12. NUTRITIONAL STUDIES IN THE DEVELOPMENT OF *HELMINTHOSPORIUM* LEAF SPOT

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Outbreak of *Helmiethosporium* Leaf Spot

1. The Circumstances of Natural Infection in Paddy Field.

Helminthosporium leaf spot outbreaks throughout the whole growth period of the rice plant. The primary infection emerges in the nursery bed. But this disease mainly outbreaks in the paddy field from the midsummer, and the disease symptom is accelerated after heading. The disease outbreak invites the growth deterioration called as "Akiochi" which can be classified into three types: 1) Growth deterioration at the relatively early stages i. e. the end of tillering stages; 2) Growth deterioration at the young ear formation stage; 3) Growth deterioration during the ripening stage (Arashi, 1951–2). Among these three types 1) and 2) cases are accompanied with Helminthosporium leaf spot.

2. Characteristics of the Paddy Soil Subjected to *Helminthosporium* Leaf Spot.

The disease mainly outbreaks in the fields composed of sandy soil, peat soil, muck soil or volcanic soil. Especially the rice plants grown in the well-drained sandy or sandy loam soil and those grown on peat soil are highly susceptible to the disease. Sandy or sandy loam soil is called "degraded soil" in which free iron is leached from the top soil manifesting hydrogen sulfide gas. Peat soil is ill-drained soil with excessive humus, and is usually accompanied with the manifestation of hydrogen sulfide, acetic acid or butyric acid, and ferous iron influenced by high temperature in midsummer. On the contrary, in the clay loam soil especially in the paddy field with deep top soil, the disease seldom outbreaks.

3. Morphological Characteristics of Infected Rice Plant, Especially on the Root of Diseased Plant.

As mentioned above, since the disease outbreaks with "Akiochi", poor growth of rice plant is manifested in the latter stage characterized by such phenomena as drooping leaves, death of lower leaves, shortening of the culm and the ear, but the lower internodes are elongated and the upper internodes shortened, and the percentage of effective tillers are droop-down. A careful observation of the root of the infected rice plant is important. Yokogi *et al.* (1949) observed that the roots of diseased plants are short and spread at the soil surface where the infection has taken place. This phenomenon can be seen prior to the disease outbreak. He thought that the deterioration of root activity may be due to shallow rooting, thus breaking the Top Root ratio and as the result the disease outbreaks due to the malnutrition. Arashi (1951–2) observed the same conditions concerning the roots. Ogiwara et al. (1950) studied the roots of rice plant grown at both "Akiochi" field and "Non-Akiochi" field, and found that after heading the difference of roots between these two fields becomes distinct, and at the harvesting stage the root of "Akiochi" field is only 40 cm. in length, while that of "Non-Akiochi" field is 1 m. in length. The color of the root in the degraded field is whitish or blackish and in the ill-drained field is reddish brown or blackish, and in both cases root rot outbreaks.

4. The Relationship between Grain Yield and the Outbreak of *Helminthosporium* Leaf Spot.

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Tanba (1948) considered the low yield in the disease-outbreak is attributable to unfavourable soil condition rather than the direct impact of the disease. Okamoto (1949) stated that the disease must be considered from the standpoint of correlation between the disease outbreak and potassium as an indicator of the abnormal nutrient condition of the rice plant. Baba (1958) observed that the yield is affected by root rot rather than the disease outbreak. Gotoh (1958) also advocated that the yield is mainly controlled by growth condition and the effect of disease is not so significant. From these studies and observations, it can safely be assumed that the disease itself does not cause such a large impact on the yield, but under such a condition that the disease outbreaks a high yield can not be expected. By studying the cause of the disease from the stand point of nutritional physiology it is possible to clarify the cause of the abnormal nutritional condition.

Inorganic Nutrient in Connection with the Outbreak of *Helminthosporium* leaf spot.

1. Content of the Inorganic Nutrient of the Rice Plant Grown on the 'Akiochi' Paddy Field.

There are differences in inorganic nutrient content between the normal rice plant and

Table 1. Percentage content of inorganic constituents of the rice plant grown on normal paddy field and degraded one. (Dry wt. basis)

(1) Mitsui (1949)

	N	P_2O_5	K_2O	SiO_2	Mn	MgO	CaO	SO_2
Normal field	0.56 (1.03)	0.33 (0.51)	1.87	3.80	0.074	0.40	0.48	0.42
Degraded field	0.74 (1.07)	0.39 (0.46)	1.25	2.46	tr.	0.27	0.28	0.84

Note: 1) The rice plants were grown in 1/5000 are Wagner pots filled with soil of normal and degraded field.
2) The analysis was made on straws at harvesting time.
3) The value in parenthesis indicates the analytical data of the paddy.

