17. NUTRITIONAL DISORDERS OF RICE PLANT AND ITS COUNTERMEASURES IN JAPAN

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Introduction

Systematic research and experiments on nutrient deficiency or excess of the rice plant have been launched in 1940's with the improvement of degraded paddy field. A soil survey initiated on a nation-wide scale in 1950 under the Low-productive Land Investigation Project has clarified the distribution of poor soils in Japan. The distribution and acreage of poor paddy soils according to the findings of the above mentioned surveys are shown in Table 1. The table shows that the low productive land covers about 60 percent of all paddy land, and defective soil (for example, volcanic ash soil, peaty soil, acidic soil and others, cover 27 percent of total[3]). This paper intends to make some observation with additional information on those findings, with particular emphasis on the factors inhibiting the growth of rice plants by nutrient deficiency or excess, from the standpoint of fertilizer application.

Table 1. Acreage of low productive land in Japan [Paddy field] (ha)

Total acreage of paddy field	Defective soil	Shallow top soil field	Excessively percolated field	Ill-drained field	Draught field
2, 859, 517 (100.0%)	780, 866 (27. 3%)	109, 940 (3. 9%)	132, 221 (4. 6%)	272, 108 (9. 5%)	140, 755 (4. 9%)

Field irrigated by low temp. water	Soil with salt injury	Soil often be inundated	Field injured by mining	Others	Total of low productive land
111, 748 (3. 9%)	22, 883 (0. 8%)	51, 707 (1. 8%)	18, 340 (0. 7%)	168, 135 (1. 8%)	1, 693, 462 (59. 2%)

Nutritional disorder of paddy rice growing in degraded field

In the 1940's Shioiri published a theory of the causes possible for the degradation of paddy soils and advocated the term "Degraded paddy field". In those days it has been discovered that 'akiochi'* disease of paddy rice, which is found in paddy fields in various parts of the country, is closely related to the degradation of paddy fields. Originating from this finding, a series of very revealing researches followed explaining the causes of the role of essential minor elements and the effect of special nutrients (and some soil components).

Osugi advocated that the formation of sulfide by soil reduction is closely related to the occrrence of this disease.

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* Akiochi—autumn decline—, a complex of soilborn factors is involved in this physiological disorder, which manifests itself in poor later growth inspite of vigorous early growth, yellowing of lower leaves, poor ripening and low yield.

Those researches clarified that in paddy fields deficient in active iron, the root is damaged by free hydrogen sulfide which has been generated by soil reduction. The disorder in growth caused by root damage is quite identical to 'akiochi'.

As generally accepted, that paddy fields behave different from upland fields with respect to soil degradation. The degradation process in paddy soils is slower and their fertility can be retained longer than upland soils. However, the paddy soil is not so liable to the degradation of fertility due to water percolation as upland soil. But this is particularly true in case where the parent materials of the soil consist of acidic rocks such as granite, liparite, quartzite, and sandstone of paleozoic strata. There is a strong tendency of leaching of nutrients from the soil because of low clay content and high permeability of soil due to its coarse texture. Accordingly, as the degradation of paddy field progresses, various bases, phosphorus and silica are leached to subsoil. Of particular importance is

