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RICE DISEASES - PROBLEMS AND PROGRESS

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ABSTRACT

Several rice diseases, caused by fungal, bacterial and viral pathogens, as well as nematodes, occur in Sri Lanka. Those induced by fungi include blast (*Pyricularia oryzae*), sheath blight (*Thanatephorus cucumeris*), brown spot (*Cochliobolus miyabeanus* (syns. *Drechslera oryzae, Helminthosporium oryzae*)), stem rot (*Leptosphaeria salvinii* (syn. *Helminthosporium sigmoideum*)), foot rot or Bakanae disease (*Gibberella moniliforme*) and sheath rot (*Acrocylindrium oryzae* (syn. *Sarocladium oryzae*)). The most serious disease encountered, blast, caused severe crop losses in the traditional varieties such as Pachchaiperumal 2462/11, formerly widely cultivated, and overcoming this disease was recognised early as an important research objective.Bacterial leaf blight caused by *Xanthomonas oryzae* (syn. *Xanthomonas campestris* pv. *oryzae*) has been the only bacterial disease recorded. Severe epidemics of this disease have occurred from time to time.The presence of some viruses infecting rice crops has been established. They include rice tungro bacilliform virus (RTBV), rice tungro spherical virus (RTSV), rice grassy stunt virus (RGSV) and rice ragged stunt virus (RRSV). Their impacts have yet to be accurately assessed.Two rice nematodes have been recorded, *Aphelenchoides besseyi*, which causes the white tip disease, and the root nematode, *Hirschmanniella oryzae* (syn. *Radopholus oryzae*).The principal physiological disease that occurs in this country is bronzing.Yellowing conditions have been observed from time to time. However, the factors causing them have yet to be elucidated.Twenty-seven genera of fungi have been identified as being seed-borne, the most important of which are *D. oryzae* and *Trichoconis padwickii* (syn. *Alternaria padwickii*). *P. oryzae* has never been detected in a viable form although non-viable spores have been found in a few seed samples. None of the seed-borne fungi cause serious effects in the new improved varieties cultivated when crops are raised from well-filled mature seed harvested and processed under favourable conditions. Weed species able to serve as alternate hosts for some rice pathogens occur in the vicinity of rice fields. They include *Panicum repens* and *Digitaria marginalis* for *P. oryzae*, *Cynodon dactylon, Digitaria sanguinalis* for *C. miyabeanus* and *Echinochloa colonum* for *H. sigmoideum* and *C. dactylon, Cyperus rotundus* and *E. colonum* for RGSV and RTBV. The impacts of diseases on rice crops include reduced yields, poor plant stands, loss of functional leaf tissue and weakened stems which predispose plants to lodging. Strategies to combat rice diseases adopted include the prevention of their occurrence by ensuring that the causal agents are not disseminated, the cultivation of disease resistant varieties, the adoption of cultural practices which minimise disease incidence and the application of agro-chemicals.Great emphasis has been placed on the development of disease resistant varieties. Methods have been devised and systems developed for screening against the most important diseases - blast, bacterial leaf blight and sheath blight. Resistant donors have been identified, among them Dissi Hatif, DNJ-129, Ta-poo-cho-z, Engkatek, Remadja, C-46-15, Carreon, Murungakayan 302, Tadukan, Tetep and Tres Marias for blast, BJ1, DZ 192, Malagkit Sungsong, RL Gophar and Zenith for bacterial leaf blight, and Nahn Praya 132, Ta-poo-cho-z, Pankaj, Bahagia and Remadja for sheath blight. Many thousands of hybrids emerging from breeding programmes have been screened. The performance of the most promising selections has been observed in multi-location field trials and those released as improved varieties all have adequate resistance to the major rice diseases under normal cultivation conditions. As a second line of defense against diseases, numerous agro-chemicals have been screened to select suitable fungicides and bactericides to be used if required. Those selected for controlling blast include Kasumin (kasugamycin), Hinosan (edifenphos) and Benlate (benomyl). Highly effective mercurial fungicides identified were never recommended in view of health hazards. The application of

chemicals to control other diseases has not resulted in significant yield increases, generally. Accordingly, the adoption of chemical control measures has not been recommended except in the case of blast in certain situations. Crop losses attributable to diseases are minimal at the present time. This has been achieved largely by the incorporation of resistance against the important diseases into the improved varieties now widely cultivated. This situation needs to be maintained by continued intensive research and vigilance, especially against the introduction of virulent strains of pathogens into this country from elsewhere by adopting stringent quarantine safeguards. In the recent past, seeds have been imported into the country for crop improvement from the People's Republic of China. The detection of *Tilletia barclayana* and *Ustilaginoidea virens* in consignments of hybrid seeds is noteworthy.

Key words: rice diseases, crop loss, control strategies, quarantine, Sri Lanka.

INTRODUCTION

When an individual plant, or a stand of a single plant species in a plot or field, fail to yield the expected produce under a given set of cultural and environmental conditions, the cause for this failure may be one or more factors such as diseases or pests. Rice is subject to attack by many pathogens, the agents that cause diseases - bacteria, fungi and viruses. Abnormalities are also caused by other factors such as nutritional deficiencies.

Whatever the cause, differences from normal form and performance in growing plants or developing crops are recognised by symptoms, indicators of ill-health. Such symptoms may be conspicuous. Necrotic spots or patches may appear on various plant parts such as leaves and stems. Plants may wilt and die, leaves usually showing the first signs of the condition. Plants may be reduced in size, dwarfed or deformed. The foliage may be affected by abnormal colourations such as bronzing or yellowing. The nature of the symptoms observed may often give an indication of the probable cause as with lesions which may readily be associated with fungal pathogens, and wilts which are often caused by pathogenic bacteria. However, with abnormal colourations or deviations from size and form as with yellowing, the causes are not always apparent; they may be due to nutritional deficiencies or viral infections.

Experienced farmers usually observe damage to their crops and recognise visible symptoms. Yet, they may be little aware of the sources which account for the incidence of diseases or the manner in which pathogens are transmitted. Thus, irrigation water may be a carrier of important bacterial pathogens. Weeds may serve as reservoirs or alternate hosts of pathogenic agents which are transmitted to crop plants by wind, insects or other means. Seeds harbour a variety of pathogens, not readily detected, which may cause serious problems with far-reaching consequences as when virulent pathogenic strains are introduced to places hitherto free of them. Combating problems of this nature is invariably beyond the perceptions of unsophisticated peasant farmers and the responsibility of containing them is the concern primarily of the technical establishment overseeing paddy cultivation. In discharging that responsibility, the record of the Department of Agriculture may be said to be impressive. At the present time, losses caused by diseases are negligible.

