EPIDEMIOLOGY AND CONTROL OF SHEATH ROT DISEASE OF RICE

By

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DECLARATION

I hereby declare that this thesis entitled " Epidemiology and control of sheath rot disease of rice " is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship, or other similar title of any other University or Society.

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Vellayani,

7th March, 1986.

CERTIFICATE

Certified that this thesis, entitled " Epidemiology and control of sheath rot disease of rice " is a record of research work done independently by Sri B.KRISHNAKUMARAN NAIR, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

INTRODUCTION

INTRODUCTION

Sheath rot of rice was first described by Sawada in 1922 from Formosa and named the causal organism as *Acrocylindrium oryzae* Saw. Even though this fungal disease of rice was reported long back in 1922, reports on the destructive nature of the disease began to come only during the last one decade. The pathogen was renamed as *Sarocladium oryzae* by Gams & Hawksworth during 1975 and still it is reckoned by both the names in literature. Recent literature shows that the disease is prevalent in almost all the rice growing areas of the world and cause severe yield losses in certain countries like Japan, China, Taiwan, Vietnam, Thailand and Philippines and it is estimated that the disease cause an average yield loss of 20 to 60 per cent.

In India the occurrence of this disease was first reported by Agnihothrudu during 1973 from Karnataka and this was followed by reports from Tamil Nadu, Kerala, Andhra Pradesh, Orissa and from other parts of the country. In Kerala this disease has gained very much importance recently in terms of its endemic nature and extent of damage in many parts especially in the southern districts. Information on various aspects of the disease in the country including Kerala is very scanty particularly with respect to effective control measures.

Recent studies undertaken in Kerala showed that the use of fungicides alone is not at all able to give satisfactory control of the disease. But some preliminary informations available showed that certain crop management practices are able to minimise the disease to satisfactory level. It has also been pointed out that certain associated organisms also aggravate the disease syndrome.

In the above circumstances the present study was taken up with the following objectives.

a. To establish the role of associated organisms in the etiology of the disease.

b. To study the epidemiology of the disease.

c. To study the effect of nutritional factors in combination with fungicides in controlling the disease.

The results of these studies are presented here.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Sheath rot of rice caused by *Sarocladium oryzae* Gams & Hawksworth (= *Acrocylindrium oryzae* Saw.) was first described by Sawada from Formosa in 1922. Tasugi and Ikeda (1956) have established its pathogenicity in rice plants and provided more cultural and physiological information about the pathogen from Japan. Chen (1957) reported the nature of damage by the pathogen in rice from Taiwan and he observed about 20 per cent crop damage due to the disease. Subsequently this disease was reported from Vietnam (Anon., 1962) and from Thailand (Ou,1965).

The occurrence of this disease in India was first reported by Agnihothrudu (1973) from Karnataka followed by reports from Tamil Nadu (Prabakaran *et al.*, 1974), Andhra Pradesh (Amin *et al.*, 1974) and from Kerala (Nair and Sathyarajan, 1975).

Gams and Hawksworth (1975) from Netherlands, questioned the validity of the name of the causal organism and they renamed the sheath rot organism as *Sarocladium oryzae* as a new combination. However, the organism is referred by both the names in literature.

Eventhough this disease was described long back in 1922 by Sawada, it was considered as a minor one till recently. The observations on the destructive nature of the disease and the yield loss due to this disease are reported only in recent years. Attabhanyo and Rush (1973) reported the disease as a severe problem in the breeding nurseries in the United States of America. Shajahan *et al.* (1974) after a detailed field survey in major rice growing areas of South America reported about 11.4 per cent tiller infection by the pathogen. Prabakaran *et al.*(1974) reported a yield loss of 85 per cent due to this disease from Annamalainagar. According to Hsieh *et al.*(1977) the higher sterility of rice plants in Taiwan was due to the association of *S.oryzae.* Chakravarty and Biswas (1978) have assessed the reduction in grain weight of rice panicles due to sheath rot incidence and recorded a reduction of 79 per cent. Estrada *et al.*(1979) from Philippines reported that artificial inoculation of rice plants with *S.oryzae* at boot stage caused a reduction of 28.1 and 75 per cent of panicle production and grain yield respectively. Mohan and Subramanian (1979) and Srinivasan (1980) also reported the severe occurrence of this disease and yield loss in rice from Tamil Nadu. Similarly Vidhyasekaran *et al.*(1984) from Tamil Nadu reported that the sheath rot of rice caused by *S.oryzae* results in poor grain filling and severe reduction in seed germination. Estrada *et al.*(1984) from Philippines reported that infection by *S.oryzae* in rice caused a yield loss of 53 per cent.

Symptomatology

Sawagi and Ikeda (1956) reported that the fungus chiefly attacked the upper most leaf sheath resulting in rotting. The greyish-brown lesions coalesce and form large irregular blotches. Ou (1972) observed that the rot occurred on the upper most leaf sheath enclosing the panicle. The lesions started as oblong spots with brown margins and grey centres or greyish-brown throughout. The young panicles remained within the sheath or only partially emerged. Abundant whitish powdery growth could be noticed on the affected sheath. Amin et al.(1974) found that lesions started as oval in shape and dark chocolate brown in colour surrounded by a diffused light brown halo. Lesions were most conspicuous on the sheath of the flag leaf. In severe infection the entire sheath became dark brown in colour with irregular outlines of several overlapping lesions. The panicles did not emerge and were compressed inside the flag leaf sheaths. Shajahan et al.(1974) reported that the disease occurred primarily on the upper leaf sheaths and most conspicuous on the flag leaf sheath. The colour of lesions varied from grey-brown to purple-brown depending upon the varieties. Panicles of the affected plants often did not emerge and the glumes of the infected florets were discoloured to purple-brown to black and often were not filled. In Kerala, Nair and Sathyarajan (1975) described the symptoms of this disease in detail. They found that the young spots appeared on boot leaf sheath and were uniformly turned whitish-grey with a dark brown margin. In the infected field the panicles could be observed at various stages of emergence. A whitish powdery mass of fungal growth could be detected over the matured lesions inside the affected sheath.

Seed-borne nature of the pathogen

Shajahan *et al.*(1974) reported that sheath rot of rice was seed-borne. Similarly Mohan and Subramanian (1981) observed the seed borne nature of *S. oryzae* and they reported the pathogen as both externally and internally seed-borne.

Sachan and Won (1980) have suggested that the sterility of rice grains of sheath rot affected rice plants might be due to the effect of toxic metabolites produced by the pathogen. The effect of toxic metabolites of *S. oryzae* in the pathogenesis of sheath rot disease has also been observed by Balakrishnan (1981)

Morphology of the causal organism

According to Tasugi and Ikeda (1956) the rod shaped hyaline conidia from the host measured 2.1 to 8.5 x 0.5 to 1.6 µm and 1.8 to 13 x 1 to 1.6 µm from culture.

Ou (1972) gave the following descriptions for the organism. Mycelium white, sparsely branched and septate which measure 1.5 to 2.0 µm in diameter. Conidiophore arise from the mycelium which is slightly thicker than the vegetative hyphae, branched in one or two whorls with three to four branches in each whorl. The conidia formed consecutively on the tip. Conidia were hyaline, smooth, single celled, cylindrical and measured 4.0 to 9.0 x 1.0 to 2.5 µm.

According to Shajahan *et al.*(1974), mycelium colourless, septate and 1.5 to 3.0 µm in diameter. Conidiophores single or branched 15.0 to 25.0 µm long or with secondary branches in whorls of 2 to 5 phialides and 13.0 to 19.0 µm long. The conidia were formed singly at the tip of conidiophores and they were hyaline, smooth, cylindrical, single celled and measured 3.0 to 17.0 x 1.0 to 2.0 µm from P.D.A. culture. But variations were noticed in the different media. Conidia from the infected leaf sheath measured 2.5 to 8.0 x 1.0 to 2.0 µm with an average of 5.0 x 1.0 µm.

Nair and Sathyarajan (1975) described the fungus from Kerala as follows. The mycelium was septate, purplish white profusely branched and measure 1.25 to 2.0 µm in diameter. Conidiophores were short, slightly thicker than the hyphae and ending in a whorl of 3 to 6 branches and often one or two side branches were also noticed from the main conidiophore. The main branch of conidiophore measured 10.0 to 15.0 µm in length and 2.0 to 2.5 µm in breadth. Conidia were consecutively formed at the tip of conidiophores. The hyaline single celled conidia measured 3.5 to 7.0 x 1.0 to 1.5 µm in size from the host and 4.0 to 8.0 x 1.0 to 1.5 µm from the culture on potato dextrose agar.

Balakrishnan (1981) compared different isolates of the pathogen obtained from rice varieties and naturally infected weed hosts. They observed that the hyphae of certain rice isolates and one weed host namely, Echinochloa crusgalli Linn. were slightly thicker than those of isolates from the rice variety Jyothi. Similarly the conidia from the weed host were comparatively smaller than those from rice varieties.

Pathogenicity

Tasugi and Ikeda (1956) established the pathogenicity of S.oryzae by artificial inoculation of rice plants using conidial suspension. Chen (1957) had shown that, different isolates of the fungus differed in their pathogenicity. Shajahan et al.(1974) established the pathogenicity of the fungus successfully by injecting the hyphal and conidial suspension behind the sheath with a hypodermic needle. Nair and Sathyarajan (1975) proved that inoculation of rice plants at boot leaf stage with conidial suspension of the fungus could produce typical sheath rot symptoms. Estrada et al.(1979)

obtained successful infection of rice plants inoculated by the method of inserting a single grain culture between leafsheath and culm and also by injecting a spore suspension behind the sheath. Balakrishnan (1981) proved that successful infection of rice plants by the pathogen could be obtained by inserting actively growing culture bit behind the sheath or by injecting the spore suspension of the pathogen inside the sheath with the help of a hypodermic needle. According to Mukherjee *et al.*(1981) culture of the organism on rice grain inserted inside the flag sheath of rice plant was the most effective method of inoculation for successful infection.

Associated organisms with the disease

Shajahan *et al.*(1974) reported, *Fusarium roseum* Link.ex Fries and a species of *Hyalostachybotrys* were two other organisms, constantly associated with the sheath rot disease of rice. They proved that these organisms could produce atypical sheath rot symptoms on rice plants by artificial inoculation, whereas in combination with *A.oryzae* these organisms could produce typical sheath rot symptoms. Similarly Balakrishnan (1981) have observed the complex occurrence of *Fusarium* species with the disease. Sung *et al.*(1982) isolated *Gaeumannomyces graminis* var. *tritici* Walker from the sheath rot affected rice seedlings. They have also observed that this fungus produce sheath rot symptom from the crown to the leaf sheath above ground level. Kang and Rattan (1983) isolated *Fusarium equiseti* (Corda) Sacc. and *Fusarium moniliforme* Sheldon from the sheaths of sheath rot affected rice. According to the above workers these fungi could produce typical sheath rot symptoms as resulted by infection with *S. oryzae*. Shajahan *et al.* (1983) isolated a *Pyrenochaeta* species from the outer leaf sheaths of rice plants and proved its pathogenicity. Ngala (1983) reported that the fungus *Sarocladium attenuatum* Gams & Hawksworth could be frequently isolated from discoloured grains of rice plants and he also proved that this fungus could produce dirty panicle disease in rice in the absence of insects.

Varietal reaction

Subramanian and Ramakrishnan (1975) reported that the rice variety Annapurna was comparatively more susceptible while varieties like SN-1, SNM-6, Kanto and Sigadis showed least susceptibility to the disease. Amin (1976 a) from Andhra Pradesh and Naik (1976) from Orissa also reported certain rice varieties resistant to this disease (Ramtulsi, Manoharsali, Sigadis, Zenith and Tadukan). According to Datta and Purkayastha (1978) sheath rot disease was more severe in high yielding dwarf cultivars. Lin (1978) from China has also observed some newly developed rice cultivars like Sen YU-NO.229 resistant to the disease. Chien (1981) reported that *japonica* rice cultivars were more susceptible than *indica* types to sheath rot. A number of other workers also have reported variations in varietal reactions to the disease (Srinivasan, 1980; Balakrishnan & Rajan, 1981; Singh & Raju, 1981; Chien & Huang, 1982; Anon., 1983 a).

Post infectional changes in the host physiology

Mohan and Subramanian (1979) observed that total and orthodihydroxy phenols were much less in the susceptible varieties. They have also reported that phenolics accumulated in the infected plants while reducing and non-reducing sugars decreased. Balakrishnan and Nair (1983) observed that inoculation of rice sheaths with *A. oryzae* caused a considerable reduction of total sugar and phenolic contents after the symptom development. Purkayastha *et al.* (1983) reported that *S. oryzae* infected leaf sheaths of tall cultivars (resistant) had much higher levels of the phytoalexin (momilactone-A) than those of semi dwarf (susceptible) cultivars.

Influence of management practices on sheath rot incidence

Amin *et al.* (1974) observed severe incidence of sheath rot disease in densely planted rice fields with high yielding dwarf varieties. They also reported that disease incidence was higher during Rabi crop season in Andhra Pradesh. Rajan (1980) observed that intensity of sheath rot disease of rice could be considerably reduced by the soil amendment with various non edible oil cakes and other organic materials.

Srinivasan (1981) from Aduthurai, Tamil Nadu reported that incidence of sheath rot of rice was extremely high on crops planted from mid June to mid August and control measures were needed only for the crop planted during first crop only. In a study undertaken by Balakrishnan and Nair (1986) in Kerala observed the maximum sheath rot incidence in rabi crop (crop planted during mid September) and the minimum disease incidence in normal kharif crop (crop planted during mid May to June beginning) and one month delayed rabi crop. Misra and Mathur (1983) suggested that susceptibility of rice plants to Sarocladium oryzae increased with increasing nitrogen application over the range of 50 to 200 kg per hectare. Zhuge and Lapis (1985) reported that appropriate application of NPK fertilizer checked the sheath rot disease and they have also pointed out that excessive or deficient nitrogen conditions favoured the disease development. Balakrishnan and Nair (1986) in Kerala, noticed that application of neem coated urea (slow release of nitrogen) as basal dose and a higher dose of potash could minimise the sheath rot disease of rice considerably in endemic areas. Alagarsamy et al.(1985) observed that slow release nitrogenous fertilizers (neem cake coated urea) could minimise sheath rot incidence significantly.

Effect of fungicides and other chemicals on control of S.oryzae (sheath rot of rice)

Ranganathan and Vijayaraghavan (1976) observed in their laboratory studies that Benlate and Hinosan at 0.005 and 0.05 per cent respectively could effectively inhibit the growth of A.oryzae. Chinnaswamy et al.(1977) by a randomised replicated field experiment proved that, Bavistin followed by IBP-EDO, Aureofungin-Sol, Hinosan and Difolatan were effective in reducing the infection as well as intensity of the disease. Chien and Huang (1979) found that Bavistin (Carbendazim), Ducan (TCMTB) and Benlate (Benomyl) were able to inhibit effectively the in vitro growth of the fungus. Pot culture studies carried out by Kannaiyan (1979) in Tamil Nadu with Benlate (Benomyl) and Daconil (Chlorothalonil) revealed that these chemicals could check sheath rot incidence effectively. Raina and Singh (1980) have suggested carbendazim (0.1 per cent) for the effective control of the disease in field. Vasavan et al.(1980) in a field trial conducted in Kerala observed that foliar application of saturn (Benthiocarb) at 2 kg a.i. per hectare could check the sheath rot disease also besides checking weed growth. Chaudhuri and Purkayastha (1980) suggested that two consecutive foliar sprays of Gibberellic acid at 100 µg per ml,seven days before inoculation with

S. oryzae in nine week old plants of a susceptible semi dwarf cultivar, could reduce the incidence of the disease. They have also pointed out that the Gibberellic acid treated plants showed increased ferulic acid content in the sheaths and this treatment may cause other biochemical changes in the host which create conditions unfavourable for growth of the pathogen. Raju and Singh (1981) from a field trial observed that the fungicides, Carbendazim and Benomyl could effectively check the sheath rot disease and enhance the grain yield. Balakrishnan and Nair (1982) from Kerala have also suggested that fungicides Hinosan and Vitavax, were equally effective in reducing both the incidence and intensity of sheath rot disease in field. Similarly another field trial conducted in Kerala, revealed that Vitavax (0.1 per cent), Hinosan (0.1 per cent) and Captafol (Difolatan 0.3 per cent) as foliar sprays at boot leaf and earhead stages of the crop could effectively control the sheath rot disease (Anon., 1983 b). Reddy et al. (1984) from laboratory studies observed that Bavistin (Carbendazim) was the most effective fungicide against Sarocladium oryzae. Lakshmanan (1984) from Tamil Nadu reported that Calixin-Bavistin mixture (each at 100 g/ha) could effectively reduce the incidence as well as intensity of sheath rot disease of rice in field.

MATERIALS AND METHODS

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I. Symptomatology

The symptomatology of the sheath rot of rice was studied by observing the naturally infected rice plants in the field and also by noting the course of development of the disease on the plants artificially inoculated and incubated.

II. Comparative morphological studies of the causal organism

a. *Sarocladium oryzae*

Isolates of *Sarocladium oryzae* Gams and Hawksworth used for the present study were obtained from naturally infected rice plants from different locations as detailed below. Isolations from infected sheath and grains were carried out following standard techniques. The affected sheaths showing typical sheath rot symptoms were cut into small bits, surface sterilized with 0.1 per cent mercuric chloride solution for two minutes, followed by washing in three changes of sterile distilled water. These bits were then planted on potato dextrose agar medium (P.D.A.) poured in sterilized petri dishes. The dishes were incubated at room temperature (28 ± 2°C). The grains also were similarly surface sterilised, washed repeatedly and plated on P.D.A. On second or third day when mycelial growth was observed bits were aseptically transferred to P.D.A. slants. Culture was then purified by frequent transferring of hyphal tips.

From the various isolates seven different cultures as detailed below were selected based mainly on symptomatological variations for further detailed study. Isolations were from three different locations and also from four varieties of rice.

Details of isolates of *S.oryzae* used for comparative morphological studies

A. From Trivandrum District

Isolate S_1 - from variety Jaya

Besides the typical sheath rot symptoms, a uniform discolouration of the affected sheath also was observed.

Isolate S_2 - from variety Jaya with mild sheath rot symptom

Isolate S_3 - from variety Triveni with mild sheath rot symptoms and also stem discolouration.

Isolate S_4 - from variety Triveni with typical sheath rot symptom.

Isolate S_5 - from variety Jyothi with severe sheath rot symptoms.

B. From Kuttanad

Isolate S_6 - from infected rice grains of the variety Jaya.

G. From Kayamkulam

Isolate S_7 - from a local variety, " Kochuvithu " with mild sheath rot symptom.

Note: The symbols S_1, S_2 ... S_7 as detailed above were used to designate these isolates elsewhere in this thesis.

The morphological characters of all the above seven isolates were studied by growing them in 9 cm petri dishes on P.D.A., incubated under laboratory conditions. The nature of growth and colour of mycelium were noted. In addition the measurements of hyphae, conidiophore and conidia were made and also the conidial ontogeny studied in detail. On the tenth day of incubation, slide cultures were prepared following the technique described by Riddell (1950) for detailed study of the conidial ontogeny.

Sterile plain agar medium was poured into sterilized petri dish to a thickness of 2 mm and after solidification blocks of 6 mm square were cut out using a sterile needle. One such square was placed in the centre of each sterile microscope slide and all the four sides of the agar block were inoculated with small culture bits of the required isolate of the fungus. A cover slip was placed on top of the square of agar and the slide was kept in a damp chamber (sterile petri dish with wet sterile filter paper in the bottom on which two glass rods kept as supports for the slide). The dish with the slide was then incubated at room temperature for two to three days. After this the cover slip lifted off gently, a drop of 95 per cent alcohol was placed in the centre and before drying, the cover slip was mounted using lactophenol cotton blue on another slide. The square of agar was removed from the original culture slide and another mount was prepared in the similar manner without any disturbance to the fungal growth on the slide. These slides were observed for the various morphological characters.

b) Isolation of associated fungi

Specimens of rice sheath showing varying symptoms of sheath rot, collected from the experimental field of the Cropping Systems Research Centre, Karamana, Trivandrum, were used for the study. All the associated fungi were isolated and brought into pure culture following standard techniques. Their growth characters were studied in detail by culturing on PDA and also on rice grain medium. Detailed morphological characters of the associated fungi were also studied following the slide culture technique described earlier.

III. Pathogenicity studies

All the seven isolates of *S.oryzae* and three isolates of the associated fungi obtained during the studies as mentioned earlier were utilized for detailed pathogenicity tests. Four high yielding varieties of rice, Jaya and Pavizham (medium duration) and Jyothi and Triveni (short duration) were used for the studies.

Necessary inoculum of all the isolates of S.oryzae and the associated fungi required for inoculation studies were raised as pure cultures on rice grains. Twenty five gramme each of milled rice grains were taken in 250 ml conical flasks, to which 25 ml water was added and autoclaved at 1.2 kg/cm^2 pressure for 20 minutes and after cooling, the culture bits of the required isolates of S.oryzae or the associated fungi were inoculated and incubated under laboratory conditions. Test plants were raised in 32 x 38 cm earthen pots and managed as per Package of Practices Recommendations of the Kerala Agricultural University (Anon., 1982).

These plants were artificially inoculated at boot leaf stage by inserting one rice grain culture each behind the boot sheath and the lower two sheaths in each of the test plant. Inoculations were done using all the seven isolates of S.oryzae and three isolates of associated fungi alone and also the associated fungi in combination with S_5 - the most virulent isolate of S.oryzae. The inoculated plants were maintained under high humid conditions by providing polythene covers for six days after inoculation. Plants which were not inoculated, but maintained under identical conditions side by side, served as control.

The plants were observed for the development of symptoms and observations were recorded from 5th to 20th day after inoculation. The nature of infection, colour and size of lesions, time taken for complete development of symptoms and type of symptoms on 20th day of inoculation were observed and recorded. The severity of infection was arbitrarily graded into mild, moderate and severe forms based on the incubation period taken by various isolates of the pathogen for the initial symptom expression and the differences noted in its further development. In the " mild " form, the symptoms initiated on eighth day of inoculation and there were no demarcated typical lesions noticed except a mild yellowish discolouration of the inoculated sheath. Grain discolouration and panicle choking were below 10 per cent. In the " moderate " form, the symptoms initiated on fifth or sixth day of inoculation, characteristic lesions were developed on boot leaf sheath by 15th day and about 30 per cent panicle sterility could be observed. In the " severe " form symptoms initiated on 5th day of inoculation, characteristic lesions developed on boot leaf sheath by 15th day and complete choking of the panicles observed by 20th day of inoculation. The diseased plants showed a burned up appearance thereafter.

IV. Post infectional changes in Total soluble sugars and Total phenolics

Post infectional changes in the total soluble sugars and total phenolic substances were analysed in four varieties of rice, viz., Jaya, Pavizham, Jyothi and Triveni. The representative samples for these were collected from the artificially inoculated plants with S_5 isolate of S.oryzae on 20th day of inoculation. Samples from healthy plants raised under identical conditions and of the same age served as control.

Quantitative changes in total soluble sugars and total phenolics were estimated as per the following procedures.

a) Total soluble sugars

The total soluble sugars in various samples were determined by following " Phenol Sulphuric acid Method ", described by Dubois et al.(1951). One gramme of plant sample was ground with 10 ml of 96 per cent boiling ethanol, cooled down the extract in a pan of cold water, passed through two layers of cheese cloth and reextracted the ground tissues for three minutes in 5 ml of hot 80 per cent ethanol.

Cooled the second extract and passed through cheese cloth. The extracts were pooled together and filtered through Whatman No.41 filter paper. The volume of extract was reduced to 10 ml by evaporation. The extract was then made free of alcohol by further evaporation in a water bath. The volume of the final extract was finally made to one ml by adding distilled water.

