Mode of the Occurrence of Bronzing in Rice Plant

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Several kinds of physiological disease of rice plants widely occur in the Southeast Asian countries. In Ceylon, so-called "bronzing" occurs in the ill-drained paddy fields of the low nd wet zones. The extent of the area affected by this disease is estimated to be about 40,000 hectares, and in severe cases the yield of rice is markedly decreased.

Symptoms of bronzing

At first, many small spots appear at the tips of older leaves, which later spread downwards to the basal parts of the leaves and finally, the leaf surface turns brown, leaving the midrib region green. As the symptoms advance, brown discoloration appears even on the uppermost expanded leaves; particularly after the middle stage of growth, diseased plants are easily recognized from a distance. Though in severe cases, plant growth is markedly retarded, growth of shoots is not seriously affected but the grain yield becomes low owing to a high proportion of sterile spikelets (Fig. 1). The root formation and development are markedly retarded. The root system becomes scanty, coarse and dark brown, and is damaged (Ponnamperuma, 1958; Ota and Yamada, 1962).

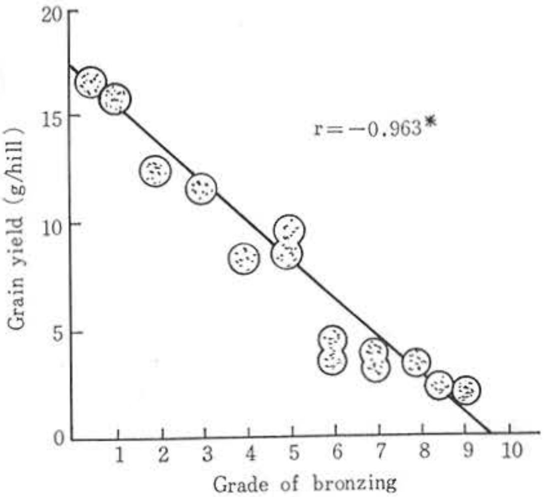


Fig. 1. Relation between bronzing severity and grain yield. (Ota and Yamada 1962)
*Significant at 1% level.

Properties and location of soil producing bronzing

According to Ponnamperuma (1958), the following four soil conditions are favorable in causing this disease: (1) a low pH value of dried soils; (2) a high content of iron oxide; (3) poor drainage; and (4) contiguity with the ferruginous lateritic highland. Ponnamperuma et al. (1955) also suggested that the disease is associated with excess iron in the soil solution.

The IRRI (1966) reported that bronzing occurs on sandy soils derived from acidic rocks. The soils contain a large amount of quartz sand and have rather low pH value, low cation exchange capacity, low amount of exchangeable cations, and low phosphorus-absorbing power. The soils do not contain excessive amounts of active iron, aluminum, or reducible manganese (Table 1).

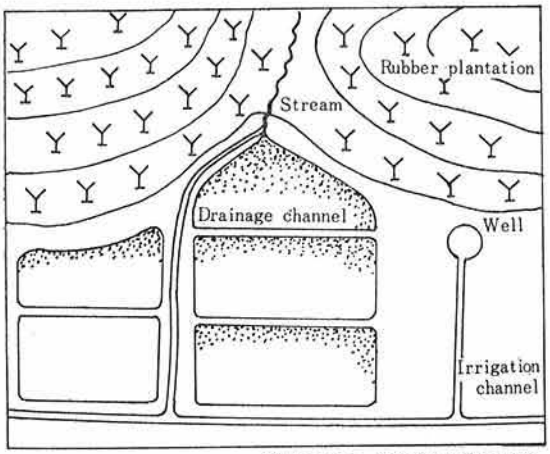
Ota and Yamada (1962) observed on an area where bronzing occurs that though the boggy soil had higher iron content and lower pH value than the sandy soil, plants exhibited no bronzing on the former soil, while on the latter soil bronzing was severe. Furthermore, even the application of much iron to the soil did not

Table 1. Some chemical characters of soils producing bronzing (IRRI. 1966)

Soils	pH	C (%)	CEC (me/100)	Exchangeable cations (me/100 g) K	Na	Ca	Mg	Phosphorus absorbing power (mg/100 g)	KCl ex-tractable Al	Active Fe (%)	Re-ducible Mn (ppm)
Pussellawa	5.18	4.0	9.5	0.17	0.26	2.0	1.2	802	7.2	0.508	8.0
Bombuwela	5.15	2.3	3.6	0.15	0.17	2.0	1.2	229	7.0	0.159	0.8
Karapincha	5.15	2.9	5.2	0.15	0.17	1.5	1.2	344	8.7	0.280	23.0
Malacca laterite	4.80	5.3	8.1	0.31	0.30	2.0	1.2	847	34.0	0.574	4.0

induce bronzing, and they suggested that the free iron content in soil itself was not associated with bronzing. Inada (1965) also observed the same phenomenon.

