Studies on the Occurrence of "Tomehagare", a Newly Found Physiological Disease of Rice, and Its Preventive Measures*

II. Varietal difference in "Tomehagare" occurrence and the effect of fertilizer application on its prevention

Tadatoshi IWATA, Kinya MATSUURA and Tsuyoshi HASEGAWA

(Fukui Prefectural Agricultural Experiment Station, Fukui)

INTRODUCTION

Physiological diseases causing color change and withering of the leaves have been observed in Japan^{1,4,7)} and among South-East Asian countries^{2,5,6,9)}. As was described in the previous paper³⁾, "Tomehagare" appeared like "Akagare" diseases, but it was quite different in the symptoms that occurred on the flag leaves at the ripening stage and the Fe/Mn ratio of the leaves, being associated with the physiological disturbance which was estimated from the lower contents of nutrients. The varietal differences in susceptibility of the disease were also

reported by many authors in cases of "Akagare"^{1,4)} and "Bronzing"²⁾.

In order to select the varieties resistant to "Tomehagare" disease, associated with the improvement of fertilizer application methods, several field experiments were conducted from 1968 to 1970 at Ono City. The results will be described in this paper.

MATERIALS AND METHODS

Based on the results of the preliminary experiment, Honenwase was used as the most susceptible variety and Fujiminori as the most resistant one. Twelve varieties were examined under cultivation treatments

Table 1 Design of the field experiments

Year	Fertilizer treatment	Amount of nitrogen fertilizer (kg/10a)***			Date of top-dressing (starting)	Location	Date of transplanting	Variety**
		Basal	Additional	Top-dressing				
1968	1. Control	6	3 (May 28)	3 (3 times)	June 29	Shinzaike	May 7	Fukei-77, Kanto-80, Koshijiwase, Tohoku-108, Hokuriku-87
	2. Heavy	5	1 (/)	6 (6 times)	July 2	Gojoho	May 17	
	3. Deep	5	1 (/)	6 (1 time)	(June 20, 25)			
1969	1. Control	6	3 (May 29)	2	July 4	Gojoho	May 15	Seirei, Shurei, Chubu-3, Kanto-81, Hokuriku-77
	2. Heavy	5	1 (/)	2+2+1	July 6			
1970	1. Control	6	2 (May 28)	2	July 1	Gojoho	May 15	Shurei, Seirei, Todorokiwase, Toyonishiki
	2. IB	8	0	2	July 1			

Control: Top-dressing was given at about the flower differentiation stage. In 1968, it was done three times with the interval of seven days.

Heavy: Heavy topdressing was given at the end of spikelet differentiation stage and also three or six times repeatedly with the interval of 6 or 7 days.

Deep: Compound fertilizer (5-5-5) was applied in the soil layer of 10~15 cm depth at about the neck node differentiation stage.

** : Honenwase and Fujiminori were a control variety.

*** : Compound fertilizer Ine-13 (14-14-14) was applied for basal fertilizer, Ine-8 (12-4-12) for additional and topdressing.

* Received for publication on February 27, 1973.

as described in table 1.

The traditional fertilizer application method was compared with improved ones such as the heavy topdressing and the deep placement of additional fertilizer and the use of IB compound fertilizer.

Seeds were sown every year on April 10 and grown in the low land nursery bed covered with oil paper at Fukui Agricultural Experiment Station. Then the seedlings were planted to the experimental fields in Ono City.

"Tomehagare" symptom was graded into five classes according to the visible affected area of leaf blade. Through several periodical surveys, the most typical symptoms appeared generally around August 15–20, between the heading and maturing stage, the survey was focussed at this period.

RESULTS AND DISCUSSIONS

As shown in tables 2–4, all varieties grew normally and the grain yield exceeded the average yield by farmers around there. In 1968, some varieties grown at Shinzaike lodged at the maturing stage because of excess growth in the vegetative stage. No damage was observed as caused by other diseases and insect pests to the varieties with the single exception of

Fujiminori which headed so early that it was pecked slightly by sparrows.

