13. CONDITIONS THAT FAVOUR *HELMINTHOSPORIUM* LEAF SPOT DISEASE AND ITS CONTROL IN CEYLON

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Introduction

Brown Spot disease of rice caused dy *Helminthosporium oryzae* has been a major contributory factor to a famine in Bengal in 1942. In Ceylon, an epidemic of this disease occurred in mid-1943 in the Uva Province attacking all the cultivated varieties and severely reducing their grain yield. Though accurate records of crop losses are not available, it is estimated that the yield in the Uva Province was reduced to about 5 bushels per acre. More recently, in 1952, an epidemic occurred in the dry zone and severely affected crops in the Polonnaruwa district. The disease generally occurs endemically in the wet zone areas of the country where unfavourable soil conditions exist for rice cultivation.

Commonly three phases in the development of the disease are recognized in Ceylon. They are (1) seedling disease, causing postemergence mortality of seedlings (2) lesion development on the leaves and leaf-sheaths, thereby reducing the potential photosynthetic area and impairing the productive capacity of the crop and finally (3) grain infection resulting in partly filled or unfilled grain thus directly affecting the crop yield and causing a reduction in the germination of infected seed. The last phase, that is, grain infection is by far the more predominant, especially in the dry zone areas of the country.

Surveys of the Disease

In 1956, Peiris and Suriyadasa surveyed the extent of internal infection of rice seed and demonstrated a relatively high incidence of *H. oryzae* compared to other seed borne fungi[13], While the severity of the disease varied considerably with the seed-stock, 89.1 per cent of the seed-stocks tested showed positive infection. In a more comprehensive survey of the diseases of rice seed-stocks conducted over the last five years, 51.2 per cent of them were found to be infected with the Brown Spot disease. A great majority of the seed for this survey originated from the dry zone areas of the country.

No systematic survey of the disease in the leaves and leaf-sheaths has been yet made but from available information it is clear that grain infection is predominant in the dry zone whereas both foliage and grain infection occur commonly in the wet zone.

Conditions Affecting Disease Development

Work in Japan emphasized unfavourable soil conditions and nutrient deficiency as the predominant causes of predisposition of the rice crop to the Brown Spot disease. Baba produced evidence of a close correlation of resistance to *Helminthosporium* with unfavourable soils and deficiencies in potassium, silica and magnesium[6]. Baba and coworkers also reported increased susceptibility to Brown Spot under conditions of low soil moisture and high atmospheric humidity[5]. Corbetta working in Italy found susceptibility as due to potassium deficiency in the soil while Abeygunawardena experimentally demonstrated in Ceylon that correction of silica and potassium deficiency in the soil caused a substantial reduction of

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disease in the growing crop[9),1)].

1. Climatic Environment Inducing Disease

The influence of climate and soil in inducing disease epidemics was tested in four different climatic conditions in Ceylon. Soils from four locations namely Peradeniya, Bombuwela, Batalagoda and Nalanda were separately tested at each location. The variety of rice grown, fertilizer treatments and cultural operations were uniform at all four experimental sites and for the different soil types. The plants were dusted with spores from infected grain and leaf at different stages of development of the crop.

As illustrated in Table 1 Brown Spot appeared under one climatic condition, namely Bombuwela. At first a mild infection occurred in the crop grown in Bombuwela soil 9 weeks after planting. Thereafter the disease increased progressively and in 13 weeks crops in all four soils were infected. The degree of infection, nevertheless, varied considerably with the soil type and showed the following decreasing order of severity of the disease (1) Bombuwela soil (2) Nalanda soil (3) Batalagoda soil and (4) Peradeniya soil. Analysis of the disease component revealed no significant difference between Bombuwela and Nalanda soils, the highest incidence of the disease however being in the former. The crop in Peradeniya soil suffered least from Brown Spot disease. Two important conclusions could be based on the results of these studies. They are, first, that certain critical climatic conditions are essential for disease development and secondly, the severity of the disease is largely determined by soil conditions. The former could be attributed to the development of epiphytotics only in certain years in the dry zone although soil conditions are generally favourable to crop growth.