One ml aliquot of the aqueous solution of the extract was pipetted out into a test tube. Added one ml of five per cent phenol solution to it and mixed thoroughly. Blanks were maintained with one ml of water instead of the extract. Rapidly added five ml of 96 per cent sulphuric acid to the tubes and gently agitated, allowed to stand for 10 minutes. The tubes were then placed in a water bath for twenty minutes, maintained at 25 to 30°C. The yellow-orange colour thus developed was measured for the absorbance at 490 nm using a spectronic-20 Spectrophotometer. The quantity of total soluble sugars were estimated using a standard curve prepared with glucose. The quantities of sugars were expressed as µg per g of fresh weight of the samples.

(b) Total phenolics

The modified Folin-Denis method (Swain and Hills, 1959) was followed to determine the total phenolic content of both healthy and diseased plant samples.

The aqueous extract of the samples (prepared as described earlier) was taken in graduated test tubes, 0.5 ml each, and diluted to seven ml with distilled water. Added 0.5 ml Folin-Denis reagent to it (prepared by adding 100 g of sodium tungstate, 20 g of phosphomolybdic acid and 50 ml of 85 per cent phosphoric acid into 750 ml distilled water and refluxed the mixture, cooled and diluted to one litre). Exactly three minutes later one ml of saturated sodium carbonate (prepared by adding 35 g of anhydrous sodium carbonate to 100 ml of distilled water and warming the solution at 70-80°C, supersaturated solution was cooled overnight and then seeded with crystals of sodium carbonate and after crystallisation filtered through glass wool) was added and the volume made upto 10 ml. The contents in the test tubes were thoroughly mixed. Blanks were maintained with distilled water and reagents only. After one hour the absorbance of the solution at 735 nm was recorded using a Spectronic-20 Spectrophotometer. A standard curve was prepared using catechol as the standard and the total phenolics expressed as µg per g of fresh weight of the plant samples as catechol equivalent.

V. <u>Influence of management practices in sheath rot incidence</u>

The effect of various agronomic practices on sheath rot incidence was critically studied. For this purpose few of the ongoing agronomic experiments at the Cropping Systems Research Centre, (C.S.R.C.), Karamana, Trivandrum under the Kerala Agricultural University were made use of. Observations on intensity of disease was assessed in respect of experiments on varieties, crop nutrition, time of planting, effect of plant population and weed population. The details of experiments selected for this purpose are detailed below.

V(1) Long range effect of continuous cropping and manuring

The technical programme of this experiment consists of varying levels of N, P and K as shown below:

Treatments

$N_0 P_0 K_0$	-	No application of fertilizers (control plots)
N_1	-	40 kg N/ha
N_2	-	80 kg N/ha
N_3	-	120 kg N/ha
P_0	-	No phosphorus application
P_1	-	40 kg P/ha
P_2	-	80 kg P/ha
K_0	-	No potash application
K_1	-	40 kg K/ha

Variety used - Jaya

Duration of the experiment - 10 years (1977-78 kharif to 1986-87 Rabi).

The observations were recorded for the following three seasons, 1984 Kharif and Rabi and 1985 Kharif.

V(2). Crop technology for optimum production under resource constraints.

The technical programme consists of different dates of planting, different plant population, adoption of weed control practices and application of graded fertilizer levels.

Treatments

D - Date of planting

D_1 - Normal date of planting

D_2 - Three weeks after D_1.

P - Plant population

P_1 - 100 per cent population

20 x 15 cm spacing during Kharif

20 x 10 cm spacing during Rabi

P_2 - 75 per cent population

20 x 20 cm spacing during Kharif

20 x 13.3 cm spacing during Rabi.

F - Fertilizer doses

F_1 - NPK @ 90:45:45 kg/ha

F_2 - NPK @ 45:22.5: 22.5 kg/ha

W - Weed control

W_1 - Chemical weed control + hand weeding on 40th day of transplanting.

Chemical used - Benthiocarb - 50 E.C.(Saturn 50 E.C.)

W_2 - Two hand weeding on 20th and 40th day of transplanting.

Variety used - Jaya

The observations were recorded for the following three seasons.

1984 Kharif and Rabi, 1985 Kharif.

V(3) Agronomic evaluation of promising newly released varieties of rice.

Technical programme include changes in time of sowing with varying fertility levels for different varieties. The dates of planting were, normal date of each cropping season and 15 days after the same. Graded fertilizer dose consists of N : P : K - 60 : 30 : 30; 120:60:60 and 180:90:90 kg per hectare.

Treatments

D - Date of planting

D_1 - Planting on normal date

D_2 - Planting 15 days after normal date

V - Varieties

V_1 - Jaya (locally popular and recommended check variety)

V_2 - Pavizham (newly released variety)

V_3 - Karthika (newly released variety)

F - Fertilizer level

F_0 - N : P : K @ 0:0:0 No fertilizer application

F_1 - N : P : K @ 60:30:30

F_2 - N : P : K @ 120 : 60 : 60.

F_3 - N : P : K @ 180 : 90 : 90.

The observations were recorded for the following two seasons.

1984 Kharif and Rabi.

V(4) Slow release nitrogen fertilizers and nitrification inhibitors

In this experiment slow release nitrogen by neem cake treated urea, gypsum coated urea and rockphosphate coated urea were used.

<u>Treatments</u>

T_1 - (L_0S_1, S_2, S_3 and S_4) control

T_2 - L_1S_1 - Urea 56 kg nitrogen per hectare applied in split doses.

T_3 - L_2S_1 - Urea 84 kg nitrogen per hectare applied in split doses.

T_4 - L_3S_1 - Urea 112 kg nitrogen per hectare applied in split doses.

T_5 - L_1S_2 - Neem cake treated urea @ 56 kg N/ha (50 per cent as basal and 50 per cent as top dressing in two splits).

T_6 = L_2S_2 - Neem cake treated urea @ 84 kg N/ha (50 per cent as basal and 50 per cent as top dressing in two splits).

T_7 = L_3S_2 - Neem cake treated urea @ 112 kg N/ha (50 per cent as basal and 50 per cent as top dressing in two splits).

T_8 = L_1S_3 - Gypsum coated urea @ 56 kg N/ha(as basal and incorporated)

T_9 = L_2S_3 - Gypsum coated urea @ 84 kg N/ha (as basal and incorporated)

T_{10} = L_3S_3 - Gypsum coated urea @ 112 kg N/ha (as basal and incorporated)

T_{11} = L_1S_4 - Rockphosphate coated urea @ 56 kg N/ha (as basal complete).

L_2S_4 - Rockphosphate coated urea @ 84 kg N/ha (as basal complete).

L_3S_4 - Rockphosphate coated urea @ 112 kg N/ha (as basal complete).

Where L_0, L_1, L_2, L_3 and L_4 are levels of application and S_1, S_2, S_3 and S_4 are sources of application.

Variety used - Jaya

The observations were recorded for the following two seasons - 1984 kharif and Rabi.

V_5 - Weed control studies in crop sequence

The technical programme include no weeding, hand weeding once and twice, use of herbicides and their possible combinations.

Treatments

H_0 - No weeding

H_1 - Two hand weeding

H_2 - Herbicides (Benthiocarb 50 E.C. at the rate of 4 l/ha sprayed with water at the rate of 500 ml/ha).

H_2+H_1 - Herbicide on 6th day + weeding on 40th day

Variety used - Jaya

Duration of the experiment - 1982-1983 kharif to 1984-1985 Rabi.

The observation was recorded for 1984 Rabi season only.

V_6 Varietal reaction to sheath rot incidence

The intensity of sheath rot was recorded from a field experiment for evaluation of rice cultures laid out at the Instructional Farm, College of Agriculture, Vellayani, by the Department of Plant Breeding. This experiment was for the critical assessment of performance of some of the pre-release cultures in comparison with already known varieties. The experiment was laid out in randomised replicated trial. The following 26 varieties were scored.

M 210, Cul.25337, Cul.26-1-1, Karthika, Cul.23332-2, IR-36, Cul.43-1-4, Cul.1907, Cul.169, M.102, Jaya, M.109, M2, M.O.5, MM-9, Jyothi, Cul.4-4, Triveni, M.6, Cul.25331, Cul.1954, Cul.4, MO-6, IR-50, Cul.52-3-6, Cul.126. The observation was done for one cropping season of Kharif 1985.

<u>Measuring Disease Intensity (Disease Index)</u>

For recording the disease index in the above experiments, scoring of random rows was done in the experimental plots, following the system developed by Amin (1976 b). Three random rows from each treatment plot and 12 random hills from each row were selected and scored for the disease intensity.

The description of the scale used in this system of measurement was as follows:

Disease Index	Description
1	No visible symptoms on sheath of any leaves. Panicles were fully emerged and grains free from discolouration.
3	Two to three small lesions 0.5 to 1.0 cm long and 0.2 to 0.5 cm wide developed on flag leaf sheath, which were oval, dark chocolate brown and were surrounded by diffused light brown halo, while the colour of the healthy sheaths around the lesion remained green. Grains not discoloured.

Disease Index	Description
5	Large lesions 2 to 3 cm long and 1 cm wide, most conspicuous on flag leaf sheath, but occurred on all the leaf sheaths. Lesions overlaped and formed irregular large chocolate brown blotches on flag sheaths. Emergence of panicles was affected and it was half way from flag leaf sheath. Grains inside were partially chaffy and covered with white pink mycelium and spore masses of the causal organism. Affected panicles ranged upto an estimated 25 per cent.
7	Flag leaf sheaths were completely chocolate brown in colour due to many overlapping lesions. Flag leaves of affected sheaths gradually turned yellow to straw coloured. Affected panicles were fully compressed by flag leaf sheaths and were dark brown chaffy and covered with white to pink mycelium and spore masses (Commonly known as " choking "). Affected panicles ranged upto an estimated 50 per cent).
9	The entire flag leaf sheath had dark chocolate brown colour. Subsequently turned yellow to straw in colour. Flag leaves were straw coloured. Grains were dark brown and chaffy. Severe choking of panicles. Affected panicles ranged upto 100 per cent.

The disease index was worked out using the formula,

$$\text{Disease index} = \frac{\sum \text{ratings} \times 100}{\text{Number of hills observed} \times \text{Maximum score in the scale.}}$$

Where, $\sum$ ratings = sum of the scores and

maximum score in the scale = 9.

VI. *In vitro* evaluation of fungicides against *S. oryzae*

Five isolates of the *S. oryzae* namely, S_1, S_3, S_4, S_5 and S_7 which were used for comparative morphological studies were used for this experiment also. The following fungicides at three different concentrations were assayed against the five isolates.

The poisoned food technique described by Zentmeyer (1955) was adopted for this study. The required quantity of each fungicide was weighed out/measured and added to 225 ml of sterilized potato dextrose agar medium in 500 ml conical flasks to give the required concentrations, mixed well and poured into sterile petri dishes at the rate of 15 ml per dish. After solidification of the medium, the dishes were inoculated by mycelial discs of 5 mm diameter, cut out from

Sl. No.	Fungicides	Formulations used	Active ingredients	Concentrations of the formulations used (ppm)
1	Tridemorph	Calixin	N-Tridecyl-2,6-dimethyl morpholine	500 750 1000
2	Carbendazim	a. Bavistin	Methyl benzimidazole-2yl carbamate	500 750 1000
		b. Carbistin	Methyl benzimidazole-2yl carbamate	500 750 1000
3	Tridemorph-carbendazim	Calixin-Bavistin mixture	N-Tridecyl-2,6-dimethyl morpholine + Methyl benzimidazole-2yl carbamate	50 75 100
4	No fungicide	(control)	PDA without fungicide	

an actively growing colony of the fungus. Controls consisted of unamended PDA inoculated in the same way. All the dishes were incubated at room temperature (28 ± 2°C). The growth of the fungus was observed daily and final observations were recorded on 8th day of incubation. Per cent inhibition of growth over control was calculated by using the formula,

$$\text{Per cent inhibition} = \frac{C - T}{C} \times 100$$

Where, C = Radial growth in control

T = Radial growth in treatment.

VII. <u>Control of sheath rot under field conditions</u>

A field experiment was laid out during the first crop season (May to September, 1985) at the Cropping Systems Research Centre, Karamana, Trivandrum, to find out the best crop nutrition schedule for imparting resistance in rice plants and increasing the efficiency of fungicide in the disease control. The details of the experiment were as follows:-

Layout design	2 X 7 RBD - Factorial
Variety used	Jyothi
Spacing	15 X 10 cm
Gross plot size	3.5 X 3.45 m
Replications	3
Number of treatments	14

<u>Factors</u>

1. <u>Fungicide</u> - Two levels F_0 - No fungicide
F_1 - Carboxin @ 500 g/ha

2. <u>Crop nutrition schedules followed</u>

a) N_1 - Organic manure alone @ 5t/ha — Organic manure in the form of farm yard manure applied as recommended in Package of Practices Recommendations of Kerala Agrl.University (Anon.,1982)

b)	M_2	M_1+ N:P:K @ 70:35:52.5 kg/ha	Nitrogen in the form of urea in three splits in soil, half the quantity as basal and the remaining half in two equal splits. K in the form of MOP in two equal splits in soil, 50 per cent as basal and the remaining 50 per cent at second top dressing.
c)	M_3	M_1+ N:P:K @ 70:35:52.5 kg/ha	Nitrogen in the form of Ammonium sulphate and potash in the form of Muriate of potash. These fertilisers were applied as described under M_2.
d)	M_4	M_1+ N:P:K @ 70:35:52.5 kg/ha	Nitrogen in the form of urea in three splits as described under M_2. The first two splits in soil and the last split applied as foliar. K was given as under M_2. But the top dressing was given as foliar.
e)	M_5	M_1+ N:P:K @ 70:35:52.5 kg/ha	Nitrogen in the form of Ammonium sulphate and K in the form of Muriate of potash and applied as described under M_4.

f) M_6 $M_1 + M_4 + Zn$ @ 10 kg/ha and Mn @ 10 kg/ha — Zn in the form of Zinc sulphate and Mn in the form of Manganese sulphate were applied as foliar at the active tillering stage of the crop.

g) M_7 $M_1 + M_5 + Zn$ @ 10 kg/ha and Mn @ 10 kg/ha — Applied as described under M_6.

Phosphorus applied at the recommended rate in all treatments in the form of superphosphate in the soil as basal.

Nursery

Ten kg seeds were sown on 30--5--1985 in a wet nursery of 150 sq.m.

Main field

Seedlings from the nursery were transplanted in the main field on 19th day of sowing. Phosphorus in the form of superphosphate was applied in full dose as basal for all the treatment plots and control and the basal dose of the other nutrients were applied during the final preparation time of the main field as per treatment schedule described earlier. The crop was maintained in the main field following the cultivation methods described in the Package of Practices Recommendations of KAU (Anon., 1982) with respect to all other operations except for the treatments. Fifteen days after transplanting the crop was top dressed as per the treatment schedule. The remaining part of fertilizers were applied as second top dressing one week before the panicle initiation stage of the crop. The crop was sprayed with carbaryl as per recommended dose on 40th day of transplanting against stem borer and at earhead stage methyl parathion spray was given to check earhead bug.

Fungicidal application

Two sprays were given. The first spraying on 45th day and the second on 60th day after transplanting.

Observations

The intensity of attack by sheath rot disease was recorded 15 days before harvest of the crop. Three random rows in each experimental plot were scored using the system of " Standard Assessment of Disease of Rice " as described earlier.

Harvest

The crop was harvested at 110th day and the yield of grain and straw were recorded after proper drying.

RESULTS

RESULTS

I. Symptoms of sheath rot disease of rice

The sheath rot disease of rice is characterised by the initiation of light purplish to brown oblong lesions on the sheath of the flag leaf. The young lesions were surrounded by a light yellow-brown halo, which on maturity turned dark brown with papery white or grey white centre. Lesions were usually 0.5 to 2.5 cm long and 0.5 to 1.5 cm broad. The size varied with the variety. Eventhough, in severely affected plants symptoms could be noticed on lower sheaths also, the most conspicuous symptom was seen only on the sheath of the flag leaf. The individual lesions coalesced together in advanced stages and covered almost the entire flag leaf sheath. Often the panicles did not emerge and were choked inside the flag leaf sheath and gradually rotted. This stage is often referred to as " choking ". Depending upon the stage of infection of the plant, different stages of partially emerged panicles with discoloured and fully or partially chaffy grains also could be noticed in the affected field. Often a pinkish-white powdery mass of fungal growth could be detected over the choked panicles and flag leaf sheath of the affected plants (Plate I).

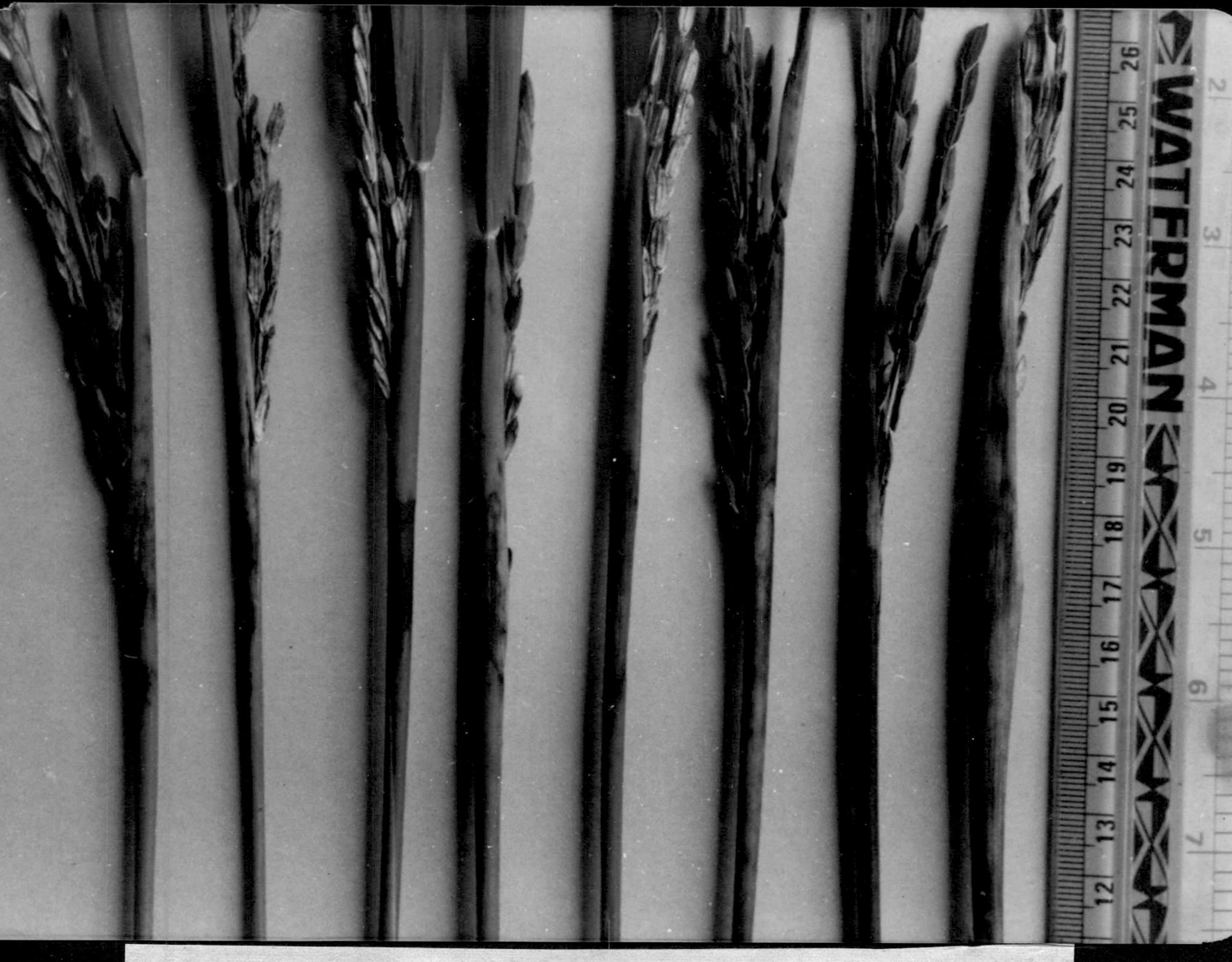


Plate I. Symptoms of sheath rot - different stages of development.

Under artificial inoculation when the inoculated plants were kept under high humid conditions, it took an average of five to eight days for the initiation of the disease and 15 to 20 days for complete development of the symptoms as described above.

II(a) Comparative morphology of different isolates of *Sarocladium oryzae* Gams & Hawksworth

The comparative morphological characters of the seven isolates of *S.oryzae* were critically studied and are summarised in Table (1).

From the data presented here it can be seen that the isolates vary in their morphological characters. The variations noted were with respect to colony character, size and nature of branching of conidiophore and also size of conidium.

(b) Associated fungi

From a number of isolations tried using the specimens collected from the Cropping Systems Research Centre, (C.S.R.C.), Karamana, Trivandrum, it yielded three different fungi constantly associated with sheath rot symptoms besides the causal organism *S.oryzae*.

Table 1

Comparative morphological characters of seven isolates of *Sarocladium oryzae* from rice

Characters	Isolates						
	S_1	S_2	S_3	S_4	S_5	S_6	S_7
A. <u>Mycelium</u>							
Septation	septate	septate	septate	septate	septate	septate	septate
Colour of colony (on PDA)	pinkish-white	grey-brown	pinkish-white	pinkish-white	milky-white	orange-white	pinkish-white
Nature of growth(on PDA)	profuse	slow and poor bran-ching.	slow	moderate	slow and appeared as cottony cushion over the medium.	slow and sparsely branched	moderate and poor branching
Hyphal * thick-ness	1-1.75 (1.6)	3-3.5 (3.2)	3-3.4 (3.2)	3-3.4 (3.2)	2.4-3.2 (2.8)	1.6-3.2 (2.4)	3-3.4 (3.2)

Table 1 (Contd.)

Characters	S_1	S_2	S_3	S_4	S_5	S_6	S_7
B. <u>Conidio-phore</u>							
Bran-ching	branched in one or two whorls with two to three branches in each whorl.	bran-ching very seldom noticed.	poorly branched and branched in single whorl.	bran-ched, usually in one whorl.	branched in two or three whorls.	non-bran-ching, more or less perpendi-cular to the hyphae.	usually seen at one side of the hyphae in large numbers and branched usually in single whorl and rarely in two whorls.
Length* main axis	14.20-19.00 (16.6)	34.8-37.9 (36.4)	18.5-19.5 (19)	9.2-9.8 (9.5)	15.8-34.8 (25.3)	60-65 (63)	15.5-16 (15.8)
Breadth*	2.75- 3.5 (3.2) thicker than hyphae.	3-3.4 (3.2)	3-3.4 (3.2)	3-3.4 (3.2)	3-3.4 (3.2) slightly thicker than hyphae	3-3.4 (3.2) thicker than hyphae.	3-3.3 (3.2)
C. <u>Conidium</u> colour, shape and septa-tion.	hyaline, cylindri-cal, single celled.	hyaline, cylindri-cal, single celled.	hyaline, cylindri-cal, single celled.	hyaline, cylindri-cal, single celled.	hyaline, cylindri-cal, single celled.	hyaline, cylindri-cal, single celled.	hyaline, cylindri-cal, single celled.

Table 1 (Contd.)

Characters	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Attachment to the conidiophore.	singly at the tip of branches.	singly at the tip of branches.	singly at the tip of branches and rarely two conidia were also noticed in sucession.	singly at the tip of branches.	singly at the tip of branches.	three to four in bunches at tip.	singly at terminal branches.
Length*	6.3-6.6 (6.5)	6.3-9.5 (7.9)	6.3-9.5 (7.9)	4.8-6.4 (5.5)	4.7-6.3 (5.5)	4.7-9.5 (7.1)	3.2-6.4 (4.7)
Breadth*	1.4-1.75 (1.6)	1.6-3.2 (2.4)	1.6-3.2 (2.4)	1.4-1.8 (1.6)	3-3.4 (3.2)	2.4-3.2 (2.8)	1.4-1.8 (1.8)

The morphological characters of all the seven isolates are illustrated in the photomicrographs in Plate II and camera lucida drawings in Fig. 1.