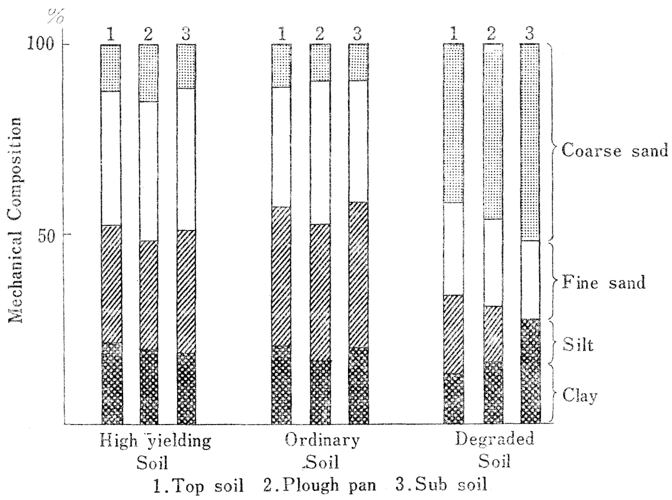

Fig. 1-a Characteristics of degraded paddy soil

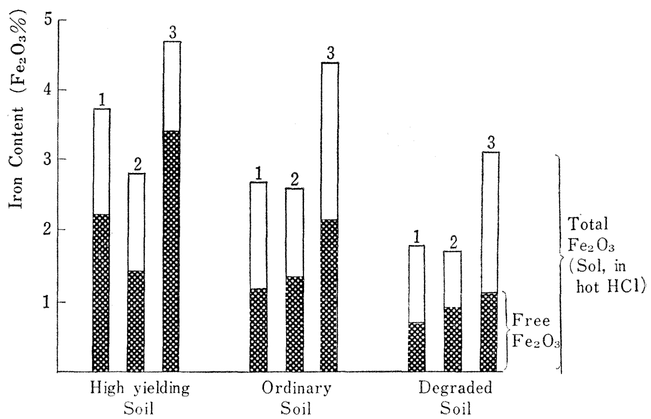

Fig. 1-b Characteristics of degraded paddy soil

also the leaching of iron.

In the efforts to improve such paddy soil and to prevent the root damage due to the formation of free hydrogen sulfide in the soil, use of sulfur-free fertilizers and the application of iron oxide has been advocated.

Rice plants grown in degraded paddy fields are deficient in various cations and silica in most cases, so that in order to ensure increased paddy rice production, the research work was directed toward the necessity not only to control the inhibition of nutrient absorption caused by root damage but also to maintain a high level of available nutrients content in the soil.

To increase soil fertility of degraded soils, researchers recommended the application of nutrients such as lime, manganese, magnesium, silicate, and clayey materials rich in various cations and high in cation exchange capacity.