Table 1. The influence of the soil type and climatic condition on development of Brown Spot (Disease index)

Soil Type	Climatic Type			
	Bombuwela	Nalanda	Batalagoda	Peradeniya
Bombuwela	3.125	0	0	0
Nalanda	2.625	0	0	0
Batalagada	2.250	0	0	0
Peradeniya	1.850	0	0	0

L.S.D. 0.605

2. Soil Environment Inducing Disease.

The disease occurs in varying severity in crops grown in different soil types. The results of an islandwide survey illustrated in Table 2 revealed a close correlation between soil type and severity of the disease. For example, crops in sandy soil are highly susceptible while in peaty and clayey or clay-loams they are susceptible and moderately tolerant respectively. Sandy soils are generally known to be deficient in potassium, silica and other important

Table 2. Severity of infection of seed-stock in relation to soil type

Soil Type	% Seed-stock infected
Sandy	61.54
Peaty or humic	53.84
Clayey or Clay-loams	42.15

nutrients required for rice. Also because of their acute deficiency of iron, hydrogen sulphide toxicity is common resulting in root-rot and general weakening of the plants. Peaty or humic soils, on the contrary, contain carbon-di-oxide and organic acids that are injurious to plant growth thereby weakening the plants and inducing increased susceptibility to disease.

3. Conditions Influencing Endemicity.

The disease is endimic in the wet-zone and occurs in every cropping season. Endemicity of the disease in the wet-zone is generally associated with imperfect sub-soil drainage and unfavourable soil conditions for crop growth. Baba, working in Ceylon in 1958 recognized three types of rice soil in the wet-zone[7]. They are (1) lateritic soil with high concentration of ferrous iron causing damage to the roots of the rice plant and serious disturbances to crop growth, (2) peaty or humic soils containing injurious substances like carbon-di-oxide and organic acids which are inimical to root growth and (3) sandy soils deficient in iron thereby causing hydrogen sulphide toxicity and weakening of the plants. He reported that sandy soils are deficient in potassium, silica, manganese, magnesium, nitrogen and phosphorus. Rodrigo reporting the quantities of plant nutrients available in different types of soils observed an acute deficiency of potassium, silica, free iron and Manganese[14]. The relative values of these nutrients in differents soils in the wet zone are summarised in Table 3. The deficiency of plant nutrients in the wet zone was further substantiated by Amerasiri in a study of the irrigation waters in Ceylon[3]. He found that the quantities of potassium, magnesium, calcium and sodium were lower in the wet zone compared to the levels in the dry zone. The relative quantities of these nutrients in the irrigation waters are summarised in Table 4. It was also observed that the availability of these nutrients to the growing rice crop becomes further limited as the quantity of irrigation water used in the wet zone is relatively less.

Observations on foliage infection have covincingly demonstrated that crops in sandy soils show increased susceptibility to Brown Spot disease than those in humic or lateritic soils. Increased susceptibility of crops in sandy soils in the wet zone and the high incidence of seed infection in crops grown in similar soils in the dry zone suggests the importance of

Table 3. Relative quantities of plant nutrients in different wet zone soils (From Rodrigo 1961)

Soil Type	Relative quantity of nutrient				
	Potassium* m. e/100 gm	Available phosphorus p. p. m	Available Silica p. p. m	Free Iron %	Easily Reducible Manganese %
1. Acid Lateritic (Mirigama)	0.07	4.7	39.0	4.35	0.00070
2. Peaty (Bombuwela)	0.07	12.5	33.5	1.40	0.00044
3. Sandy (Bombuwela)	0.03	7.1	7.0	0.20	0.00019

* Personal communication (Rodrigo 1967).

Table 4. Chemical constituents in Dry and Wet zone irrigation water

	Na	K	Ca	Mg	Fe	Al	Si	HCO_3	Cl	P	N
Dry Zone	26.15	4.35	25.05	15.85	0.05	0.04	6.30	154.55	52.00	0.04	0.23
Wet Zone	3.00	1.00	3.65	1.50	0.09	0.07	6.15	27.70	9.35	0.03	0.20

silica, potassium and other nutrients that are normally deficient in such soils, in reducing the severity of the disease.

Control

Studies in the control of Brown Spot disease of rice in Ceylon have followed several lines. They are (1) seed health certification (2) seed treatment with chemicals (3) prophylactic spraying of the standing crop (4) growing of resistant varieties and (5) soil ammendment and amelioration of physiological disturbances arising out of poor soil conditions.

1. Seed Health Certification

Disease free seed is vital in avoiding disease outbreaks and postemergence mortality in rice. Rice seed acts as an efficient vehicle for transport of *H. oryzae* and other disease causing fungi, bacteria and nematodes. Transmission of these diseases with the seed and consequent outbreak of epidemics could be effectively overcome by seed health certification. Illustrated in Table 5 are the seed borne fungus and nematode diseases observed in foundation seed-stocks from 1963–65 (1). It is evident that Brown Spot is by far the commonest disease infecting seed-stocks and by rejection of heavily infected seed reduction in germination of seed and outbreak of epidemics are prevented. Seed with moderate and mild infection is recommended for planting after treatment with organo-mercurial dressings.