* Measurements are all in microns (μm)
Figures in parenthesis represent average values.

Plate II. Morphological characters of *S.oryzae* - S_1 (X 770).

Morphological characters of *S.oryzae* - S_2 (X 610).

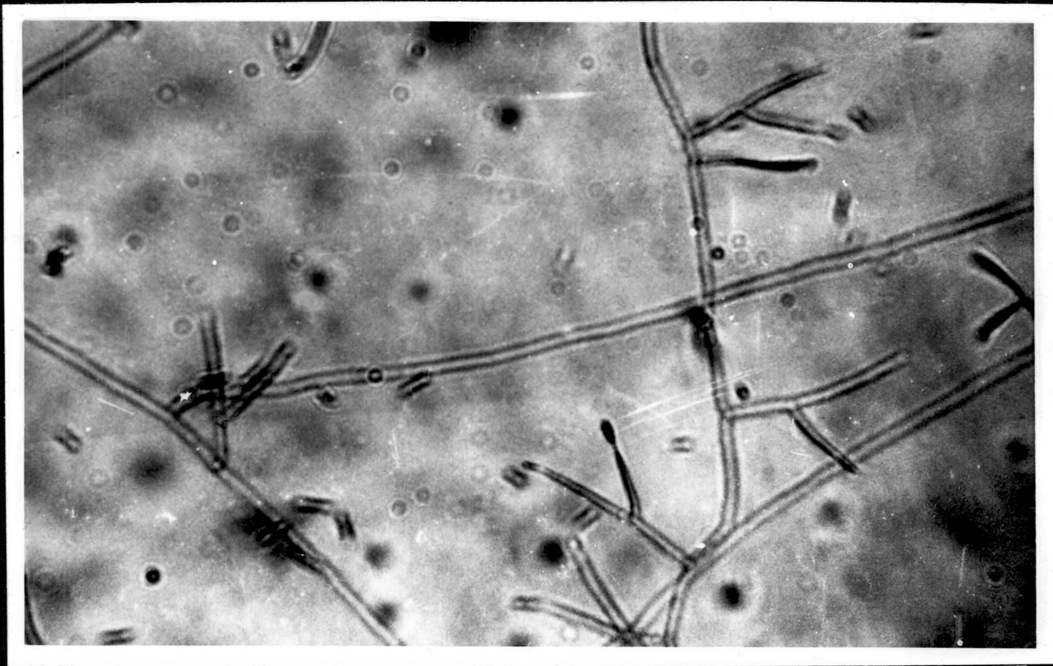
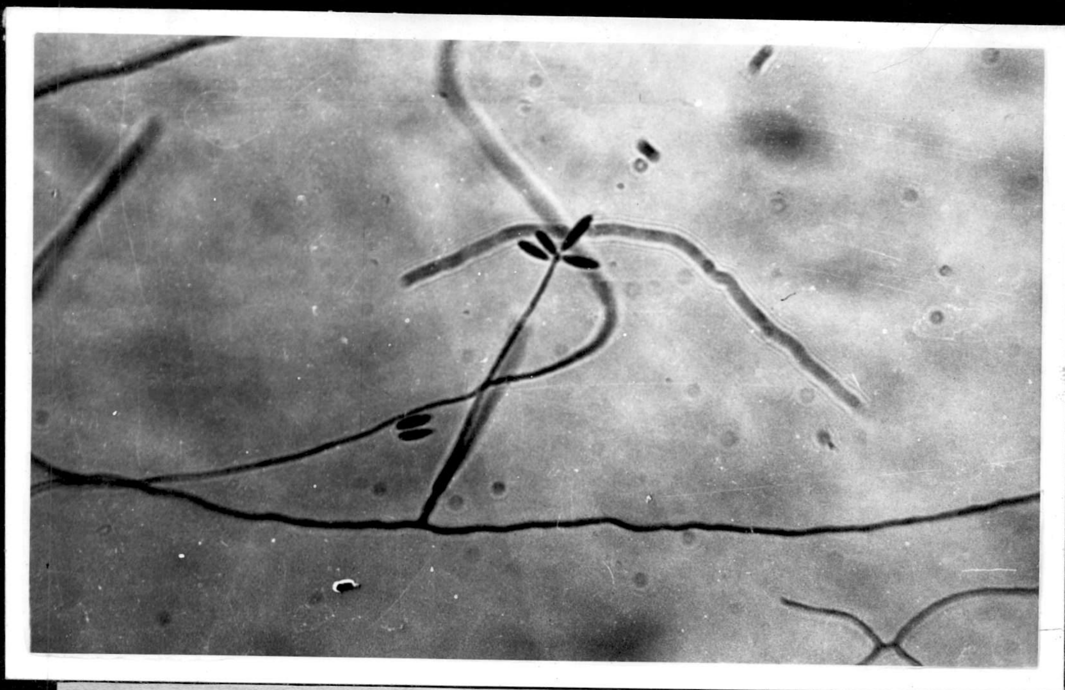


Plate II (Contd.) Morphological characters of *S. oryzae* - S_3 (X 610)

Morphological characters of *S. oryzae* - S_4 (X 560).

Plate XX(Contd.) Morphological characters of *S.oryzae* - S_5 (X 600).



Morphological characters of *S.oryzae* - S_6 (X 650).

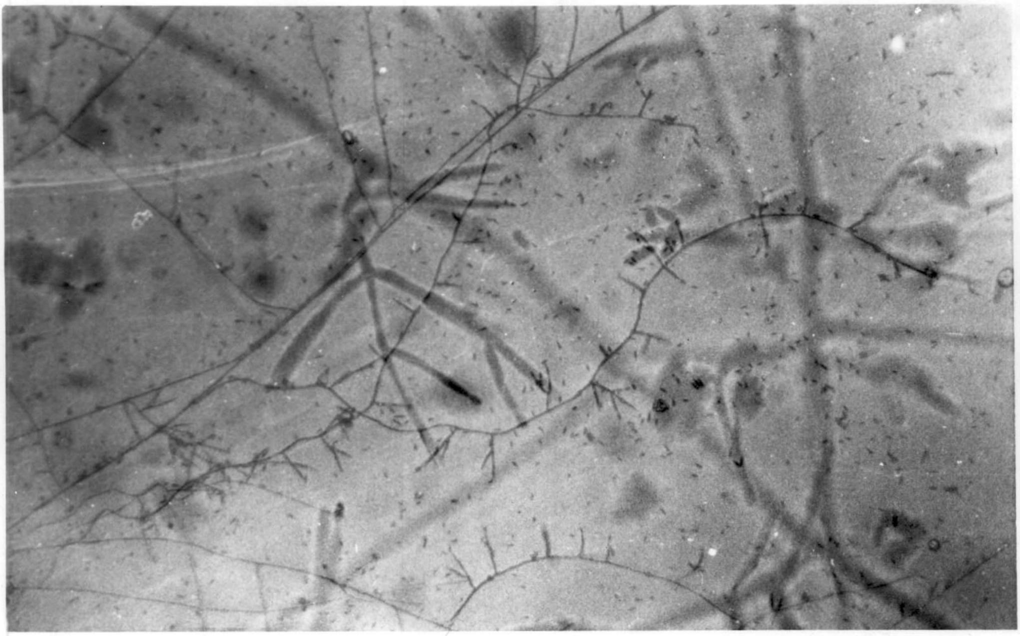


Plate II (Contd.). Morphological characters of *S. oryzae* - S_7 (X 690).

Fig.1. Morphological characters of *S.oryzae* - S_1.

Morphological characters of *S.oryzae* - S_2

a. Conidium
b. Conidiophore

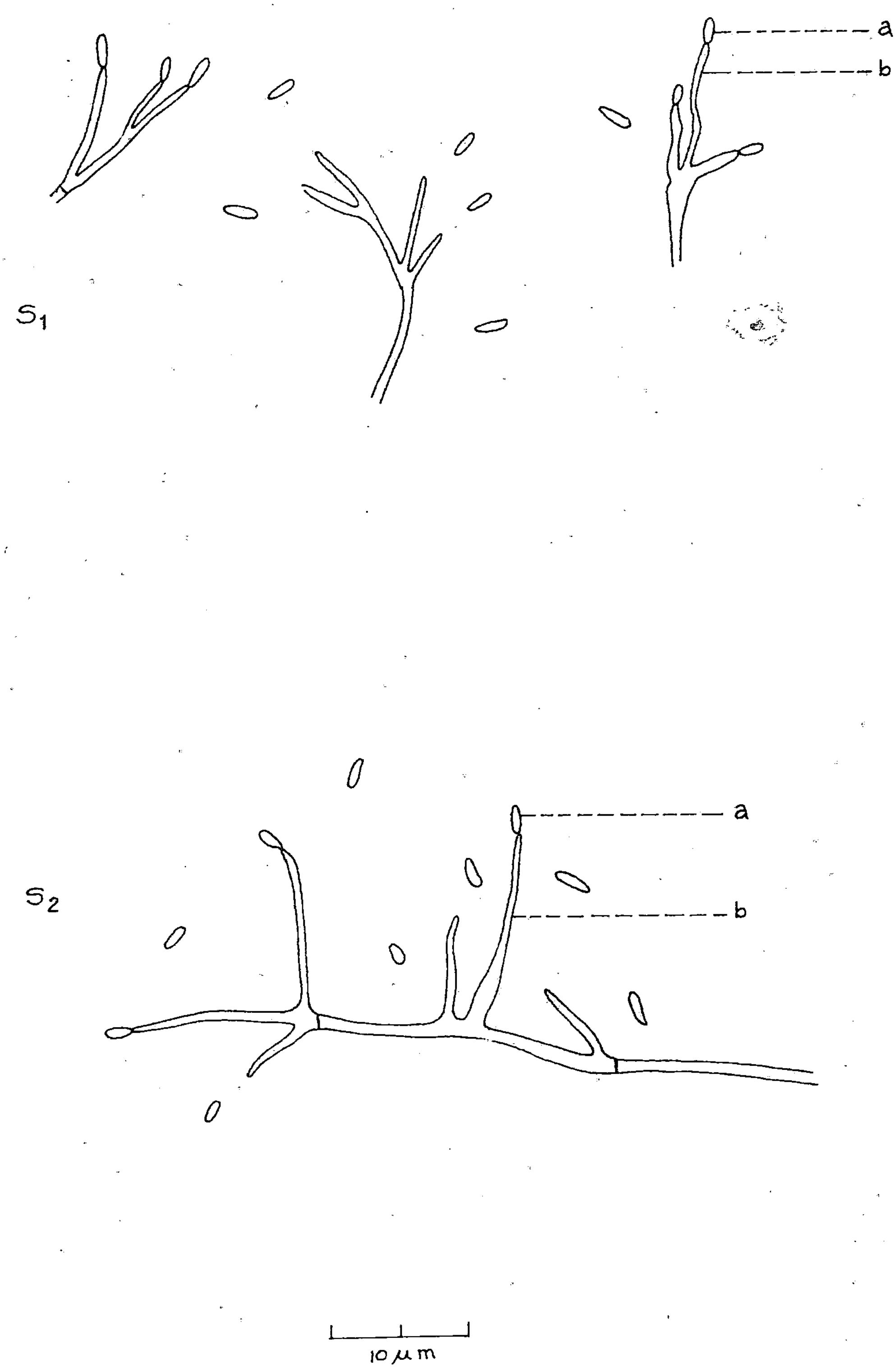


Fig.1.

Fig.1. (Contd.) Morphological characters of
S.oryzae - S_3.

Morphological characters of
S.oryzae - S_4

a. Conidium
b. Conidiophore

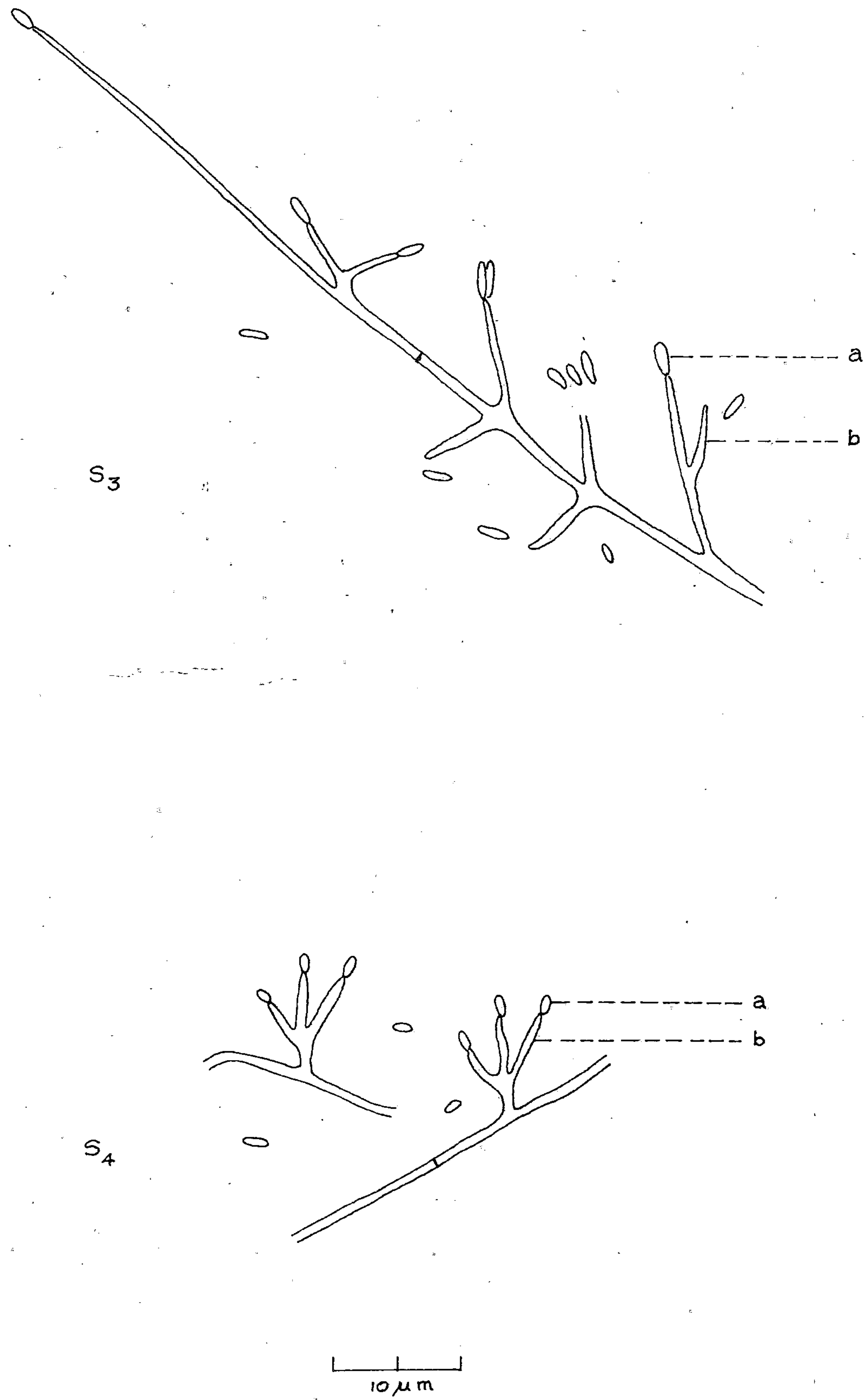


Fig.1 (Contd.)

Fig. 1. (Contd.) Morphological characters of *S. oryzae* - S_5

Morphological characters of *S. oryzae* - S_6

Morphological characters of *S. oryzae* - S_7

a. Conidium
b. Conidiophore

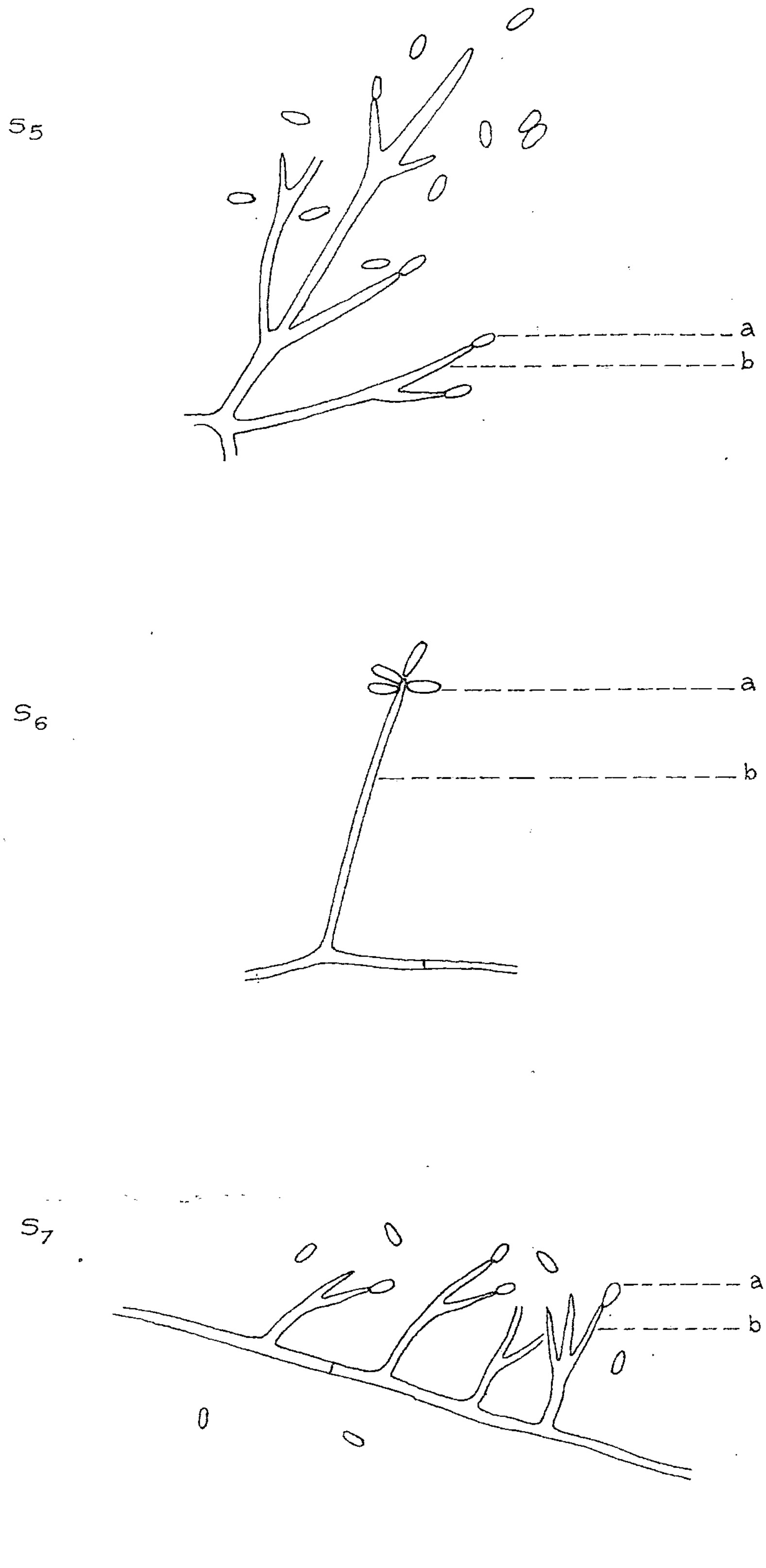


Fig.1 (Contd)

The morphological characters of these three fungi are enumerated in Table (2).

From the morphology of the organisms these were identified as

A_1 = *Fusarium* sp.

A_2 = *Fusarium* sp.

A_3 = *Alternaria padwickii* (Ganguly) M.B. Ellis.

III. Pathogenicity studies

The observations on pathogenicity trials revealed that all the isolates of *S. oryzae* (S_1 to S_7) and associated fungi (A_1, A_2 & A_3) individually and the combinations of the isolates of associated fungi with the most virulent isolate (S_5) of *S. oryzae* were able to infect the different rice varieties. However, they varied in the nature of symptoms produced. The observations made on the pathogenicity trials with various isolates on different rice varieties are presented in Table (3).

From the observations presented in Table 3 above, it is clear that virulence of the isolates vary and to a certain extent it is dependent on the variety also. Isolate (S_2) showed only mild reaction to all the four varieties tested, whereas the isolate (S_5) recorded the maximum virulence in all

Table 2

Morphological characters of associated fungi, other than the causal organism *S. oryzae*, isolated from rice with sheath rot symptoms.

Characters	Isolates A_1	A_2	A_3
A. Mycelium			
Septation, colour and nature of growth on medium.	septate, purplish-white, profuse, PDA medium turned to light brown in older cultures.	septate, creamy-white profuse growth with light yellow discolouration in the PDA and rice grain medium in older cultures.	septate, greyish-white, profuse with blackish-white in the grown up cultures in PDA as well as in rice grain medium. Small spherical sclerotia in large numbers were noticed in the culture. The grey-white young sclerotia were turned to varying intensity of brown colour in older culture.
Hyphal * thickness	0.8 - 3.2 (2)	1.5 - 1.75 (1.6)	0.8 - 3.2 (2)
B. Conidiophore *	branched and sporodochium development was noticed. Conidiophore measured 6.3 - 9.5 (7.9) X 3 - 3.5 (3.2).	sporodochium noticed. Conidiophore measured 15.5 - 16.1 (15.8) X 1.6 - 2.4 (2).	conidiophores were not seen demarcated in the mycelium

Table 2 (Contd.)

Characters	A_1	A_2	A_3
C. Conidium *			
Colour, shape, size, septation and attachment of conidia.	macroconidia only were seen which were three to seven septate, hyaline, fusiform and slightly curved with 15.8 - 31.6 (23.7) X 2.4 - 3.2 (2.8).	macroconidia were in large numbers which were two to four septate hyaline, fusiform and developed from the tip as well as from the sides of the conidiophores, measured 9.5 - 19 (14.3) X 2.4 - 3.2(2.8).	conidia light brown, elongately fusoid, slightly curved three to seven septate and slightly constricted at septa and with a long straight beak at the tip. Conidia measured (including beak) 75.8 - 205.4 (127.0) X 6.3 - 11.1(8.7) and(excluding beak) 37.9 - 69.5 (55.5) X 6.3 - 11.1 (8.7).

The morphological characters of the three isolates are illustrated in the photomicrographs in Plate III and camera lucida drawings in Fig.2.

* Measurements are all in microns (µm).
Figures in parenthesis represent average values.

Plate III. Morphological characters of *Fusarium* sp - A_1 (X 670).

Morphological characters of *Fusarium* sp - A_2 (X 850).

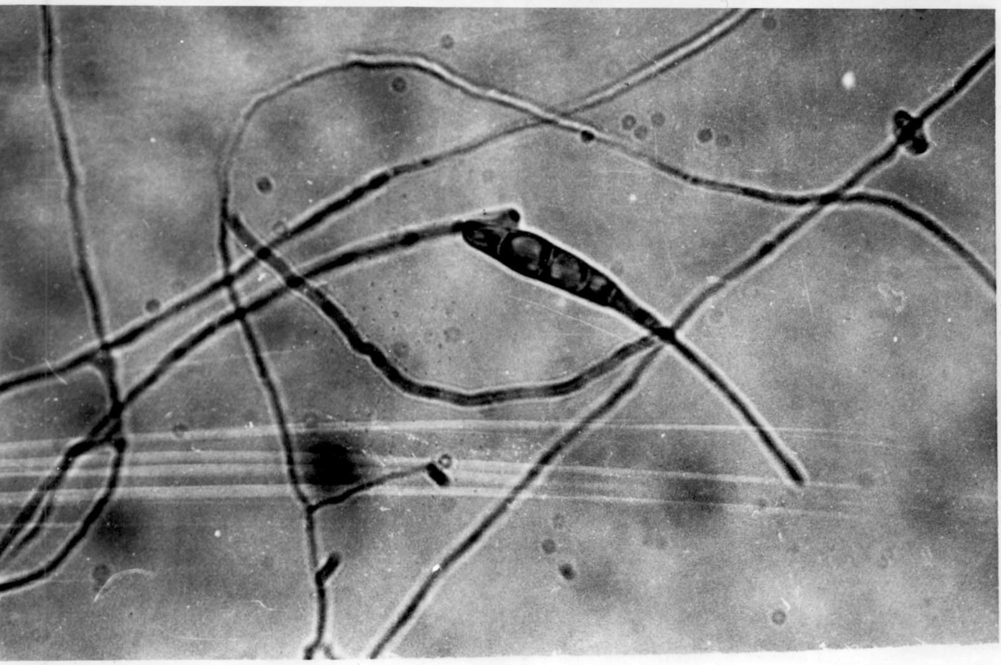


Plate III (Contd.) Morphological characters of
Alternaria padwickii - A_3 (X 475).

