

Nutrient deficiency and physiological disease of lowland rice in Ceylon

III. Remedy for bronzing disease of rice

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More than 10 years ago bronzing disease of rice was stated to be prevailing over approximately 40,000 hectares of rice fields in the wet zone of Ceylon (11). Bronzing disease is one of the physiological diseases of rice fairly common to some Asian countries and resembles other kinds of physiological diseases such as Penyakit Merah in Malaya (4) and Akagare in Japan (1). Symptoms of bronzing are generally initiated with the development of a bluish-green colour in the leaves occasionally following wilting, followed by the appearance of minute rusty brown spots at the tips of the old leaves. As symptoms progress, the entire leaf assumes finally a 'bronzed' or scorched brown colour. The disease has been observed to develop on boggy rice fields where soils are acidic in reaction coarse in texture and mostly rain-fed and situated below the rubber forests (2, 6). Although severe occurrence of the disease ceased recently with the extension of resistant varieties, it is still of sufficient importance to merit investigations directed at finding a practical remedy for the disease.

MATERIALS AND METHODS

Pots and field experiments, and chemical analyses of straw samples were conducted as described in the previous paper (9) except for special treatments.

Air-drying treatment in the pot experiment was done by leaving the soil in pots to dry for two weeks being protected from rain. On the other hand, in the wet series, soils were kept submerged more than one

month before planting. In the field experiments conducted at Bombuwela, surface soil was ridged in many rows by deep ploughing and kept air-dried continuously and in a well-drained condition before cropping. In the wet series experimental plots were subjected to ordinary operations until planting. Lime (watered) was mixed with surface soil as thoroughly as possible at one week before planting. The amount of lime applied was calculated to raise the soil pH to 6.0. Fig. 1 shows one of the soil pH-lime curves.

Murungakayan 302, a local variety very susceptible to bronzing, was grown in Maha 1967-68 while in Yala 1968 the improved variety, H8, was used.

RESULTS AND DISCUSSIONS

Nutrient contents of bronzed plants

Already in 1952, Kandiah (3) anticipated that bronzing might occur owing to potassium deficiency prevailing in Minuwangoda area though he could not prove the actual effect of increased application of potassium fertilizer. Later many workers made efforts to find the main cause of bronzing disease. In spite of the prevalence of conflicting points of view on the possible causes, most results are similar to each other in reporting a nutritional disturbance produced by low nutrient supplying power and reduced status of the soil.

On comparing the nutrient composition of straw listed in Table I, bronzed plants are generally very high in nitrogen and iron, and very low in the other nutrients, especially potassium, magnesium and silica. These plants were sampled from Bombuwela and Pussellawa fields, typical bronzing susceptible areas in Ceylon. Both are boggy and undrained throughout the season. Soils are characterized by abundant ferrous iron and scanty nutrients for the plants which frequently showed symptoms of phosphorus deficiency being associated with bronzing appearance and assuming purplish leaf colour. In Minuwangoda area near Colombo yellowish bronzing was observed to dominate in the sampling survey (9). The plants were deficient in magnesium and silica but were not opposed to have low potassium and high iron contents as the cause of bronzing. Such being the situation, it may be difficult to select a single cause for the occurrence of this disease.

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Effect of N, P, K and slags on the growth and yield of rice

Pot experiments using bronzing susceptible soils were conducted to examine nutrient factors which will interact with growth inhibition. Significant difference in growth was obtained among treatments with N, P, and K. Results summarized in Table 2 give an indication that in Bombuwela soils response of the plants is stronger to potassium than to phosphorus and growth is disturbed most severely by the treatments with nitrogen only or nitrogen + phosphorus, particularly in the humic soil. However, no typical bronzing symptoms appeared in all treatments. Instead, small brown spots of necrosis, probably symptoms of potassium deficiency, developed on the leaves of stunted plants. This observation was justified by the element content in straw given in Table 3. Single application seems to cause iron intrusion to the plant. Slags are more or less effective to increase calcium and silica content in straw though they were less effective on the increase of panicle yield than nitrogen and phosphorus.

Experiments were continued with same designs in the next season and presented more definite results. Without potassium applied, the plants showed severe potassium deficiency, bearing extremely big spots of necrosis.