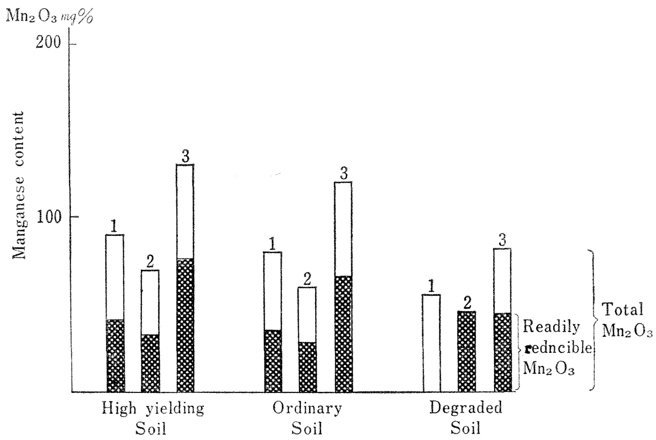

Fig. 1-c Characteristics of degraded paddy soil

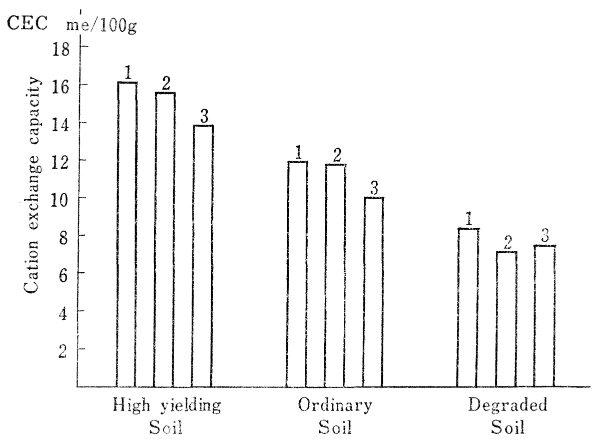

Fig. 1-d Characteristics of degraded paddy soil

As mentioned before, generally the growth pattern of 'akiochi' rice plant is characterized by its poor growth in the later growth period in spite of vigorous growth during the vegetative stages. It shows yellowing of lower leaves, poor ripening and poor grain yield in relation to the straw yield. However, such disorders are not of degraded paddy field only. The same pattern is also often found in ill-drained paddy fields, peaty soil, and in improperly fertilized fields.
Outbreaks of 'akiochi' are most common on degraded fields in the warm region of southern Japan, promoted by vigorous early growth due to high temperature in summer.

The total acreage of cultivated paddy fields in 1948 was 2, 919, 209 ha. According to the 1951 survey, 'akiochi' paddy fields covered 595, 489 ha or 20. 3% of the total. Out of total 'akiochi' acreage, 58. 2% was due to degraded paddy soil, and 37. 2% due to ill-drained paddy fields[6].

Figure 1[7] shows some characteristics of degraded paddy fields. Fig 1. a. indicates the coarseness of degraded paddy soil. In the degraded soil, content of coarse sand overs 40 percent, and the clay content is least, Fig 1. b. shows the iron content. In the degraded soil both total and free iron content are least. Fig 1. c. shows the manganese content of the soil. Degraded soil contains least amount of total and readily reducible manganese. Fig 1. d. indicates that the cation exchange capacity is also lowest in degraded soil. Because of low content of clay, a shallow top layer, and a gravel layer in the subsoil in most cases, water percolates easily and the soil is poor in retaining nutrients.

Based on these facts, beside the experiment on the application of iron oxide and sulfur-free fertilizer, experiments on the use of lime, potash, manganese, silicate and clay have been carried out in various regions of the country. Furthermore, to increase soil fertility, so called' ed soil dressing' *sometimes combined with the application of iron oxide and other materials were carried out under the Government Program of Cultivating Soil Improvement Law enacted in 1950. Table 2 indicates the distribution of soil deficient in bases and other nutrients revealed by the systematic soil survey under the Low-productive Land Survey project[3].

Table 2. The kinds and acreage of defective soil in Japan [Paddy field]

(ha)

Total acreage of paddy soil	Acidic soil	Volcanic ash soil	Peat soil	Heavy clay soil	Soil containing excess humus
2, 859, 517 (100%)	178, 613 (6. 2%)	64, 686 (2. 3%)	87, 544 (3. 1%)	62, 422 (2. 2%)	69, 284 (2. 4%)

Iron deficent soil	Sand and gravelly soil	Soil deficient in Mn and B	Soil containing injurious materials	Total acreage of defective soil
163, 121 (5. 7%)	98, 406 (3. 4%)	52. 266 (1. 8%)	4. 524 (0. 2%)	780, 866 (27. 3%)

The effect of 'akiochi' improvement by the application of bases is indicated in Table 3.[8] Although some effect in single application of each base can be seen, the yield is particularly high in the case of combined application of bases. At the early period of ex-

* red soil application—application of upland of mountain soil high in ferric iron and clay counted as amelioration of the furrow slice.

Table 3. Effect of application of various bases and silica in degraded paddy soil

