Akagare Disease of Rice Plant

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Akagare disease which literally means red wilting is a kind of physiological injury of the rice plant. It is also known as Stifle disease. When rice plants are affected by this disease, reddish brown spots appear on the lower leaves. *Akagare* simply but clearly characterizes the symptom of the affected plant.

Since more than fifty years ago, the occurrence of this disease was extensively observed in ill-drained paddy fields, and attributed to an unusual anaerobic soil condition due to impeded drainage[1].

However, recent investigation showed that a physiological injury of the rice plant showing *Akagare*-like symptom on the affected leaves often appeared on the occasion of bringing upland soils under paddy rice cultivation[5].

This injury was also taken as a kind of *Akagare* disease although the primary cause of the injury seemed somewhat dissimilar to that of the previously known *Akagare* disease.

It seems to be reasonable, however, to designate the newly found injury as *Akagare* disease because the *Akagare* designation is generally based on its brown-spot symptom appearing on the affected plant leaves.

Now *Akagare* disease can be classified, according to the differences in the fine symptoms and causes, into three major types: Types I, II and III[2),3)].

Symptoms of affected plant

Type I This type is observed in the ill-drained sandy paddy field soils or in the ill-drained muck (a soil dark in color and abundant in organic matter) or boggy (a swampy or poorly drained soil abundant in plant residue) lowland paddy field soils.

Generally, the leaves first turn dark green and then small reddish brown spots appear in the tips of older leaves. The spots spread over the leaves and the leaves die, starting from the tips. The roots turn light brown (in sandy soil) or dark reddish brown (in muck or boggy soil). In many cases, blackened and rotten roots are observed.

Type II This type occurs mostly in ill-drained muck or boggy lowland soils. First, the midribs of the leaves turn yellow, then reddish brown spots appear around the discolored part until the whole leaf becomes reddish brown. In acute cases, reddish brown spots often appear without the previous yellow discoloration. The roots of the affected plant are reddish brown or dark brown, often mingled with black or rotten roots.

Type III This type occurs in reddish heavy clay loams, volcanic-ash soils, or humic volcanic-ash soils newly converted from upland soils to lowland rice soils. All of these soils are extremely deficient in phosphorus and are often acidic. The disease is most severe in the first year of the conversion to paddy field and becomes less as the years go by.

The above-mentioned decline of disease occurrence is largely dependent on the field drainage. In well-drained field the disease occurrence disappears after few years, whereas

in ill-drained field the disease still continues to occur in considerable severity.

In the affected plant, small brown spots first appear in the tips of older leaves. The spots subsequently spread all over the surfaces, giving the leaves a yellowish brown or brown discoloration.

From a distance, the affected plants appear like those which have been heavily attacked by leaf blast. One of the most characteristic symptoms in *Akagare* Type III is the black or dark brown discoloration in the inside of the basal node and internode of the severely affected plant.

Cause of *Akagare* disease

Type I It is obvious from the following fact that *Akagare* Type I is caused by potassium deficiency. (1) The symptoms are closely similar to that of potassium deficiency in solution culture. (2) K_2O/N ratio in the leaf blade of the affected plant is low as the same level to that of potassium deficiency and reddish-brown-spotted leaf blade in the solution-cultured plant. (3) This disease is almost completely controlled by potassium application.

Generally, rice root potassium absorption is supported by the aerobic root respiration. Accordingly, the occurrence of *Akagare* Type I