Effect of air-drying and liming the soil

Soils used in the above experiments had been once air-dried before submergence. Air-drying was thought to be a possible reason in preventing occurrence of bronzing, by alleviating production of ferrous iron which might be involved in this process. Experiments were thus undertaken to determine the effect of air-drying and liming the soil on the growth and yield of rice Bombuwela sandy soil was sampled from a farmer's field and taken to the plant cage in C. A. R. I. with the least delay to prevent drying on the way. The sample soil was then subjected to treatments of wetting and air-drying, and to the other treatments as described already. Data obtained are excerpted in Table 4. Typical bronzing disease appeared on the plants receiving N, P, and K in the wet series with a descending degree of symptom expression by the application of potassium, slag and lime, while in the air-dry series symptoms were alleviated remarkably except for the treatment with N. P. K. only. Almost all symptoms occurred on plants treated with slag or lime.

A high dose of phosphorus seemed effective in the prevention of symptoms only in the dry series. Plants in this series grew much taller and produced more tillers resulting in higher grain yields than in the wet series. Moreover in the dry series, effect of slag and lime

addition was recognized but in the wet series no significant difference was obtained among treatments except for high potassium addition. Leaf colour in the dry series remained more green throughout the growth stage suggesting higher effect of nitrogen to the plants besides possibly alleviated iron toxicity (2, 4, 7, 10). Soil pH determined after crop was in general higher in the dry series increasing with usage of soil amendments (Table 5).

Field experiments to ascertain effects of similar treatments were conducted in Bombuwela Station and farmer's field. Because of the difficulty in drainage operation, air-drying of the surface soil seemed to be not enough to realize good effects as expected from the results of pot experiments. Moreover in the Experiment Station, field used for the dry series was not uniform and less fertile comparing field for the wet series. Nevertheless, bronzing symptoms observed in the course of growth were different between two series indicating almost complete prevention by liming and slight effect by slag application as is given in Table 6. Same situations were noticed also in the farmer's field experiment.

Yield data are excerpted in Table 7. In the Station field where acre yield is usually less than 40 bushels, good growth and yields resulted on the whole. Lime and potassium were quite effective in increasing grain yield especially in the wet series of the Station field while in the farmer's field slag addition appeared to promote yield increase. Taking account of the average grain yield of 20 bushels paddy in this area, growth status in all plots were so vigorous to be attractive to the farmers. If the drainage system was complete higher yields could be expected through the means of drying the soil.

Mechanism of the occurrence of bronzing disease

Disorder in the physiological activities in the bronzed leaves has been studied in detail by Inada (2) and Ota (6) who worked in Ceylon as Colombo-Plan experts following Yamada's research on the bronzing problem (11). With respect to the main cause of bronzing, iron toxicity theory was first presented by Ponnampereuma (7) who initiated the practical measure of liming as remedy for the disease (8). Aluminium toxicity theory by Ota (6) succeeded, assuming the low calcium medium as an associated condition. Recently, iron toxicity was supplemented with a condition of low potassium medium (5), and with an initial root damage by hydrogen sulphide (10).

In Ceylon, low supply of potassium by the soil evidently dominates in the bronzing-susceptible fields followed by low supply of phosphorus and magnesium. Single application of nitrogen fertilizer

(sulphate form) and low available silica in the soil are not excluded as the nutritional causes. Moreover, frequent observations that bronzing disease is apt to occur in the boggy and reduced field condition on spots adjacent to rubber plantings, where abnormal meteorological conditions such as temperature and solar radiation may be somewhat unfavourable for plant growth. Although these secondary causes need further investigation, primarily the disease depends on the field conditions. Fig. 2 illustrates the mechanism of occurrence as supposed from the the research and observation results.

Draining the field should be accompanied by liming the soil as an important remedy for bronzing. This measure is of general concern for improving soil conditions and increasing rice production in Ceylon together with the enhanced use of fertilizers and other soil amendments.

Details of results reported, are available in the reports of Colombo-Plan on the same title presented to Ceylon Government 1968 and Japanese Government (OTCA) 1969.

SUMMARY

Pot and field experiments using bronzing-susceptible soils were conducted from 1967-1968 to find remedies for the disease, based on the results of sampling survey.

1. Application of potassium fertilizer was most effective to increase the growth and yield of rice, followed by phosphate fertilizer and slag. However, even the balanced dose of NPK fertilizers did not eliminate bronzing symptoms.