1. Varietal differences in "Tomehagare" occurrence.

Based on the results in tables 2–5, the varieties were classified into three major groups according to the symptoms developed:

The most susceptible group—Honenwase, Todorokiwase and Shurei, which were affected at grades 3–4.5; the moderate group—Seirei, Chubu-3, Kanto-81 and Toyonishiki, the grade of which were 1–2 grades; the resistant group—Tohoku-108, Hokuriku-87, and Fukei-77, Fujiminori and Kanto-80, 0.5 grades (table 5).

"Tomehagare" seems to have occurred more seriously in the early ripening varieties. The varietal differences according to the heading date were listed in fig. 1. "Tomehagare" was not observed in Fujiminori, the earliest variety, but was fairly frequent in Hokuriku-77, the latest one among the varieties, suggesting no relation of the occurrence with heading date as far as these two varieties are concerned.

Taking a broader view of the whole varieties, however, "Tomehagare" seems to have some relations with the heading date, occurrence being most

Table 2 Effects of manuring methods for rice varieties on the occurrence of "Tomehagare" (1968)

Variety	Treatment	Date of heading	Date of maturity	Grade of * "Tomehagare"		Yield (hulled rice-kg/a)	
				Shinzaike	Gojoho	Shinzaike	Gojoho
Honenwase	1. Cont.	July 22	Aug. 29	3	4	56.8	58.7
	2. Heavy	〃	〃	1.5	1	58.5	57.2
	3. Deep	〃	〃	1	1.5	58.0	62.7
Fujiminori	1. Cont.	July 18	Aug. 29	0	0	66.4	49.8
	2. Heavy	〃	〃	0	0	69.3	44.0
	3. Deep	〃	〃	0	0	71.7	54.7
Koshijiwase	1. Cont.	July 29	Sept. 10	—	0.5	—	57.4
	2. Heavy	〃	〃	—	0	—	57.2
Kanto-80	1. Cont.	Aug. 1	Sept. 6	0	0	49.0	56.5
	2. Heavy	〃	〃	0	0	54.3	58.0
Tohoku-108	1. Cont.	July 25	Sept. 6	0.5	0	56.4	59.3
	2. Heavy	〃	〃	0	0	50.4	62.2
Hokuriku-87	1. Cont.	Aug. 1	Sept. 5	0.5	0.5	44.6	48.1
	2. Heavy	〃	〃	0	0	45.9	48.8
Fukei-77	1. Cont.	July 25	Sept. 1	0.5	—	62.8	—
	2. Heavy	〃	〃	0	—	67.8	—

* Grade shows the ratio of colored length to the whole leaf blade length, taking the wholly colored blade as 5.

Table 3 Varietal differences in nitrogen content of the leaf blade at ripening stage and the grade of “Tomehagare” (1969)

Variety	Treatment	Nitrogen content		Grade of “Tomehagare”	Yield
		July 29	Aug. 23		
Honenwase (susceptible)	Cont.	2.39%	1.04%	4.5	52.2 kg/a
	Heavy	2.54	1.11	2.0	50.1
The other varieties (moderate)	Cont.	2.07	0.87	2.1	51.6
	Heavy	2.25	0.88	0.6	51.9
Fujiminori (resistant)	Cont.	2.38	0.74	0.5	46.3
	Heavy	2.49	0.78	0.5	40.9

() showing susceptibility to “Tomehagare” occurrence.

severe in those that headed on July 26–30, although low grades in Toyonishiki and Hokuriku-87 might be due to the heading date which was too late to reveal the symptoms.

2. Preventive effect of fertilizer application methods against the occurrence of “Tomehagare”.

1) Effect of the methods of fertilizer application.

Plants receiving the heavy topdressing produced better yield in some varieties and almost the same in some varieties both in 1968 and 1969, except for considerable decrease in the panicle weight type varieties such as Fujiminori and Tohoku-108 (tables 2, 3).

The deep placement of additional fertilizer examined in 1968 increased the yield of Honenwase and Fujiminori as described in table 2.