(2) Kawashima *et al.* (1952)

	SiO_2	CaO	MgO	MnO	Fe_2O_3	K_2O
Normal field	19.54	0.574	0.201	0.0474	0.0218	0.745
Degraded ficld	14.84	0.621	0.235	0.0371	0.0356	1.175
Normal field	19.20	0.406	0.237	0.0345	0.1124	0.834
Degraded field	18.19	0.445	0.228	0.0219	0.0404	0.775
Normal field	7.87	0.596	0.251	0.0336	0.0593	0.803
Degraded field	8.45	0.650	0.322	0.0410	0.0382	0.756
Normal field	16.14	0.548	0.291	0.0920	0.0372	0.563
Degraded field	9.73	0.582	0.246	0.0620	0.0368	0.797
Normal field	11.34	0.546	0.350	0.1170	0.0790	0.803
Degraded field	14.07	0.288	0.106	0.0113	0.0230	0.839

Note: The analysis was made on the leaves taken from farmers' fields.

the diseased rice plant in 'Akiochi' field. As shown in table 1, normal rice plant contains a larger amount of silica, potassium, manganese and magnesium than infected rice plant. (Mitsui 1949, Suzuki 1951, Ishibashi 1952, Kawashima *et al*, 1952). From this fact it can be said that the inorganic nutrients are closely related to the disease outbreak.

2. Relation between the Outbreak of *Helminthosporium* Leaf Spot and the Addition or Lack of Nutrient.

Many investigations have been carried out on the relationship between the disease outbreak and nutrient. As shown in table 2, lacking in silica, potassium, manganese and magnesium, the rice plant becomes susceptible to the disease and show unhealthy appearance with poor yield just as in 'Akiochi'-damaged paddy field (Baba 1958). It has been clarified that in 'Akiochi' field the addition of furnace slag containing silicate, calcium and magnesium and manganese fertilizer is very effective in controlling the disease and increasing the yield.

Table 2. Yield and susceptibility to *Helminthosporium* leaf spot with different supply of nutrient by water culture. (Baba 1958)

	Wt. of ears g.	No. of lesions		L+S	$\frac{L}{L+S}$
		Large (L)	Small (S)		
Controt	52. 7	0. 22	0. 83	1. 05	0. 21
−K	42. 4	0. 46	1. 23	1. 69	0. 28
−Mg	48. 2	0. 54	1. 27	1. 81	0. 29
+Mn	51. 6	0. 11	0. 49	0. 60	0. 18
+Si	58. 7	0. 01	0. 05	0. 06	0. 16

Note: No. of lesions = No. of lesions on flag leaf of main stem/Length (cm.) × width (cm.) of the same leaf (on Sept. 29)

In some cases the disease is intensified by supplying nitrogen but in other cases it decreases. These differences depend upon the nutritional condition of the rice plant. When the rice plant is grown under the nitrogen deficient condition throughout the whole life cycle, practically no infection is witnessed, but under the growth condition with excessive nitrogen at the early growth stage and then subjected to a deficiency of nitrogen in latter stage, it becomes easily susceptible to the infection (table 3). The ratio of nitrogen to other nutrients, especially to sillica and potassium also has an impact on the disease outbreak. If

Table 3. Yield, root rot and susceptibility to *Helminthosporium* leaf spot as affected by method of nitrogen application in water culture. (Baba 1958)

	Wt. of ears g.	Degree of root-rot		No. of leaions		L+S	$\frac{L}{L+S}$
		Aug. 25	Sept. 10	Large (L)	Small (S)		
N–N	55. 2	0. 5	0. 8	0. 10	0. 16	0. 26	0. 40
2N–O	49. 5	1. 2	1. 5	0. 18	0. 15	0. 33	0. 54
1. 5N–1. 5N	57. 8	0. 7	0. 8	0. 13	0. 31	0. 44	0. 30
3N–O	48. 5	1. 5	3. 0	0. 22	0. 31	0. 53	0. 41

Note: 1) Degree of root-rot······Increasing in the order 0–3.

2) No. of lesions were counted on flag leaf and the next leaf and averaged by the same method as adopted in Table 2.

the SiO_2/N ratio or the K_2O/N ratio in the constituents of rice plant becomes lower, the disease shows an increasing tendency (Baba 1958). Okamoto (1951) reported K_2O/N ratio in the soil or the absorbed nutrients in rice plant has some relation to the disease outbreak. In liquid culture if the ratio of potassium to nitrogen is lower, the disease outbreak is increased, but when the ratio is changed increasingly from 1 : 1 through 2 : 2 to 3 : 3 the more increase in outbreak. (Akai 1954). But the disease outbreak pattern is not always parallel to the K_2O/N ratio. In liquid culture the changes in the K_2O/N ratio makes rice plant susceptible under low or high potassium concentration regardless of the nitrogen concentration, and also susceptible under high nitrogen concentration regardless of the potassium concentration (Baba 1958). The others also reported that under small quantity of ammonium sulfate the disease was decreased by a supply of potassium sulfate but under large quantity of ammonium sulfate the disease was not decreased in supply of potassium sulfate (Doi 1951).