Treatments	Yield index in field exp.	Yield index in field and pot exp.	Treatments	Yield index in field exp.	Yield index in field and pot exp.
Control	100 (—)	100 (—)	〃, 〃, 〃, 〃, +Si	115 (41)	123 (54)
+Fe	112 (69)	112 (96)	+Ca,	101 (23)	105 (40)
〃, +Ca	110 (16)	122 (31)	+Mg,	103 (27)	108 (34)
〃, +Mg	106 (14)	124 (26)	+Mn,	104 (27)	104 (37)
〃, +Mn	108 (20)	122 (35)	+Si,	106 (28)	108 (36)
〃, +Si	110 (8)	140 (23)	+Si, +Mn	— (—)	153 (4)
+Fe, +Si, +Ca	— (—)	273 (1)	〃, +Ca	— (—)	157 (4)
〃, 〃, +Mg	— (—)	270 (1)	〃, +Mg	— (—)	148 (4)
〃, 〃, +Mn	134 (8)	153 (10)	+Si, +Mn, +Ca	115 (1)	— (—)
〃, +Ca, +Mg	— (—)	188 (4)	〃, +Mg, +Ca	128 (1)	— (—)
〃, 〃, +Mn	— (—)	183 (4)	〃, 〃, +Mn	113 (1)	— (—)
〃, +Mg, +Mn	— (—)	104 (4)	〃, 〃, 〃, +Ca	117 (61)	122 (77)
〃, 〃, 〃, +Ca	— (—)	125 (3)	Limonite	115 (1)	214 (8)

( ) Numbers of experiments carried out

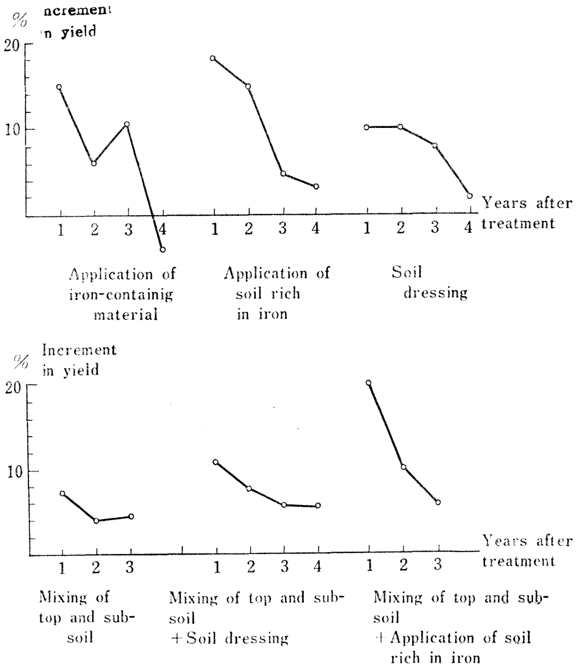

Fig. 2. Residual effect of Soil improvements in degraded paddy soil

periment on silicate application not much effect of silicate was recognized, because the rate of application was low, but later, it has been found that a large amount of calcium silicate application was effective. Researches on the silicate application has developed to the stage where the rational rate of application of this element can be determined by soil and rice

Table 4-a Effect of phosphorus and nitrogen application in volcanic ash soil

Rate of N.P.K application (kg/ha)			Yield (tons/ha)	
N	P_2O_5	K_2O	Weight of straw	Weight of hulled rice
0	300	75	2.95	2.72
56	300	75	3.52	2.92
113	300	75	3.56	3.17
150	300	75	4.58	3.94
188	300	75	5.29	4.76
113	0	75	2.71	1.64
113	113	75	5.40	4.54
113	225	75	5.44	5.57
113	450	75	4.84	4.13
113	675	75	5.78	4.77
113	938	75	3.79	3.44

Table 4-b Effect of P and N application in volcanic ash soil and its economical evaluation

Rate of N,P,K Application (kg/ha)			Expense for fertilizer (A)	Income (B)	(B)/(A)×100
N	P_2O_5	K_2O			
0	300	75	2,850 yen	18,800 yen	660
56	300	75	3,413	27,200	800
113	300	75	3,975	28,400	715
150	300	75	4,350	31,500	727
188	300	75	4,725	43,600	934
113	0	75	1,575	13,100	834
113	113	75	2,475	35,200	1,420
113	225	75	3,375	37,100	1,100
113	450	75	5,175	32,800	635
113	675	75	6,975	40,800	575
113	938	75	8,075	30,800	381

plant analyses.

The application of calcium silicate has an additional effects of strengthening disease and insect resistance as well as resistance to lodging.