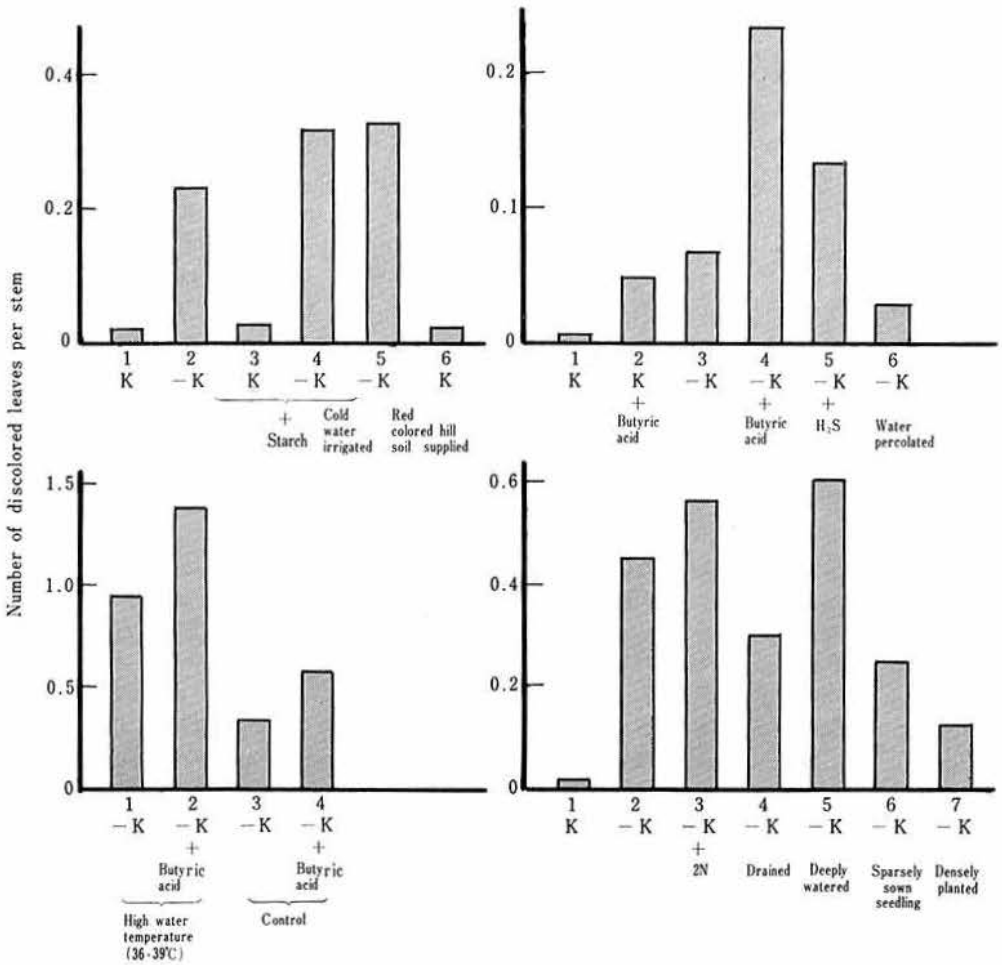

Fig. 1. Effects of environmental factors on the occurrence of *Akagare* type I

is induced by the environmental conditions which arrest rice root aerobic respirations: adding H_2S, butyric acid or starch to the soil, cold water irrigation, and higher temperature of irrigated water than optimum one for plant growth (Fig. 1).

After extensive observations on the *Akagare* occurring paddy soils, YAMAGUCHI et al.[9] reported that the following soil conditions were cited as the factors inducing *Akagare* disease: (1) a poor natural supply of potassium, (2) a high content of easily decomposable organic matter, (3) the production of much hydrogen sulfide in the soil, (4) the low iron content of the surface soil (Fe_2O_3 content below 0.3%) which induces a fast decline in Eh and the evolution of H_2S in the soil, (5) an excess of ferrous iron, and (6) the abnormal reducing power of soil (Eh_6 below 100 mV).

Type II Potassium application in a large amount partly prevents *Akagare* Type II whereas *Akagare* Type I is almost completely controlled by potassium application. It is also observed that the disease occurrence is markedly stimulated by adding to the soil an organic acid such as acetic or lactic, a large amount of organic material as starch, and a large amount of ferrous iron (Fig. 2).