Table 4. Effect of nutrients on No. of lesions and enlargement of lesion in *Helminthosporium* leaf spot. (Baba 1958)

		No. of lesions per unit leaf area	Enlargement of lesion
N	Ordinary level at early stage and deficient after middle stage	△	○
	Surplus level at early stage and deficient alter middle stage	○	◎
P	Deficient after middle stage	△	△
K	〃	□ ~ ○	○ ~ △
Mg	〃	○	○
Si	〃	◎	○ ~ △
Mn	〃	◎	○

Note: ◎ remarkably increases, ○ slightly increases, □ hardly or not affected, △ slightly decreases.

Table 5. Relationship between susceptibility and growth of the plants, and respirstory—and photosynthetic intensity of levels. (Tanaka & Akai 1962)

	Susceptibility		Growth of top	Intensity of respiration (R)	Intensity of photosynthesis (P)	P−R ratio (P/R)
	Total number of spot	Enlargement of spot				
+Mn	−−	−	±	+	±	−
+K	−	−	++	−	+	+
+N	−	−	+	++	++	+
+Mg	−	±	±	±	±	±
+Si	−−	+	±	++	+	−
−P	−	+	−	±	+	+
−K	+	±	−	+	±	−
−N	−	++	−−	++	±	−−
+P	+	+++	−−	++	++	++
−Mg	+	+++	−−	++	++	−

Note: + : Larger than control, − : Smaller than control.

With respect to the correlation between the number of lesions or enlargement of lesions and the nutrients, Baba (1959) summarized his many experiments as shown in table 4. He observed that dificiency in manganese and magnesium promoted both the number and enlargement of lesions, but deficiency of silica and potassium mainly affected the numbers. He also observed that deficiency of the nitrogen in latter stages after having surplus supply in earlier stage promote both the number of lesions and enlargement of lesions. Akai (1954) observed the same effect of manganese as reported by Baba. Misawa (1955) also observed that nitrogen was more active to expand the lesion than other nutrients. In contradiction to Baba's result, Okamoto (1949) and Gotoh (1958) observed that potassium deficiency accelerated the expansion of lesions. As mentioned above, the result of each experiment was not always the same. As to the hydrogen sulfide it is reported that the enlargement of lesions are accelerated by this substance (Baba 1958, Gotoh 1958). Baba (1958) advocated that susceptibility had to be indicated by the enlargement rather than the number thereof. Tanaka and Akai (1963) have observed as shown in table 5, that such treatments as low level of K, N and Mg supply which have distinct effects on the enlargement, also have the effects inhibiting growth, increasing respiration rate and decreasing ratio of P/R. Considering these findings they also advocated that the susceptibility had to be indicated by the degree of enlargement.

Relationship between the Outbreak of *Helminthosporium* Leaf Spot and the Environmental Conditions

As mentioned above, the disease is caused by the deficiency of inorganic nutrients. Such a deficiency is closely related with the lack of these inorganic nutrients in soil. Furthermore, the rice plant is cultured under the environment in which the absorption of nutrients by the rice plant is inhibited.

1. Soil Conditions.

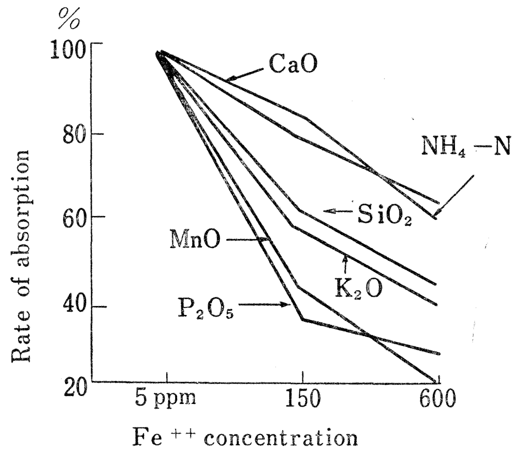
The paddy field where the *Helminthosporium* leaf spot outbreaks is the degraded paddy field with sandy soil or the ill-drained paddy field with large humus, so called 'Akiochi' field. In such fields the contents of bases and silica are not so high. Moreover, some harmful inorganic substances such as hydrogen sulfide, ferous iron and organic acids such as acetic acid or butyric acid are diverged from the soil. These substances inhibit the nutrient absorbing activity of the roots, and the inhibitory grade is differed according to the kind of nutrients in the descending order; $-K_2O \cdot P_2O_5 > SiO_2 > NH_4\text{-}N \cdot MnO > H_2O > CaO \cdot MgO$ (table 6). In case of ferous iron MnO belongs to the most inhibited groups (fig. 1). In case of

Table 6. Inhibition coefficient (I. C.) of the nutrient absorption by several inhibitors. (Mitsui *et al.* 1953)

	I. C.									
	K_2O	P_2O_5	SiO_2	NH_4-N	MnO	MgO	CaO	SO_3	Br	H_2O
H_2S	182	147	107	42	43	24	16	100	85	46
Butyric acid	274	147	–	52	61	45	55	–	–	64
NaCN	222	147	118	45	47	37	37	–	–	67
NaN_3	242	132	–	52	60	34	47	–	–	67

Note: 1) $\text{I. C.} = \frac{\text{Absorption in control plot} - \text{Ultimate absorption}}{\text{Absorption in control plot}} \times 100$

2) Ultimate absorption……Value of absorption when the concentration of the inhibitor becomes infinite.