The so-called 'red soil dressing' is one of the common measures of soil improvement to increase soil fertility, and the effects and residual-effects have been confirmed by some field experiments.[9] Fig 2. shows the residual effect of soil improvement. All of the treatments are effective for 3-4 years after treatment. Though the occurence of sulfur deficiency been feared, up to present no concrete evidence of sulphur deficiency has been found in Japan.

Nutrient deficiency in peaty and other special soils

On peaty soils, similar nutrient deficiencies as in degraded paddy field have been often found. Potassium deficiency is a major factor in peaty soils. There are many ex-

Table 5-a Improvement of reclaimed land and its economical evaluation

Methods of improvements	Yield (brown rice) (tons/ha)	(B) Expense for improvement	(A) Income	(A)−(B)	Increase of net income
No treatment	3.33	0 yen	44,600 yen	44,600 yen	0 yen
Application of calcium equivalent to readily oxidizable sulfur (5.7 tons/ha)	5.47	2,508	73,300	70,792	26,192
Application of calcium to adjust the soil pH 5.0 (25.90 tons/ha)	6.65	11,400	89,100	77,700	33,100

Brown rice 1 kg=134 yen, Calcium Carbonate 10 kg=44 yen

amples of the increase in yield with increased rate (40-50% increment) by the application of potash.

Manganese deficiency also occures frequently, but there are many analytical data showing that in spite of a very low content of manganese, ric plants does not show deficiency symptoms. Proper manganese nutrition in peaty soil has not yet been clarified.[11] There are also some reports on boron deficiency in some special soil. Copper deficiency has not yet been reported but recently a case of zinc deficiency was found.

Phosphorus deficiency in volcanic ash soil

About 64,656 ha of volcanic ash soil with a very high phosphorus absorption coefficient are distributed throughout Japan. Rice plants grown in such soil easily develop phosphorus deficiency. Retardation of growth, poor tillering, the delay in heading and poor ripening are typical symptoms. Because volcanic ash soil in Japan is mostly found in high plateaus and is characterized by high water permeability and cation retaining power, rice plants grown in such a soil are often also deficient in cations also.

In 1955, it was discovered that a most remarkable yield increase could be achived by applying a very large amount of phosphate to such paddy field. See Table 4.[2] Not only phosphate but the increase in nitrogen application has also been found to be effective. From various research findings on volcanic ash soil, the effect of phosphate application can be expected in a soil in which 1 % citric acid-soluble P_2O_5 is below in 15mg/100gr soil. To increase the yield of rice in such soil, very large amount of phosphate is required. For example 200 kg of P_2O_5 per ha. is required in the soil with a phosphorus absorption coefficent of 2,000 (as expressed mg P_2O_5/100g soil).

Nutritional disorders in Polder soils

Disorder due to soil acidity are often found polders, particularly in polder land reclaimed from lagoons. As the counter-measure two methods have been employed with good results, namely neutralization of acidity by lime and washing off the acidic matter. Table 5-a indicates some examples of improvement and residual effect of lime. The table shows the application of 5.7 tons/ha $CaCO_3$ increased the yield of brown rice and farmer can get the increased net income. Table 5-b shows the effect of leaching and residual effect of liming. From 1959 to 1961 liming is required to adjust the soil acidity every year, but after the application of 50 tons $CaCO_3$/ha mall, liming was not necessary.

Various improvement methods of poor paddy field stated above aimed to remove major

Table 5-b The change of soil pH and brown rice yield during 5 years after reclamation (* t/ha)

Treatments	1959 pH initial	1959 $CaCO_3$* applied	1959 pH after cultivation	1959 Brown rice yield*	1959 pH after harvest
1. No $CaCO_3$, no leaching	2.8	0	3.2	0	3.7
2. 〃 , leaching	2.8	0	3.1	0.45	4.0
3. $+CaCO_3$, no leaching	2.7	27.5	6.0	2.25	6.3
4. 〃 , leaching	2.3	27.5	6.0	3.36	6.4