RICE DISEASES IN SRI LANKA

Till the turn of the 1960s, traditional varieties had been grown throughout the country. They were generally low yielding but were characterised by other desirable traits such as grain quality. The practice of applying artificial fertilizers, which increases the susceptibility of plants to attack by pathogens, had not been adopted to any appreciable extent. Foliar and stem diseases affected these varieties to varying extents, and with one notable exception, rice blast, caused by the fungus *Pyricularia oryzae*, they did not cause extensive damage to crops (Table 1). Perhaps, there was some kind of equilibrium existing between the pathogens and the traditional varieties cultivated which had evolved over centuries. The brown spot disease caused by the fungus *Cochliobolus miyabeanus (syns. Drechslera* oryzae, *Helminthosporium oryzae)* was common as was another similar disease, narrow brown leaf spot caused by the fungus *Sphaerulina oryzina (Cercospora oryzae*). The stackburn disease affecting the foliage caused by the fungus *Trichoconis padwickii* occurred sporadically. Stem diseases observed included stem rot and sheath blight caused by the fungal pathogens *Leptosphaeria salvinii* (syn. *Helminthosporium sigmoideum)* and *Thanatephorus cucumeris* respectively. Other fungal diseases of relatively minor importance recorded included foot rot or Bakanae disease (*Gibberella moniliforme*) (Peiris, 1951) leaf scald (*Rhynchosporium oryzae*), sheath rot (*Acrocylindrium oryzae* (syn. *Sarocladium oryzae*), and "Udbatta" disease (*Ephelis oryzae*). The most serious disease encountered was blast, the causal fungus, *P. oryzae*, severely attacking the foliage and also nodes and necks of panicles, a particularly damaging phase because it resulted in poor grain filling or sterility. Most traditional varieties were susceptible to blast which sometimes caused devastation of crops of the three months variety Pachchaiperumal 2462/11, widely cultivated in the Dry Zone because it matured in three months, an important requirement for that zone.

The only bacterial disease recorded was bacterial leaf blight (BLB) caused by *Xanthomonas oryzae* (Seneviratne, 1962), later described as *Xanthomonas campestris* pv. *oryzae*. However, it was not associated with conspicuous damage in the areas around Kandy such as Gelioya, Gampola and Aladeniya where it occurred. The situation was to change dramatically as the 1960s advanced. Serious outbreaks of the disease were observed in numerous locations all over thecountry. The Central Rice Breeding Station at Batalagoda also experienced a severe incidence of the disease. It is possible that the shift in disease severity was due to the introduction, carelessly or accidentally, of one or more virulent strains of the pathogen into this country with indiscreet seed imports and the dispersal of these strains in seeds and water. Another serious epidemic of BLB occurred at Batalagoda in 1987, also probably associated with an introduced virulent strain of the pathogen.

From time to time, yellowing conditions were observed but their cause was not established with certainty. They were the result of either site factors or viral infections. The elucidation of such problems required the commitment of more resources, facilities and expertise than national allocations, normally provided for agricultural research, could accommodate. Nevertheless, with the advent of the era of high yielding varieties and the incidence of several virus diseases such as tungro, grassy stunt and yellow dwarf in rice growing countries, the need to acquire the capability to research in depth into conditions suggestive of being induced by viral causes could no longer be ignored. New ground had to be broken in areas such as vector-borne virus diseases and seed-borne diseases. The plea that due attention be given to these needs was made at the Rice Improvement Programme Annual Research Conference in May 1983:

Table 1. Micro-organisms associated with rice diseases

Disease	Micro-organism detected*
Causal agent: Bacterium	
Bacterial leaf blight	*Xanthomonas campestris* pv. *oryzae* (Ishiyama) Dye
	Synonyms
	Xanthomonas oryzae pv. *oryzae* (Ishiyama) Swings *et al.*
	Xanthomonas oryzae (Uyeda & Ishiyama) Dowson
	Xanthomonas kresek Schure
	Bacterium oryzae (Ishiyama) Elliott
Causal agents: Fungi	
Bakanae	*Gibberella fujikuroi* (Sawada) Wollenworth (teleomorph)
	Synonyms
	Gibberella moniliforme (Sheldon) Wineland
	Lisea fujikuroi Sawada
	Fusarium moniliforme Sheldon (anamorph)

	Synonyms *Fusarium fujikuroi* Nirenberg *Fusarium verticillioides* (Saccardo) Nirenberg.
Blast	*Pyricularia oryzae* Cavara (anamorph) Synonyms *Pyricularia grisea* (Cooke) Saccardo *Magnaporthe grisea* (T. T. Hebert) Yaegashi & Udagawa (teleomorph) Synonym *Dactylaria oryzae* (Cavara) Sawada
Brown spot	*Bipolaris oryzae* (Breda de Haan) Shoemaker (anamorph). Synonyms *Drechslera oryzae* (Breda de Haan) Subramanian. & P. C. Jain; *Helminthosporium oryzae* Breda de Haan *Cochliobolus miyabeanus* (Ito & Kuribayashi) Drechsler ex Dastur (teleomorph)
Leaf scald	*Microdochium oryzae* (Hashioka & Yokogi) Samuels & Hallett (anamorph) Synonyms *Geralchia oryzae* (Hashioka & Yokogi) W. Gams; *Rhynchosporium oryzae* (Hashioka & Yokogi) *Monographella albescens* (Thümen) Parkinson, Sivanesan & Booth (teleomorph) Synonyms *Metasphaeria albescens* Thümen *Micronectriella pavgii* R.A. Singh *Griphosphaerella albescens* (Thümen) van Arx
Narrow brown leaf spot	*Cercospora janseana* (Racib.) O. Const. (anamorph) Synonyms *Cercospora oryzae* Miyake *Sphaerulina oryzina* K. Hara (teleomorph)
Sheath blight	*Rhizoctonia solani* Kühn (anamorph) *Thanatephorus cucumeris* (Frank) Donk (teleomorph) Synonyms *Corticium solani* (Prill & Delacr.) Bourd & Galz. *Pellicularia filamentosa* (Pat.) Rogers
Sheath rot	*Sarocladium oryzae* (Sawada) W. Gams & D. Hawksworth (anamorph) Synonym *Acrocylindrium oryzae* Sawada
Stackburn	*Alternaria padwickkii* (Ganguly) M. B. Ellis (anamorph) Synonyms *Trichoconis padwickkii* Ganguly *Trichoconiella padwickkii* (Ganguly) Jain
Stem rot	*Magnaporthe salvinii* (Cattaneo) R. A. Krause & R. K. Webster (teleomorph) Synonym *Leptosphaeria salvinii* Cattaneo, *Sclerotium oryzae* Cattaneo (anamorph) Synonyms

	Helminthosporium sigmoideum Cavara *Nahataea sigmoidea* Hara *Vakrabeeja sigmoidea* (Cavara) Subramanian *Curvularia sigmoidea* (Cavara) Hara
"Udbatta"	*Ephelis oryzae* Sydow (anamorph) Synonym *Ephelis pallida* Pat. *Balansia oryzae* (Sydow) Narasimhan & Thirum. (teleomorph) Synonym *Balansia oryzae* - sativa Hashioka
Causal agents: Nematodes	
Root knot	*Hirshmaniella oryzae* (van Breda de Haan) Lue & Goodey Synonyms *Tytenchus oryzae* van Breda de Haan *Tytenchus apapillatus* Imamura *Anguillulina oryzae* (van Breda de Haan) T. Goodey; *Rotylenchus oryzae* (van Breda de Haan) filipjev & Schuurmans Stekhoven *Radopholus oryzae* (van Breda de Haan) Thorne; *Hirshmania oryzae* (van Breda de Haan) Lue & Goodey; *Hirshmaniella nana* Siddiqi
White tip	*Aphelenchoides bessayi* (Christi) Drozdovski Synonym *Aphelenchoides oryzae* Yokoo.
Causal agents: Viruses	
Stunting, yellow-orange leaves	Rice tungro (bacilliform) badnavirus (RTBV) Synonym Rice yellow orange leaf virus
Slight stunting, yellowing	Rice tungro (spherical) waikavirus (RTSV) Synonyms Rice leaf yellowing virus Rice yellow leaf virus
Stunting, excessive tillering, pale green leaves	Grassy stunt tenuivirus (RGSV) Synonym Rice rosette virus
Stunting, ragged leaves, enations	Ragged stunt oryzavirus (RRSV) Synonym Rice infectious gall virus