Considerable decreases in the grade of “Tomehagare” symptoms were observed. For example, the control plots of Honenwase showed grade 3–4, while those of the heavy topdressing and the deep placement decreased to grade 1–1.5. Similar trends were seen on the other varieties such as Koshijiwase, Tohoku-108, Hokuriku-87, Fukei-77 and the moderate varieties. However, yield increases were not always realized through the preventive effect of these manuring treatments upon the occurrence of “Tomehagare” since there was not always close correlation observed between the two in tables 2–4.

The results of chemical analysis for nitrogen in the leaf blade were arranged in three groups in table 3, according to the resistance to “Tomehagare”. The nitrogen content of the heavy topdressed plots was higher than that of the control in all varieties.

Fig. 1 Relation between heading date and the occurrence of “Tomehagare”

Numbering of variety corresponds to the one used in table 5.

It is clear from table 3 that, except for the single case of Fujiminori which is the most resistant to “Tomehagare”, the increase in nitrogen content in the leaf due to heavy topdressing is always coupled with the decreased occurrence of the disease in all the susceptible and moderately susceptible varieties.

Taking these results altogether, manuring improvement to maintain a favorable level of nitrogen is fairly effective to control “Tomehagare” disease. This is quite a different situation from that of “Aka-gare”⁴⁾ and “Bronzing”^{2,5,6)} in which additional nitrogen application invariably hastens the occurrence of the disease.

2) Effect of the kinds of fertilizer.

It has been reported that heavy application of the fertilizer nitrogen is associated with a decrease in the manganese content of the plants¹⁰⁾. Ammonia, which is the major nitrogen form in the paddy soil, is noted to control the manganese uptake by plants in comparison with nitrate nitrogen which is the major form in the upland soils⁹⁾. There was no difference in the controlling effect between nitrogen

Table 4 Effects of IB compound fertilizer on the occurrence of "Tomehagare" and its varietal differences (1970)

Variety	Treatment	Date of Heading	Date of Maturity	Grade of "Tomehagare"	Yield (Hulled rice)	Yield in percent to Cont.
Honenwase	Cont.	July 28	Sept. 3	3	54.2 kg/a	100%
	IB	〃	〃	1.5	51.0	94
Todorokiwase	Cont.	〃	〃	3.5	62.6	100
	IB	〃	〃	2.5	60.6	97
Toyonishiki	Cont.	July 30	〃	1	60.5	100
	IB	〃	〃	0.5	62.9	104
Fujiminori	Cont.	July 23	〃	0	63.3	100
	IB	〃	〃	0	64.7	102
Shurei	Cont.	July 26	〃	1.5	61.3	100
	IB	〃	〃	1.5	63.6	104
Seirei	Cont.	July 28	〃	1.5	61.9	100
	IB	〃	〃	1	64.5	104

IB (10-10-10) compound fertilizer is a slow-acting one, containing iso-butyridene diurea as 80% of the total nitrogen.

forms of ammonium and urea in the authors' experiments simultaneously conducted in 1968.

As for the compound fertilizers which contain the slow-acting organic nitrogens, CDU did not succeed in preventing "Tomehagare", while IB compound fertilizer (containing iso-butyridene diurea as 80% of the total nitrogen) was found effective in "Tomehagare" control, although it seemed to cause yield decrease depending on the varieties. For instance, Honenwase had less yield, in spite of the remarkably decreased grade of "Tomehagare" as compared with the resistant varieties (table 4). Therefore, simple application of IB compound fertilizer as basal would be insufficient to increase the rice yield as well as to prevent the disease.

3) The nutrient content of the leaf blade as affected by the fertilizer application.

