって集積量が異り，老葉ほど多かった。又 Na と Cl は常に当量を集積し，あたかも与えられた Na, Cl が mass flow しているようであった。

Na 又は Cl の直接の害作用は本実験の範囲内では考察できないので，この点の検討は今後に待つとしても，塩害の発現に際しては単なる吸水の制限によってのみ起るという考え方よりも，之等イオンの多量に集積されることも支配的であると考えることが妥当のように思われる。特に集積に伴って起される葉中の水分利用性の変化については更に考究されねばならない。