1960				1961			
pH initial	$CaCO_3$ applied*	pH after lime application	Brow rice yield*	pH initial	$CaCO_3$ applied*	Total of Ca applied*	Brown rice yield*
2.6	0	2.8	0	3.0	0	0	0.15
2.6	0	2.8	0.93	3.0	0	0	3.86
3.7	10.7	6.2	5.31	6.2	12.04	50.24	3.71
3.2	19.31	6.2	6.16	5.2	9.43	56.27	5.40

1962				1963			
pH initial	$CaCO_3$ applied*	Total of Ca applied	Brown rice yield*	pH initial	$CaCO_3$ applied*	pH	Brown rice yield*
3.3	0	—	0.15	3.1	0	3.5	7.55
3.3	0	—	6.97	2.9	0	3.2	6.47
4.8	0	—	7.68	3.9	0	3.9	6.30
5.7	0	—	8.02	4.1	0	4.5	7.10

inhibiting factors. At the same time, the improvement of the fertility status of soil by balanced fertilizer application and by increasing available nutrients in soil was recommended.

In a defective soil, unless careful attention has been paid to the balance in fertilizer application, sometimes an unexpected yield decrease may be caused.

The writer wishes to present here two examples to elaborate these phases.

Wilting of paddy rice or "Aogare"

Recently in many place of southern warm regions of Japan, a physiological disorder called 'Aogare' which manifests itself in violent wilting during the ripening period of the rice plant, the so-called 'Aogare,' has been found. The cause of this disorder is assumed to be a disturbance in the carbohydrate and protein metabolism as a result of potassium deficiency and nitrogen excess. The carbohydrate content in lower part of the stem decreases, particularly all starch disappears about 20 days after heading and the lower parts of the stem becomes weak. It has been accepted that paddy rice in the nutritional status of this kind is likely to suffer from a violent wilting when subjected to such conditions as

Table 6. Effect of shading and drainage on Aogare disease

Treatments		Grade of Aogare	
		19th Sept.	27th Sept.
Control	+K	−	−
	−K	−	−
	−K, +N	+	+++
Shading in late stage of growth	+K	−	−
	−K	−	+
	−K, +N	++	++++
Drained in non-effective tillerimg stage	+K	−	−
	−K	−	±
	−K, +N	−	−

water-drainage, dry wind or low temperature. The survey of this phenomenon revealed that those districts closely coincide with the distribution of degraded paddy field. So, it has been considered as one kind of 'akiochi'-like disorder.

Because 'Aogare' breaks out widely in warm region, Suzuki concluded from his experimental data that the cause of this disease must be a soil disorder of high universality rather than the damage by any specific inju- rious substance generated in a special soil.

The soils in 'Aogare' endangered area are in most cases characterized by a shallow top soil layer, sand or gravel in subsoil, high permeability, and low content of bases.

These soil characters are almost identical to those of degraded paddy soil. Furthermore, the total nitrogen content and the mineralization of organic nitrogen by drying of 'Aogare' soil is rather higher than in a normal soil. The most severe cases of 'Aogare' disease are found in the soils remarkably deficient in potassium. The rice plant grown in such soil has a high nitrogen and low potassium content, a high N/K ratio, low protein and low starch contents.

Therefore, a high N/K ratio has been considered to be one of the causes of 'Aogare'. The outbreak of 'Aogare' is often found not only in the soil deficient in available potassium but in the soil improperly fertilized. The application of large amount of nitrogen and small amount of potassium often caused the 'Aogare' disease. Suzuki et al.[10] have found that the occurrence of 'Aogare' is more frequent under excess nitrogen and poor potassium condition at the non-effective tillering stage. Particularly, the excess in nitrogen and deficiency in potassium at about 40 days before heading have been suggested as a major cause of 'Aogare'. From these observations the following theories have been presented.

In a normal plant the changes of starch content in the straw during the growth period shows a maximum after heading, and declining gradually toward ripening. In the case of a normal plant generally the minimum value is observed at about 20—30 days after heading. The minimum value is 1/2-1/3 of maximum value.