Note: Rate of absorption of each nutrient is indicated as percentages to the absorption in case of 5 ppm Fe^{++}

Fig. 1. Influence of exessive ferous iron on the nutrition absorption. (Baba & Tajima 1960)

Table 7. Influence of H_2S on the inhibition rate in nutrient absorption. (Baba 1958)

		H_2O	NH_4-N	P_2O_5	K_2O	SiO_2	MgO	MnO
Aug. 4 – Aug. 6	H_2S	2	4	37	22	29	−6	−9
	$2H_2S$	5	20	72	92	65	−8	0
Aug. 24 – Aug.30	H_2S	16	12	14	34	20	20	22·
	$2H_2S$	31	30	29	58	51	40	72

Note: 1) Inhibition rate=[(Amount of absorption per 1 g. of dry wt. in non H_2S plot)−(Amt. of absorption per 1 g. of dry wt. in H_2S plot)/(Amt. of absorption der 1 g. of dry wt. in non H_2S plot)] × 100

2) Aug. 4–Aug. 6: Immediately after H_2S application.

3) Aug. 27–Aug. 30: After continuous addition of H_2S.

Table 8. Influence of water temperature on the nutrient absorption. (Calculated from Baba 1958)

	N	P_2O_5	K_2O	SiO_2	MnO	CaO
Low	68	65	66	59	72	79
High	82	84	73	66	91	92

Note: 1) Expressed by the percentage for the Optimum temp. plot.

2) Low ···············24–25 °C
Optimum······28. 5–32 °C
High············37–38. 5 °C

3) Grown in water culture, and absorption amount from Aug. 7 to Aug. 18 was determined by analysing the top of plant.

Table 9. Influence of soil temperature on yield and susceptibility to *Helminthospohium* leaf spot of the rice plants grown on different type of soil. (Baba 1958)

		Wt. of paddies per pot g.	No. of lesions per 10 cm. length of leaf on Oct. 6	Evolution of H_2S
Kohnosu soil (normal)	L	20.8	23.7	−
	O	23.3	15.5	−
	H	20.6	21.1	−
Hofu soil (degraded)	L	17.4	69.2	+
	O	16.3	59.5	++
	H	11.4	58.0	++
Matsuo soil (ill-drained rich in humus)	L	17.0	65.5	±
	O	16.2	30.3	±
	H	17.1	37.6	+

Note: 1) 1/5000 are Wagner pots were used.
2) L (low)…………21.4–22.7 °C
O (optimum) …26.9–31.8 °C
H (high) ………31.5–36.0 °C

Table 10. Influence of night temperature on nutrient absorption. (Baba 1958)

	Amount nutrients and water absorbed per plant						Ratio of absorption	
	H_2O (g.)	NH_4–N (mg.)	P_2O_5 (mg.)	K_2O (mg.)	MnO (mg.)	SiO_2 (mg.)	K_2O/N	SiO_2/N
H	103.3	6.28	3.50	1.97	0.129	51.8	0.314	8.25
M	101.7	7.42	3.66	3.40	0.150	63.7	0.458	8.58
L	82.0	7.28	3.79	2.95	0.153	59.0	0.405	8.10

Note: 1) Measured during 24 hours from Sept. 14, 10 a.m. to Sept. 15, 10 a.m. by analysing the nutient solution, using uniform plants in liquid culture.
2) Night air temperature was treated from 6 p.m. 14th to 6 a.m. 15th.
3) H (high) Night air temperature was kept around 28 °C
M (middle) ——ditto—— 22–25 °C
L (low) ——ditto—— 17–21 °C

Table 11. Influence of high night temperature on yield, susceptibility to *Helminthosporium* leaf spot and percentage content of nutrients in plant. (Baba 1958)

	Wt. of ears per pot g.	No. of lesions	Percentage content					K_2O/N	SiO_2/N
			N	P_2O_5	K_2O	SiO_2	MnO		
H	43.5	62.6	0.451	0.267	1.32	3.18	0.041	0.293	7.05
C	47.0	34.0	0.444	0.274	1.58	3.33	0.046	0.356	7.50

Note: 1) Rice plants were grown in 1/2500 are pots and treated from Sept. 5 (after heading) to Oct. 5.
2) H (high) Minimum average night temp. during one month is 24.4 °C
C (control) ——ditto—— 20.4 °C
3) No. of lesions……Total No. of lesions occurring in the flag and the next leaves on all culms in one plant.

Table 12. Influence of inorganic nutrients on percentage content of nitrogen fractions.

(1) Ishizuka & Hayakawa (1951) (mg./100 g. fresh wt.)