In consequence, the major cause of *Akagare* Type II is presumably attributable not to the potassium deficiency but to the disturbance in the plant metabolic processes from the injurious substances which are produced under the extremely low soil oxidation-reduction potential. Actually, in solution-culture experiment rice leaves often show midrib yellowing when organic acid or methanol is added to the culture solution.

It is reported that *Khaira* disease in India and *Hadda* disease in Pakistan are attributable to zinc deficiency. According to TANAKA[7], some resemblance can be seen between the symptoms of these diseases and that of *Akagare* Type II characterized by midrib yellowing. He concluded that the *Akagare* Type II must be caused by zinc deficiency. It seems to be necessary, however, to do further extensive investigations before coming to his

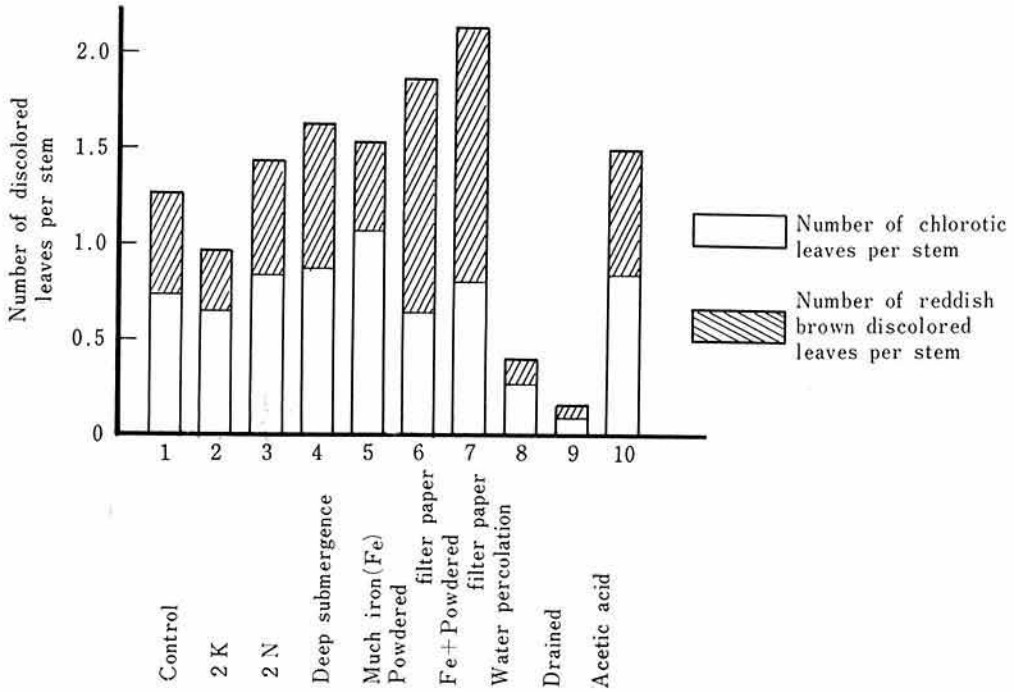

Fig. 2. Effects of environmental factors on the occurrence of *Akagkre* type II

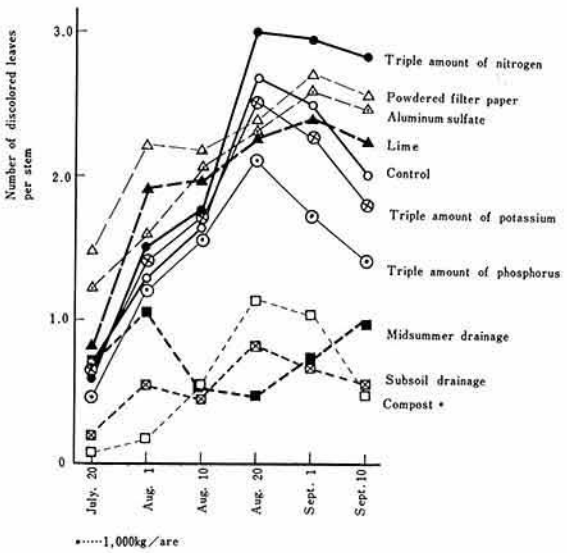

Fig. 3. Effects of environmental factors on the occurrence of *Akagare* type III

conclusion.