But in rice plant which suffered from 'aogare' disease and which is showing poor growth of cell wall in the stem, the maximum value of starch content is not so high and at about 20 days after heading the starch content becomes completely zero. Even in the rice plant showing only slight symptoms of 'Aogare' the starch content is lower than that of a normal one.

Table 7-a Effects of phosphorus silica and cation balance on the yield of rice

(g/pot)

Plots		Yield	
Soil	Fertilizer Treatment	Straw	Ear
Morioka (Volcanic ash soil)	P_2O_5 1.0g	84.5	66.7
	3.0	112.5	98.6
	9.0	120.5	109.2
Himeji (Normal∼slightly degraded soil)	P_2O_5 1.0g	97.0	81.9
	3.0	94.5	87.2
	9.0	93.5	89.5
	3.0+Si+Mg	109.0	101.2
Kadera (Heavily degraded soil)	P_2O_5 1.0g	103.0	97.4
	3.0	86.0	87.9
	9.0	91.3	93.3
	3.0+Si+Mg+Ma	126.5	123.6

Remark : N=2.0g (basal), 1.0g (top-dressing) ; SiO_2=51g (basal), K_2O=3.0g (basal), Mn_2O_3=10mg/100gsoil, MgO=50mg/100g soil

Table 7-b Mineral contents of rice straw in different level of P, Si, Mg, and Mn application

Plots		Straw						
Soil	Fertilizer Treatments	N %	P_2O_5 %	K_2O %	SiO_2 %	CaO %	MgO mg%	Mn_2O_3 mg%
Morioka (Volcanic ash soil)	P_2O_5 1.0	0.92	0.054	1.92	7.03	0.58	157	145
	3.0	0.84	0.125	1.90	4.22	0.12	193	104
	9.0	0.84	0.241	1.74	4.36	0.54	184	111
Himeji (Normal∼slightly degraded soil)	P_2O_5 1.0	0.84	0.268	1.82	4.22	0.52	202	86
	3.0	0.80	0.280	1.76	4.35	0.60	201	80
	9.0	0.85	0.372	1.71	4.21	0.55	200	68
	3.0+Si+Mg	0.59	0.171	1.49	10.74	0.49	184	53
Kadera (Heavily degraded soil)	P_2O_5 1.0	0 81	0.275	2.24	3.50	0.56	217	49
	3.0	0.87	0.380	2.41	3.88	0.57	127	59
	9.0	0.98	0.878	2.22	4.11	0.50	218	31
	3.0+Si+Mg+Mn	0.56	0.197	1.69	9.15	0.41	188	79

Rice plants suffering from 'Aogare' are characterized by slender stems, thin and weak cell walls in the stem, low retaining power of weight, and waxy or light brown color of the stems.

In such a condition, the rice plant loses its ability to regulate the water metabolism, especially the balance of water absorption and transpiration and ultimately gives rise to the outbreak of 'Aogare' disease. Such a paddy rice easily wilts under a slight moisure stress in which a healthy rice plant will not wilt. High night temperature which accelarate the translocation of carbohyrates and mutual shading which inhibits the accumulation of carbohydrate in the stem, promote the outbreak of 'Aogare'. Table 6 shows in the -K+N treatments in control and shading plots, the 'Aogare' disease occure, and more severely in shading plot. Drainage was very effective to prevent this disease even in the -K+N treatment. The removal of ears which induces the accumulation of carbohydrate in the lower stem, drainage at non-effective tillering stage which lowers the N/K ratio, and the addition of N and K in low N/K ratio at 40 days before heading suppresses 'Aogare'. Top-dressing with potassium at 40 days before heading is very efficient. This fact is interesting in that even in a normal rice plants the efficiency of potash top-dressing at that growth stage is considerably high. Similar observations are also reported from Taiwan. As shown in the case of 'Aogare', an unbalanced application of fertilizers sometimes can induce a physiological disorder in a soil with low buffering capacity. Therefore, special attention should be directed towards a properly balanced application of nutrient elements.