Varieties		Leaves		Stems	
		Sol.-N	Insol.-N	Sol.-N	Insol.-N
Nakate-Eikoh	+Mg+Si	6.80	32.35	5.01	1.69
	+Mg−Si	9.45	45.81	6.29	2.88
	−Mg+Si	13.95	50.93	7.16	6.16
	−Mg−Si	14.91	52.12	6.53	6.53
Ishikari-Sirake	+Mg+Si	5.60	30.15	3.75	4.30
	+Mg−Si	8.31	36.00	5.60	6.68
	−Mg+Si	11.25	37.05	6.85	10.80
	−Mg−Si	12.60	38.25	7.95	14.21

(2) Noguchi & Sugawara (1952) (% dry wt. basis)

		Protein-N	Non-protein-N	$\frac{\text{Non-protein-N}}{\text{Total-N}} \times 100$
Rikuu-132	NP	1.30	0.91	41
	NPK	1.54	0.32	17
	NPK_2	1.51	0.25	14
Fusakushirazu	NP	1.18	0.97	45
	NPK	1.42	0.36	20
	NPK_2	1.46	0.28	16

(3) Baba (1958) (% dry wt. basis)

	Soluble-N	Protein-N	Soluble-N/Protein-N
+K	0.457	3.024	0.151
−K	0.558	3.136	0.188

(4) Baba (1958) (% fresh wt. baais)

	Soluble-N	Protein-N	Soluble-N/Protein-N
N − Si	0.137	0.583	0.235
N − Si	0.113	0.562	0.201
2N − Si	0.167	0.631	0.264
2N + Si	0.153	0.602	0.254

(5) Baba (1958) (% dry wt. basis)

		Leaf blade			Leaf sheath		
		Sol.-N	Prot.-N	Sol.-N/Prot.-N	Sol.-N	Prot.-N	Sol.-N/Prot.-N
1st Experiment	−Mn	0.275	1.531	0.180	0.170	0.495	0.343
	+Mn	0.263	1.495	0.171	0.166	0.471	0.352
2nd Experiment	−Mn	0.341	2.609	0.165	0.175	0.612	0.286
	+Mn	0.378	2.256	0.168	0.196	0.650	0.302

hydrogen sulfide, according to Baba (1958), in the later stage after the continuous addition thereof the inhibition of manganese and magnesium absorption becomes severe and that of phosphorus becomes slight (table 7). From these findings it can be said that the root injury is caused by harmful substances, and the nutrients absorption is inhibited, imposing a favourable condition for the disease outbreak.

2. Meteorological Conditions.

When the water temperature becomes higher or lower than the optimum temperature of 30°–32°C or when the night air temperature is high and the difference between day and night air temperature is less, the normal activity of the root is inhibited and the noot becomes susceptible to rot and thus, the inhibition of nutrient absorption begins to occur accompanied with the outbreak of *Helminthosporium* leaf spot (table 8, 9, 10, 11). In the southwestern warm district of Japan, in midsummer the water, soil or night air temperature becomes higher than optimum. It is considered that in these districts such meteorological conditions cause the 'Akiochi' by disturbing the absorption of nutrient.

Relationship between the Outbreak of *Helminthosporium* Leaf Spot and the Metabolism in Rice Plant

The disease outbreak is closely related to the deficiency of silica, potassium, manganese and magnesium, as mentioned above. The deficiency of these elements except manganese is considered to disturb the protein synthesis resulting in an increase of soluble nitrogen (table 12). Just after the infection of *Helminthosporium* leaf spot, the protein synthesis in rice plant normally takes place but in later stage after the infection, the decomposition of protein occurs in the infected rice plant and this soluble nitrogen decomposed serves as the nutrient of fungus (Asada and Tachibana 1959). The rice plants grown on the paddy field where the root rot outbreaks contain a large amount of soluble nitrogen and sugar (Yamane *et al.* 1952). In liquid culture added with hydrogen sulfide, soluble nitrogen and sugar increase in the rice plant. From these facts abnormal nitrogen and carbohydrate metabolism are expected to be closely related to the outbreak of *Helminthosporium* leaf spot. Asada (1957) clarified that by the infection of *Helminthosporiun* leaf spot the respiration rate increased but this increase was not accompanied with energy production (table 13).

Table 13. Changes of oxidative phosphorylation in normal and Akiochi rice leaves with the infection of *C. miyabeanus*. (Asada 1957)

Days after inoculation	Normal leaves				Akiochi leaves			
	0	2	4	6	0	2	4	6
P decreasec (γ)	7.0	13.7	24.9	10.6	5.6	6.0	5.8	8.6
O_2 uptake (μl)	14.0	14.2	19.2	19.6	14.0	14.8	18.0	18.0
Ratio	0.5	0.9	1.3	0.5	0.5	0.4	0.3	0.4

Varietal Resistance to *Helminthosporium* Leaf Spot

Varietal resistance to *Helminthosporium* leaf spot has been clarified. Especially, the Indica varieties have high resistance as compared with Japonica varieties (table 14 and 15). This difference does not depend on the resistance to the intrusion of fungus, but on the resistance to the disease expansion namely, the difference being derived from the cell-physiological characteristic of the varieties.