Fig.2. Morphological characters of *Fusarium* sp. - A_1

Morphological characters of *Fusarium* sp. - A_2

a. Conidium
b. Conidiophore

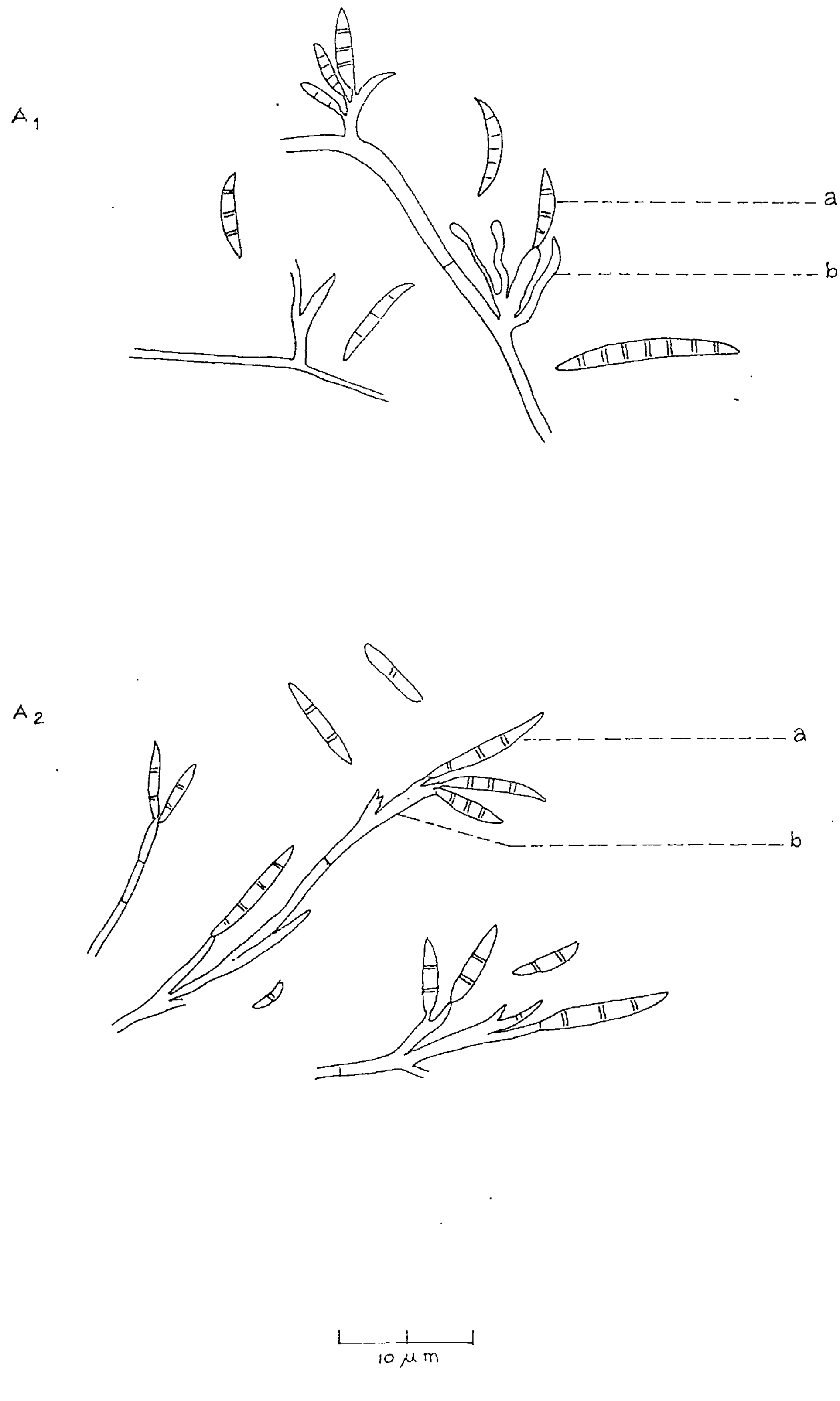


Fig.2.

Fig.2. (Contd.) Morphological characters of *Alternaria padwickii* - A_3

a. Conidium

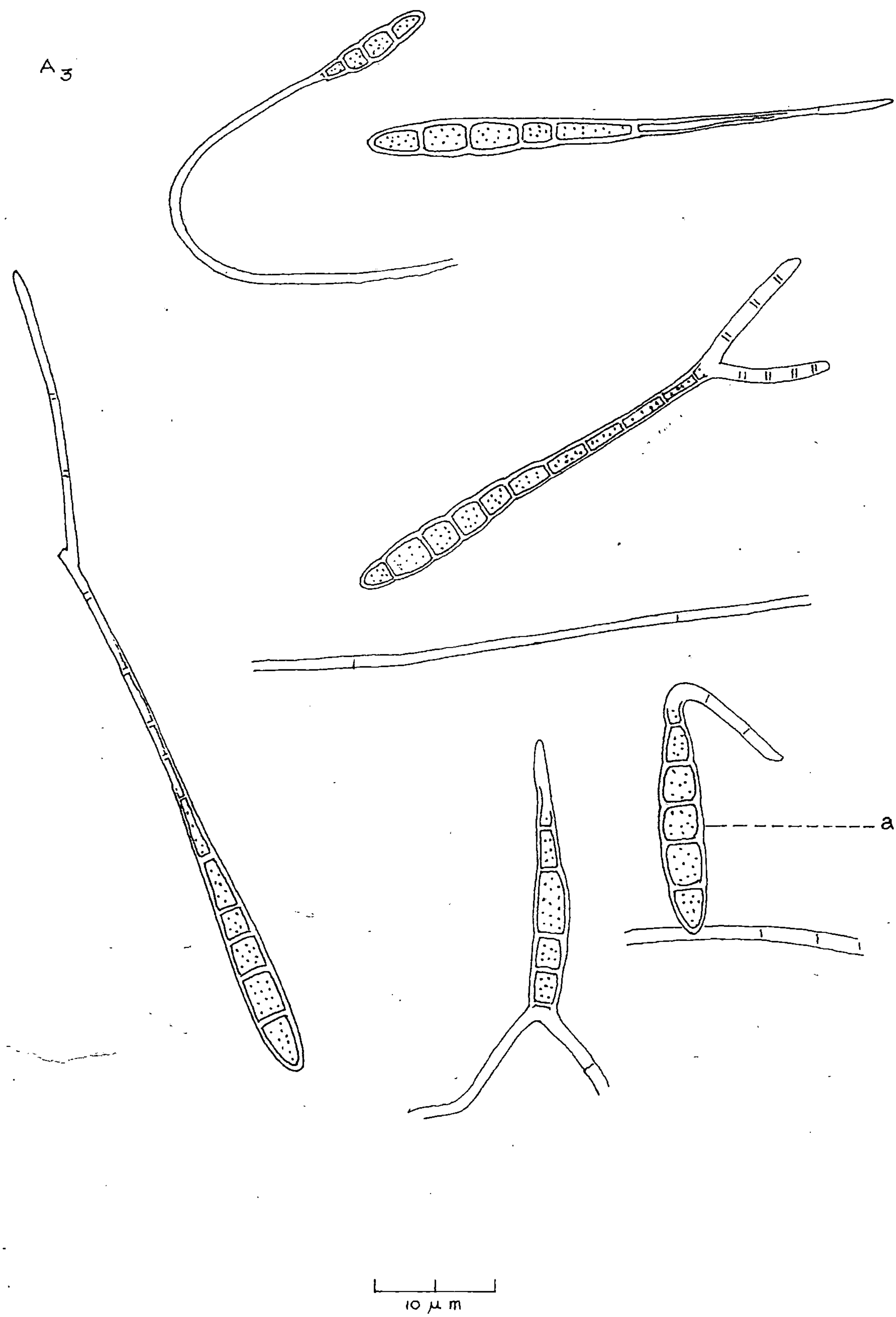


Fig.2 (Contd.)

Table 3

Pathogenicity of different isolates of S.oryzae (S_1, S_2, S_3, S_4, S_5, S_6 and S_7) and associated fungi (A_1, A_2 and A_3) on different rice varieties (The symptoms are illustrated in Plate IV)

Isolate		Reaction of different varieties			
		Jaya	Pavizham	Jyothi	Triveni
S.oryzae					
S_1	Symptom	symptom initiated on 5th day of inoculation as yellowish-brown lesions. Advanced lesions turned brown with greyish centres. The sheaths of lower two leaves of boot leaf also showed mild symptoms. About 40 per cent of the infected plants showed partial emergence of the panicles.	symptom initiated on 5th day and subsequent development as under Jaya.	symptom initiated on 5th day as dark brown larger areas. Gradually centre of lesions turned light grey in colour. More than 50 per cent of the infected plants showed partial emergence of panicles.	symptom initiated as in Jyothi. But gradually the boot leaf sheaths turned uniformly pinkish brown. About 40 per cent panicles partially emerged. Spread of symptom to lower sheaths was restricted.
	Nature of virulence	moderate	moderate	moderate	moderate

Table 3 (Contd.)

Isolate		Jaya	Pavizham	Jyothi	Triveni
S_2	Symptom	initiated on 8th day of inoculation, but no demarcated lesions were developed but a uniform yellowish discolouration on boot leaf sheath was noticed. Gradually the lower two sheaths also showed mild yellowish brown discolouration. A low panicles sterility was noticed.	same as in Jaya.	initiated on 8th day, but the development was slow. A mild light brown discolouration of all inoculated sheaths was noticed. Low panicle sterility.	initiated on 8th day, but development was veryslow. A dark brown discolouration was noticed in the inoculated portion of boot leaf sheath. Panicles sterility very low.
	Nature of virulence	mild	mild	mild	mild
S_3	Symptom	appeared on 6th day of inocculation. Boot leaf sheath showed typical symptom with pinkish-brown lesions. Spread to lower sheaths was limited. Choking of panicles was noticed in 30 per cent of infected plants.	initial symptoms a little delayed. Only boot leaf sheath showed typical lesions. Low sterility of panicles.	initiated on 6th day. Faster development on boot leaf sheath. Sterility of panicles heavier.	initiated on 6th day. Boot leaf sheath showed typical symptoms. Higher sterility of panicles. Spread to lower sheaths was less.
	Nature of virulence	moderate	mild	severe	severe

Table 3 (Contd.)

Isolate		Jaya	Pavizham	Jyothi	Triveni
S_4	Symptom	Initiated on 6th day. Only mild symptoms on all the inoculated sheaths. About 10 per cent choking of panicles.	same as in Jaya.	Initiated on 6th day. Light brown lesions on boot sheath in advanced stage. Panicle choking below 30 per cent.	Initiated on 6th day. Boot leaf sheath showed yellowish-brown localised lesions. Poor spread on lower sheaths and less panicle sterility.
	Nature of virulence	moderate	moderate	moderate	moderate
S_5	Symptom	Initiated on 5th day and developed quickly on boot sheath with typical dark brown lesions. More than 60 per cent panicles choked. All the inoculated sheaths showed uniform brownish colour on 20th day.	same as in Jaya.	Initiated on 5th day. Faster spread on all the sheaths. More than 60 per cent panicles choked. A burned up appearance on 20th day.	same as in Pavizham and Jaya.
	Nature of virulence	severe	severe	severe	severe

Table 3 (Contd.)

Isolate		Jaya	Pavizham	Jyothi	Triveni
S_6	Symptom	initiated on 6th day. Light brown larger lesions developed only on boot leaf sheath. Poor spread to lower sheaths. About 30 per cent panicles choked.	initiated little later. Lesions developed only on inoculated spots in the boot leaf sheath. Lower sheaths free of symptom. Less panicle sterility.	initiated on 5th day. Typical lesions on boot leaf sheath developed by 15th day. Lower sheaths uniformly discoloured to brown. About 40 per cent panicles choked.	initiated on 5th day. Typical symptoms on boot sheath developed by 15th day. Lower sheaths were also discoloured to yellow-brown. About 30 per cent panicles choked.
	Nature of virulence	moderate	mild	severe	severe
S_7	Symptom	initiated on 6th day. All the inoculated sheaths showed pinkish-brown uniform discolouration. About 40 per cent panicles choked.	initiated on 6th day. Inoculated sheaths showed yellowish-brown discolouration. Less panicle damage.	initiated on 6th day. Pinkish-brown uniform discolouration of boot sheath with 40 per cent panicle choking.	same as in Jyothi
	Nature of virulence	moderate	moderate	moderate	moderate

Table 3 (Contd.)

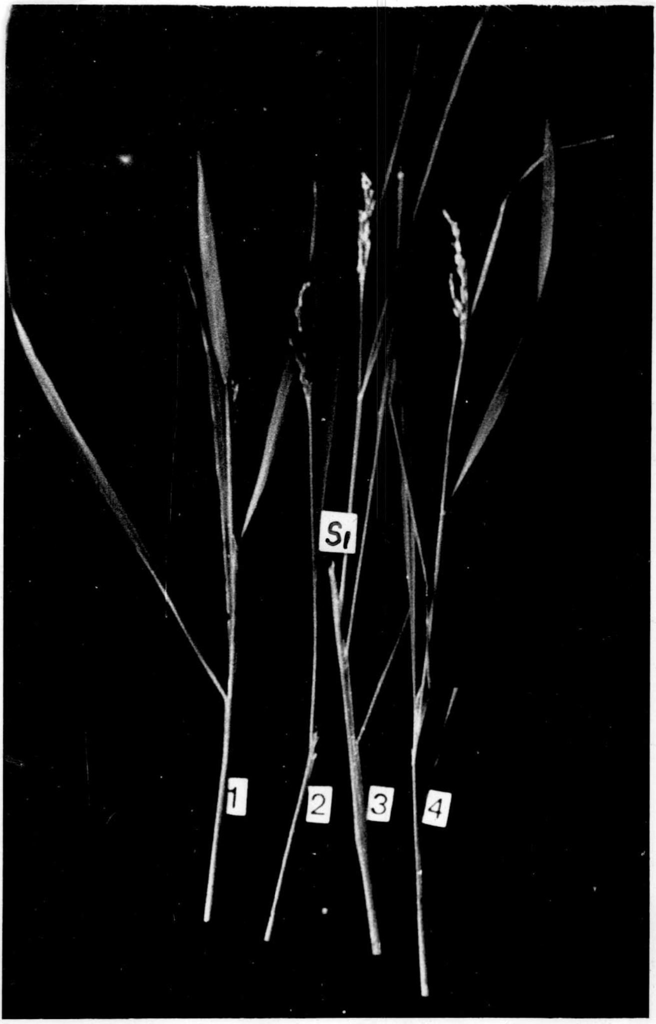
Isolate		Jaya	Pavizham	Jyothi	Triveni
A_1	Symptom	initiated on 8th day. Boot sheath and middle sheath showed blackish discolouration and gradually these sheaths showed a greyish powdery appearance on the surface and finally the sheaths dried up. Less panicle sterility but grain discolouration noticed.	same as in Jaya.	initial symptoms same as in Jaya and Pavizham. Severe grain discolouration noticed.	appeared on 7th day. Boot sheath turned yellowish which quickly spread to the whole plant. Brownish discolouration in grains was severe.
	Nature of virulence	moderate	moderate	moderate	moderate
A_2	Symptom	initiated on 10th day. Uniform yellowish discolouration of all the inoculated sheaths. Finally the plant showed a burned up appearance. Panicles emerged normally. Severe grain discolouration.	same as in Jaya.	initiated same as in Jaya and Pavizham but the development was faster. Higher grain discolouration.	same as in Jaya and Pavizham.
	Nature of virulence	moderate	moderate	moderate	moderate

Table 3 (Contd.)

Isolate		Jaya	Pavizham	Jyothi	Triveni
A_3	Symptom	initiated on 10th day and in certain cases even later. Inoculated sheaths turned blackish and the discolouration covered the entire sheath by 20th day. Panicles emerged normally but with severe grain discolouration.	same as in Jaya.	initiated in the same way as in Jaya but partial emergence of panicles noticed in certain cases along with grain discolouration.	same as in Jyothi.
	Nature of virulence	moderate	moderate	moderate	moderate
S_5+A_1	Symptom	initiated on 5th day and even earlier. Typical pinkish-brown lesions first developed on boot sheath, later spreading to the lower sheaths. Gradually lesions turned dark brown and covered the entire boot leaf sheath. About 60 per cent panicles choked inside the sheath. Finally a pinkish-white powdery fungal growth seen on entire surface of the choked panicles.	same as in Jaya.	same as in Jaya.	same as in Jaya.
	Nature of virulence	severe	severe	severe	severe

Table 3 (Contd.)

Isolate		Jaya	Pavizham	Jyothi	Triveni
$S_5 + A_2$	Symptom	initiated on 5th day and even earlier. Typical sheath rot lesions developed by 15th day and a higher percentage of panicle choking were observed.	same as in Jaya.	same as in Jaya.	same as in Jaya.
	Nature of virulence	severe	severe	severe	severe
$S_5 + A_3$	Symptom	initiated on 5th day and even earlier. Boot sheath uniformly discoloured to brown by 15th day. The lower sheaths turned yellowish-brown. Poor panicle emergence. Severe grain sterility and grain discolouration were noticed.	same as in Jaya.	same as in Jaya.	same as in Jaya.
	Nature of virulence	severe	severe	severe	severe



IV. Reaction of four different var
of rice to infection by *S.oryz*
(isolate-S_1).

1. Jaya
2. Pavizham
3. Jyothi
4. Triveni

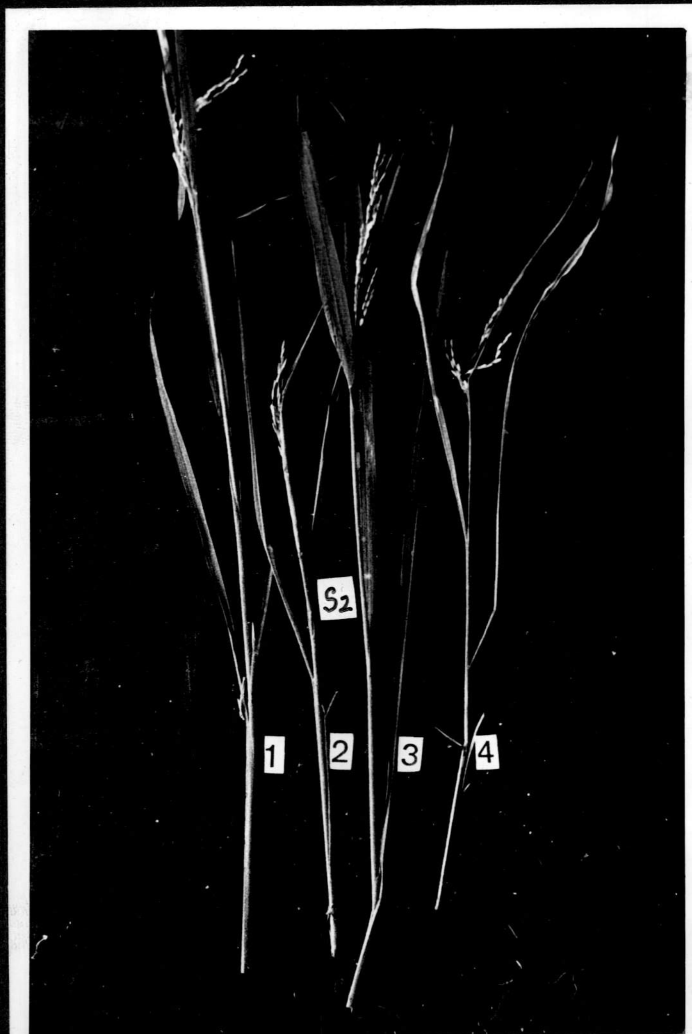
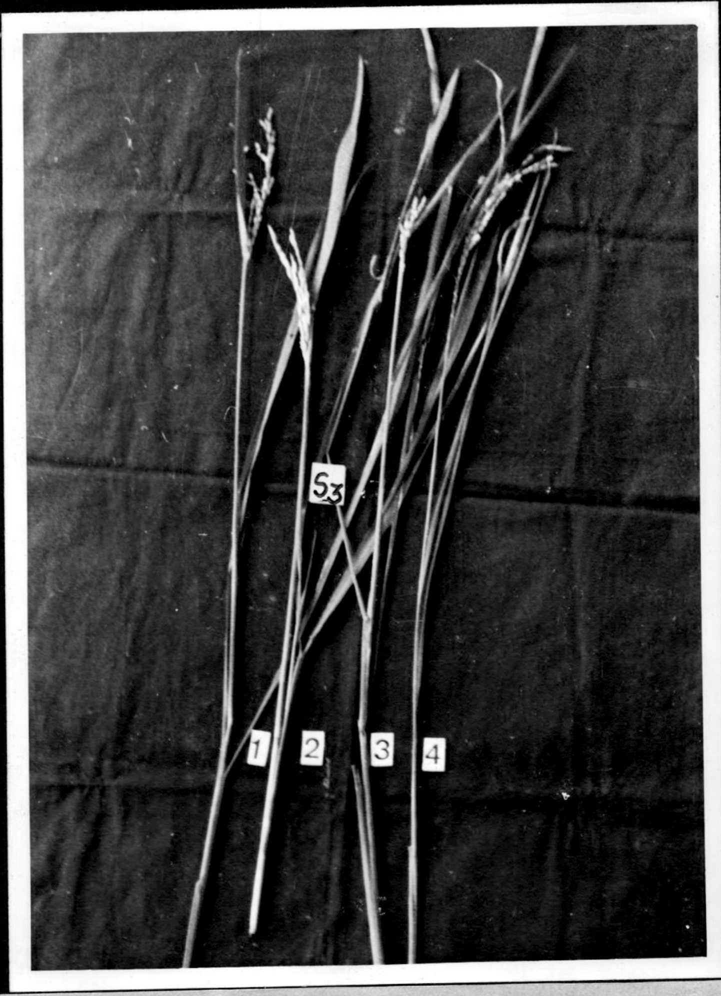


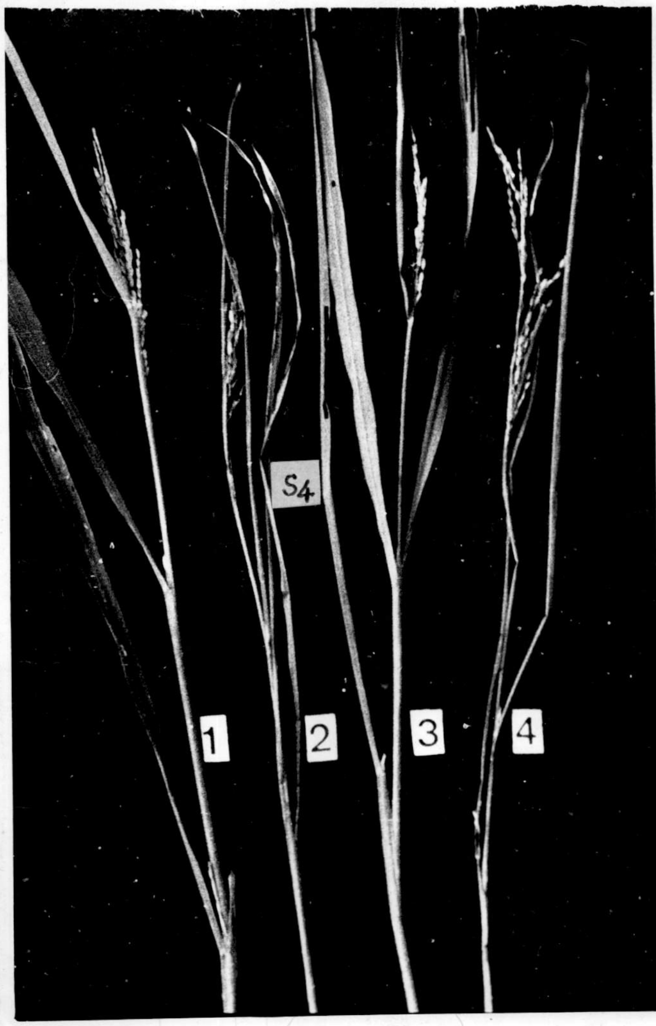
Plate IV (Contd.). Reaction of four different varieties of rice to infection by *S.oryzae* (isolate - S_2).