* Synonyms from references: Agarwal *et* al. (1989); Descriptions of pathogenic fungi and bacteria, C.A.B International Mycological Institute; Descriptions of plant parasitic nematodes, C.A.B. Commonwealth Institute of Helminthology; Ou (1985); Plant viruses online: Descriptions and Lists from the VIDE Database; and Rice Doctor, (2003), International Rice Research Institute;

"In rice pathology, we have been on the right course. Yet, we have concentrated on the more 'applied' aspects. Now, we must go more deeply into areas we have not probed sufficiently before, perhaps some "basic" aspects too. Our younger researchers who show ability and promise must be developed as competent scientists encouraged to study them. We have been concerned for a long time about the seed transmission of diseases. Only recently have we acquired a capability to research into this field in depth. We are now better able to research into diseases where the causal agents persist in the soil. We need a more specialised capability to probe bacterial diseases such as bacterial blight. That capability is presently being developed in one of our younger researchers. We must be prepared to face the challenge from vector transmitted virus diseases. We have yet a long way to go to acquire that capability. But we know the direction in which we have to move and we are aware of the problems before us." (Seneviratne, 1983).

From about the late 1970s, conditions, the causes of which were not readily diagnosed, were encountered. Sometimes, conclusions were drawn unsupported by experimental evidence. So in the celebrated ragged stunt fiasco in 1978, environmental stresses and gall midge infestation, which caused abnormalities such as nodal tillering, were, without investigation, attributed to a viral cause by a local "big noise" propped up by a foreign hireling.

In 1983, a yellowing condition was reported from the Ampara District. The variety Bg 94-1, extensively cultivated there, was affected. The cause of the condition was not clear. The tracts in which it was observed had certain distinctive features and the factors operative in them and their interplay were not fully understood. They were in a region developed for irrigated farming with fields served by irrigation channels. Crops grown in them were subjected to periodic flooding, fluctuating water tables and drainage problems accompanied by changes in the levels of macro- and micro- nutrients. The indiscriminate and heavy application of pesticides was aggressively promoted by distributors who made huge profits from the sale of agro-chemicals. Rice crops were subjected to a variety of stresses under those conditions and appropriate traits were required of the varieties cultivated there to withstand the stresses imposed. The limited investigations conducted by a multi-disciplinary team did not establish the cause of the condition. Although the incidence of the green leaf hopper, *Nephotettix* sp., was observed in these fields, the yellowing condition was not transmitted by this vector species in transmission tests.

In Maha 1983/84 much publicity was given to a yellowing condition that occurred in the Hambantota District, "kaha rogaya". The Deputy Director of Agriculture (Extension), uninformed about virus diseases, attributed the condition to the ragged stunt virus, a myth that was widely propagated by the media. In the Hambantota District, crops were affected while yet in an early stage, large contiguous tracts developing yellowing symptoms. Virus transmitting vectors were not present in any great numbers. There was too little time, considering the stage of the crops affected, for the vectors to acquire the virus from whatever source available, for its incubation within the insect vector and its transmission thereafter to rice plants and for the plants so infected to develop symptoms. It was unlikely that the real cause of the yellowing condition observed was a virus, although viruses were detected in some samples sent to the International Rice Research Institute (IRRI) by employing techniques requiring sophisticated equipment available there. However, the Cabinet was misinformed and ill-advised by the relevant authorities when it approved Rs 15 million to spray 50,000 acres of paddy in the Hambantota District "to counter the yellow disease" now positively identified as a virus spread by the brown plant hopper according to a newspaper report (The Island, 15.12.1984). Afterwards, the clamour about "kaha rogaya" and the ragged stunt virus died down, unworthy short-term objectives having been achieved by unscrupulous elements. As at Ampara, areas to be researched in depth failed to get the attention with the Hambantota problem too. In that region also, nature had been drastically tampered with in expanding agricultural activities - forests cleared, rainfed lands irrigated, heavy machinery used on fragile soils, alien germplasm incorporated in newly bred varieties, chemical fertilizers applied and agro-chemicals poured liberally into cropped lands. There are many areas relating to the effects of these changes and inputs and their interrelationships about which little is known and about which experiences in other countries have flashed alarm signals. Intensive studies need to be done on rice virus diseases too. Until appropriate approaches to elucidate such problems are formulated and implemented, abnormalities in rice crops will continue to occur, their real causes not identified with certainty.

During the Maha 1964/65 season, a survey of the yellowing malady in the central region of Sri Lanka which includes the Kandy and Matale Districts was done by Peries, Wijesekera and Bandaranayake (Peries *et al* 1965). They made collections from 45 locations and samples were tested by ELISA at IRRI for the presence of rice tungro bacilliform virus (RTBV), rice tungro spherical virus (RTSV), grassy stunt virus (RGSV) and ragged stunt virus (RRSV). The results indicated that 53% of the field samples were infected with RGSV, 49% with RRSV, 58% with RTSV and only 4% with RTBV. However, typical symptoms of any viruses were not observed during the survey. It was concluded that this could either be due to late infection of the plants or viruses being latent in them. Also, the yellowing disorder observed in the field could not be experimentally transmitted by the green leafhopper. It was suspected that the widespread yellowing disorder observed in the survey was due to a severe strain of RGSV. In this preliminary survey, the presence of RTBV and RTSV were confirmed for the first time.

Symptoms, resembling those of certain virus diseases, had been observed in this country in various locations in the mid 1960s. On the basis of symptoms and transmission studies with insect vectors, Abeygunawardena (1967) reported the presence of three virus diseases here - orange leaf, yellow dwarf and grassy stunt.

Diseases caused by nematodes have also been recorded in Sri Lanka. *Aphelenchoides besseyi*, the nematode which causes the white tip disease was found to be very common in seed paddy in the early 1960s (Peiris, 1962). The root nematode *Hirschmanniella oryzae* (syn. *Radopholus oryzae)* was also recorded in the early 1960s (Seneviratne, 1962).

The principal physiological disease that occurs in this country is bronzing. It is common in ill-drained paddy tracts. The leaf spot disease caused by *H. oryzae* is largely induced by nutritional deficiencies. Not infrequently, diseases occur when crops are raised on poor soils and not properly fertilized as was demonstrated by the high incidence of stem rot caused by *H. sigmoideum* in the Matara District in 1965 and in other places.

THE IMPACTS OF RICE DISEASES

Diseases make their impacts essentially in two ways. Firstly, by adversely affecting seed germination and seedling establishment which result in poor stands, and secondly, by preventing the normal functioning of plant parts to varying extents consequent on the damage to plants by pathogenic agents.