Table 14. Varietal differences in resistance to *Helminthosporium* leaf spot. (Yoshii & Matsumoto 1951)

Heading date	Resistant	Middle	Susceptible
Aug. 12 – 21	Bomba (E) Ginnen (C) Toto (C)	Oohata (J)	Iwate-Kamenoo–1 (J) Mongolian (T) Norin–1 (J)
Aug. 22 – 31	Chokato (C) Louisiana non-beard (NA) Tadukan (S)		Shin-nigo (J)
Sep. 1 – 10	Jamaica (SA) Te-Tep (S)		Aichi-Asahi (J) Matsuyama-Omachi (J) Nep-Vai (S)
Sept 11 – 20	Harawara-djidok (S) Kataeentjar (S) Kannonsen (C)	Ketan-Nangka (S)	

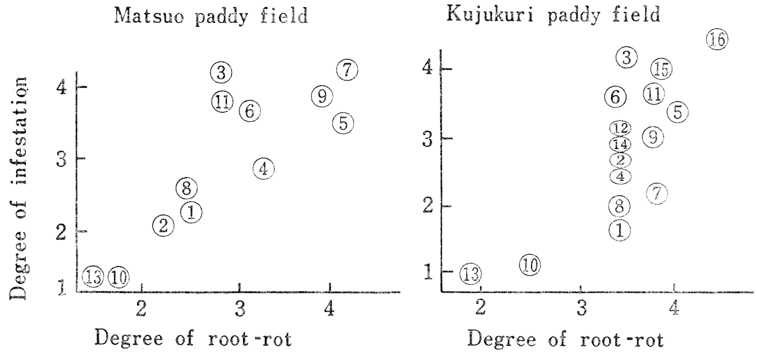
Note: S……South Asia C……China T……Taiwan NA……North America
SA……South America E……Europe J……Japan

Table 15. No. of varieties classified by susceptibility to *Helminthosporium* leaf spot. (Hashioka 1952)

Group of varieties	No. of varieties tested	Susceptibility					
		1	2	3	4	5	6
		←resistant				susceptible→	
Japanese lowland rice	29		15	6	6	1	1
Japanese upland rice	22		16	3	3		
Taiwan (Horai)*	34		4	7	12	8	3
Taiwan (Native)	22	12	8	1	1		
Taiwan (Mountainous lowland rice)	10	2	4	2	1		1
Taiwan (Mountainous upland rice)	14	4	6	3			1
Mongolia & North China	3	2	1				
Middle China	11	1	3	2	4	1	
South China	33	14	8	10		1	
Hainan	3	2	1				
Philippines	13	5	7		1		
Celebes	20	6	10	3	1		
Small Sundas	24	11	9	3		1	
Java	3	1	2				
Indo-China & Malay	24	17	3	4			
Siam	4	1	2		1		
Burma	3	3					
India	6	3	1	2			
Europe & America	5	3	2				

Note: * Horai……Japonica lowland rice bred in Taiwan.

Among the Japonica types no variety with such a high resistance as Indica type has been detected. Difference in the resistance among Japonica varieties depends on the resistance to root rot or nutritional characteristic caused by root rot (Baba 1958).



Note: Varietal No. 1. Norin–6 2. Norin–32 3. Chiba-asahi 4. Norin–25 5. Norin–36 6. Norin–29 7. Norin–22 8. Norin–3 9. Norin–8 10. Norin–37 11. Aichi-asshi 12. Haruta-asahi 13. Kameji 14. Senbon-asahi 15. Omachi 16. Shinriki.

Fig. 2. Relationship between the degree of root-rot and the degree of infestation to *Helmiuthosporium* leaf spot in rice varieties grown on "Akiochi" paddy field. (Baba 1958)

As shown in Fig. 2, the degrees of infestation among Japorica have some correlation with root rot. In 'Akiochi' paddy field, the content of manganese and silica and the ratio of calcium to sulphur content, Ca/S, in the resistant varieties are higher than in non-resistant varieties (table 16). The varieties resistant to *Helminthosporium* leaf spot show less reaction to sulfide in the base of culm (table 17). Moreover, the deep rooting character of the resistant varieties is considered to be favorable for nutrient absorption (Yokogi *et al.* 1949, 1950). Generally, the Indica varieties are very susceptible to root rot. Therefore, high resistance to *Helminthosporium* leaf spot in these plants may depend on the physiological character of the cell which has no relation to the degree of resistance to root rot.