Type III This type differs from *Akagare* Types I and II in that it occurs even when the soil oxidation-reduction potential is high (Eh_6 around 300 mV) and the soil is not reduced. It is also observed, however, that *Akagare* Type III occurrence is favored by strong soil reduction due to addition of such organic material as powdered filter paper, while it is lessened by subsoil and surface drainage (Fig. 3).

In an experiment, the percolate from the soil on which *Akagare* Type III occurs was left standing for several days, and precipitates were removed by filtration.

The filtrate was used for solution culture of the rice plant. Brown spots quite similar to the symptom of *Akagare* Type III appeared on the leaf blade[5]. The concentrations of iron in the filtrate after the precipitate had been removed were about 0.15 ppm, and the pH of the filtrate was 6.8 to 7.2, so that free aluminum was absent. Therefore, the symptoms are not caused by the direct influence of iron or aluminum.

An extract by organic solvent such as acetone or ethyl acetate from the above-mentioned filtrate had as well an activity giving rise to brown-spot symptom on water-cultured rice leaves, when the extract was added to the culture solution. These results indicate that the primary cause of *Akagare* Type III should be a harmful substance which can be present in a stable state under oxidized condition of the soil. This substance was ascertained as iodine[6),8)].

An extreme soil reduction will presumably arrest the physiological activity of the rice root and will favor for the harmful substance, iodine, invading rice leaf.

Differences in disease occurrence with growth stages

Types I and II In general, both Type I and Type II *Akagare* diseases begin to occur two or three weeks after transplanting and reach their peak occurrence at the most active tillering stage.

At this time the ratio of soluble nitrogen to protein nitrogen in the plants is high, the total carbohydrate and starch contents decrease, and the oxidation-reduction potential of the plant sap falls markedly (Fig. 4).

This trend in the occurrence can be explained as follows:

Vigorous development of new roots after transplanting increases nitrogen absorption

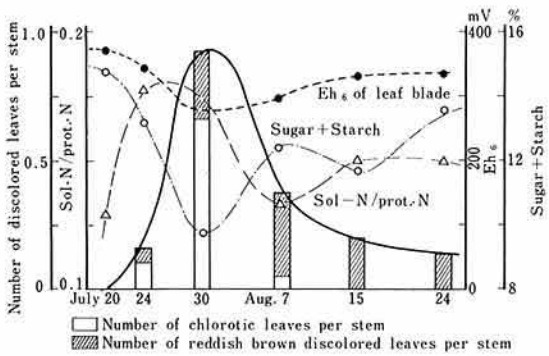

Fig. 4. Changes Eh value, soluble-N/protein-N, and total sugar+starch percentage at different growing stages in relation to the occurrence of *Akagare* type II

by roots, whereas potassium absorption is inhibited due to the severe soil reduction through the decomposition of humus.

As a result, potassium absorption cannot keep pace with nitrogen absorption, thus lowering the ratio of K_2O/N, and increasing the invasion of harmful substances.

Accordingly, in the top of the plant protein synthesis is inhibited due to the lowered respiratory activity of the cytochrome system[2),3)], and the ratio of soluble-N to protein-N is increased.

The abnormal increase in the respiratory rate[2),3)] decreases the total carbohydrate and starch contents. The decreased Eh value of the plant sap and the decreased supply of the respiratory substrate to roots increase harmful substances which invade the tops, thus intensifying *Akagare* symptoms.

After panicle initiation, nitrogen absorption and the ratio of soluble nitrogen to protein nitrogen decrease while carbohydrate and starch contents increase and the Eh value of the plant sap rises. The severity of the *Akagare* disease then diminishes.