Content of nutrients in the leaf blades was analyzed in Honenwase and Fujiminori. These varieties were cultivated with three different fertilizer application methods at Kamigojoho in 1968 and sampled on

Table 5 Varietal differences in the grade of "Tomehagare" occurrence

No.	Variety	1968		1969	1970
		Shin-zaike	Gojoho	Gojoho	Gojoho
1.	Honenwase	3	4	4.5	3
2.	Fujiminori	0	0	0.5	0
3.	Koshijiwase	—	0.5	—	—
4.	Kanto-80	0	0	—	—
5.	Tohoku-108	0.5	0	—	—
6.	Hokuriku-87	0.5	0.5	—	—
7.	Fukei-77	0.5	—	—	—
8.	Shurei	—	—	3.5	1.5
9.	Seirei	—	—	1.5	1.5
10.	Chubu-3	—	—	1.5	—
11.	Kanto-81	—	—	2	—
12.	Hokuriku-77	—	—	2.5	—
13.	Todorokiwase	—	—	—	3.5
14.	Toyonishiki	—	—	—	1

Refer to tables 2 and 4.

August 12. The leaf blades were subjected to chemical analysis after they were classified by the "Tomehagare" grade.

The changes of nutrient content in the leaf blade

Table 6 Varietal differences in the nutrition of flag leaf blade (1969)

Variety	P ₂ O ₅	K ₂ O	CaO	MgO	Fe ₂ O ₃	MnO	SiO ₂	Fe/Mn
	%	%	%	%	ppm	ppm	%	
Honenwase	0.77	1.99	0.51	0.24	203	2686	7.42	0.069
Seirei	0.83	1.84	0.59	0.29	254	1691	8.83	0.136
Fujiminori	0.70	1.48	0.88	0.25	272	1937	6.88	0.127

Samples on maturity were collected from control plots on which fertilizer application experiments were conducted at Kamigojoho.

of the flag and second leaves are shown in fig. 2, which shows nearly the same tendency as in the previous report⁸⁾. All nutrient contents of Honenwase decreased according to the "Tomehagare" severity, which was observed with the manuring treatments. Manganese was the exception although it did not so increased as in the previous paper. Although the level of manganese might be enough to cause its toxicity under the malnutritional condition.

Compared with Fujiminori, nitrogen, iron and silica contents were lower in Honenwase, especially when symptom was severe, but definite difference were not seen among other nutrients such as potassium, magnesium, phosphorus and manganese. Potassium and magnesium seemed to have some influence on the occurrence of "Tomehagare" for its sharp decrease in the severity, however, there is no difference in the two varieties.

According to Kurosawa's report⁴⁾, Fujiminori was not resistant to "Akagare" type-3, and high iron content was found in the diseased leaf blade and field soil, while Hatsunishiki, a sister variety of Honenwase, had a strong resistance to this disease. Inada²⁾ and Ota⁵⁾ recognized the high positive correlation between the iron content and the grade of "Bronzing", concluding that the higher iron content in leaf blade was primarily related to the cause of this physiological disease. The varietal differences of resistance to root-rot mainly came from the resistance to iron in the soil¹⁾ it was found that Hatsunishiki had almost the same susceptibility as Honenwase in "Tomehagare" severity, 1973).

As far as Honenwase and Fujiminori are concerned, the resistant ability to "Tomehagare" seems closely related to the iron content in the leaf blade (fig. 2). Table 6 also informs that the nutrient content of Honenwase, the most susceptible one, is essentially high in manganese and low in iron, resulting in the lowest Fe/Mn ratio compared with other varieties. These facts together with the behavior of iron in the plant might explain the main reason why "Tomehagare" is quite different in its mode of occurrence from other nutritional disorders.

Fig. 2 Changes in the nutrient content affected by the manuring method (1968)

Grade shows the ratio of colored length to the whole leaf blade length, taking the wholly colored blade as 5 (20 days after heading).

SUMMARY

Results of the field experiments conducted on the affected areas with respect to the varieties and fertilizers applications are described as follows:

1. Differences in resistance to "Tomehagare" disease were seen among many varieties. Honenwase, an early and leading variety was found to be the most susceptible, while Fujiminori, early ripening as well, was resistant and promising.

2. The reason why "Tomehagare" was quite different in its mode of occurrence from "Akagare" and "Bronzing" might be explained mainly by the behavior of iron in the plant.

3. Fertilizer application methods such as heavy topdressing and deep placement of additional fertilizer were recommended as a remedy for "Tomehagare" because of favorable effect on nitrogen status of the plant maintained over the ripening period.