Table 16. Varietal differences in the contents of manganese, silica, and Ca/S ratio grown on the "Akiochi" field. (Suzuki 1951)

	Mn_2O_3	SiO_2	Ca/S	Degree of infestation
Norin–37	0.0457	9.51	3.27	low
Kameji	0.0194	10.37	1.75	low
Norin–18	0.0134	8.40	0.75	high
Dokai-shinriki	0.0119	8.66	0.79	high

Dry wt. basis %

Table 17. Relationship between Sulphide reaction or Fe·· reaction at the base of shoot and the degree of blackening of root among rice varieties treated with H_2S. (Baba 1958)

	June 13			June 18		
	Sulphide reaction	Fe·· reaction	Blackening of root 4 days after treatment	Sulphide reaction	Fe·· reaction	Blackening of root 4 days after treatment
Norin-36	2.3	3.0	2.3	2.3	4.0	2.3
Norin-22	4.3	3.0	3.0	1.0	2.0	2.0
Chiba-asahi	3.7	4.0	1.5	0.8	2.0	1.5
Norin-29	2.0	2.5	1.7	1.7	2.5	1.5
Norin-32	2.0	2.5	0.7	0.7	2.0	0.8
Norin-37	0.6	2.0	0.7	0.7	2.0	1.0

Note: 1) Two seedliogs and 20 ml. H_2S sol. containing about 100 ppm were used.
2) Varieties showing a lower degree of blackening of root, namely, having a higher ability to oxidize FeS show less marked reactions to Sulphide and Fe·· as compared with that showing higher degree of blackening and a lower ability to oxidize FeS.

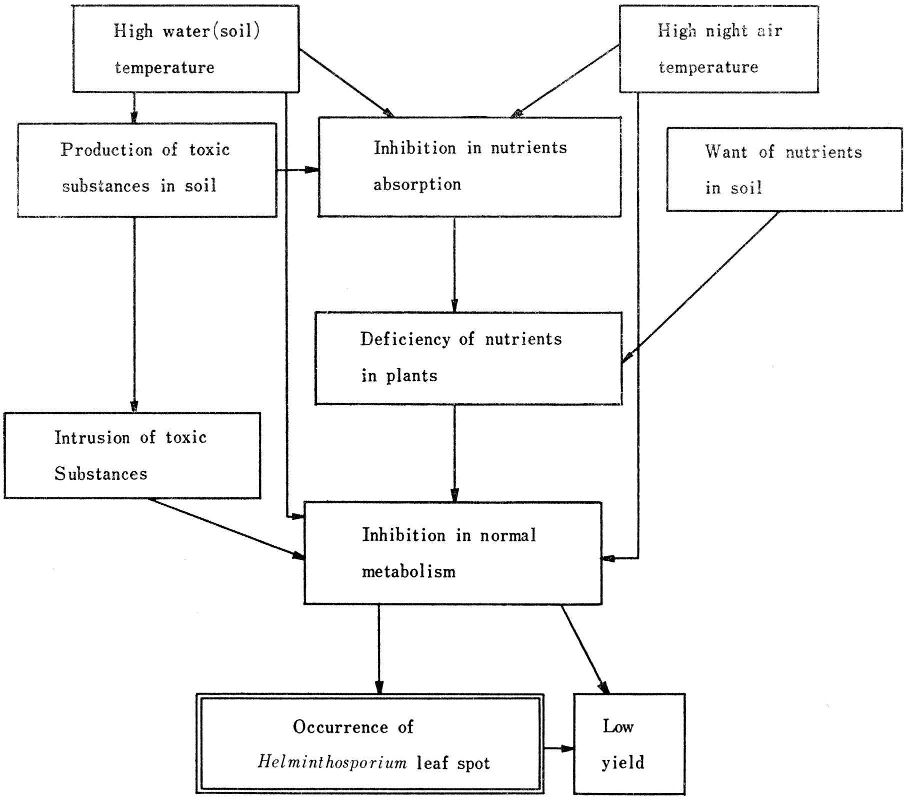


Fig. 3. A diagram on the process of occurrence of *Helminthosporium* leaf spot.

Conclusion

As a conclusion, the outbreaking process of *Helminthosporium* leaf spot and methods of control are shown in Fig. 3 and Fig. 4.

(1) The main cause of *Helminthosporium* leaf spot are unfavorable soil conditions as shown in Fig. 3. Other environmental conditions such as high soil temperature and high night temperature promote the unfavorable conditions by inhiaiting both the nutrient absorption and the normal metabolism. Unfavorable soil conditions are indicated as the lack of nutrient in soil itself and also the formation of harmful substances such as H_2S, organic acid and ferous iron. The normal metabolism of rice plant is inhibited by the direct injury of the harmful substances as well as by the inhibition of the nutrient absorption caused by such substances. Thus, the disease outbreaks inviting low yield.

(2) As methods to control the *Helminthosporium* leaf spot, two major procedures can be indicated. The one is soil reclamation and the other is improvement of fertilization practices. Water control plays a role of supplemental importance. Under these improvements it is possible to grow healthy plant free from *Helminthosporium* leaf spot and to ensure high yield.