Type III In *Akagare* Type III, the symptoms appear also two or three weeks after transplanting, and with the advance in soil reduction the severity increases. Unlike Types I and II, however, the disease is not alleviated at the young-panicle-developing stage, and even the flag leaf is attacked by the disease (Fig. 5). This is presumably due to the presence of a harmful substance which is independent of the soil reduction.

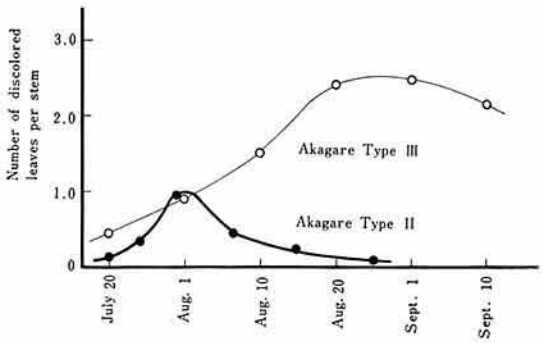

Fig. 5. Difference in disease occurrence with growth stage in *Akagare* Type III compared with Type II

Varietal difference in resistance to *Akagare*

The resistance to *Akagare* disease varies widely according to the rice varieties. In general, the varieties with strong resistance to Type I are also resistant to Types II and III.

Compared with the less resistant varieties, they are characterized by a high content of total carbohydrate or starch and also a high root activity to oxidize α-naphtylamine or to reduce triphenyl tetrazolium chroride, an indicator of the physiological activity of roots (Table 1).

Those varieties with a high total carbohydrate or starch content provide adequate respiratory substrates to roots, and thus such physiological activities of roots as aerobic respiration, nutrient (especially potassium) absorption and oxidizing activity are main-

Table 1. Relationship between resistance to *Akagare* disease and total carbohydrate or starch content, by rice varieties

Rice variety	Resistance to *Akagare* disease	Stems and leaf sheaths		Roots	
		Total carbohydrate content	Starch contents	α-naphthylamine oxidizing activity	TTC reducing ability
		%	%	γ/dry weight/hr	γ/dry weight/hr
Norin No. 36	Susceptible	14.96	6.16	716	1,171
Norin No. 22	〃	13.92	6.60	705	1,058
Norin No. 29	Resistant	15.23	8.13	798	1,362
Norin No. 32	〃	18.51	9.89	925	1,449
Norin No. 37	〃	20.98	11.18	825	1,457

tained at high level. These varieties are resistant to *Akagare*.

Prevention of *Akagare*

Types I and II The followings are generally accepted preventive measures which follow from the cause of the disease:

(1) Application of potash (the effect is not so marked in the case of Type II).
(2) Application of red upland soil.
(3) Application of nonsulphate fertilizer.
(4) Soil ridging in off-season to stimulate the decomposition of soil organic matter.
(5) Rough puddling and leveling to prevent the reduction of the soil.
(6) Surface drainage at the ineffective tillering stage (so-called *Nakaboshi* or midsummer drainage).
(7) Running water irrigation preventing rise in soil temperature (in case *nakaboshi* cannot be practiced).
(8) Subsoil drainage.
(9) Avoiding the application of green manure or immature compost.
(10) Use of resistant variety.

Type III As previously shown in Fig. 3, the application of fully ripened compost markedly prevents *Akagare* of this type. Subsoil drainage and surface drainage are effective as well for preventing the disease. Resistant varieties should be used. A heavy application of phosphorus seems to be somewhat effective since the soil on which this disease occurs is generally deficient in phosphorus.

The application of green manure or immature compost and intensive puddling and leveling, which intensify soil reduction, should be avoided. As mentioned above, the soil on which this disease occurs is generally acidic.

In an experiment with reddish heavy clay loam soil (Fig. 3), the effect of liming seems to be rather a stimulus for the disease occurrence. It is reported, however, that in an experiment with humic volcanic ash soil liming is somewhat effective for preventing the disease[4].

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