2. Air-drying and liming the surface soil before planting increased rice production and prevented bronzing. Both measures are recommended as remedies to be used in association with an increased doses of potassium fertilizer and slag.

3. A mechanism for bronzing occurrence was postulated including some meteorological factors as secondary causes.

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Table 1.—Comparison of element content in straw between normal and bronzed rice plants sampled at heading or milk-ripe stage

A.—Mean element content :

Authors	Varieties	Growth status	N %	P ₂ O ₅ %	K ₂ O %	CaO %	MgO %	Fe ₂ O ₃ ppm	SiO ₂ %
1. Ota	Mur. 302.	Normal	1.20	0.44	1.74	0.43	0.08	2620	7.80
(6)	H-4	Bronzed	1.73	0.57	0.84	0.22	0.03	3600	4.00
2. Mulleriyawa(5)*		Bronzed	1.11	0.19	0.68	0.15	0.09	680	7.45
3. Takijima	H-4, H-6.	Normal	1.13	0.41	2.02	0.58	0.20	1290	9.90
(9)	H-8	Bronzed	1.62	0.30	0.95	0.66	0.11	2330	6.60

B. Ratio of Bronzed to normal (%)

1	144	129	48	51	28	138	5
2	98	46	34	26	45	53	70
3	143	73	47	114	55	181	66

* Because of the absence of normal samples, those of (3) were used for calculating ratios. MnO content of bronzed plants was 406 ppm.

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TABLE 2.— Effects of N. P. K. fertilizers and slag on the growth and yield of rice

(POT EXPERIMENTS, MAHA 1967-68, M-302)

Soils used	Treatments*	Plant height (cm)	Maximum tiller Number	Panicke number	Yield (per pot)		
					Straw	Panicke	Total
I. BOMBUC- WELA sandy	1. N only	96.8	20.5	22.5	43.0	18.5	61.5
	2. NP only	86.8	29.0	27.0	39.4	39.9	89.3
	3. NPK	89.8	33.5	33.0	56.0	57.0	113.0
	4. NP2K	92.8	35.0	34.0	62.2	67.8	130.0
	5. NPK + Ca-s	98.2	28.5	28.5	48.5	57.8	106.3
	6. NP2K+Ca-s	112.8	26.0	25.0	58.9	68.6	127.5
	7. NPK+Ca-s +Mn-s	100.2	26.5	24.0	53.8	58.9	112.7
	8. NP2K+Ca-s + ..	110.6	25.0	28.5	58.6	82.7	143.5
II. BOMBUC- WELA humic (Clayey)	1. N only	86.2	23.5	22.0	36.3	29.1	65.4
	2. NP only	80.8	32.0	31.0	38.5	36.1	74.6
	3. NPK	96.4	39.5	34.5	76.7	71.8	148.5
	4. NP2K	99.5	40.5	40.0	90.5	81.5	172.0
	5. NPK+Mn-s	101.4	41.0	39.5	83.4	86.8	170.2
	6. NPK**	91.3	42.0	39.5	75.4	81.4	156.8
	7. NPK** + Mn-s	92.7	41.0	38.5	82.9	82.6	165.5

Remarks: Standard fertilizers were added as follows: (g/pot)
 N (ammonium sulphate)—1.5 g
 P₂O₅ (conc. super phosphate)—1.0 g
 K₂O (potassium chloride)—1.0 g
 Slags—10 g

*Ca-s—Ca. Mg slag; Mn-s—Mn slag (minor-element fertilizer).

**Mixture of conc. superphosphate and fused magnesium phosphate in equal amount was applied for P.

TABLE 3.—Element content in the straw of rice plants grown in Bembuwela humic soil

(MAHA 1967-68—MURUNGAKAYAN 302)

Treatments	N %	P ₂ O ₅ %	K ₂ O %	CaO %	MgO %	Fe ₂ O ₄ ppm	SiO ₂ %
1. N only	1.02..	0.17..	0.25..	0.84..	0.31..	1,610..	2.27
2. NP only	1.78..	0.34..	0.20..	1.16..	0.18..	1,290..	2.55
3. NPK ..	1.09..	0.17..	0.57..	0.78..	0.38..	1,040..	2.08
4. NP2K..	0.97..	0.16..	1.09..	0.82..	0.38..	1,040..	2.08
5. NPK + Mn slag	0.90..	0.12..	0.66..	1.00..	0.35..	1,290..	2.95
6. NP* K..	0.96..	0.22..	0.48..	0.71..	0.38..	1,040..	1.99
7. **K + Mn slag	1.07..	0.17..	0.51..	0.69..	0.36..	1,290..	2.65

Values are expressed on air-dry weight basis.
 Refer to Table 2.