Seedbed problems occur mainly because of the use of seed paddy of inferior quality. Normally, farmers take great care to set aside good seed for use during the subsequent season. However, the practice of securing seed paddy from other sources such as the Department of Agriculture has increased consequent on the development of the improved high yielding varieties. Occasionally, paddy used for seed purposes may have been subjected to adverse conditions at the time of harvesting or not properly processed. Imperfectly dried seed provides conditions for fungal infestation which could result in seed failures and poor stands.

Seedling diseases are caused by seed-borne pathogens. Seed transmission of pathogenic agents also poses a serious threat as new and virulent strains of such pathogens as *P. oryzae* and *X. oryzae* could be introduced to areas free of them. This danger is especially present when seeds are introduced from other countries or regions where virulent pathogenic strains exist. These dangers emphasise the need for healthy seed which could produce vigorous stands, a prime requisite for successful crop production. They also underline the importance of observing precautions dictated by plant quarantine.

The impacts of diseases may be observed on all parts of plants which develop symptoms when attacked by pathogens. However, the most conspicuous effects are produced on the foliage. The loss of fully functional leaf area is accompanied by reduced yields. Leaf spots caused by such fungi as *C. miyabeanus* and *S. oryzina* generally do not render a large extent of leaf area ineffective. However, with the blast fungus, *P. oryzae,* extensive damage could occur to the foliage with spreading lesions which later coalesce and destroy the leaves. This fungus also attacks nodes and panicles resulting in considerable damage. Thus, in a severely affected crop of Pachchaiperumal at Karadian Aru, a yield loss of the magnitude of 92% has been recorded. Pathogens which attack the foliage and especially the flag leaf after flowering such as *X. oryzae* prevent normal grain filling and the development of well-formed panicles. Sterility to varying extents will also occur.

Fungal pathogens such as *T. cucumeris* and *A. oryzae* affect the stems, infections being conspicuous in the extensive brown lesions they induce. The damage they cause, besides impairing the normal functioning of affected plants, also weaken them mechanically and predispose them to lodging. Sheath rot restricts emergence and the normal development of panicles.

The nature of the effects of diseases on crop losses depends on the stage at which crops are attacked, how wide spread a disease is, and the extent of the damage caused. Invariably, there will be some reduction of yield. The thrust of measures to control diseases is therefore directed to reducing such yield losses. This has been the objective vigorously pursued in the research done by the Department of Agriculture.

COMBATING RICE DISEASES

Strategies in combating rice diseases include the prevention of their occurrence by ensuring that the causal agents are not disseminated, the cultivation of resistant varieties which could withstand attack by pathogens, the adoption of cultural practices where feasible to reduce disease occurrence and the application of agro-chemicals in so far as they are practical, effective and economical to control the causal agents. All these measures can be adopted simultaneously, each to varying extents as appropriate.

PREVENTIVE MEASURES

Seeds are an important determinant of the health of crops. Accordingly, the use of good seed, free of disease inducing pathogens and in a physiologically good condition to produce vigorous seedlings is of the utmost importance in combating disease problems. Seed pathology addresses these aspects.

Alternate hosts of rice pathogens and the stubble and ratoons of infected crops serve as important reservoirs of infection by providing primary inoculum. Eliminating such sources can facilitate the production of healthier crops.

Cultural practices too influence the incidence of diseases and the extent of their severity. Attention to aspects which could reduce the occurrence of diseases can play an important role in improved crop production.

Seed-borne pathogens of rice

A comprehensive study was done on the fungi seed-borne in rice (Jeyanandarajah and Seneviratne, 1990) where a method devised using locally produced earthenware dishes (Jeyanandarajah, 1983) was used to advantage (Plate I). Seed samples used in this study were of the improved varieties from crops grown in both the Maha and Yala seasons from Karadian Aru, Mahailluppallama, Paranthan and Polonnaruwa in the Low Country Dry Zone, Alutharama and Batalagoda in the Low Country Intermediate Zone, Bombuwela and Labuduwa in the Low Country Wet Zone and Gampola in the Mid Country Wet Zone. Samples were also collected from selected fields where sterility was observed at Gampolawela, Pasgama and Marassana in the Mid Country Wet Zone and from crops where blast was observed at Udupihilla and Tenna in the Mid Country Intermediate Zone.

Twenty-seven genera of fungi were identified in these samples (Table 2). The most important pathogens recorded were *D. oryzae* and *T. padwickii*. Although non-viable spores of *P. oryzae* were found in some seed samples, the fungus was never isolated in a viable form. Fungi were detected in seed samples from all the agro-ecological regions of the country sampled (Plate II). However, there were differences in the extent of seed infection in different locations (Table 3), seasons and cultivars (Figures 1 & 2). 'Seed spotting' was a symptom widely prevalent, the fungi commonly associated with this condition being species of *Curvularia* and to a lesser extent, *D. oryzae, T. padwickii* and *Fusarium* spp. None of these seed-borne fungi caused serious effects in the new improved cultivars when crops were raised from well-filled mature seed which had been harvested and processed under favourable conditions. The results of this study indicated that the new improved cultivars widely grown in Sri Lanka are not adversely affected by endogenous seed-borne fungi. In particular, they have adequate resistance to indigenous races of the blast fungus, *P. oryzae*, but as numerous races of this pathogen occur elsewhere, every precaution must be taken to ensure that virulent races do not enter the country. For instance, the variety Tetep, which is highly resistant to local races of *P. oryzae* is attacked by races of the fungus present in the Philippines and Pakistan. Their introduction into this country will be accompanied by disastrous consequences. The importance of adopting necessary precautions to prevent this happening cannot be over-emphasised.

Captions for Plate I

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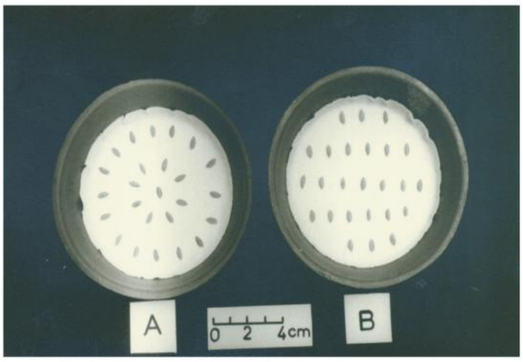
Plate I



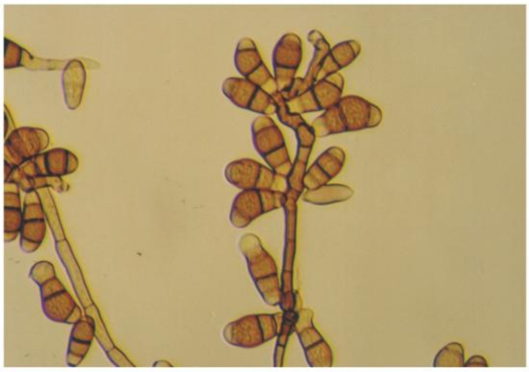


Plate I

1. Placement of seeds in earthenware dishes.

2. Shelves of the irradiation room fitted with banks of black light tubes and white cool fluorescent tubes controlled by a time switch to induce sporulation of fungi in incubation tests.