1. Jaya 2. Pavizham
3. Jyothi 4.Triveni



e IV (Contd.). Reaction of four differ
varieties of rice to infection by
S. oryzae (isolate - S_3).

1. Jaya
2. Pavizham
3. Jyothi
4. Triveni



IV (Contd.). Reaction of four differ
varieties of Rice to infection by
S. oryzae (isolate – S_4).

1. Jaya
2. Pavish
3. Jyothi
4. Triveni

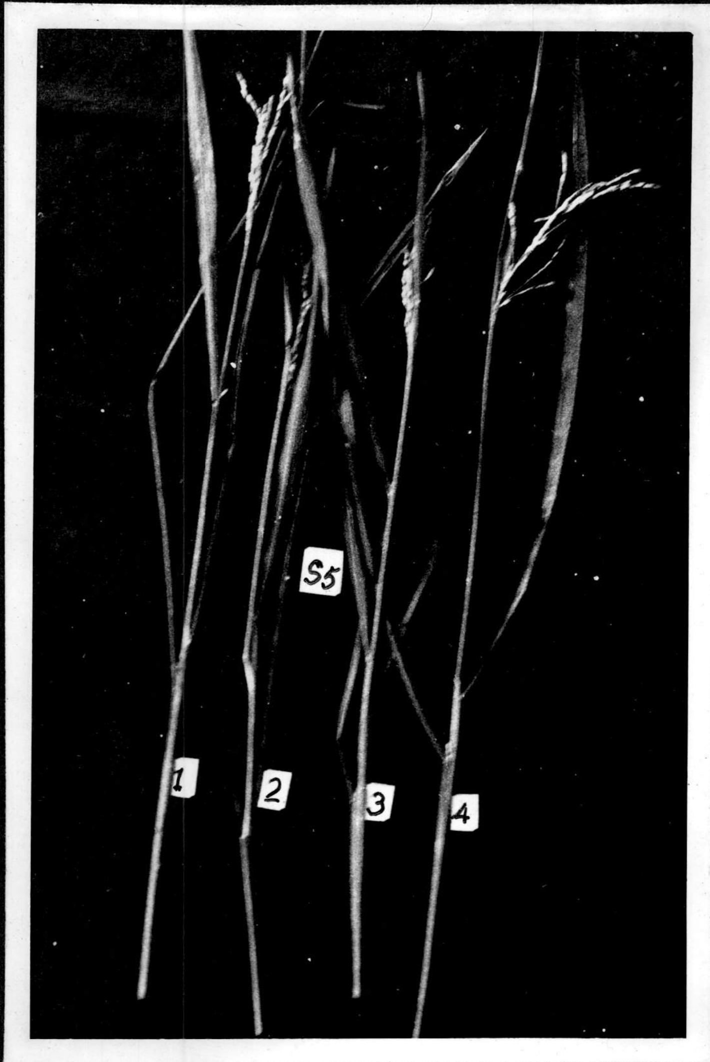
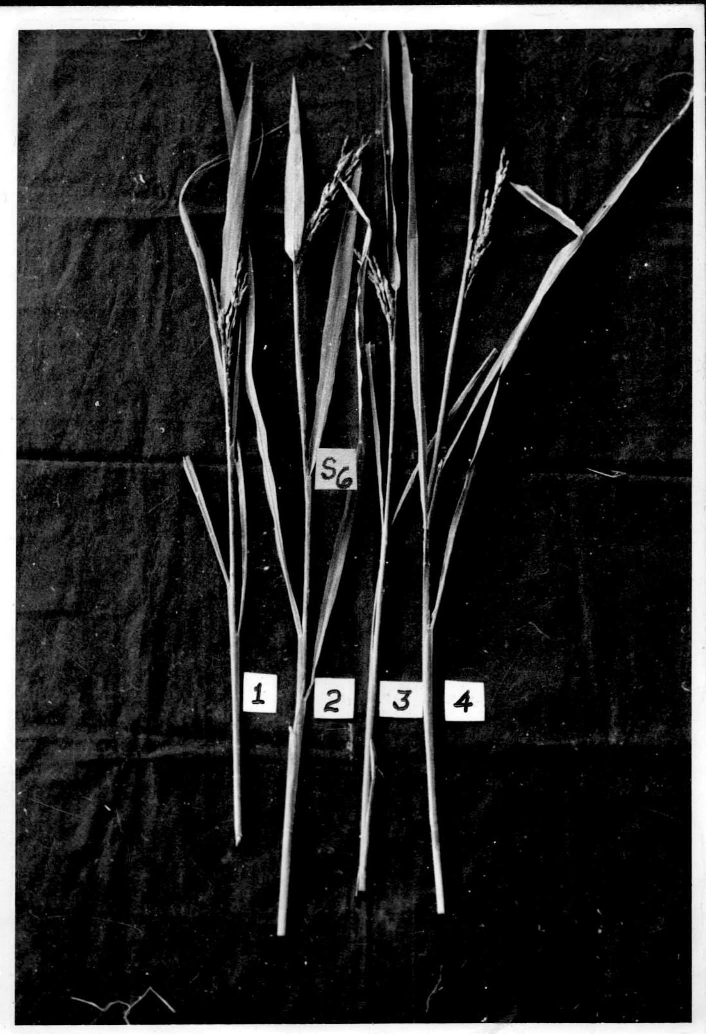


Plate IV (Contd.) Reaction of four different varieties of rice to infection by <u>S.oryzae</u> (isolate - S_5)

1. Jaya 2. Pavizham
3. Jyothi 4. Triveni

Close up view of sheath rot symptoms produced by S_5 isolate on Jyothi.



IV (Contd.). Reaction of four diffe
varieties of rice to infection by
S.oryzae (isolate - S_6)

1. Jaya
2. Pavizham
3. Jyothi
4. Triveni

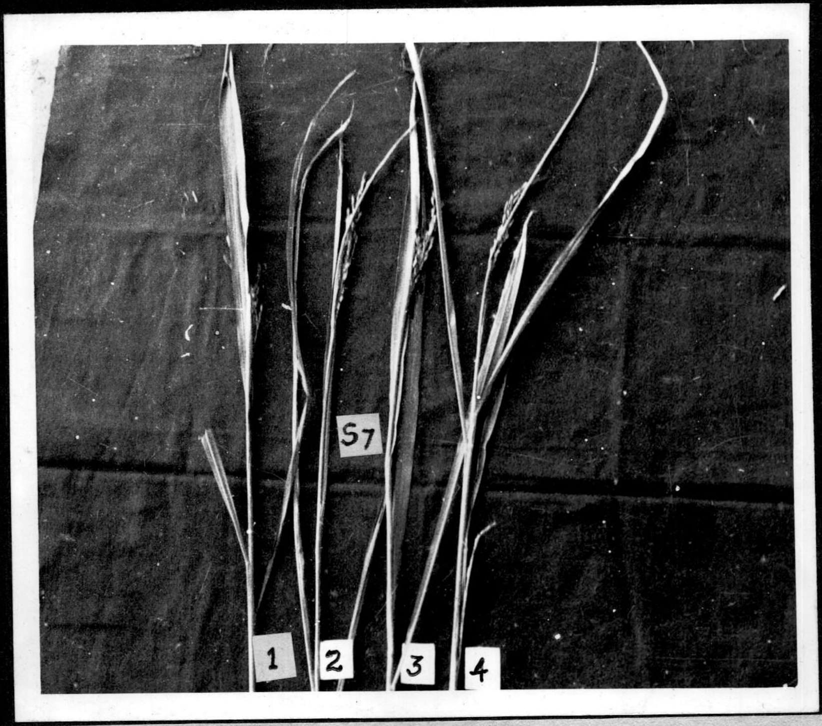


Plate IV (Contd.) Reaction of four different varieties of rice to infection by *S.oryzae* (isolate - S_7).

1. Jaya
2. Pavizham
3. Jyothi
4. Triveni

Plate IV (Contd.) Reaction of rice variety Jyothi to infection by

1. *Fusarium* sp - A_1
2. *Fusarium* sp - A_2
3. *Alternaria padwickii* - A_3

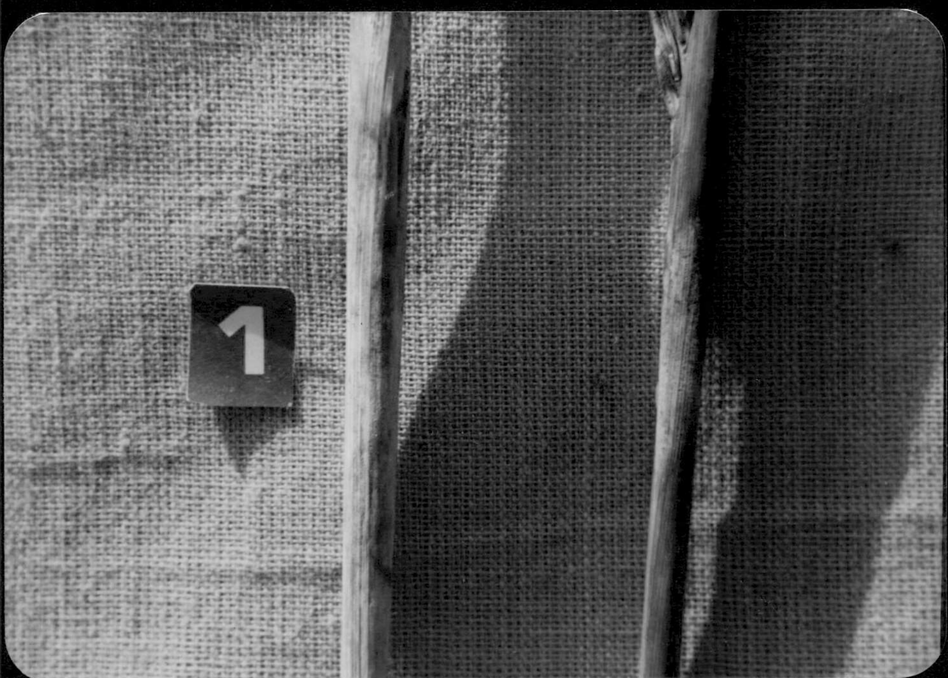


Plate IV (Contd.) Sheath rot symptoms produced by combined inoculation of *S. oryzae* (S_5) and *Fusarium* sp (A_1) on Jyothi.

Plate IV (Contd.) Sheath rot symptoms produced by combined inoculation of S. oryzae (S_5) and Fusarium sp (A_2) on Jyothi.

IV (Contd.)

Sheath rot symptoms prod
combined inoculation o
S. oryzae (S_5) and *Altern*
padwickii (A_3) on Jyothi

the varieties tested. The variety Pavizham has exhibited a certain extent of resistance reaction to the isolates (S_3) and (S_6), while all the varieties tested showed susceptible reaction to the other isolates. It was also observed that the combined inoculation of S.oryzae and the associated fungi, viz., isolates of Fusarium sp (A_1), Fusarium sp (A_2) and Alternaria padwickii (A_3) could hasten the infection rate and symptom development in all the rice varieties tested.

IV. Post infectional changes in total soluble sugars and total phenolics in four varieties of rice

a. Total soluble sugars

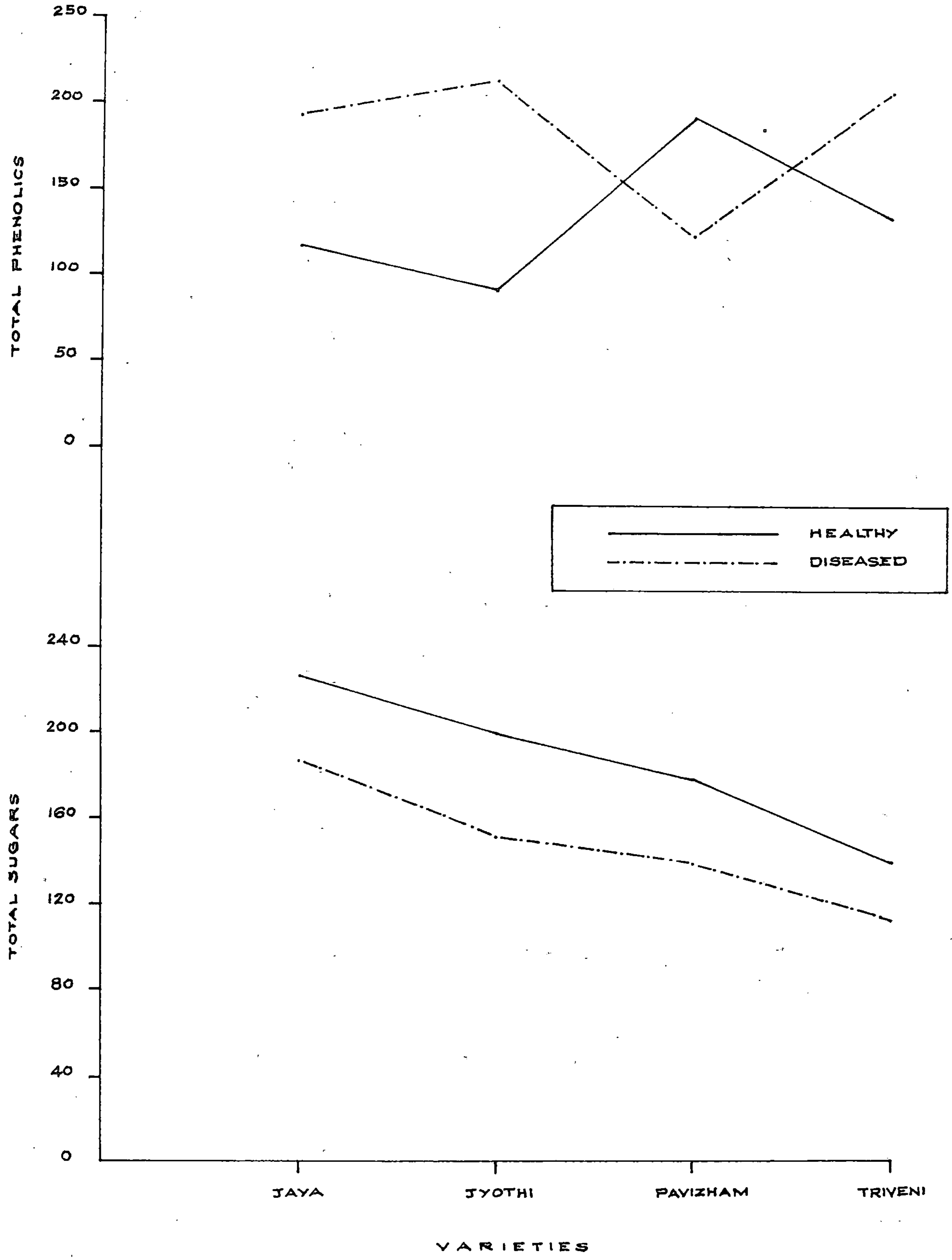
The results are presented in Table (4). From the data it is clear that the quantity of total soluble sugars gradually decreased due to infection. Under uninoculated healthy condition, the variety Jaya recorded maximum sugar content (226.67 µg/g fresh plant sample) as against the lowest quantity of 140 µg/g in Triveni. But while the rate of decrease of sugar was compared in infected varieties, as with the healthy ones, the maximum reduction was recorded in the variety Jyothi (23.34 per cent reduction over healthy). The minimum reduction was observed in the variety Triveni (16.19 per cent reduction over healthy). In the varieties Jaya and Pavizham the reductions were almost uniform ie., 17.65 and 18.52 per cent respectively over healthy (Fig.3).

Table 4

Changes in total sugars and phenolics in four different rice varieties due to infection by <u>S. oryzae</u> (isolate No. S_5).

Sl. No.	Rice variety	Total soluble sugars (µg/g of fresh plant sample)			Total phenolics (µg/g of fresh plant sample)		
		Healthy	Diseased	Per cent decrease over healthy	Healthy	Diseased	Per cent increase (+)/ decrease (-) over healthy
1	Jaya	226.67	186.67	17.65	116.67	193.33	+ 65.71
2	Jyothi	200.00	153.33	23.34	93.33	213.33	+128.58
3	Pavizham	180.00	146.67	18.52	193.33	126.67	- 34.48
4	Triveni	140.00	117.33	16.19	136.67	206.67	+ 51.22

Fig.3. Changes in total soluble sugars and phenolics in different rice varieties due to infection by _S.oryzae_.



250
200
150
100
50
0
TOTAL PHENOLICS
HEALTHY
DISEASED
240
200
160
120
80
40
0
TOTAL SUGARS
JAYA
JYOTHI
PAVIZHAM
TRIVENI
VARIETIES

Fig.3.

(b) Total phenolics

The data on total phenolics are presented in Table (4). In general in all the rice varieties tested except in Pavizham the diseased plants showed an increase of total phenolics than healthy. An exception to this was noticed in the case of Pavizham where in a reduction in total phenolics was noticed in affected plants (34.48 per cent reduction over healthy). The variety Jyothi recorded a maximum increase in total phenolics than the healthy ones (120.58 per cent over healthy) and the least increase was recorded in the variety Triveni (51.22 per cent over healthy). In the variety Jaya the increase observed was 65.71 per cent over healthy (Fig.5).

V. Influence of management practices in sheath rot incidence

V.1. Long range effect of continuous cropping and manuring on sheath rot incidence

The data collected on disease index for three seasons are presented in Tables (5ato 5g).

In the pooled analysis Year X treatment interaction was not observed to be significant with respect to disease index. Nitrogen (N) levels differed significantly. The least disease index was recorded by the N_1 (40 kg N/ha) and was observed

Table 5 a

Effect of continuous cropping and manuring on sheath rot incidence

Sl. No.	Treatments (kg/ha)		Disease index 1984 Kharif	Disease index 1984 Rabi	Disease index 1985 Kharif	Pooled mean
1	$N_0P_0K_0$	(Control)	17.457	5.961	8.797	10.738
2	$N_1P_0K_0$	(40:0:0)	19.791	6.540	7.871	11.401
3	$N_1P_0K_1$	(40:0:40)	19.676	8.507	8.566	12.250
4	$N_1P_1K_0$	(40:40:0)	16.146	9.086	13.427	12.886
5	$N_1P_1K_1$	(40:40:40)	21.155	10.648	10.650	14.151
6	$N_1P_2K_0$	(40:80:0)	20.543	11.343	7.003	12.963
7	$N_1P_2K_1$	(40:80:40)	16.666	6.424	7.005	10.031
8	$N_2P_0K_0$	(80:0:0)	20.081	11.748	7.871	13.233
9	$N_2P_0K_1$	(80:0:40)	18.113	6.250	7.698	10.687
10	$N_2P_1K_0$	(80:40:0)	18.634	7.350	10.959	12.307
11	$N_2P_1K_1$	(80:40:40)	18.287	13.775	13.427	15.162
12	$N_2P_2K_0$	(80:80:0)	25.289	10.707	12.791	16.262
13	$N_2P_2K_1$	(80:80:40)	18.634	10.070	13.949	14.217
14	$N_3P_0K_0$	(120:0:0)	21.701	8.970	18.694	16.455
15	$N_3P_0K_1$	(120:0:40)	19.791	6.308	11.807	12.635
16	$N_3P_1K_0$	(120:40:0)	28.009	11.748	11.981	17.246
17	$N_3P_1K_1$	(120:40:40)	21.065	14.005	14.122	16.397
18	$N_3P_2K_0$	(120:80:0)	19.733	9.375	15.164	14.757
19	$N_3P_2K_1$	(120:80:40)	19.560	14.989	19.504	18.018
	C.D.		N.S.	N.S.	N.S.	N.S.

N_0 - Zero Nitrogen (N)
N_1 - 40 kg N/ha
N_2 - 80 kg N/ha
N_3 - 120 kg N/ha

P_0 - Zero Phosphorus (P)
P_1 - 40 kg P/ha
P_2 - 80 kg P/ha

K_0 - Zero Potash (K)
K_1 - 40 kg K/ha

Table 5 b

Effect of different levels of Nitrogen (N) on sheath rot incidence

Sl. No.	Treatments (kg N/ha)	Disease index			Pooled mean
		1984 Kharif	1984 Rabi	1985 Kharif	
1	40	18.996	8.758	9.067	12.280
2	80	19.839	9.985	11.112	13.645
3	120	21.643	10.899	15.212	15.918
	C.D.	N.S.	N.S.	2.632	1.5072

Table 5 c

Effect of different levels of Phosphorus (P) on sheath rot incidence

Sl. No.	Treatments (kg P/ha)	Disease index			Pooled mean
		1984 Kharif	1984 Rabi	1985 Kharif	
1	2020	19.859	8.054	10.418	12.777
2	40	20.549	11.101	12.424	14.691
3	80	20.071	10.484	12.569	14.375
	C.D.	N.S.	2.572	N.S.	1.5072

Table 5 d

Effect of different levels of Potash (K) on sheath rot incidence

Sl. No.	Treatments (kg K/ha)	Disease index			Pooled mean
		1984 Kharif	1984 Rabi	1985 Kharif	
1	Zero	21.103	9.652	11.749	14.168
2	40	19.216	10.108	11.858	13.727
	C.D.	N.S.	N.S.	N.S.	N.S.

Table 5 e

Effect of interaction of Nitrogen (N) and Phosphorus (P) on sheath rot incidence

Sl. No.	Treatments (kg N X P/ha)		Disease index 1984 Kharif	1984 Rabi	1985 Kharif	Pooled mean
1	N_1P_0	(40:0)	19.733	7.523	8.219	11.825
2	N_1P_1	(40:40)	18.650	9.867	12.038	13.518
3	N_1P_2	(40:80)	18.605	8.883	7.003	11.497
4	N_2P_0	(80:0)	19.097	8.999	7.784	11.960
5	N_2P_1	(80:40)	18.460	10.562	12.183	13.735
6	N_2P_2	(80:80)	21.961	10.388	13.370	15.240
7	N_3P_0	(120:0)	20.746	7.639	15.250	14.545
8	N_3P_1	(120:40)	24.537	12.876	13.051	16.821
9	N_3P_2	(120:80)	19.647	12.182	17.334	16.387
	C.D.		N.S.	N.S.	N.S.	N.S.

N_1 - 40 kg N/ha
N_2 - 80 kg N/ha
N_3 - 120 kg N/ha

P_0 - Zero Phosphorus
P_1 - 40 kg P/ha
P_2 - 80 kg P/ha

Table 5 f

Effect of interaction of Nitrogen (N) and Potash (K) on sheath rot incidence

Sl. No.	Treatments (kg N X K/ha)		Disease index 1984 Kharif	1984 Rabi	1985 Kharif	Pooled mean
1	N_1K_0	(40: 0)	18.827	8.969	9.454	12.417
2	N_1K_1	(40:40)	19.165	8.526	8.759	12.143
3	N_2K_0	(80:0)	21.335	9.935	10.534	13.935
4	N_2K_1	(80:40)	18.344	10.031	11.691	13.355
5	N_3 K_0	(120:0)	23.148	10.031	15.279	16.153
6	N_3 K_1	(120:40)	20.139	11.767	15.144	15.683
	C.D.		N.S.	N.S.	N.S.	N.S.