Table 5. Per cent seed stock infected with different diseases

Disease	% seed stock
Brown Spot (*Helminthosporium oryzae*)	39.13
Grain Spot (*Curvularia* sp.)	29.81
White Tip (*Aphlenchoides besseyi*)	13.66
Foot Rot (*Fusarium moniliforme*)	8.70
Stackburn (*Tricochonis padwikii*)	3.73
Blast (*Pyricularia oryzae*)	0.62

2. Seed Treatment.

The problem of seed disinfection to control seed transmission of Brown Spot has engaged the attention of several workers in the past. Nishikado and Miyake claimed that treatment with mercuric chloride, silver nitrate, copper sulphate and formaldehyde gave partial or complete control whereas Maung Thet Su observed that formalin, copper sulphate, ceresan and hot water gave no control of the disease[12),15)]. Cralley and Tullis demonstrated the effectiveness of organo-mercurial compounds in controlling the disease[10)]. In Ceylon, Peiris and Suriyadasa determined from laboratory experiments the superiority of organo-mercury seed dressings over thiram, copper oxychloride or cuprous oxide containing chemicals[13)]. They pointed out, nevertheless, that maximum control of the disease was not obtained with the organo-mercury compounds evaluated. In the field tests, however, infection of seedlings was found to be considerably lower and there was no measurable disparity in the infection of treated and untreated seed. This further points out that the control of Brown Spot disease attained with organo-mercury seed protectants was partial and that the problem requires re-examination. However, although seed treatment has no special advantage under unfavourable conditions to the pathogen, it would be a useful insurance against seed transmission and seedling blight under soil and climatic conditions that favour the disease.

3. Prophylactic spraying of the standing crop.

Several workers have reported efficient control of secondary airborne infection by prophylactic spraying with fungicides. In India, control of secondary infection has been attained by the application of organo-mercurial dusts or copper fungicide to the standing crop while in British Guiana spraying with 'verdasan' an organo-mercury compound has given satisfactory results[8),4)]. In Japan, infection was substantially reduced by the application of pentachlorophenol or pentachlorophenoxy acetic acid but these compounds proved to be phytotoxic to rice[2)]. In Ceylon experiments on fungicidal control of Brown Spot disease conducted from 1963–64 have given disappointing results. In an area where the desease is endemic a variety of chemicals were tested repeatedly in statistically planned experiments. An assortment of formulations including copper, tin and mercury compounds, dithiocarbamates, captan, blasticidin-S, actidione, organoarsenical and others were evaluated on a growing crop. The crop received 14 spray applications at weekly intervals and uniform manurial and cultural treatments. Regardless of regular and intensive application of the sprays, none of the chemicals tested showed substantial reduction of foliage infection. While the great majority of the chemicals were not phytotoxic to rice, all organo-mercury compounds produced signs of phytotoxicity ranging from dark brown localised discolorations to withering and dieback of the leaves. Chemical control of the disease therefore will have to await the development of potent fungicides that could cause a substatial reduction of foliage infection.

4. Varietal Resistance.

Work on selection of rice varieties for Brown Spot resistance is reported from Japan, India and other countries. Ganguly and Padmanabhan evaluated 538 different rice varieties from India, China, Japan, Pakistan, the U. S. S. R, and the U. S. A. and rated the varieties Ch. 13, Ch. 45, T 141, T 498–2A, Co. 20 and BAM 10 as resistant to disease[11)]. Bedi and Gill, also working on the relative reaction of 148 rice varieties to Brown Spot considered 11 varieties to exhibit partial resistance while Ch. 972 and Ch. 996 were rated resistant. In Ceylon 191 varieties originating from Ceylon, India, Indonesia, Taiwan, Philippines, Japan etc. were evaluated from 1962–67 under severe epiphytotic conditions. The disease affecting the foliage and grain were rated rigidly and subjected to analysis. None of the varieties tested emerged to be immune or exhibited a high order of resistance. The rice varieties Ch. 13, T. 498–2A, Co. 20, T 141 and BAM 10 reputed to be resistant in India failed to exhibit an exploitable degree of resistance under Ceylon conditions. While selection for resistance to Brown Spot should be continued the present study revealed that an exploitable high order of resistance is absent or rare among *indica* rice varieties. Further, the differential resistance observed among rice varieties in India and Ceylon clearly demonstrate the existence of pathogenic strains of *H. oryzae* with varying virulence in different countries, a problem that requires sufficient recognition in selecting rice varieties for Brown Spot resistance.