3. Growth of *Aspergillus flavus* on the seed surface as seen under the stereoscopic microscope (X20).

4. Growth of *Aspergillus* spp. on the seed surface and spread on the blotter as seen under the stereoscopic microscope (X10)..

5. Seed covered with the growth of *Curvularia lunata* as seen under the stereoscopic microscope (X15).

6. Conidia and conidiophore of *Curvularia lunata* as seen under the compound microscope (X 400).

The bacterial pathogen, *X. oryzae*, which causes leaf blight, is also seed-borne and it exists as different strains in various countries. In these case too, while strains of the pathogen occurring locally do not cause severe damage to the new improved cultivars, those like the Isabella strain, if introduced, may change this situation and its entry into this country must be prevented by adopting appropriate precautions.

Figure 1. Histogram showing average percentages of *Drechslera oryzae,* ; *Trichoconis padwickii,* ; and *Fusarium* spp., in seed lots from rice crops of different cultivars grown at Bombuwela in the 1977/78 Maha season.

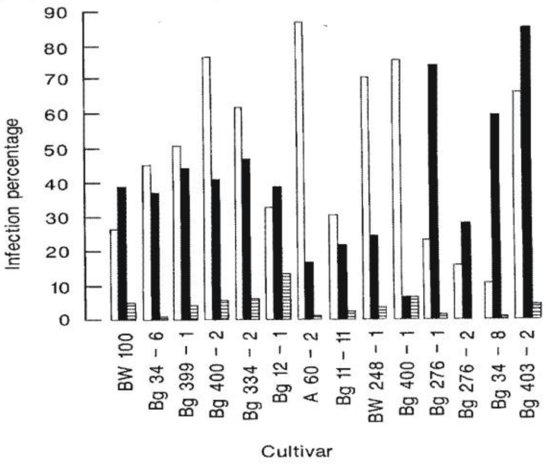


Figure 2. Histogram showing average percentages of *Drechslera oryzae*, ; *Trichoconis padwickii*, ; and *Fusarium* spp., in seed lots from rice crops of different cultivars grown at Bombuwela in the 1978 Yala season.

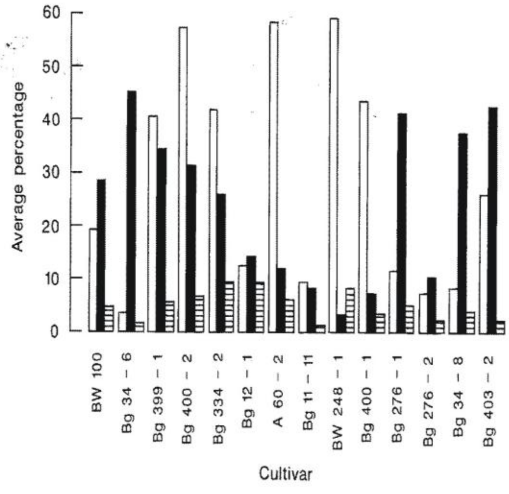


Table 2. Fungi detected in incubation tests on rice seeds from locally grown crops

Acrocylindrium oryzae Sawada, syn. *Sarocladium oryzae* (Sawada) W. Gams & D. Hawskw.
Alternaria longissima Deighton & Mac Garvie
Alternaria tenuis C. G. Nees, syn. *Alternaria alternata* (Fr.) Kiessler
Alternaria spp.
Aspergillus flavus Link ex Fries
Aspergillus niger Van Tieghem
Aspergillus ochraceus Wilhelm
Cephalosporium sp.
Cercospora oryzae Miyake
Chaetomium funicola Cooke
Chaetomium globosum Kunze ex Steud.
Chaetomium sp.
Cladosporium oxysporum Berk. & Curt.
Curvularia affinis Boedijn
Curvularia clavata Jain
Curvularia fallax Boedijn
Curvularia intermedia Boedijn state of *Cochliobolus intermedium* Nelson
Curvularia lunata (Wakker) Boedijn state of *Cochliobolus lunatus* Nelson
Curvularia pallescens Boedijn
Curvularia senegalensis (Speg.) Subram.
Curvularia verruculosa Tandon & Bilgrami ex M. B. Ellis
Drechslera hawaiiensis (Bugnicourt) Subram. & Jain ex M. B. Ellis
Drechslera oryzae (van Breda de Haan) Subram. & Jain, syns. *Helminthosporium oryzae* van Breda de Haan, *Ophiobolus miyabeanus* (Ito & Kuribay) Drechsler ex Dastur
Drechslera rostrata (Drechsler) Richardson & Frase state of *Setosphaeria rostrata* Leonard
Drechslera sorokiniana (Sacc.) Subram. & Jain, syns. *Helminthosporium sorokinianum* Sacc., *Helminthosporium sativum* Pamm. King & Bakke, *Cochliobolus sativus* (Ito & Kuribay) Drechsler ex Dastur
Drechslera tetramera (McKinney) Subram. & Jain
Epiccoccum sp.
Fusarium dimerum Penzig
Fusarium equiseti (Corda) Sacc.
Fusarium fusarioides (Frag. & Cif.) Booth
Fusarium moniliforme Sheldon
Fusarium semitectum Berk. & Rav. syn. *Fusarium pallidoroseum* (Cooke) Sacc.
Fusarium solani (Mart) Sacc.
Macrophomina phaseolina (Tassi) Goid
Magnaporthe salvinii (Catt.) Krause & R. K. Webster, syns. *Leptosphaeria salvinii* Catt., *Helminthosporium sigmoideum* Cav., *Sclerotium oryzae* Catt.
Myrothecium roridum Tode ex Fr.
Myrothecium verrucaria (Alb. & Schw.) Ditman ex Fr.
Nigrospora oryzae (Berk & Br.) Petch, syn. *Khuskia oryzae* Hudson
Penicillium oxalicum Currie & Thom.
Penicillium spp.
Phoma multirostrata (Mathur *et al*.) Dorenbosch & Boerema
Phoma sorghina (Sacc.) Boerema, Dorenbosch & Van Kest, syn. *Phoma insidiosa* Tass.
Phoma sp.
Phomopsis oryzae Punith.
Pyrenochaeta sp.
Rhizopus spp.
Sordaria sp.
Stemphylium sp.
Trichoconis padwickii (Ganguly), syn. Alternaria padwickii (Ganguly) M.B.Ellis
Trichoderma hamatum (Bon.) Bain. aggr.
Trichoderma harzianum Rifai aggr.
Trichothecium roseum (Pers.) Link ex S. F. Gray

Table 2. Continued....

Verticillium sp.

Plate II

Captions for Plate II

1		2
3		6
4	5	7

1. Fungal growth on seeds after incubation.
2. Fungal growth on inert matter after incubation.
3. Conidia and conidiophore of *Drechslera oryzae* on seed surface as seen under stereoscopic microscope (X 50).
4. Conidia of *Drechslera oryzae* as seen under lower power of compound microscope (X 100).
5. Conidium of *Drechslera oryzae* as seen under higher power of compound microscope (X 400).
6. Fruiting structures of *Pyrencochaeta* sp. on seed surface as seen under stereoscopic microscope (X 50).
7. Spores seen of *Pyrenochaeta* sp. under compound microscope (X 200).