N_1 - 40 kg N/ha
N_2 - 80 kg N/ha
N_3 - 120 kg N/ha

K_0 - Zero Potash
K_1 - 40 kg K/ha

Table 5 g

Effect of interaction of Phosphorus (P) and Potash (K) on sheath rot incidence

Sl. No.	Treatments (kg P X K/ha)		Disease index 1984 Kharif	1984 Rabi	1985 Kharif	Pooled mean
1	P_0K_0	(0:0)	20.524	9.086	11.479	13.696
2	P_0K_1	(0:40)	19.193	7.022	9.357	11.857
3	P_1K_0	(40:0)	20.929	9.394	12.116	14.146
4	P_1K_1	(40:40)	20.169	12.809	12.733	15.237
5	P_2K_0	(80:0)	21.855	10.475	11.653	14.661
6	P_2K_1	(80:40)	18.287	10.494	13.485	14.089
	C.D.		N.S.	N.S.	N.S.	N.S.

P_0 - Zero Phosphorus

P_1 - 40 kg P/ha

P_2 - 80 kg P/ha

K_0 - Zero Potash

K_1 - 40 kg K/ha

to be on par with N_2 (80 kg N/ha). N_3 (120 kg N/ha) recorded the maximum disease index. Phosphorus (P) levels also differed significantly. Zero application of P recorded the least disease incidence. Potash (K) levels did not differ significantly in the initiation of disease. However, K_1 (40 K/ha) recorded the least disease index. None of the interactions was observed to be statistically significant. However, among the NPK combinations $N_1P_2K_1$ (40:80:40) level was observed to be the best combination for minimising the disease and $N_3P_2K_1$ (120:80:40) combination was observed to be highly congenial for disease severity (Fig.4).

V.2. Crop technology for optimum production under resource constraints and their effect on sheath rot incidence

Among the various agronomic practices which determine crop productivity tested in this trial, the pooled analysis showed that only the date of planting was found to be significant in the initiation of disease. The second treatment under date of planting i.e., three weeks after normal planting recorded the least disease index (12.729). The normal date of planting was found to favour the maximum disease incidence (15.316), (Tables 6a & 6b , Fig.5).

Fig.4. Effect of different levels of Nitrogen (N), Phosphorus (P) and Potash (K) on sheath rot incidence.

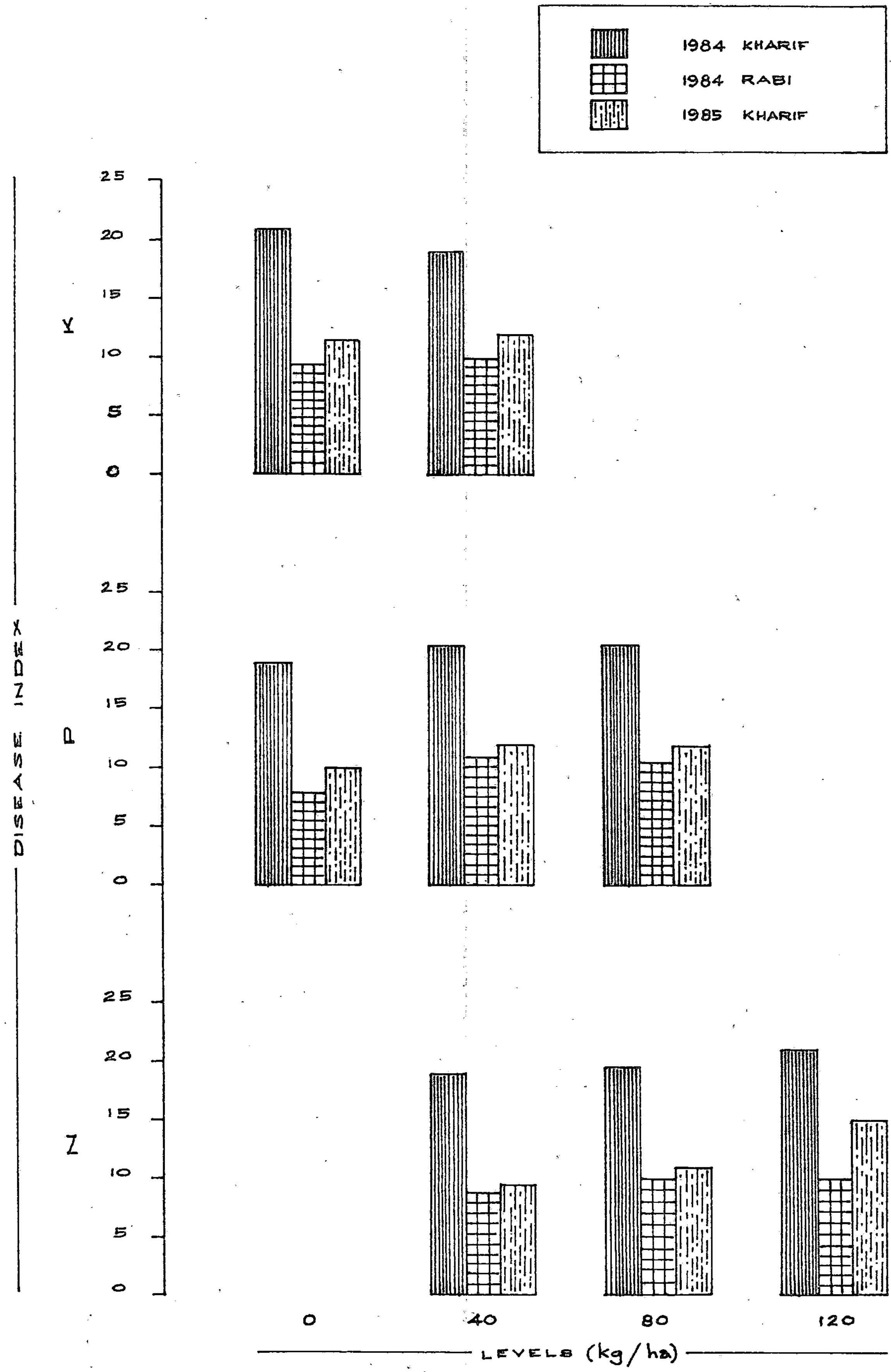

1984 KHARIF
1984 RABI
1985 KHARIF
DISEASE INDEX
Y
P
Z
0
5
10
15
20
25
0
40
80
120
LEVELS (kg/ha)

Fig.4.

Table 6a

Effect of date of planting, plant population, weed control and different levels of fertilizers on sheath rot incidence

Sl. No.	Treatment combinations	Disease index 1984 Kharif	1984 Rabi	1985 Kharif	Pooled mean
1	$D_1P_1F_1W_1$	33.774	6.305	8.951	16.343
2	$D_1P_1F_1W_2$	32.142	6.041	8.818	15.667
3	$D_1P_1F_2W_1$	29.761	5.600	8.157	14.506
4	$D_1P_1F_2W_2$	30.467	5.997	7.452	14.638
5	$D_1P_2F_1W_1$	35.053	6.526	7.937	16.505
6	$D_1P_2F_1W_2$	30.467	5.467	10.053	15.329
7	$D_1P_2F_2W_1$	29.982	5.423	12.478	15.961
8	$D_1P_2F_2W_2$	26.058	5.512	9.171	13.580
9	$D_2P_1F_1W_1$	20.943	8.642	10.406	13.330
10	$D_2P_1F_1W_2$	20.811	8.865	10.053	13.242
11	$D_2P_1F_2W_1$	19.180	9.700	6.790	11.890
12	$D_2P_1F_2W_2$	20.370	10.009	13.007	14.462
13	$D_2P_2F_1W_1$	21.957	7.011	10.318	13.095
14	$D_2P_2F_1W_2$	20.502	6.570	12.743	13.272
15	$D_2P_2F_2W_1$	20.943	5.732	10.955	12.537
16	$D_2P_2F_2W_2$	17.592	4.982	7.451	10.009
	C.D.	N.S.	N.S.	N.S.	N.S.

D_1 - Normal date of planting

D_2 - Three weeks after D_1

W_1 - Chemical weed control (Benthiocarb 50 EC) + Hand weeding on 40th day of transplanting

W_2 - Two hand weeding on 20th and 40th day of transplanting

P_1 - 100 per cent population

P_2 - 75 per cent population

F_1 - N:P:K @ 90:45:45 kg/ha

F_2 - N:P:K @ 45:22.5:22.5 kg/ha

Note: Since none of the other factors and interactions are significant in the pooled analysis (Table 6 a) the corresponding tables are not given.

Table 6 b

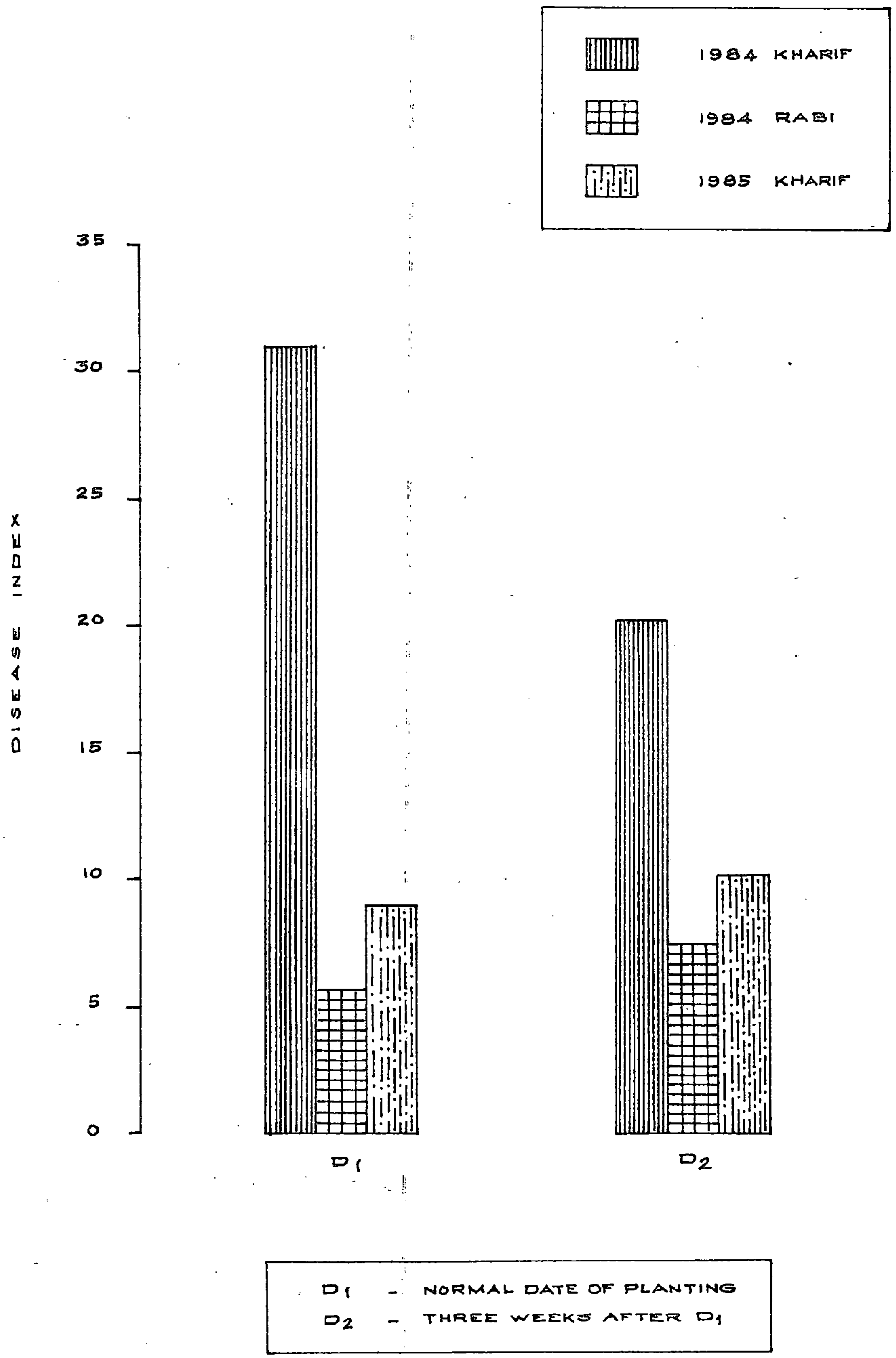
Effect of date of planting on sheath rot incidence
(Mean disease index)

Treatments	Disease index			Pooled mean
	1984 Kharif	1984 Rabi	1985 Kharif	
D_1 (Normal date of planting)	30.965	5.859	9.127	15.316
D_2 (Three weeks after D_1)	20.287	7.688	10.213	12.729
C.D.	S	S	N.S.	S

Levels of 'D' differ significantly

C.D. is not given since there were only two levels.

Fig.5. Effect of different dates of planting (D_1 & D_2) on sheath rot incidence.



1984 KHARIF
1984 RABI
1985 KHARIF
DISEASE INDEX
35
30
25
20
15
10
5
0
D1
D2
D1 - NORMAL DATE OF PLANTING
D2 - THREE WEEKS AFTER D1

Fig. 5.

V.3. Effect of various agronomic practices adopted for newly released rice varieties on sheath rot incidence

Data collected on disease index for two seasons are presented in Table 7a, b, c and d. Under this experiment with two different planting time, four fertilizer combinations and three varieties of rice, the data on sheath rot incidence showed Season X Treatment interaction be significant. Season influences treatments. Levels of D (Date of planting) differed significantly. Second date of planting i.e., 15 days after normal planting recorded significantly the least disease index than that of normal date of planting. The fertilizer levels also differed significantly. At zero fertilizer level the least disease index was noticed which was on par with F_1 (N:P:K @ 60:30:30 kg/ha). The highest disease index was noticed at maximum fertilizer level (N:P:K @ 180:90:90 kg/ha). Varieties also differ significantly in their reaction to disease. Jaya recorded the least disease index and was on par with Pavizham, while Karthika recorded the maximum disease index. None of the interactions of the various factors was observed to be statistically significant (Fig.6).

V. 4. Effect of slow release nitrogen fertilizers and nitrification inhibitors on sheath rot incidence

None of the treatments or their interactions were found to be statistically significant. However, among the levels

Table 7 a
Effect of date of planting (D), different levels of fertilizers (F) and varieties (V) on sheath rot incidence (Mean disease index)

Sl. No.	Treatments	Disease index 1984 Kharif	1984 Rabi	Pooled mean
1	$D_1F_0V_1$	10.821	7.234	9.028
2	$D_1F_0V_2$	12.847	4.204	8.526
3	$D_1F_0V_3$	19.444	7.465	13.455
4	$D_1F_1V_1$	16.493	6.597	11.545
5	$D_1F_1V_2$	12.731	7.523	10.127
6	$D_1F_1V_3$	21.007	9.028	15.018
7	$D_1F_2V_1$	15.625	13.079	14.352
8	$D_1F_2V_2$	18.518	11.806	15.162
9	$D_1F_2V_3$	25.115	11.227	18.171
10	$D_1F_3V_1$	18.460	23.843	21.152
11	$D_1F_3V_2$	26.388	20.465	23.427
12	$D_1F_3V_3$	33.159	22.685	27.922
13	$D_2F_0V_1$	2.150	2.141	2.146
14	$D_2F_0V_2$	1.909	1.852	1.881
15	$D_2F_0V_3$	7.696	4.051	5.874
16	$D_2F_1V_1$	4.109	4.745	4.427
17	$D_2F_1V_2$	4.108	2.025	3.067
18	$D_2F_1V_3$	6.076	6.771	6.424
19	$D_2F_2V_1$	5.960	4.919	5.440
20	$D_2F_2V_2$	4.861	5.267	5.064
21	$D_2F_2V_3$	8.333	8.449	8.391
22	$D_2F_3V_1$	7.465	9.896	8.681
23	$D_2F_3V_2$	12.095	11.574	11.835
24	$D_2F_3V_3$	14.699	12.790	13.745
	C.D.	N.S.	N.S.	N.S.

D_1 - Planting on normal date
D_2 - Planting 15 days after normal date
V_1 - Jaya
V_2 - Pavizham
V_3 - Karthika

F_0 - NPK @ 0:0:0 kg/ha
F_1 - NPK @ 60:30:30 kg/ha
F_2 - NPK @ 120:60:60 kg/ha
F_3 - NPK @ 180:90:90 kg/ha

Table 7 b

Effect of date of planting (D) on sheath rot incidence

Sl. No.	Treatments	Disease index		Pooled mean
		1984 Kharif	1984 Rabi	
1	D_1(Planting on normal date)	19.217	12.096	15.657
2	D_2(Planting 15 days after D_1)	6.622	6.207	6.415
	C.D.	S	S	S

Levels of 'D' differ significantly.

C.D. is not given since there are only two levels.

Table 7 c

Effect of different levels of fertilizers on sheath rot incidence

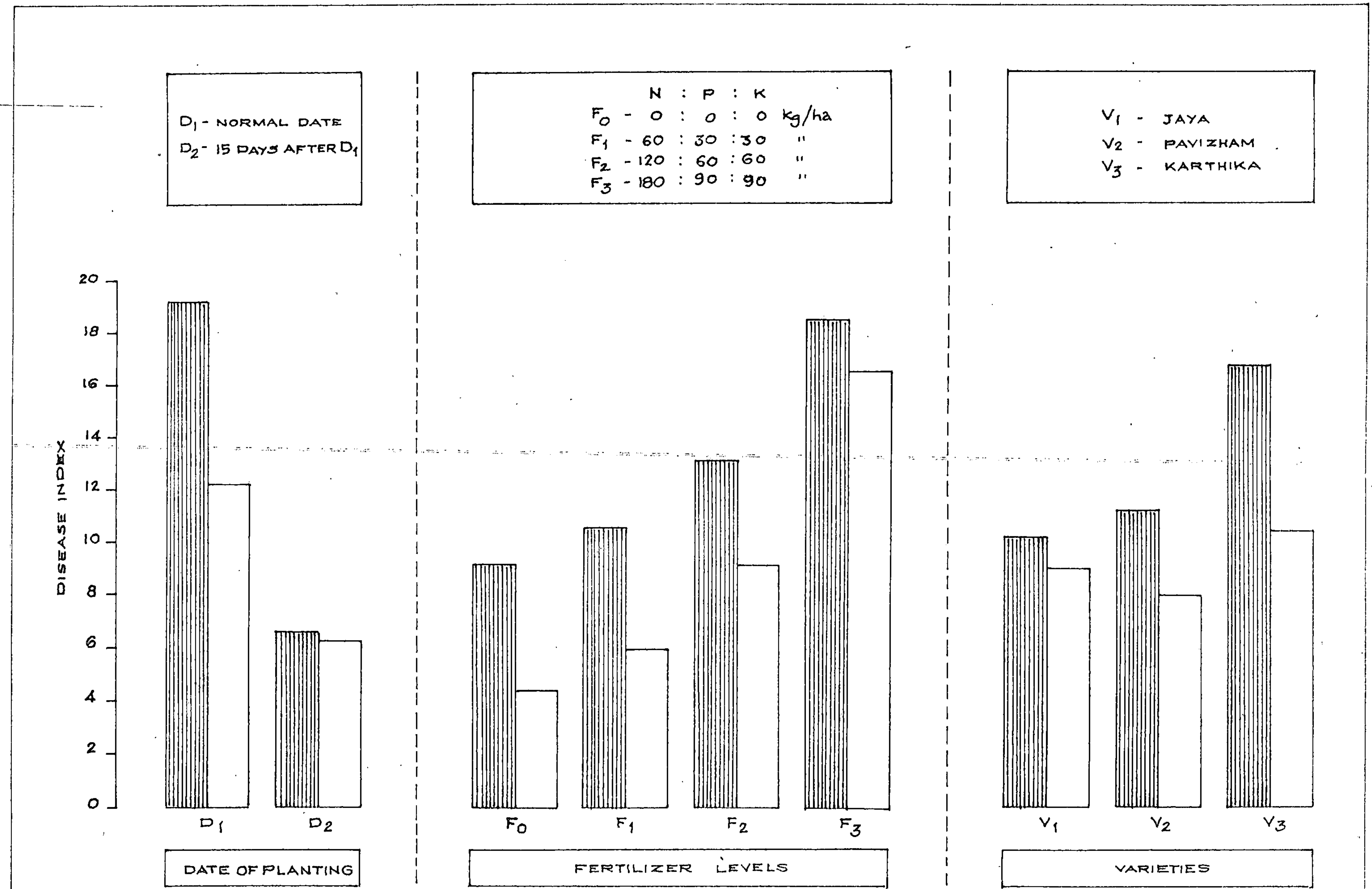
Sl. No.	Treatments (kg N x P x K/ha)	Disease index 1984 Kharif	Disease index 1984 Rabi	Pooled mean
1	0:0:0	9.145	4.491	6.818
2	60:30:30	10.754	6.115	8.435
3	120:60:60	13.069	9.124	11.097
4	180:90:90	18.711	16.875	17.793
	C.D.	3.7664	4.1984	2.9354

Table 7 d

Reaction of two newly released varieties of rice to sheath rot incidence in comparison with Jaya

Sl. No.	Varieties (V)	Disease index		Pooled mean
		1984 Kharif	1984 Rabi	
1	V_1 (Jaya)	10.135	9.057	9.596
2	V_2 (Pavizham)	11.682	8.089	9.886
3	V_3 (Karthika)	16.941	10.308	13.625
	C.D.	2.4397	N.S.	2.5421

Fig.6. Effect of date of planting, fertiliser levels and varieties on sheath rot incidence.



D1 - NORMAL DATE
D2 - 15 DAYS AFTER D1
N : P : K
F0 - 0 : 0 : 0 kg/ha
F1 - 60 : 30 : 30 "
F2 - 120 : 60 : 60 "
F3 - 180 : 90 : 90 "
V1 - JAYA
V2 - PAVIZHAM
V3 - KARTHIKA
DISEASE INDEX
20
18
16
14
12
10
8
6
4
2
0
D1
D2
F0
F1
F2
F3
V1
V2
V3
DATE OF PLANTING
FERTILIZER LEVELS
VARIETIES

Fig. 6

of fertilizers, L_1 (56 kg Nitrogen per hectare) recorded the least disease index (Table 8a). Among the sources of fertilizers S_3 (Gypsum coated urea) recorded the least disease index followed by Neem cake treated urea (Table 8b). The disease index under different levels of nitrogen fertilizers and also in treatments with slow release nitrogen fertilizers recorded for two seasons are tabulated and presented in Table (8c).

V.5. Influence of weed control practices on sheath rot incidence

Treatments were not significantly different. However, application of the weedicide (Benthiocarb) recorded the least disease index (Table 9).

V.6. Reaction of different rice cultures to sheath rot incidence

Data on mean disease index in respect of 26 varieties, including a number of pre-release cultures, already released varieties etc. as detailed under materials and methods are presented in Table (10). It can be seen from the data that four of the pre-release cultures viz., Cul.4-4, Cul.1954, Cul.1907 and Cul.25331 recorded very low disease index. So also the variety Triveni. All the others recorded higher disease index.

Table 8 a

Effect of different levels of nitrogenous fertilizers on sheath rot incidence

Treatments	Disease index		Pooled mean
	1984 Kharif	1984 Rabi	
L_1 (56 kg N/ha)	8.333	7.755	8.044
L_2 (84 kg N/ha)	9.863	6.867	8.365
L_3 (112 kg N/ha)	9.876	8.899	9.388
C.D.	N.S.	N.S.	N.S.

Table 8 b

Effect of different sources of nitrogenous fertilisers on sheath rot incidence

Treatments	Disease index		Pooled mean
	1984 Kharif	1984 Rabi	
S_1(Urea alone)	9.447	7.665	8.556
S_2(Neem cake treated urea)	8.573	7.887	8.230
S_3(Gypsum coated urea)	7.853	8.453	8.153
S_4(Rock phosphate coated urea)	11.557	7.356	9.457
C.D.	N.S.	N.S.	N.S.