TABLE 4. Effect of air-drying and liming the soil on the growth and yield of rice, and its degree of bronzing as cultured in the Bombuwela sandy soil

(POT EXPERIMENT, YALA 1968, H-8)

Treatments	Effective tillers %	Longest panicle length (cm)	Straw	Yield (gm)			(per pot) Grain/ straw ratio %
				Panicle	Grain	Chaff	
A—Series (Wet group)							
1. NPK ****	63	24.5	48.7	34.4	27.7	2.8	57
2. N2PK ****	63	25.5	47.5	34.1	27.7	3.6	58
3. NP2K **	68	26.6	49.1	35.9	29.7	3.1	61
4. NP2K + Slag*	71	24.4	50.7	34.1	27.9	2.7	55
5. Limed, NPK*	72	25.1	44.9	30.7	24.5	3.1	55
6. Limed, NP2K	67	25.8	44.6	34.4	28.1	3.5	64
7. Limed, NP2K - Slag*	66	24.9	48.8	33.5	27.0	3.5	55
B—Series (Dry group)							
1. NPK***	71	25.2	73.1	42.4	33.3	5.2	46
2. N2PK*	78	25.6	74.9	43.1	33.7	4.8	51
3. NP2K**	77	24.6	75.1	43.9	33.7	6.0	45
4. NP2K + Slag	78	26.3	74.9	49.4	38.9	5.8	52
5. Limed, NPK	87	26.5	69.5	47.3	38.7	4.5	56
6. Limed, NP2K	81	26.6	65.5	47.4	38.4	5.0	59
7. Limed, NP2K - Slag	90	26.0	76.6	53.4	42.1	6.7	55

Remarks.—Soil was sampled from the farmer's field where bronzing occurred every season. Degree of bronzing was recorded at maximum tiller number stage, 5 weeks after transplanting. Marks * to ****, indicate portion of the bronzed leaves to the total leaves in one plant.

TABLE 5.—pH of Bombuwela farmer's field soil after a crop

(POT EXPERIMENT, YALA 1968)

Treatment No.	Wet series	Air-dry series
1	4.88	5.02
2	5.15	5.18
3	5.10	5.32
4	5.20	5.42
5	6.10	6.15
6	6.16	6.13
7	6.20	6.20

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TABLE 6. Growth status of rice plants at milk-ripe stage under varying the treatments for bronzing remedy

BOMBUWELA SANDY SOIL, YALA 1968, H-8

Series	Treatments	Bronzing symptoms	Other diseases**			Plant height (cm)	Tiller* number
			Hl	Bl	Sh		
Wet	1. NPK	Severe	-	-	-	143	35
	2. NP2K	severe	-	-	+	151	35
	3. NPK + slag	weak	-	+	+	143	38
	4. NP2K + slag	moderate	-	-	+	141	38
	5. Limed, NPK		-	-	-	157	32
	6. Limed, NP2K		+	-	+	144	42
	7. Limed, NPK - slag		+	-	+	143	44
	8. Limed, NP2K - slag		+	-	+	154	42
Air-dry	1. NPK	weak	-	-	-	121	30
	2. NP2K		-	-	+	134	34
	3. NPK + slag	moderate	-	+	+	139	44
	4. NP2K - slag		-	+	-	137	34
	5. Limed, NPK		-	+	+	137	41
	6. Limed, NP2K		-	+	+	140	34
	7. Limed, NPK - slag		-	-	-	145	30
	8. Limed, NP2K - slag		-	-	+	152	38

Remarks : * Per 5 hills.

** Hl—Helminthosporium spot : Bl—leaf blast :

Sh—sheath blight. - - - many : - - - some : + few.