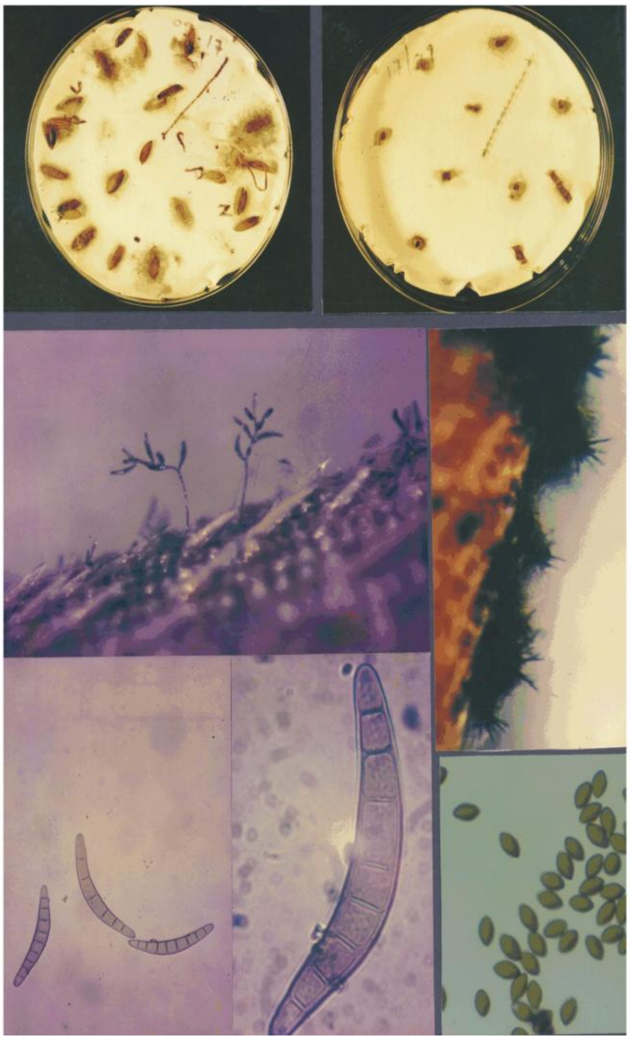


Table 3. Percentage infections of fungi recorded on seeds of the rice cultivar Bg 34-8 from crops grown at six different locations during the 1978/80 Maha season and their percentage germination on blotter and in sand.

Fungi	Location					
	Aluthharama	Batalagoda	Bombuwela	Paranthan	Gampola	Polonnaruwa
Drechslera oryzae	05	10	07	03	63	02
Fusarium spp.	00	02	07	11	07	00
Trichoconis padwickii	14	25	84	35	43	41
Germination in blotter	98	94	60	88	65	67
Germination in sand	94	73	58	84	73	73

Introduction of pathogens with imported seeds

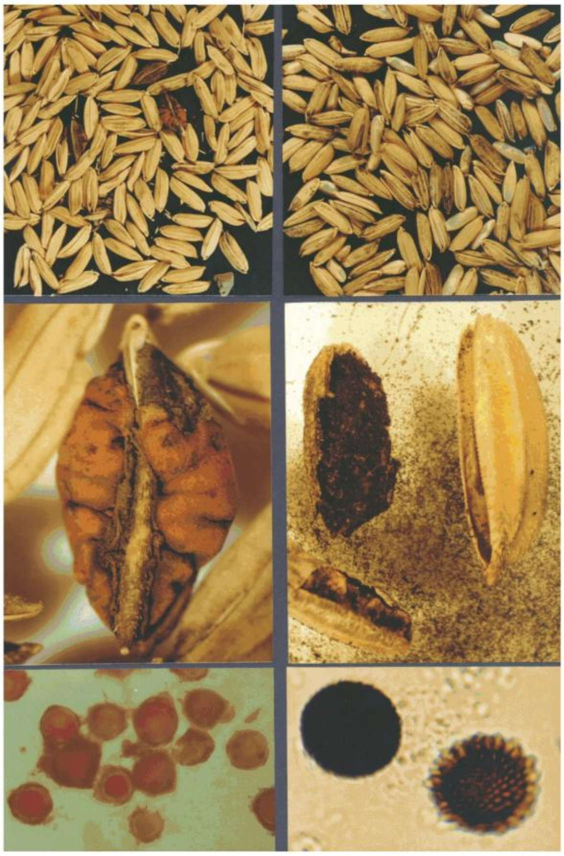
At the present time, there is an extensive international movement of seeds in trade and for research purposes. Recently, hybrid rice seeds were imported into Sri Lanka from the Peoples' Republic of China for crop improvement programmes. When tested for their health status, bunted grains (*Tilletia barclayana*) and abnormal seeds due to the false smut fungus, *Ustilaginoidea virens* were detected in the consignments received (Plate III). Other pathogens observed in these samples included *C. oryzae, D. oryzae, Sarocladium oryzae* and *X. oryzae* (Jeyanandarajah and Gamage, 2000).

Seed transmission of pathogens has resulted in the introduction of many diseases into various countries over the years (Baker, 1972, Neergaard, 1979). A classic example is the introduction of *Tiltetia caries,* which causes bunt of wheat, to the USA from Australia about the middle of the nineteenth century. Another danger is the introduction of new pathogenic races with infected seed. A good example is the introduction of Asian races of the blast fungus, *P. oryzae* to Burkina Faso with seeds of new rice varieties introduced from The International Rice Research Institute which devastated rice crops in that country in 1971 (Neergaard, 1979).

The risk of introduction of seed-borne pathogens has greatly increased in recent times with greater use of hybrid seeds and readily available air transportation facilitating the wide distribution of seeds. Accordingly, efforts need to be intensified to mitigate dangers from seed introductions.

With seeds imported for breeding purposes, it is important that the whole sample be subjected to adequate examination and tests to ensure freedom from infection with such pathogens as those causing bunt and smuts besides the pathogens which exist as numerous races.

Plate III



Captions for Plate III

1	4
2	5
3	6

1. Seed lot imported from The Peoples' Republic of China showing concomitant contamination with abnormal Seeds, stones and chaff.
2. Hybrid seed paddy imported from The Peoples' Republic of China infected with *Ustilaginoidea virens* showing abnormality.
3. Sticky spores of *Ustilaginoidea virens* (X 400).
4. Seed lot imported from The Peoples' Republic of China showing concomitant contamination with bunted grains and inert matter.
5. Hybrid seed paddy imported from The Peoples' Republic of China infected with kernal smut showing ruptured glumes containing a black powdery mass of spores of *Tilletia barclayana.*
6. Teliospores of *Tilletia barclayana* (X 400).

Alternate hosts of rice pathogens

Several pathogens of rice are able to infect other plant species as well. Sources of infection may continue to exist around rice fields long after diseased crops have been harvested and crop residues disposed of. Graminaceous species from part of the permanent vegetation cover in the vicinity of fields, on bunds and along channels. They may serve as alternate hosts in which rice pathogens can perpetrate from season to season and provide the initial inoculum for the occurrence of a disease even when healthy seed is used. Thus, two common grasses, *Panicum repens* and *Digitaria marginalis* serve as alternate hosts for the blast fungus, *P. oryzae*. *C. miyabeanus* perenates in *Cynodon dactylon* and *Digitaria sanguinalis*. *Echinochloa colonum* is an alternate host for *H. sigmoideum*. Symptoms similar to those associated with some of the rice virus diseases have also been observed in weed species and some grasses identified as alternate hosts. *C. dactylon Cyperus rotundus* and *E. colonum* are associated with tungro and grassy stunt. Little or nothing is known about the role, if any, played by graminaceous hosts in the incidence of the various yellowing conditions, if virus induced, in this country.