Table 8 c

Effect of different sources and levels of nitrogenous fertilizers on sheath rot incidence

Sl. No.	Treatments	Disease index 1984 Kharif	Disease index 1984 Rabi	Pooled mean
1	Control	12.139	7.022	9.581
2	L_1S_1	10.545	7.253	8.899
3	L_1S_2	6.564	10.256	8.410
4	L_1S_3	6.481	7.974	7.228
5	L_1S_4	9.722	5.556	7.639
6	L_2S_1	8.384	6.996	7.690
7	L_2S_2	10.288	7.562	8.925
8	L_2S_3	10.082	6.533	8.308
9	L_2S_4	10.699	6.380	8.540
10	L_3S_1	9.413	8.745	9.079
11	L_3S_2	8.847	5.864	7.356
12	L_3S_3	6.995	10.854	8.925
13	L_3S_4	14.249	10.134	12.192
	C.D.	N.S.	N.S.	N.S.

L_1 - 56 kg N_2/ha applied in split doses

L_2 - 84 kg N_2/ha applied in split doses

L_3 - 112 kg N_2/ha applied in split doses

S_1 - Urea alone

S_2 - Neem cake treated urea

S_3 - Gypsum coated urea

S_4 - Rock phosphate coated urea

Table 9

Effect of various weed control measures on sheath rot incidence

Sl. No.	Treatments			Mean disease index
1	T_1	H_0	No weeding	6.674
2	T_2	H_0	No weeding	8.063
3	T_3	H_1	Two hand weedings	6.636
4	T_4	H_2	Herbicide (Benthiocarb 50 EC @ 4 l/ha sprayed with water 500 l/ha)	4.591
5	T_5	H_0	No weeding	7.793
6	T_6	H_1	Two hand weedings	4.784
7	T_7	H_2	Herbicide (Benthiocarb 50 EC @4l/ha sprayed with water @ 500 l/ha)	5.131
8	T_8	H_1	Two hand weedings	5.517
9	T_9	(H_2+H_1)	Herbicide on 6th day and weeding on 40th day.	7.021

Table 10

Reactions of different rice varieties to sheath rot incidence

Sl. No.	Varieties	Mean disease index
1	H 210	22.070
2	Cul-25337	21.298
3	Cul-26-1-1	16.823
4	Karthika	11.652
5	Cul-23332-2	24.771
6	IR-36	18.752
7	Cul-45-1-4	12.270
8	Cul-1907	2.547
9	Cul-169	18.366
10	H-102	14.585
11	Jaya	15.511
12	H-109	16.205
13	M-2	19.292
14	MO-5	6.096
15	TKM-9	14.739
16	Jyothi	9.106
17	Cul-4-4	0.618
18	Triveni	5.325
19	H-6	16.205
20	Cul-25351	3.473
21	Cul-1954	1.312
22	Cul-4	7.640
23	MO-6	16.977
24	IR-50	9.800
25	Cul-52-3-6	11.730
26	Cul-126	15.434

C.D. to compare variety means = 9.2544

VI. *In vitro* evaluation of fungicides against *S.oryzae*

In this study, inhibition of growth of the pathogen was tested *in vitro* on solid medium by the poisoned food technique. Five isolate of *S.oryzae* viz., S_1, S_3, S_4, S_5 and S_7 were separately used to evaluate the effect of the fungicides. Three fungicides and one fungicidal mixture were tested, each at three concentrations. There was complete inhibition of growth on potato dextrose agar medium incorporated with Bavistin and Carbistin (Carbendazim products) each at 500 ppm, 750 ppm and 1000 ppm for the isolates S_1, S_4, S_5 and S_1, S_3, S_4 respectively. Similarly Calixin-Bavistin mixture each at 50 ppm, 75 ppm and 100 ppm showed complete inhibition of growth of the isolate, S_4. On comparing Calixin with the Calixin-Bavistin mixture, the latter was found superior in inhibiting the growth of the isolates S_1 and S_7 in addition to S_4. Calixin-Bavistin mixture (100 ppm each) was on par with Calixin and Bavistin each at 1000 ppm against the isolate, S_3. Similarly Calixin-Bavistin mixture (75 ppm each and 100 ppm each) was equally effective as Calixin alone at 750 ppm and 1000 ppm respectively against the isolate S_5 (Table 11, Plate V and Fig.7).

Table 11

In vitro effect of common fungicides on five isolates of *S.oryzae* (as percentage inhibition of radial growth over control)

Sl. No.	Chemicals	Concentrations in ppm	Isolates S_1	S_3	S_4	S_5	S_7
1	C_1(Calixin)	500	68.96	72.00	71.37	77.00	77.65
		750	77.70	79.00	73.80	81.25	82.35
		1000	80.00	100.00	77.15	85.42	87.06
2	C_2(Bavistin)	500	100.00	75.00	100.00	100.00	78.81
		750	100.00	75.71	100.00	100.00	88.24
		1000	100.00	100.00	100.00	100.00	100.00
3	C_3(Carbistin)	500	100.00	100.00	100.00	87.50	82.22
		750	100.00	100.00	100.00	100.00	90.59
		1000	100.00	100.00	100.00	100.00	100.00
4	C_4(Calixin-Bavistin mixture)	50	75.80	61.20	100.00	72.57	89.41
		75	90.00	69.23	100.00	81.25	90.20
		100	100.00	100.00	100.00	86.83	100.00
	C.D.		4.0672	3.9987	1.8827	3.2811	4.5238

S_1, S_3, S_4, S_5 and S_7 – *S.oryzae* isolates

PLATE V. *In vitro* effect of various fungicides at different concentrations on different isolates of *S. oryzae* *

a. Effect of Calixin (1,2 & 3) and Bavistin(4, 5 & 6) on radial growth of the isolate (S_1).

b. Effect of Carbistin (1,2 & 3) and Calixin - Bavistin mixture,(4,5 & 6) on radial growth of the isolate (S_1).

c. Effect of Calixin (1,2 & 3) and Bavistin (4, 5 & 6) on radial growth of the isolate (S_3).

d. Effect of Carbistin (1,2 & 3) and Calixin-Bavistin mixture (4, 5 & 6) on radial growth of the isolate (S_3)

e. Effect of Calixin (1, 2 & 3) and Bavistin (4, 5 & 6) on radial growth of the isolate (S_4).

f. Effect of Carbistin (1, 2 & 3) and Calixin-Bavistin mixture (4, 5 & 6) on radial growth of the isolate (S_4)

g. Effect of Calixin (1, 2 & 3) and Bavistin (4, 5 & 6) on radial growth of the isolate (S_5)

h. Effect of Carbistin (1, 2 & 3) and Calixin-Bavistin mixture (4, 5 & 6) on radial growth of the isolate (S_5)

i. Effect of Calixin (1, 2 & 3) and Bavistin (4, 5 & 6) on radial growth of the isolate (S_7)

j. Effect of Carbistin (1, 2 & 3) and Calixin-Bavistin mixture (4, 5 & 6) on radial growth of the isolate (S_7)

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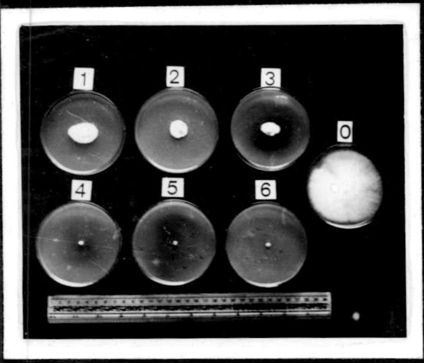
* In all the plates 'O' denotes Control - unamended PDA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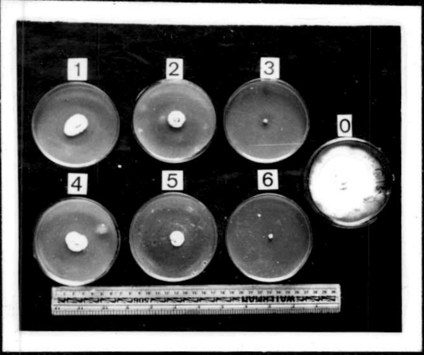
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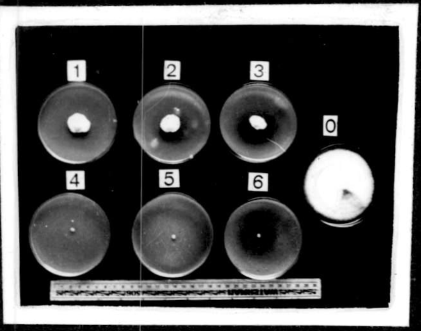
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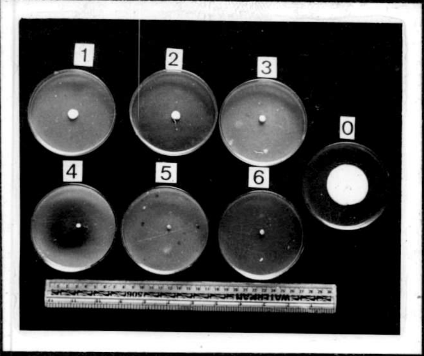
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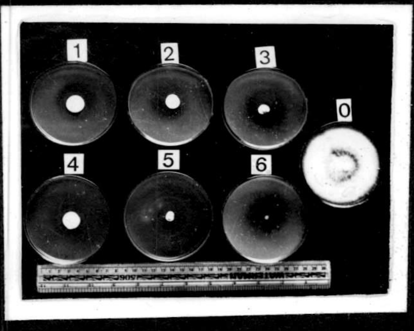
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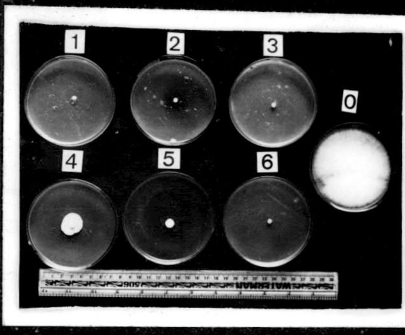
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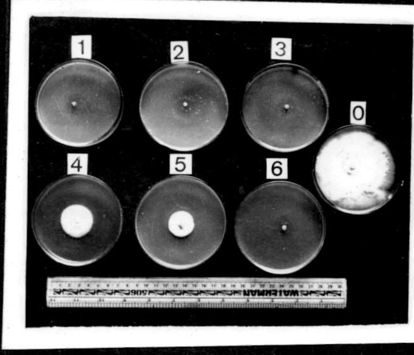
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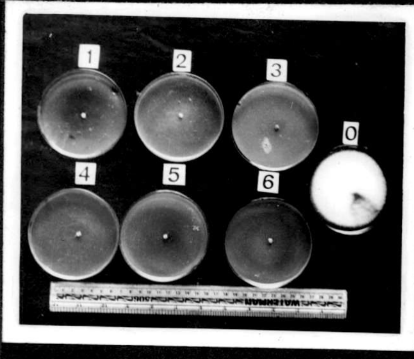
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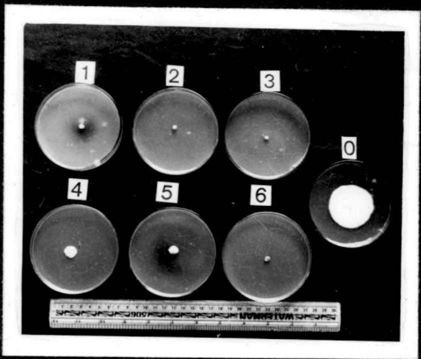
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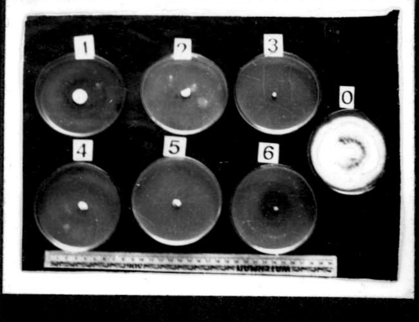
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Fig.7. *In vitro* effect of various fungicides at different concentrations on different isolates of *S.oryzae*.

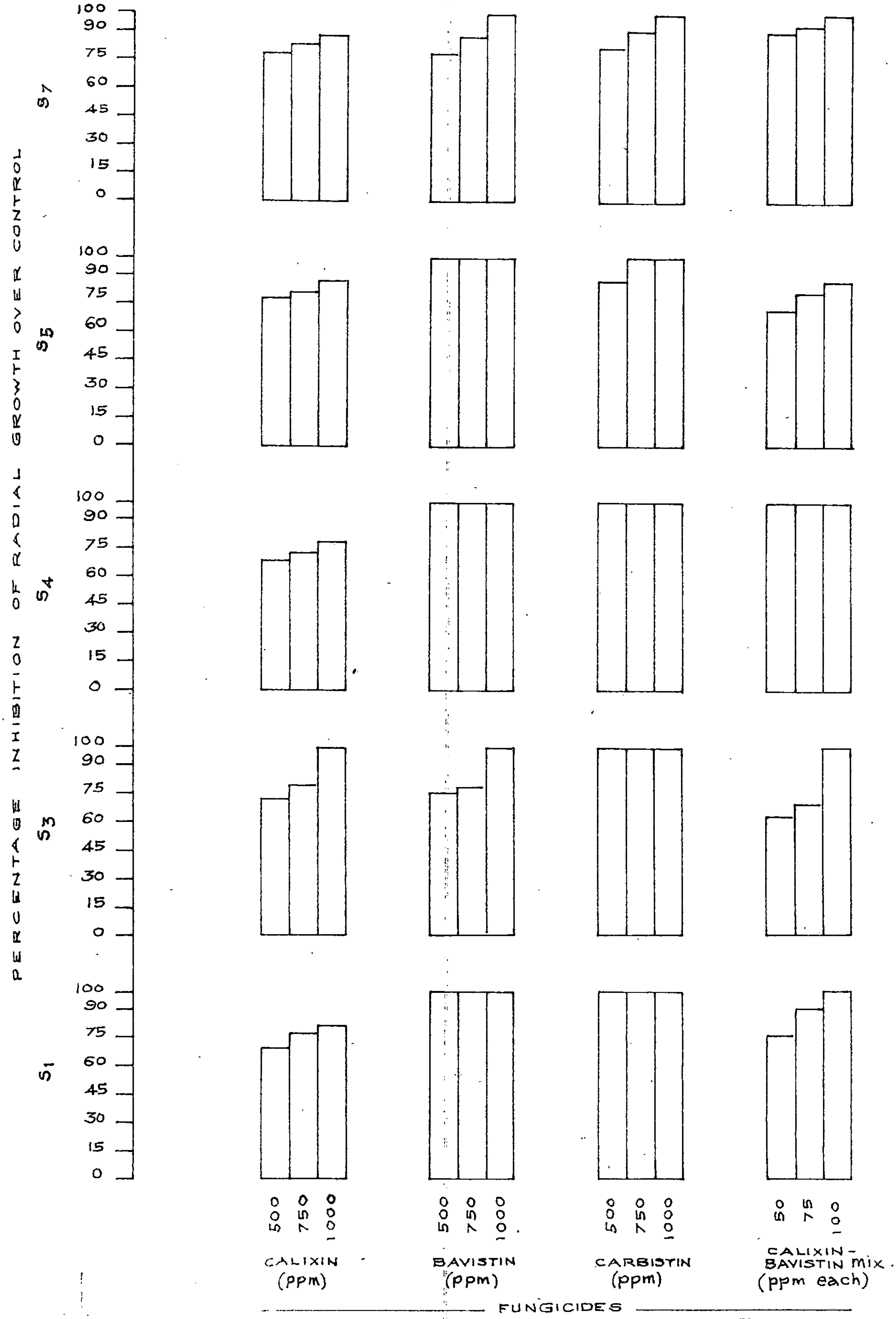

PERCENTAGE INHIBITION OF RADIAL GROWTH OVER CONTROL
S7
S5
S4
S3
S1
0
15
30
45
60
75
90
100
500
750
1000
50
75
100
CALIXIN (ppm)
BAVISTIN (ppm)
CARBISTIN (ppm)
CALIXIN - BAVISTIN MIX (ppm each)
FUNGICIDES

Fig. 7.

VII. Control of the sheath rot disease under field condition

A randomised replicated field experiment was laid out to evaluate various crop nutrition schedules along with fungicide in controlling the disease as per the details explained under the Chapter " Materials and Methods ".

a) Disease intensity

The results revealed that (Table 12, Fig.8) the levels of M (crop nutrition schedules) differed significantly. The minimum disease index was recorded for M_1 which received organic manure alone. This was followed by M_2 (nitrogen in the form of urea in three splits and potash in the form of MOP in two splits, applied in soil). M_4 (nitrogen and potash sources were same as under M_2 but their last splits were applied as foliar), M_3 (nitrogen source was ammonium sulphate applied in soil in three splits) and M_5 (nitrogen and potash sources were ammonium sulphate and MOP respectively, the last split of which were given as foliar). M_7 recorded the maximum disease index, where zinc and manganese were also given as foliar sprays along with M_5). Application of fungicide was not found significant. But the interaction effect of M (crop nutrition schedules) with fungicide differed significantly. The least disease index was observed for the combination, M_1F_1 (organic manure alone coupled

Table 12

Effect of various crop nutrition schedules with and without fungicide (Carboxin) on the incidence of sheath rot disease and on grain and straw yield

Sl. No.	Management schedules (M)	Disease index (Mean)			Grain yield (Mean) (kg/ha)			Straw yield (Mean) (kg/ha)		
		F_0 without fungicide	F_1 with fungicide	Mean	F_0 without fungicide	F_1 with fungicide	Mean	F_0 without fungicide	F_1 with fungicide	Mean
1	2	3	4	5	6	7	8	9	10	11
1	M_1 (Organic manure alone @ 5 t/ha in the form of farm yard manure applied as recommended in Package of Practices Recommendations of Kerala Agricultural University).	4.886	3.519	4.202	2993	2802	2897	2396	2401	2398.5
2	M_2 (M_1 + N:P:K @ 70:35:52.5 kg/ha Nitrogen in the form of urea in three splits in soil, half the quantity as basal and the remaining half in two equal splits. K in the form of MOP in two equal splits in soil, 50 per cent as basal and the balance at the time of second top dressing).	6.758	5.045	5.902	4565	4559	4562	4884	4847	4865.5

Table 12 (Contd.)

1	2	3	4	5	6	7	8	9	10	11
3	M_3 (M_1+ N:P:K @ 70:35:52.5 kg/ha Nitrogen in the form of ammonium sulphate and potash in the form of MOP. These fertilizers were applied as described under M_2).	7.541	4.527	6.034	4354	4471	4413	5024	5288	5156.0
4	M_4 (M_1+ N:P:K @ 70:35:52.5 kg/ha Nitrogen in the form of urea in three splits as described under M_2. The first two splits in soil and the last split applied as foliar. K was given as under M_2. But the top dressing was given as foliar).	5.908	5.921	5.915	4551	4975	4762	4658	4937	4797.5
5	M_5 (M_1+ N:P:K @ 70:35:52.5 kg/ha Nitrogen in the form of ammonium sulphate and K in the form of MOP and applied as described under M_4).	4.063	8.086	6.074	4408	4592	4500	4834	4988	4911.0

Table 12 (Contd.)

1	2	3	4	5	6	7	8	9	10	11
6	M_6(M_1+M_4 + Zn and Mn @ 10 kg/ha each. Zn in the form of Zinc sulphate and Mn in the form of Manganese sulphate were applied as foliar at the active tillering stage of the crop).	8.192	6.081	7.136	4658	4742	4700	4984	5456	5220
7	M_7 (M_1+M_5 + Zn and Mn @ 10 kg/ha each. Applied as described under M_6).	9.214	6.705	7.959	4421	4517	4469	4857	5160	5008.5
	Mean	6.652	5.698	6.175	4278.571	4379.429	4329.0	4519.571	4725.286	4622.429

C.D. for comparison between M - levels	2.148	197.08	424.73
C.D. for comparison between F - levels	N.S.	N.S.	N.S.
C.D. for comparison between F x M levels	3.038	N.S.	N.S.

Fig.8. Effect of various management schedules on sheath rot incidence.

M_1 - Organic manure alone

M_2 - M_1 + N:P:K @ 70:35:52.5 kg/ha. Nitrogen in the form of urea in three splits in soil and K in the form of MOP in two equal splits in soil.

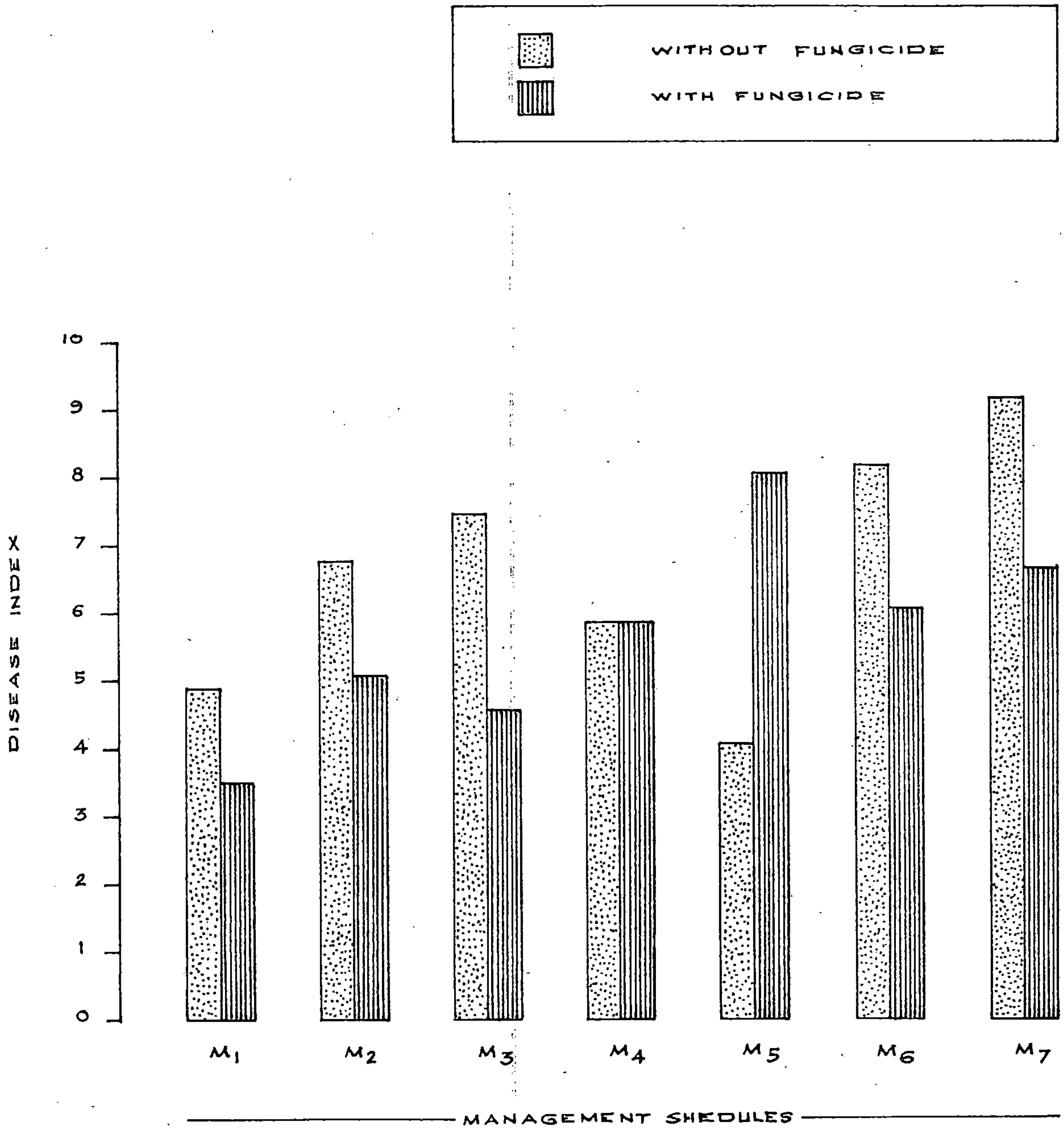
M_3 - M_1 + N:P:K @ 70:35: 52.5 kg/ha. Nitrogen in the form of ammonium sulphate and potash in the form of MOP were applied as described under M_2.