The author (1968) observed that the location of the area where severe bronzing occurs in every season was adjacent to the ferruginous lateritic highlands of tea or rubber estates. Such paddy fields were usually irrigated by streams originating from highland wells, or by the drained water from these highlands. The fields were also ill-drained and often welled out ground water of low pH. The soil is acidic sandy with low cation exchange capacity and deficient in phosphorus, potassium, and calcium. A representative geographical location on which bronzing occurs is shown in Fig. 2.



Bombuwela, Kalutara District.

Fig. 2. Topographical map of bronzing occurring field.
Bronzing severity is expressed as dotting. (Ota 1968)

Physiological aspects of bronzing

(1) Nutritional components in plants and occurrence of bronzing.

According to Ota and Yamada (1962), as compared with healthy plants, contents of manganese, potassium, magnesium, calcium and silica of the diseased plants were very low, and the iron content of the diseased plants was also rather lower than that of the healthy ones. On the contrary, the diseased plant showed a higher content of nitrogen and phosphorus. Inada (1965) and the IRRI (1966) also obtained similar results.

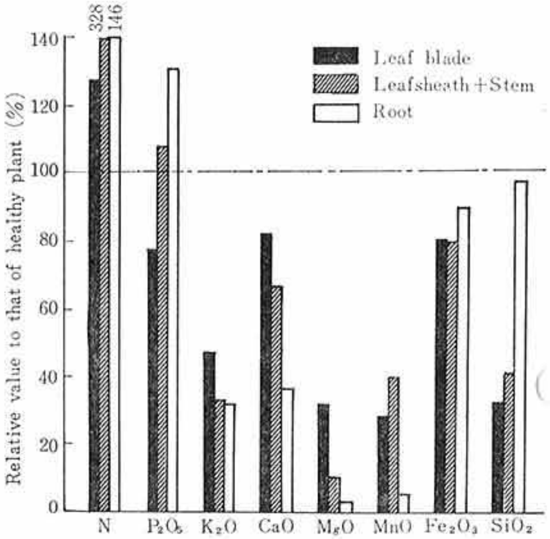


Fig. 3. Comparison of chemical components between healthy and diseased plant at heading stage. (Ota and Yamada 1962)

Fig. 3 gives the ratios of content of these elements in various parts of the diseased plants to those of the healthy ones. The ratio in nitrogen, phosphorus, iron and silica tends to decrease from root to leaf blade, indicating that the translocation of these elements was restricted in the diseased plants. On the other hand,

Table 2. Correlation coefficients between bronzing severity and various nutrients in plant (Ota and Yamada 1962).

Chemical component	CaO	K_2O	SiO_2	MgO	N	MnO	P_2O_3	Fe_3O_3	Al_3O_3
Content of nutrients in leaf blade	* −0.957	* −0.693	* −0.676	+0.246	+0.428	+0.464	* +0.678	* +0.679	
Content of nutrient in root									* +0.708
Total amount of nutrients in plant	* −0.880	* −0.923	* −0.839	* −0.733	* −0.695	+0.269	* −0.834	+0.385	

* Significant at 1% level.

magnesium, calcium, potassium and manganese tend to increase from root to leaf blade, suggesting that the translocation was not affected. However, the content of these elements was very low in the diseased plants.

The content of calcium, potassium, and silica of the affected plants had a very clear negative correlation with the grade of bronzing; lower the content of these elements, the severer the bronzing. On the contrary, the content of aluminum, iron, phosphorus and nitrogen of the affected plants showed a fairly close positive correlation with the grade of bronzing, the content being higher at higher grade of bronzing (Table 2).

Protein synthesis was inhibited in the diseased plants, the ratio of soluble nitrogen to total nitrogen being higher. Moreover, content of sugar and starch in the leaf sheaths and culms was low, while much sugar was accumulated in the leaf blades, indicating that the translocation of sugar was inhibited.

(2) Effect of bronzing on respiration and photosynthesis

Compared to healthy plants, respiratory rate of leaves of bronzed plants was considerably higher than that of healthy ones. This stimulation of respiratory rate was noticed even in the uppermost expanded leaves which appeared healthy. Furthermore, cytochrome oxidase activity declined markedly and peroxidase activity increased. Increase of respiration by 2,4-dinitrophenol was smaller in the leaves of bronzed plants than in healthy leaves, and the inhibiting rate of respiration by azide decreased in the former (Inada, 1965; Ota and Yamada, 1962). Photosynthetic rate of diseased leaves was decreased to about 3/4 of normal leaves in spite of the increased respiration (Table 3).