Research on the incidence of various diseases in the past has identified plant species which could facilitate epidemics. It is prudent that they be excluded as far as possible from the vicinity of rice fields, especially when disease outbreaks occur and alternate weed hosts provide opportunities for the causal pathogens to perpetrate in them.

Cultural practices for containing disease incidence

Favourable environmental conditions which enhance the activity of pathogens are conducive to the greater incidence of rice diseases. No control can be exercised over such factors as rain, wind or temperature favouring disease incidence. However, several cultural practices can be adopted in containing diseases.

Field sanitation is an aspect which can play an important role in the production of healthier crops. After harvest, crop residues as stubble or straw can provide inoculum for a succeeding crop to be infected with diseases such as sheath blight and stem rot because *sclerotia* persist in infected material. Infected straw can also serve as a reservoir of the causal agents of blast and bacterial leaf blight carried especially on leaves. It is therefore advisable to eliminate infected crop residues so as to ensure an environment as free as possible of primary inoculum.

Stubble remaining in paddy fields after crops have been harvested serves as reservoirs for viruses also. Where virus diseases such as tungro or grassy stunt occur, these viruses will be present in the ratoon growth providing a source of infection for the spread of virus diseases by insect vectors. Such sources of infection should also be eliminated.

Practices followed in planting, fertilizing and other operations can also influence the incidence of diseases and their severity. In the Ampara District, for instance, where broadcasting is the normal practice, an excessively high/rate of 5-7 bushels/acre is used resulting in conditions favourable for the incidence of sheath blight. High seed rates and dense planting should be avoided. In the application of fertilizers too, there is often a tendency to deviate from the recommended practices; an excess of nitrogenous fertilizer is often applied. This shifts the situation in favour of increased pathogen activity, especially with foliage diseases.

Measures which minimise disease incidence as above have been recognised and recommended which, when adopted, with other strategies can considerably reduce the occurrence and spread of rice diseases.

The cultivation of disease resistant varieties

Crop losses, especially in the Dry Zone, had identified blast as the principal disease problem to be overcome for increased rice production. Accordingly, breeding rice varieties resistant to blast had been recognised as an important objective when more serious attention was given to rice production after the attainment of independence.

In developing rice varieties resistant to blast, donors of resistance were a prime requisite. There were already a large number of varieties which had been cultivated in this country for centuries. Other countries in South and South East Asia and elsewhere also had rice cultures; donors of resistance may be found among varieties cultivated in those countries too.

Intensive research on identifying donors of resistance was initiated towards the end of the 1950s. A method for evaluating varietal resistance of paddy varieties in upland nurseries, developed by H. Okamoto was modified and used by Peiris and Marks (1958) In screening a large number of varieties under conditions of induced infection.

Indigenous varieties with high resistance to blast identified in these tests included Murungakayan 302, Murungakayan 304, SR 26B, Periavellai 538 and VI 26061. Crosses from breeding programmes were similarly screened in highland nurseries and their reaction to blast determined. Since then, this programme of testing and evaluating varieties and crosses emerging from breeding programmes of the various departmental stations has continued. The highland nursery technique was further improved by Seneviratne (1967) with a nursery lay out in which infector beds alternated with screening beds thereby enabling greater disease pressures and more uniform infection (Plate IV). After the International Rice Research Institute (IRRI) was established in the Philippines in 1962, one of the thrusts of the Institute was also to incorporate blast resistance into rice varieties which were to be developed. This led to the initiation of the International Uniform Blast Nurseries programme in which Sri Lanka also participated. Varieties with high resistance to blast identified in this country included Dissi Hatif, DNJ-129, Ta-poo-cho-z, Engkatek, Remadja, G-46-15, Carreon, Murungakayan 302, Tadukan, Tetep and Tres Marias.

Plate IV

Captions for Plate IV

1
2

1. Screening of rice lines against blast in highland nurseries at Getambe. Note the heavily infected buffer beds and disease indicator lines in the varietal beds sown with Pachchaiperumal completely killed by the disease, and test lines showing various degrees of resistance in between.
2. Mass screening of test lines for resistance to bacterial leaf blight, involving skilled workers in the field at Getambe for the inoculation process.

The blast fungus exists as many races and different races occur in different places. Accordingly, multi-locational testing was desirable to identify those varieties which showed high resistance in various situations. In the early stages of the blast-screening programme, Peradeniya and Karapincha served as testing sites. Later, Karadian Aru was also found to be a good testing station while an excellent facility was developed at Getambe in the 1970s where many hundreds of lines were screened every season. In more recent times, this programme has contracted and the adverse effects of this neglect are likely to be experienced in the years to come.

As bacterial leaf blight came into prominence, a programme similar to that for screening against blast, was also initiated to identify donors of resistance to the disease and to evaluate crosses emerging from the departmental breeding programmes. It was conducted in two phases, the first under induced infection by inoculation with virulent isolates of the pathogen in the nursery at Getambe (Seneviratne *et al* 1972) (Plate IV) followed by field evaluations in a nursery at Ambalantota under conditions of natural infection. The IRRI initiated an international programme of testing and collaboration was maintained with this programme too. The varieties with good resistance to BLB identified included BJ 1, DZ 192, Malagkit Sungsong, RL Gophar and Zenith.

A screening programme was also conducted for sheath blight and once again, collaboration was maintained with the IRRI which also launched an international programme. A method of testing was developed (Seneviratne, 1974) and the screening nursery was sited at Getambe. Varieties identified as having good resistance included Nahn Praya 132, Ta-poo-cho-z, Pankaj, Bahagia and Remadja.

While the screening programmes under conditions of induced infection yielded valuable information, such heavy disease pressures were rarely encountered under natural conditions. Accordingly, another evaluation was done on the performance of selected varieties under normal field conditions in several locations. The Co-ordinated Rice Varietal Trials (CRVT) programme initiated by Dr J W L Peiris, Deputy Director of Agriculture (Research) was designed to determine the performance of the most promising varieties emerging from the Department breeding programmes. Trials were established at a number of stations including Bombuwela, Karapincha and Labuduwa in the Low Country Wet Zone, Alutharama and Batalagoda in the Intermediate Zone, Gampola in the Mid Country Wet Zone, and Ambalantota, Karadian Aru, Malwatta and Paranthan in the Dry Zone. Evaluations were made of the performance against diseases of varieties in these trials. This approach of dual evaluations, under induced high disease pressures as well as normal field conditions has enabled a reliable assessment of the varieties eventually released from the Department. Suffice it to say that those released have been able to withstand diseases under normal cultivation conditions in the various regions of the country with virtually no serious losses attributable to diseases.