5. Amelioration of Soil and Nutritional Conditions.

In the early experiments on soil ammendment two levels each of silica, magnesium and potassium were applied as a basal dressing at planting in addition to the normal fertilizers. Analysis of grain yield revealed the superiority of all treatments over the control strongly confirming that sandy soils like those in the experimental area are deficient in silica, magnesium and potassium. The disease status of the foliage and grain in the treatments, however, did not show a significant difference and may be attributed to the absence of a sufficiently severe infection of Brown Spot in the experimental area. Illustrated in Table 6 are the yield and disease responses to treatments with silica, magnesium and potassium as a soil amendment.

In later experiments, however, substantial reduction in disease of the leaf occurred with silica and potassium application. In a trial where the cumulative and combined effects of foliar spraying with potassium, phosphate and magnesium together with basal application of silica at two levels were tested a significant reduction in leaf disease occurred with silica application. Foliar feeding with potassium, phosphorus and magnesium failed to cause a

Table 6. Effect of silica, magnesium and potassium on the incidence of Brown Spot disease and grain yield

Treatment	Mean Yield Bushels per acre	Mean Disease Spot per leaf	Per cent Seed Infection
Control at optimum level of fertilizer	33.83	10.5	42.7
Silica at 100 lbs/acre	53.14	10.9	41.0
Silica at 200 lbs/acre	55.22	10.4	48.4
Magnesium at 10 lb MgO/acre	46.03	10.5	47.3
Magnesium at 20 lbs MgO/acre	45.40	12.1	49.7
Potassium at 25 lbs K_2O/acre	39.35	11.2	51.9
Potassium at 50 lbs K_2O/acre	43.90	11.9	43.9
L. S. D.	9.61	not significant	not significant

reduction in the severity of the disease. In similar trials where foliage sprays of potassium only, potassium plus magnesium and potassium, magnesium plus a mixture of trace elements containing manganese, zinc, boron and molybdenum were tested highly significant reduction in disease occurred with soil amendment by silica application only.

Baba studying the nutritional effect of silica concluded that the disease was unfavourably affected by silica deficiency. The results of these nutritional studies confirmed that amendment of silica deficiency alone could cause an increase in resistance to disease. Foliar feeding of rice plants with major and minor elements had no effect on increasing the resistance under experimental conditions employed.

Baba, Corbetta and other workers have demonstrated the importance of potassium in increasing the resistance of rice to Brown Spot. The effects of potassium in reducing the severity of the disease were determined by applying this chemical as a basal dressing at planting or in split doses. As illustrated in Table 7 crops in potassium treated plots showed increased resistance but it was not possible to distinguish statistical difference between crops receiving potassium as a basal dressing and those treated with split doses. These results have confirmed the relationship of potassium nutrition and susceptibility to Brown Spot infection in rice.

Table 7. Effect of potassium on the control of Brown Spot

Treatment				Locations					
in lbs/ acre Basal	Split			Karapincha			Bombuwela		
	2 wks.	5 after	8 trans.	Mean Dis. of leaf	Mean Dis. of grain	Yield bush/ acre	Mean Dis. of leaf	Mean Dis. of grain	Yield bush/ acre
160	0	0	0	19.75	12.86	56.63	18.60	27.20	37.64
53.3	35.6	35.6	35.6	26.25	13.84	56.64	18.55	25.25	45.14
106.6	17.8	17.8	17.8	25.00	12.45	61.04	17.18	26.35	55.29
240	0	0	0	22.75	13.93	57.04	19.08	35.38	46.31
80	53.3	53.3	53.3	20.25	13.11	57.85	16.00	27.11	53.36
160	26.6	26.6	26.6	18.50	13.71	59.16	18.55	34.20	45.95
Untreated Control:				38.75	20.43	37.91	32.38	59.31	30.86
L. S. D.				12.08	13.96	4.91	4.27	4.66	8.66

Conclusion

Although several reports on the effect of nutritional and soil conditions on the occurrence and severity of the Brown Spot disease are available, there is little evidence on the influence of climatic factors that induce epidemics. Abeygunawardena, studying the development and severity of the disease in different soils and climatic conditions found indirect evidence of the importance of climatic conditions in developing epidemics[1]. While soil conditions increase the severity of the disease interaction of climatic conditions is apparantly necessary for disease development. These climatic conditions, which require further elucidation, possibly determine the occurrence of unexpected epidemics in regions where soil conditions are generally favourable to crop growth.

Baba, studying the nutrition of the rice plant in relation to Brown Spot closely correlated the occurrence of the disease with 'akiochi' conditions in Japan[6]. In Ceylon endemicity of the disease in the wet zone is associated with imperfect sub-soil drainage, unsatisfactory soil conditions and physiological disturbance comparable to 'akiochi' conditions.