Table 3. Comparison of photosynthetic activity and respiratory rate of leaves between healthy and diseased plants (Ota 1968).

Measurement	Healthy leaves	Diseased leaves
Photosynthetic activitiy	11.95	8.97
Respiratory rate	2.21	3.35
P_O/R	5.40	2.08

Photosynthetic activity was measured with excised leaves in the laboratory at 28°C, under saturating light intensity and normal atmospheric CO_2 concentration, and expressed as mg CO_2 100 cm² leaf area per hour. Respiratory rate was measured at 28°C, expressed as mg CO_2 per 100 cm² leaf area per hour.

On the other hand, the respiratory rate of roots of diseased plant was decreased to about 1/4 of the healthy ones (India, 1968). From these facts, it is thought that the increase of respiration in diseased leaves is mainly due to the increase of the so-called "useless respiration" which does not couple with ATP. Further, it is considered that such abnormal metabolism results in decrease in the activity of roots and causes the brown discoloration by changing biochemical reactions in the leaves.

The relationship between the notable increase in peroxidase activity in the respiratory pathway and mechanism of brown discoloration of leaves appears to be similar with the case of "Akagare", a kind of physiological disease in Japan (Baba et al., 1958).

Mode of occurrence of bronzing

Inada (1965) inferred the mechanism of the occurrence of bronzing as follows: By the production of excessive ferrous ion and of hydrogen sulphide in the soil, the physiological activity of the roots is impaired and the intrusion of ferrous ion into the roots is facilitated. Furthermore, manganese deficiency in the soil promotes the absorption of ferrous ion and its translocation to the stems and leaves. In addition, potassium deficiency owing to the inhibition in the absorbing ability of the roots will decrease the oxidizing activity of roots, resulting in the increase of intrusion of ferrous ion and hydrogen sulphide from roots to shoots. The inhibition of nutrient absorption, especially of potassium and silica, causes metabolic disturbance which leads to the occurrence of bronzing.

The author (1968) observed that the occurrence of bronzing was closely related to rainfall; the disease appeared soon after a heavy rainfall, though it disappeared during a long spell of continuous rainfall, and that the bronzing was seen in the field overflowed with ferruginous lateritic soil which flew in from the adjacent highland by heavy rain. Furthermore, it was recognized that the bronzing was experimentally induced by application of ferruginous lateritic soil, and that the occurrence of bronzing was closely related to the aluminum content in the ferruginous lateritic soil.

In diseased plants a great quantity of alminum was detected in roots, and the amount of aluminum in root showed a clear positive correlation to the grade of bronzing. The roots of the diseased plant became coarse, and scanty, and turned dark brown. This symptom is quite similar to the aluminum toxicity described in other crops. Content of calcium in diseased plants was low and had a high negative correlation to the grade of bronzing. It is already known that aluminum causes a specific inhibition of calcium absorption by the rice plant. The inhibition in absorption and translocation of phosphorus owing to the fixation of phosphorus by aluminum was observed. In a solution culture experiment, bronzing was induced artificially by treating plants with aluminum under the conditions of calcium deficiency.

Based on the above facts, it is concluded that active aluminum in combination with calcium deficiency in the soil is responsible for the cause of bronzing. Fig. 4 shows the mechanism of occurrence of bronzing diagramatically.

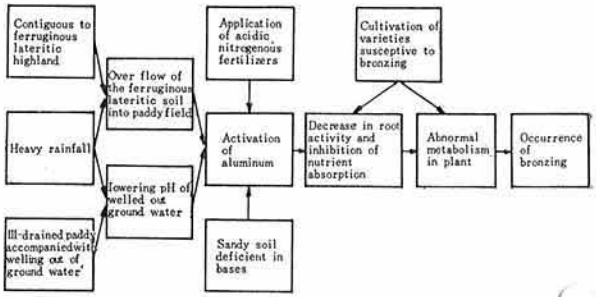


Fig. 4. Diagram on the process of occurrence of bronzing. (Ota 1968)

Preventive measures

Ponnamperuma et al. (1955) observed that the application of sodium nitrate which retards the reduction process in the soil definitely alleviated bronzing. A similar effect was also obtained with the heavy application of lime (Ponnamperuma, 1958). Inada (1965) observed that the application of compost was effective. The author (1968) observed that excellent effect of compost and lime on preventing bronzing was obtained and it was deemed to be due to the inactivation of aluminum. The substitution of urea for sulphate fertilizer (especially for ammonium sulphate) and the application of potash and phosphate were also effective. As there are many varieties resistant to bronzing in Ceylon, adoption of these varieties, either local or improved ones, is also necessary to prevent this disease.

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