The control of rice diseases with agrochemicals

Recourse to agro-chemicals is one of the common strategies adopted to control diseases. Where varieties susceptible to diseases are grown, their protection by fungicides or bactericides may become necessary when conditions favour the incidence and spread of diseases which may lead to severe crop losses.

Blast was the most feared disease affecting rice prior to the advent of varieties able to withstand the disease. At first, copper based fungicides were recommended against blast. Later, various organic and inorganic fungicides were tested for their fungistatic efficacy by observing their ability to inhibit the germination of *Pyricularia* spores on glass slides (Abeygunawardena and Peiris, 1958). In these studies, ferric dimethyl dithiocarbamate was found to be highly effective even at very low dosages. However, it was felt that it will not be as Effective under epiphytotic conditions in the field.

In the 1950s, fungicides based on mercuric compounds had been developed and used in Japan for blast control. In preliminary studies, phenyl mercuric acetate dust was found to be highly toxic to some local varieties and in a subsequent series of experiments. Marks and Peiris (1959) tested a number of mercurial formulations for their efficacy and phytotoxicity by screening them in upland nurseries. The fungicides in these experiments included dusts and wettable powders. The mercury-compounds used as active ingredients included phenyl mercuric acetate, phenyl mercuric paratoluene sulphon anilide, phenyl mercuric dinaphthyl methane disulphonate, ethyl mercuric chloride and ethyl mercuric phosphate. Lime was added to the dusts.

The mercurial fungicides were all superior in efficacy to fermate. The alkyl dusts, ethyl mercuric chloride with lime and ethyl mercuric phosphate with lime were selected as being the most suitable of the treatments evaluated for controlling blast while preparations based on phenyl mercuric acetate were found to be very toxic to the indica varieties. However, in view of the toxic hazards associated with mercury, mercurial fungicides were never recommended for blast control. In retrospect, this was a wise decision as the consequences of mercury poisoning were experienced several years later when the Minamata disease crippling humans occurred in Japan.

In the 1960s, fungicides based on organotin compounds were developed. Fungicides with triphenyltin acetate (Brestan 60) and triphenyltin hydroxide (Dut'er) as active ingredients were tested against blast by Seneviratne (1967). However, they too were phytotoxic to the indica varieties and did not perform as well as expected. In preliminary tests, the recently developed propineb formulation, Antracol, showed much promise as a non-mercury fungicide effective against blast (Seneviratne, 1965). However, the commercial product later distributed did not prove as effective as the test samples initially evaluated. Kasumin, an antibiotic formulation based on kasugamycin was selected by Abeygunawardena (1965) as more effective than products previously recommended. It gave reasonable control of the blast fungus and had no drawbacks from the point of view of phytotoxic effects. Other products later evaluated by the highland nursery technique and in field trials included the systemic fungicide, Benlate, based on benomyl (Seneviratne and Fernando, 1972; Seneviratne, 1980), and the products Derosal and Bavistin with carbendazim as active ingredient as well as the edifenphos based products, Hinosan and Hinosan TCP. Some of them, though effective, were not recommended because they were prohibitively expensive or unsuitable on account of other considerations. Kasumin, Hinosan, Hinosan TCP and Benlate were the fungicides selected as most suitable for controlling blast of the many formulations evaluated (Seneviratne, 1980).

Fungicides for the control of sheath blight were also sought and several of them tested in plate assays with the pathogen and in field trials in locations prone to disease incidence (Seneviratne and Fernando, 1972). They included Brassicol (quintozene), Benlate (benomyl), Monsan (calcium methyl arsenate), Cercobin M (thiophonate-methyl), Brestan 60 (fentin acetate + maneb), Valida (validamycin), Demosan (chloroneb) and Tuzet (methyl arsine-bis (dimethyldithiocarbamate) + ziram + thiram). Some of these fungicides, in particular benlate, reduced infection considerably but the effects on yield were not significant. The nature of occurrence of the disease and its effects do not justify application of fungicides to control it generally (Seneviratne, 198O).

As bacterial leaf blight caused anxiety in epidemics during the 1960s, various formulations claimed to be effective against the disease such as Celdion (fentiazon), Sankel (nickel dimethyl dithiocarbamate) Phenazin (phenazin-5-oxide), TF 130 (a systemic antibacterial agent) and Streptocycline (streptomycin and chlorotetracycline) were tested in field trials (Seneviratne et al., 1972). The application of these formulations had no appreciable effect either on disease incidence or on yields generally and the use of chemicals against BLB was therefore not recommended (Seneviratne, 1980).

Several fungi and the bacterium causing BLB are seed-borne. Seed dressings were sometimes applied as a precautionary measure in preventing seedling diseases and related problems. Several field trials with spotted seed paddy treated with fungicides including Ceresan Wet (methoxyethylmercury chloride), Benlate (benomyl), Bavistin (carbendazim), Vitavax-200 (carboxin + thiram) and Homai (thiophonate-methyl + thiram) did not indicate pronounced differences with and without seed treatments with respect to plant stands and crop yields. It would seem that in the warm low and mid country areas with conditions favourable for vigorous seedling development, seed-borne organisms, though present, do not normally cause serious problems. Seed failures have invariably been associated with excessive damage during threshing operations or factors unrelated to pathogenic organisms. So long as seed of good quality is used, there is no real need for chemical seed treatment. However, when seeds are imported from other countries, seed treatment is of the utmost importance to minimise risks of entry of pathogenic races alien to this country.

DISCUSSION

Rice is subject to attack by several pathogens. The fungal and bacterial pathogens associated with rice diseases occurring in Sri Lanka have been identified; some viruses have also been recorded. However, the factors associated with yellowing conditions observed remain to be established with certainty.

In combating diseases, great emphasis has been laid on the development of disease resistant varieties. Screening systems against the more important diseases such as blast and BLB have been perfected and used to advantage to identify donors of resistance for breeding and to evaluate the performance of hybrids emerging from breeding programmes. The successes achieved have been noteworthy and losses attributable to diseases have been reduced to negligible proportions because the improved varieties released for cultivation have adequate disease resistance under normal conditions.

Numerous fungicides and bactericides have been tested to select products which might be used to control diseases if required. However, no advantage has been observed in the use of fungicides to control diseases such as sheath blight. Bactericidal preparations tested against BLB have not indicated noteworthy beneficial effects either. Accordingly, their application has not been recommended. Only in the case of blast has the use of fungicides been recommended if required in certain situations. In general, there is virtually no need now to resort to agro-chemicals for the control of rice diseases.

The present status with respect to mastery over rice diseases is satisfactory. Crop losses caused by them have been reduced to negligible proportions. In ensuring that this situation is maintained, the programmes for the identification of disease resistant donors and the screening of hybrids from the breeding programmes should be pursued vigorously. Further, the entry of virulent strains of pathogens from outside with indiscreet seed introductions should be prevented by adopting appropriate measures. The need for sustained research to elucidate the causes of problems that are yet unclear and to further improve the present satisfactory situation in minimising crop losses due to diseases cannot be overemphasised - these programmes deserve the highest priority.

Crop germplasm will be vital for increasing food production in a food-needy world. Yet, risks associated with germplasm-borne pathogens warrant concern and they are being increasingly recognized. If the potential of crop germplasm is to be fully exploited, then plant scientists must recognize the factors that restrict their utilization and actively seek to resolve those limitations

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