TABLE 7.--Grain yields obtained with various treatments for bronzing remedy in the field experiments at Bombuwela—Yala 1968, H²8

Series	Treatments	Experiment Station		Farmer's field	
		bu./ac	Percent of control	bu./ac	Percent of control
Wet	1. NPK	32.5	100	—	—
	2. NP2K	58.1	179	4.73	100
	3. NPK + slag	38.4	118	—	—
	4. NP2K + slag	58.5	180	53.0	112
	5. Limed. NPK	67.1	206	46.5	98
	6. Limed. NP2K	81.1	250	66.9	141
	7. Limed. NPK + slag	63.6	196	—	—
	8. Limed. NP2K + slag	81.6	251	69.3	147
Air-dry	1. NPK	43.9	100	—	—
	2. NP2K	51.8	118	47.2	100
	3. NPK + slag	47.9	109	—	—
	4. NP2K + slag	49.3	112	61.0	129
	5. Limed. NPK	64.7	147	45.3	99
	6. Limed. NP2K	54.7	125	56.1	116
	7. Limed. NPK + slag	58.7	134	—	—
	8. Limed. NP2K + slag	54.0	123	69.1	146

Remarks : Standard fertilizers and soil amendments were applied as follows : (lbs./acre)

Lime—8,000 for Experiment Station ; 10,000 for farmer's field.

Ca, Mg slag—2,000

N (Urea)—60 (split applied, 20 + 30 + 10).

P₂O₅ (fused Mg phosphate)—80 (basal).

K₂O (potassium chloride)—80 (split applied. 60 -- 20).

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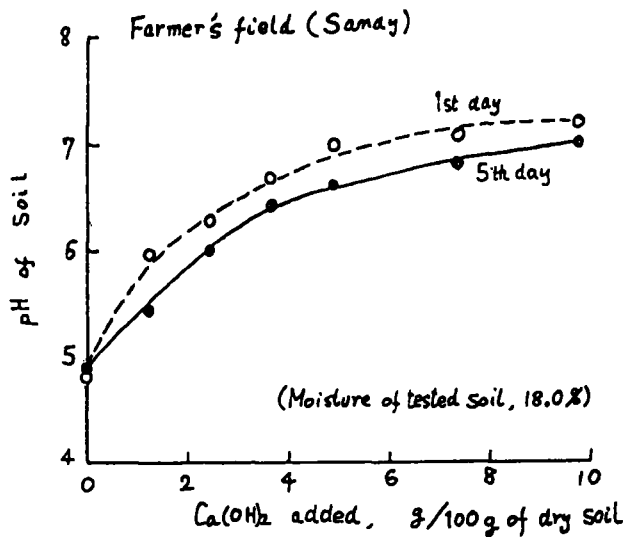


Fig. 1. $\text{Ca}(\text{OH})_2$ added and increase in pH of soil taken from Bombuwela farmer's field.

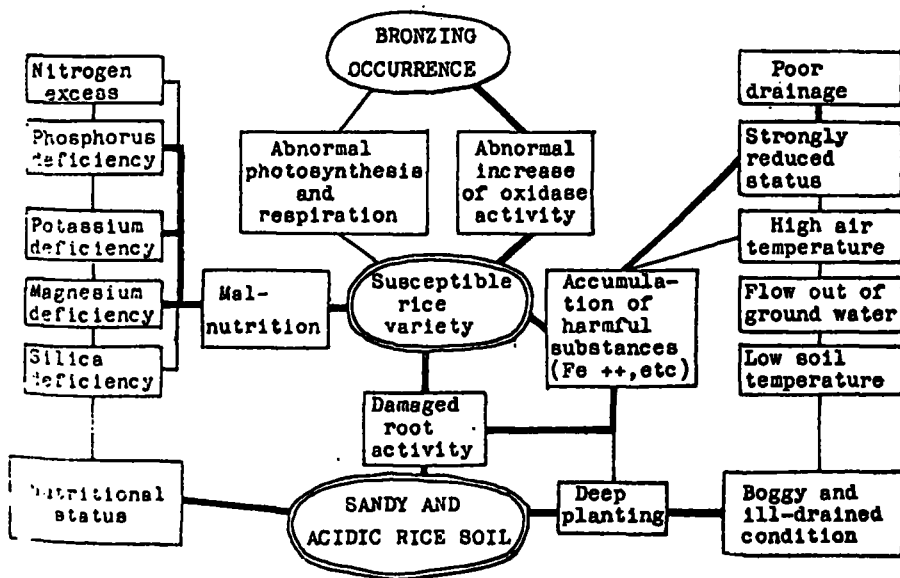


Fig. 2. Schematic diagram on the mechanism of occurrence of Bronzing disease.