BIBLIOGRAPHY

1. BABA, I. 1958. Nutritional studies on the occurrence of *Helminthosporium* leaf spot and "Akiochi" of the rice plant. *Bull. Nat. Inst. Agr. Sci.* D-7: 1-157.
2. INADA, K. 1965. Studies on Bronzing disease of rice plant in Ceylon. 1. Effect of field treatments on Bronzing occurrence and changes in leaf respiration induced by disease. 2. Mode of the occurrence of Bronzing. *Proc. Crop. Sci. Soc.* 33: 309-314, 315-323.
3. IWATA, T., K. MATSUURA and T. HASEGAWA. 1973. Studies on the occurrence of "Tomehagare", a newly found physiological disease of rice, and its preventive measures. 1. Symptoms and conditions of occurrence of "Tomehagare" and nutritional status of the leaf blade in the diseased plants. *Proc. Crop. Sci. Soc.*, 42:
4. KUROSAWA, J. et al. 1965. Bulletin of the Iwate-Ken Agricultural Experiment Station, V-9: 1-79.
5. OTA, Y. 1968. Studies on the occurrence of the physiological disease of rice "Bronzing". *Bull. Nat. Inst. Agr. Sci.*, D-18: 31-104.
6. TAKIJIMA, Y. and S. D. I. E. GUNAWARDENA. 1969. Nutrient deficiency and physiological disease of lowland rice in Ceylon. 1. Relationship between nutritional status of soil and rice growth. 11. Phosphate fertilizer used for phosphorus deficiency of rice plant. 111. Effect of silicate fertilizers and dolomite for increasing rice yield. IV. Remedy for Bronzing disease of rice. *Soil Sci. Plant Nutr.* 15: 259-266, 267-273. 16: 11-16, 17-23.
7. TAJIMA, K. 1971. Studies on the nutrition of the rice plant with reference to the occurrence of so-called "Akagare" disease. *Bull. Nat. Inst. Agr. Sci.*, D-22: 71-144.
8. TANAKA, A. and S. A. NAVASERO. 1966. Manganese content of the rice plant under water culture conditions. *Soil Sci. Plant Nutr.* 12: 67-72.
9. —, and S. YOSHIDA. 1970. Nutritional disorder of the rice plant in Asia. The International Rice Research Institute, Philippines. *Bull.* 10: 1-51.
10. TERASHIMA, T. 1973. Studies on manganese excess paddy field. The special Bulletin of the Fukui Prefectural Agricultural Experiment Station, No. 5: 1-86.

〔和 文 摘 要〕

真名川流域における「水稻止葉枯れ症」の発生機作および防止対策について

第Ⅱ報 「止葉枯れ症」発生の品種間差と施肥法による防止効果

岩田忠寿・松浦欣哉・故長谷川 毅
(福井県農業試験場)

前報において水稻の止葉が、登熟期に赤褐色に枯れる症状の原因はマンガン過剰とその他の無機成分の欠乏、とくに Fe/Mn 比の低いことにともなう生理病と推定された。この傾向は従来 of 赤枯病と著しく異なることが明らかとなつたので、その品種間抵抗性と施肥法による防止対策を検討した。

1. この発生は早生のみ認められ、中晩生には発生は認められないが、早生の中でもとくに7月26～30日に出穂するものに多発の傾向が認められた。
2. 明らかな品種間差が認められ、現地の主要品種であるホウネンワセはもつとも抵抗力が弱く、フジミノリはもつとも強く、いずれの年次においてもほとんど発生を認めなかつた。
3. このような品種間差は、従来報告されている赤枯れ病とはまったく異なる傾向を示したが、その原因は体内の鉄含量に由来すると推定された。
4. 晩期追肥・深層追肥などの施肥法による防止効果はかなり高く、このことは登熟期に体内窒素含量が高く維持されているためで、緩効性肥料などの使用によつても、ほぼ同様な効果が得られた。このように窒素の効果が高いことも、この症状が赤枯れやブロンジングと異なる特徴である。