As one example, the importance of cation, silica and phosphorus balance in a degraded paddy field shall be cited.

Phosphorus, silica, and cation balance

As previously stated, in the volcanic ash soil an increased application of phosphate can result in remarkable yield increas. However, when the same measure is applied on non-volcanic ash soil or degraded paddy field, the increase in yield is not attained as expected. On the contrary it can even be decreased. The reason of yield decrease with increasing rates of phosphate application has been clarified by pot experiments.[1] The three kinds of soil used in this experiment differ in their cation status. In the table 7-a the volcanic ash soil was rich in cations and humus, and the degrated paddy soil was poor in such components. In the case of the degraded paddy soil the increase in the rate of application of phosphate alone gave no increase of yield, but the application of phosphate together with bases and silica was found to be effective, the yield approaching to the same level as volcanic ash soil. The result is snown in Table 7. Such an example in degraded and volcanic ash soil indicates that it is proper to assume that the damage is caused by the unbalance between bases, silica, and phosphate due to base and silica deficiency, instead of assuming that the damage has emerged from phosphorus excess. A field experiment at an agricultural experiment station has showen that the decrease in rice yield due to increased phosphate applicaton could be recovered by application of magnesium.

In conclusion a well balanced application of nutrients to degraded soil and other defective soils has resulted in increased yield, and balanced use of nutrients is now encouraged throughout Japan. As a practical material in addition to N P and K fertilizers, calcium silicate, basic slags, fused magnesium phosphate, and comprehensive minor element materials are being used with good results.

Discussion

S. **Yoshida**, IRRI : Would you please discuss a little more about manganese deficiency in peaty soils and boron deficiency in some special soils? What evidence has been reported about these deficiencies? How much yield increase was obtained by application of either manganese or boron?

Answer : I would like to show the experimental data in Miyagi prefecture. In the experiment the application of manganese increased the yield of rice. The minus manganese plot gave 5.10 tons/ha brown rice, but the plot which received 22.5 kg/ha of manganese gave 5.50 tons/ha brown rice.

Boron deficiency rarely appears in paddy, but there is some experimental evidence on the effect of boron application in the field. In Ishikawa prefecture the effect of boron application in paddy field was proved. Furthermore, Dr. Yamazaki recognized that the application of boron was effective on the root development and ripening.

E. D. Reyes, Philippines : Is there no relationship in the incidence of "Aogare" and virus disease?

Answer : Virus diseases have not been found in "Aogare" rice plant. Dr. Suzuki examined the relationship between "Aogare" and virus diseases. He could not found any relations between them.

A. Fujiwara, Japan : Have you any idea about "Akagare" or Reclamation disease?

S. Yoshida, IRRI : Regarding "Akagare" type III, somebody mentioned to me that excess of iodine has been considered as the a major cause of Akagare type III. I like to know what progess is on this point?

Answer : Usually "Akagare" diseases are classified into three groups, namely "Akagare" type I, II, and III. Reclamation disease probably belongs to the "Akagare" type III. Recently Dr. Watanabe and Dr. Tensho claimed that the main cause of reclamation disease ("Akagare" type III) is the toxicity of excess iodine. They have shown the following evidences.

1. Iodine ($I^{-1}+I_3^{-1}$) content in the leachate from reclaimed paddy soil was about 1.0 ppm, and this concentration of iodine in solution induced the special symptoms that were very similar to "Akagare" type III.
2. The leachate that was treated by anion exchange resin did not induce the "Akagare"-like symptoms, but the addition of iodine reinduced the the "Akagare"-like symptom.
3. If we apply the iodine in normal paddy field, we can get the "Akagare"-like symptoms in rice plant.
4. On the tolerance to iodine toxicity there are great varietal differences in the rice plant.
5. 2.0 ppm iodine in available form in the soil is probably injurious to rice plant.

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