Rodrigo demonstrated the deficiency of potassium, silica, free iron and manganese in wet zone soils while Amarasiri reported that irrigation water contained lower potassium and magnesium contents than in the dry zone[14),3)]. The endemic occurrence of Brown Spot in the wet zone, therefore, could also result from imperfect nutrition and inherent deficiency of important elements required to decrease host susceptibility.

Work on the control of Brown Spot has followed several lines in most countries. While rigid selection of disease-free seed is an important step in arresting seed transmission of the disease, treatment of infected seed with organo-mercury dressings has not yielded outstanding results under field conditions employed. The treatment of infected seed would, however, be an effective insurance under soil and climatic conditions which favour disease development.

Some workers have acheived control of airborne secondary infection by prophylactic sprays, especially with organo-mercury compounds[2),4),8)]. Abeygunawardena stressed that none of the prophylactic sprays tested including several organo-mercury compounds, reduced the severity of the disease[1]. The organo-mercury compounds were found to be particularly phytotoxic to *indica* varieties of rice. Besides, mercury sprays can be absorbed by plants, giving residues which could concievably constitute a health hazard. For reasons of economy, unless prophylactic aprays can cause substantial reduction of disease and the returns from such treatment are profitable, spraying for Brown Spot control may not be warranted.

Investigations elsewhere have stressed the value of resistant varieties in controlling the disease. In Ceylon, an intensive study of 191 rice varieties revealed the absence of resistance of an exploitable high order. Thus the absence or rare occurrence of steady sources of resistance combined with the occurrence of physiologic strains of the pathogen limits the scope of employing crop resistance in combating the disease.

The most profitable control of Brown Spot and increase in host resistance is likely to be attained by soil amendment and elimination of physiological disturbances arising out of unfavourable soil conditions. In sandy soils in the wet zone where infection is generally heavy, substantial decrease in the severity of the disease has been possible with the application of silica and potassium to the soil. Foliar feeding of rice plants with major nutrients and trace elements, however, failed to decrease host susceptibility.

Discussion

T. Asada, Japan. Are there any root rots of rice in the wet zone of your country?

Answer: Yes. Root rot of rice is widespread in the wet-zone areas in Ceylon. This is attributed to sulphide toxicity, iron toxicity and due to the presence of organic acids like acetic and butyric acids in the soil. Wet-zone soils are chiefly humic or peaty and ill-drained. This has in fact introduced the problem of root-rot.

H. Oka, Japan: Do you have brown spots whose lesions are as large as these of the blast?

Answer: Blast spots vary in size considerably —the lesion size being dependent on the rice variety affected. Lesions, 1 cm long are not frequent; they are commonly up to 0.5 cm long.

E. Cada, the Philippines: Is it possible that in sandy soil type moisture content may be quite less compared with the peaty or humic and clayey or clay loam soil so that normal growth of the plant is affected and therefore, the susceptibility of the plants many have been induced.

Answer: Crops grown in sandy soils, even under inundated conditions suffer from brown spot. The reason for greater incidence of brown spot under such conditions may be due to hydrogen sulphide toxicity.

E. Cada, the Philippines: It may be noticed that Dr. Takahashi reported some varieties that are resistant to *Helminthosporium*. On the other hand, Dr. Abeygunawardena reported that in this study of 191 varieties no single variety was found resistant. I am wondering if the method of evaluation of resistant used by both of them is the same. If this is not so, it may be necessary that a uniform method of evaluating resistance of varieties may be developed.

Answer: Varieties were tested in a national epiphytotic in Ceylon. It is often extremely difficult to cause artificial epiphytotics of brown spot, unlike blast disease.

N. Murata, Japan: Some claims that loss in the yield by *Helminthosporium* leaf spot in "Akiochi" area is mainly due to such unfavorable soil condition that helps the development of the disease and not due to the disease itself. Does control of the disease by fungicide save the yield in your condition?

Answer: No fungicide treatment so far known has caused appreciable control of the disease in Ceylon.

H. Ishikura, Japan: In recent years infection of ear-neck by *Helminthosporium* became recognized in Japan. Do you have similar observation in Ceylon?

Answer: Ear-neck infection is not widely found; nevertheless under severe conditions of the disease neck infection can be recognized.

Comment by S. Akai. Japan: Actually, development of brown leaf spot may reduce the photosynthetic activity of leaves. But according to my experiments, just after the infection carbon assimilation was rather promoted, and the content of chlorophylls in diseased leaves increased when the number of spots were very small. However, the content of chlorophylls decreased, when severe outbreak of this disease occurred.

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