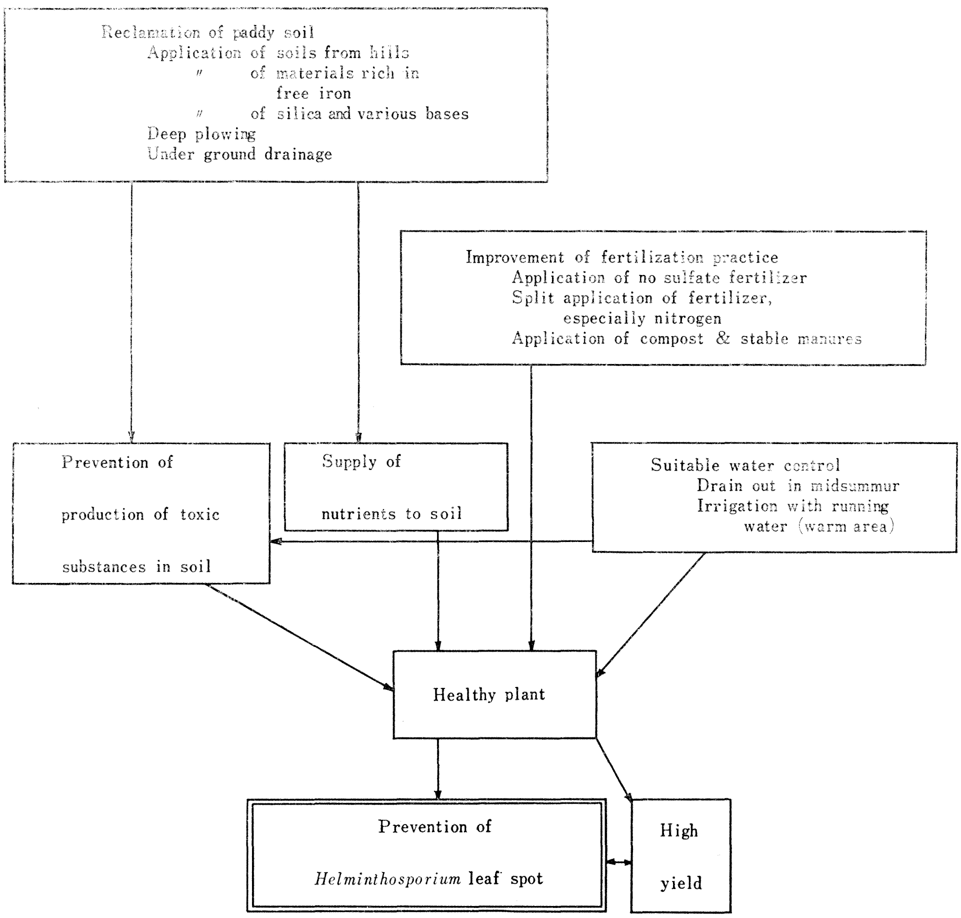


Fig. 4. A diagram on control of *Helminthosporium* leaf spot.

Discussion

T. K. Van, Malaysia: In your observation you have found that indica varieties are more resistant to leaf spot than japonica varieties. Have you found any morphological or anatomical characters which can contribute to such resistance?

Answer: From the experiment by Hiromu Yoshii & Masami Matsumoto (1951), when the fungus invades into the cells, in case of the resistant varieties the invaded cells become to be filled with much amount of wound gum and show no constriction. As a result the intercellular spaces are narrow. So the fungus hardlly extend the lesions. On the contrary in case of the susceptible varieties the reaction is reverse, namely, with little wound gum, much constriction with wide intercellular spaces. So the fungus easily extend the lesions.

A. Alim, Pakistan: What is the effect of top dressing of N at different stage compared with basic doses on the incidence of disease and its severity.

Answer: As I stated, the nitrogen deficiency in later stage, after receiving much amount of nitrogen in early stage, gives the rice plant susceptibility to the disease. So it is more desirable to give the nitrogen dividing several times than base dressing only, especially in case of using chemical fertilizers.

H. Oka, Japan: Mg, K, Fe, etc. —do they singly affect the prevalence of this disease, or a particular combination of them?

Answer: It can be said that there are no any particular combinations of the nutrients to affect the prevalence of the disease. Any nutrients except phosphorus which are relatively deficient compared with other nutrients affect the occurrence of the disease. To keep the balance of nutrients is important.

T. Mizukami, Japan: I think, air temperature at night is important. How is the relation of temperature at night to disease outbreak?

Answer: Yes, the night temperature is important. In the high temperature at night the respiration rate increases. Thus the supply of carbohydrate to the root becomes insufficient and normal metabolism of the root is damaged accompanied with inhibition of nutrient absorption. By these abnormal metabolism and inhibition of nutrient absorption the disease may be liable to occur.

E. Cada, the Philippines: Does not the presence of a large amount of ferous sulfide in the soil lead to destruction of the root system and have altered the natural resistance of the plants under normal amount of the substance,

Answer: Yes, I agree with you. In the ill drained field sometimes the much amount of ferous iron damages the root.