M_4 - M_1+ N:P:K @ 70:35:52.5 kg/ha. Nitrogen in the form of urea in three splits as described under M_2. The first two splits in soil and the last split applied as foliar. K was given as described under M_2. But the top dressing was given as foliar.

M_5 - M_1 + N:P:K @ 70:35:52.5 kg/ha. Nitrogen in the form of ammonium sulphate and K in the form of MOP and applied as described under M_4.

M_6 - M_1 + M_4 + Zn and Mn @ 10 kg/ha each. Zn in the form of Zinc sulphate and Mn in the form of Manganese sulphate applied as foliar.

M_7 - M_1 + M_5 + Zn and Mn @ 10 kg/ha each applied as described under M_6.


WITHOUT FUNGICIDE
WITH FUNGICIDE
DISEASE INDEX
0
1
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M6
M7
MANAGEMENT SHEDULES

Fig. 8.

with the fungicidal application). Therefore the results indicated that organic manure along with the fungicide Carboxin was the most superior treatment schedule for a low disease intensity. But in general it was noticed that the efficiency of all the crop nutrition schedules in minimising the disease was enhanced when the application of the fungicide Carboxin was followed except in only one case, where ammonium sulphate and potash were also given as foliar along with the fungicidal spray.

b) Grain yield

The levels of M (crop nutrition schedules) only showed significant difference with regard to grain yield. Among the various M levels tried, the maximum grain yield was recorded for M_4, where the last split of urea and potash were applied as foliar. This was on par with M_6, where micronutrients zinc and manganese were applied as foliar along with M_4. The least grain yield was recorded for the treatment M_1 (organic manure alone). The results indicated that nitrogen in the form of urea with a higher potash was most effective schedule with regard to grain yield than with ammonium sulphate as nitrogen source along with the same level of potash. The results again showed in general that the efficiency of all the treatment schedules increased the grain yield, when they were coupled with the application of the fungicide, Carboxin (Table 12, Fig.9).

c) Straw yield

The results revealed that as in the case of grain yield the crop nutrition schedules alone could enhance the straw yield significantly. The treatment M_6 recorded the maximum straw yield where, the micronutrients zinc and manganese were given as foliar sprays along with the last split of urea and MOP as foliar. This was found to be on par with the treatments M_3 (ammonium sulphate and MOP in soil), M_7 (foliar application of zinc and manganese were followed with foliar application of ammonium sulphate and MOP), M_5 (foliar application of last split of ammonium sulphate and MOP) and M_4 (foliar application of last split of urea and MOP). The least straw yield was recorded for M_1 as in the case of grain yield. The results in general indicated that the nutrients nitrogen and potash in the form of foliar spray in the later stages of crop growth irrespective of the nitrogen source, was most effective in increasing straw yield (Table 12, Fig.9).

Fig.9. Effect of various management schedules on grain and straw yield.

M_1 - Organic manure alone

M_2 - M_1 + N:P:K @ 70:35:52.5 kg/ha. Nitrogen in the form of urea in three splits in soil and K in the form of MOP in two equal splits in soil.

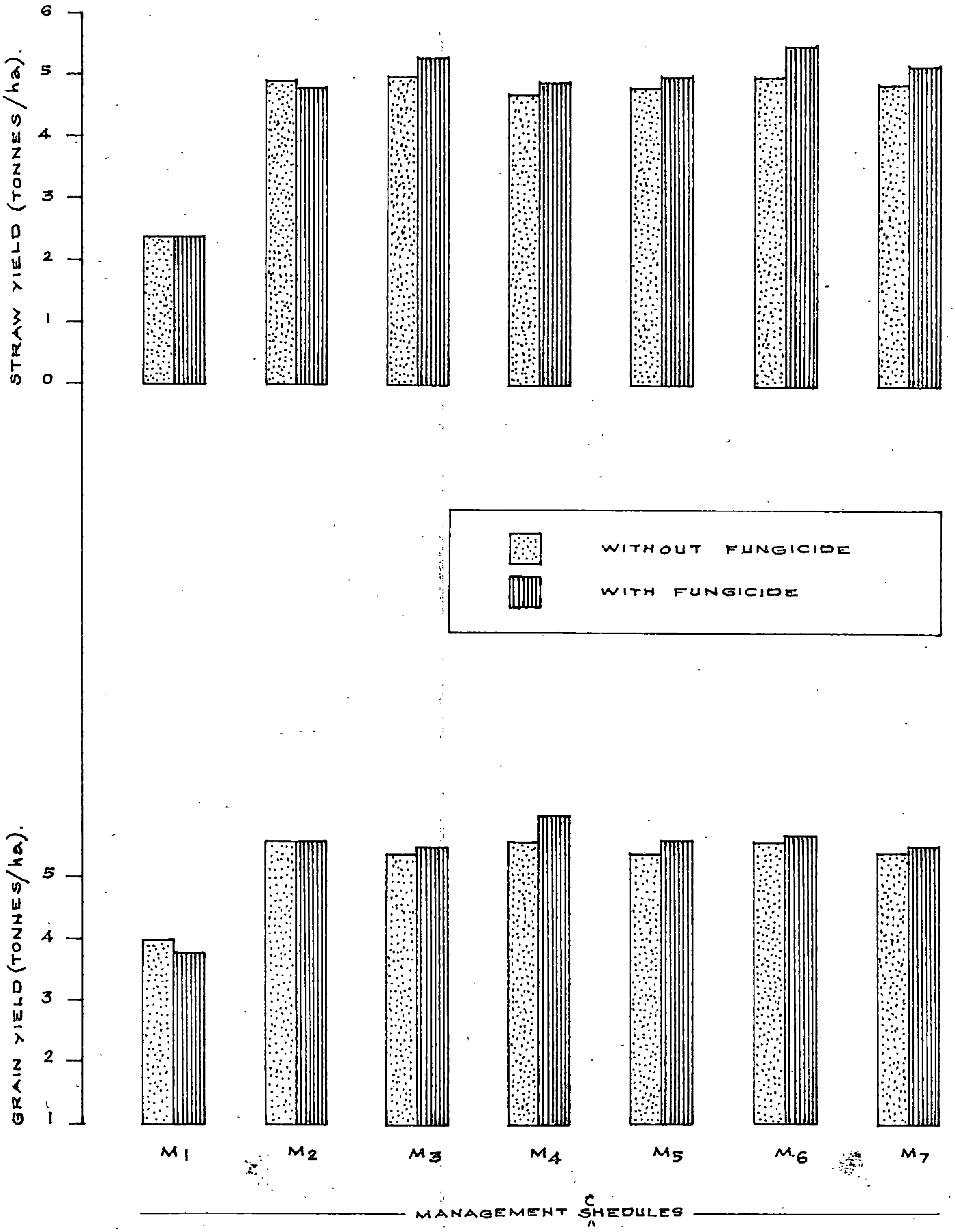
M_3 - M_1 + N:P:K @ 70:35:52.5 kg/ha. Nitrogen in the form of ammonium sulphate and potash in the form of MOP were applied as described under M_2.

M_4 - M_1 + N:P:K @ 70:35:52.5 kg/ha. Nitrogen in the form of urea in three splits as described under M_2. The first two splits in soil and the last split applied as foliar. K was given as described under M_2. But the top dressing was given as foliar.

M_5 - M_1 + N:P:K @ 70:35:52.5 kg/ha. Nitrogen in the form of ammonium sulphate and K in the form of MOP and applied as described under M_4.

M_6 - M_1 + M_4 + Zn and Mn @ 10 kg/ha each. Zn in the form Zinc sulphate and Mn in the form of Manganese sulphate applied as foliar.

M_7 - M_1+M_5+ Zn and Mn @ 10 kg/ha each applied as described under M_6.



STRAW YIELD (TONNES/ha).
6
5
4
3
2
1
0
WITHOUT FUNGICIDE
WITH FUNGICIDE
GRAIN YIELD (TONNES/ha).
5
4
3
2
1
M1
M2
M3
M4
M5
M6
M7
MANAGEMENT SCHEDULES

Fig. 9

DISCUSSION

DISCUSSION

Sheath rot of rice caused by <u>Sarocladium oryzae</u> Gams & Hawksworth is considered to be one of the major fungal diseases of rice in many partsof India especially in the Southern States including Kerala. The reports on the destructive nature of this disease from different parts of the world including India began to appear during the last decade. In Kerala this disease has gained very much importance recently in terms of its endemic nature and extent of damage in many parts especially in the southern districts.

The observations made on the symptomatology of the disease in the present study under field conditions from the naturally infected rice plants and also the artificially inoculated ones were in agreement with the descriptions of the earlier workers (Tasugi & Ikeda, 1956; Ou, 1972; Amin <u>et al</u>.,1974; Shajahan <u>et al</u>., 1974; Nair and Sathyarajan, 1975).

In the present study, the pathogen was isolated from naturally infected rice varieties namely, Jaya, Triveni, Jyothi and Kochuvithu from three different localities (Trivandrum, Kuttanad and Kayamkulam) and brought into pure culture on potato dextrose agar medium. Pathogenicity of all the isolates were proved following Koch's Postulates. Morphological characters of the different isolates of the fungus obtained were compared well with those reported by other investigators, Tasugi and Ikeda (1956), Ou (1972), Shajahan et al. (1974), Nair and Sathyarajan (1975) and Balakrishnan (1981). The results of the present study were in agreement with those of the above investigators with few variations on the morphological characters. However, the isolate S_6(isolate from rice grains collected from Kuttanad) had longer conidiophores i.e., the length of the main axis of the conidiophores measured nearly double the length of the other isolates studied. This isolate had a peculiarity in the conidial attachment also compared to others. Three to four conidia were seen in bunches at the tip of the branches, whereas in all the other isolates the conidia were borne singly at the tip of branches. This type of conidial attachment, in bunch form, was reported earlier by Balakrishnan (1981) for an isolate of the fungus from the weed host *Cyperus difformis* Linn. This isolate from seed infected the crop and this points to the possibility of the disease being seed-borne. The seed-borne nature of the pathogen in rice grains, both externally and internally, has been discussed by earlier workers viz., Shajahan *et al.* (1974), Mohan and Subramanian (1981).

During the investigation, mixed infection of *S.oryzae* and two distinct species of Fusarium and by *Alternaria padwickii* were also detected which were able to produce typical sheath rot symptoms. Artificial inoculation studies of rice plants with these associated fungi alone showed atypical or mild symptoms of sheath rot and grain discolouration. But combined inoculation of these fungi along with *S.oryzae* could hasten the initiation and development of the symptoms which finally resulted in typical sheath rot disease in rice. It was also observed that the higher percentages of grain discolouration and sterility could be detected in the combined infection of associated fungi along with *S.oryzae*. Similar type of mixed infections were observed in sheath rot disease of rice by earlier workers (Shajahan *et al.*, 1974; Balakrishnan, 1981; Kang and Rattan, 1983; Shajahan *et al.*, 1983; Ngala, 1983). The reason for heavy grain discolouration of sheath rot affected rice plants has been discussed by Tschen and Wen (1980) and they reported that the toxic metabolites produced by *S.oryzae* was responsible for grain discolouration and sterility. The toxic effect of the culture filtrate of *S.oryzae* in hastening the disease development of sheath rot has been reported by Balakrishnan(1981).

The wide spread occurrence of grain discolouration often reported from many parts of Kerala may thus be due to the combined effect of a number of associated fungi.

Artificial inoculation studies conducted with two high yielding medium duration (Jaya and Pavizham) and two high yielding short duration (Jyothi and Triveni) rice varieties with different isolates of S.oryzae, showed mild variations in the varietal reactions. The isolates also showed little variations in the severity of the disease. Among the varieties tested, Pavizham showed a slight tolerant reaction to all the isolates except for the isolate No. S_5 (isolate from rice variety Jyothi with severe sheath rot symptom), which was found to be a virulent isolates with respect to all the rice varieties tested. Similarly, among the isolates of S.oryzae used, isolate S_2 (from variety Jaya with mild symptoms) was found to be the least virulent one with respect to symptom development in all the rice varieties tested. Both the short duration rice varieties tested showed susceptible reaction to all the isolates of the pathogen except to the mild isolate viz., S_2 only. Regarding the colour and nature of lesions, no marked variations could be noticed on different rice varieties for all the isolates except the isolate (S_2) where no demarcated lesions were noticed. This isolate produced uniform yellowish discolouration on all the varieties tested. Shajahan *et al.* (1974), Subramanian and Ramakrishnan (1975) and Datta and Purkayastha (1978) reported that sheath rot disease was most severe on high yielding dwarf rice varieties. But resistant reactions of some of the varieties were reported by many workers like Amin (1976a), Naik (1976), Lin (1978), Balakrishnan and Rajan (1981), Singh and Raju (1981) and Anon (1983a). Shajahan *et al.* (1974) have also found that lesion colour may vary depending upon the varieties infected.

The critical analytical studies conducted on changes in total soluble sugars showed that there was a gradual quantitative fall in the content of total soluble sugars in diseased plants irrespective of the variety. The maximum reduction of total soluble sugars due to infection by the fungus was noticed in the variety Jyothi (23.24 per cent reduction over healthy) whereas the least reduction was noticed in the case of variety Triveni (16.19 per cent reduction over healthy). The variety Jaya recorded the maximum sugar content (226.67 µg/g fresh sample) followed by Jyothi (200 µg/g fresh sample).

It was reported earlier that the soluble sugar level influences the susceptibility of a host plant to infection by fungi (Allen, 1942; Inman, 1962). Horsfall and Dimond (1957) classified rusts, powdery mildews and chocolate leaf spot of beans which attack tissues with high sugar level as " high sugar diseases ", while Helminthosporial and Alternarial diseases occurring in tissues of low sugar content were grouped as " low sugar diseases ". Sridhar (1972) observed that the sugar reserve of susceptible tissues was higher than that of resistant ones in the case of blast disease of rice. The present observations indicated that the varieties Jaya and Jyothi which recorded the maximum sugar content and at the same time they were susceptible also to the disease. This observation agrees with the earlier findings. Mohan and Subramanian (1979) and Balakrishnan and Nair (1983) noticed that infection of rice plants by S.oryzae resulted in a considerable reduction of total soluble sugars in the tissues. Similarly Reddy and Sridhar (1976) have claimed the reduction of total soluble sugars in blast affected rice plants and also in rice plants infected with Xanthomonas oryzae. Asada (1957) and Dayal and Joshi (1968) have also reported this type of decrease of tissue sugars in the host followed by fungal infection in several host parasite interactions. These observations are in agreement with the results of the present studies also.

The present study revealed that the infection of rice plants by *S. oryzae* caused a general increase in the total phenolics level in the varieties tested, viz., Jaya, Jyothi and Triveni. But an exception to this was noticed in the case of the variety, Pavizham, where the total phenolics level was found to be decreased due to infection.

In the case of rice blast disease, Jayachandran Nair (1975) reported that infection decreased the total phenolic level in less susceptible cultivar, Rethna, while highly susceptible cultivar, Co-13, showed a general increase especially in the later stages of disease development.

Phenolic compounds and their related oxidases have been found to be associated with the defence mechanisms of plants, due to their general accumulation around the infected tissues (Mohan and Subramanian, 1979). It is reported that phenolics and their oxidation products are toxic to pathogens (Walker and Stahmann, 1955; Farkas and Kiraly, 1962; Tomiyama, 1963; Suzuki, 1965). The observations made in the present study also showed that only the less susceptible variety Pavizham (as observed in the varietal reaction studies described earlier) recorded a reduction in the level of phenol content due to infection. Whereas the other varieties tested, viz., Jaya, Jyothi and Triveni which showed a general increase in total phenolics due to infection, were proved as susceptible ones to the disease. The rate of increase of total phenolics due to infection observed in the present study was in the variety Jyothi (128.58 per cent increase over control) as against in Jaya which recorded only 65.71 per cent increase over control. This again showed that Jyothi is more susceptible to the disease than Jaya. A similar observation was made by Sridhar and Ou (1974) that the less susceptible rice variety possessed a lower phenolics due to blast disease. Therefore this may be the reason for the less quantity of total phenolics in the variety Pavizham observed in the present study.

In this study, observations were made on sheath rot incidence with respect to different crop management practices in field. The results revealed that higher levels of nitrogen (above 80 kg/ha) and lower levels of potash (below 40 kg/ha) applications were found to cause a higher incidence of the disease irrespective of cropping season. With respect to date of planting, delayed planting upto two weeks from the normal date, both in Kharif and Rabi seasons, was found to constantly decrease the incidence of the disease (Table 7a & b). Varieties were also found to vary in the reaction to this disease in the field. In the observations made it was found that the variety Pavizham showed constantly less incidence followed by the variety Jaya. Whereas, Karthika showed maximum disease incidence. The comparative performance of a number of pre-released cultures and few promising new varieties under field conditions revealed Cul.4-4, Cul.1954, Cul.25331 and Triveni were tolerant to the disease (disease index below an average of five) as against Cul.25332-2 recorded the maximum disease index (24.771). Application of nitrogen fertilizers with slow release nitrogen and nitrification inhibitors showed a positive correlation with the disease incidence. Neem cake treated urea and Gypsum coated urea recorded comparatively lower incidence of the disease than free urea application. Another observation showed that spraying of the herbicide Benthiocarb at the rate of 1.5 kg a.i/ha on 6th day of transplanting could minimise the disease incidence.

Misra and Mathur (1983) observed that susceptibility of rice plants to S.oryzae increased with increasing nitrogen application over the range of 50 to 200 kg/ha. Similarly Ebuga and Lapis (1985) reported that excessive or deficient nitrogen conditions favoured sheath rot disease and they were of opinion that an appropriate balanced NPK fertilizers could check the incidence of the disease. Muneera (1973) has observed a similar trend in sheath blight disease of rice.

She has pointed out that intensity of sheath blight disease could be checked by reducing the level of nitrogen. Similar observations have been recorded by Padwick (1956), Lee et al.(1963) and Kozaka (1970) in the case of sheath blight disease of rice. The role of higher doses of potash in minimising sheath rot incidence has been reported by Balakrishnan and Nair (1986). Similar type of results have been discussed by Chien and Chu (1970), Munsora (1973) and Jaganmohan (1977) in the case of sheath blight disease of rice and Perrenoud (1977) in the case of brown leaf spot, Cercospora leaf spot, sheath blight and Sclerotiniosis (*Leptosphaeria salvinii* Catt.) diseases in rice.

Amin et al.(1974) reported that the sheath rot incidence was higher during rabi season in Andhra Pradesh. Similarly Srinivasan (1981) from Tamil Nadu observed higher incidence of sheath rot disease on crops planted from mid-June to August and he also pointed out that control measures were needed only for the crop planted during the above season. The observations made in the present study showed that planting after 15 days than the normal planting time in both the Kharif and Rabi crops could minimise the incidence of sheath rot disease. Another study from Kerala (Balakrishnan and Nair, 1986) also showed a similar trend of sheath rot incidence with respect to the rabi crop.

Subramanian and Ramakrishnan (1975) found that the variety Annapurna was comparatively more susceptible to the disease, while varieties TN-1, TKM-6 etc. showed least susceptibility. Amin (1976 a), Naik (1976), Datta and Purkayastha (1978) and Lin (1978) have also reported differential varietal reactions to sheath rot disease.

The results of the present study also revealed that even though there are no completely immune variety, varietal tolerance can be located in some like the newly released Pavizham and Triveni varieties and also in some of the pre-release cultures like Cul.4-4, Cul.1954, Cul.1907 and Cul.25331 etc.

The effect of slow release nitrogen and nitrogen inhibitors in checking the disease have been discussed by Alagarsamy *et al.* (1985) and Balakrishnan and Nair (1986). Similarly Rajan (1980) and George (1981) also suggested that the application of certain oil cakes like neem cake, punna cake etc. as basal in soil could check the incidence of sheath blight disease. Another study conducted in Kerala using marotti cake at the rate of 60 kg/ha along with normal recommended dose of urea could minimise the incidence and severity of sheath blight disease of rice (Anon., 1983b).

The present findings also showed that application of neem cake treated urea and gypsum coated urea were able to minimise the incidence of sheath rot disease in field.

The use of herbicides in minimising the incidence of fungal diseases of rice have been reported by various workers. In a field test in Kerala, a foliar application of Saturn (Benthiocarb) at 2 kg a.i/ha controlled sheath blight and sheath rot of rice (Vasavan _et al._, 1980). Lakshmanan and Nair (1980) reported that Saturn was highly inhibitory to the growth of _Rhizoctonia solani_, the sheath blight fungus. A multilocational trial conducted by Kerala Agricultural University at Adoor and Moncompu during 1981-1982 on the effect of various herbicides, on the control of sheath blight disease in rice, revealed that Nitrofen 1.25 kg a.i/ha and 1.75 kg a.i/ha, Bentazon 1.75 kg a.i/ha are effective in controlling the incidence and severity of sheath blight (Nair _et al._ 1986). Lakshmy (1984) from a field trial observed that Nitrofen at 1.5 and 1.75 kg a.i/ha, Bentazon at 1.25 kg a.i/ha and Benthiocarb at 1.5 kg a.i/ha were equally effective in checking the sheath blight incidence in rice. The effect of herbicides on plant diseases has been reviewed by Katan and Eshel (1973) and also by Altman and Campbell (1977). Chakrabarti and Sen (1978) reported that application of Propanil can exclude <u>Helminthosporium oryzae</u> Breda de Hann from rice plants.

The present observations also showed that application of herbicide, Benthiocarb, on 6th day of transplanting could minimise the sheath rot incidence. This may be due to the effective destruction of the initial soil inoculum or by the destruction of weed hosts in the field or by altering the host physiology.

The results of the laboratory evaluation of fungicides showed that the growth of the isolates of S_1, S_4 and S_5 was completely inhibited by Bavistin (Carbendazim) 500 ppm, 750 ppm and 1000 ppm when tested by the poisoned food technique. Similarly Carbistin (Carbendazim) at 500 ppm, 750 ppm and 1000 ppm were able to completely inhibit the growth of the isolates S_1, S_3 and S_4. The effect of Bavistin in checking the growth of many fungi in nutrient media has been reported earlier by Zachos <u>et al.</u>(1965). Sen and Kapoor (1975) and Kataria and Grover (1977). Chinnaswamy <u>et al.</u>(1977), Chien and Huang (1979), Raina and Singh (1980), Raju and Singh (1981) and Reddy <u>et al.</u>(1984) have also pointed out the effect of Carbendazim in checking the fungus <u>S.oryzae</u>.

The fungicidal mixture, Calixin-Bavistin (each at 50 and 100 ppm) was found to be superior in inhibiting the growth of isolate, S_4. On comparing Calixin with Calixin-Bavistin mixture, the latter was found superior against the isolates, S_1 and S_7. Similarly Calixin-Bavistin mixture at 75 and 100 ppm each were equally effective as Calixin alone at 750 and 1000 ppm respectively against the isolate, S_5.

It was reported recently from Tamil Nadu that Calixin-Bavistin mixture (each at 100 g/ha) could effectively reduce the incidence as well as intensity of sheath rot disease of rice in the field (Lakshmanan, 1984).

The results of field trial conducted revealed that various crop nutrition schedules had varying influence on sheath rot incidence.

The minimum disease index was noticed in plots which received organic manure alone followed by the treatment with urea as nitrogen source and 50 per cent increased potash as MOP in equal splits in soil. This was found on par with the treatments where nitrogen was applied as ammonium sulphate. When the treatment, where nitrogen in the form of urea as two splits in soil and last split as foliar, is compared with the nitrogen source, ammonium sulphate applied in the same manner, the least disease index was observed for the latter nutrition schedule. This treatment schedule was able to minimise the disease to economic level without the use of fungicide. This showed that the form of nitrogen and its method of application can influence the incidence and intensity of the disease.

Henis and Katan (1975) stated that pathogen-host interactions depend more on the form of nitrogen rather than the amount of nitrogen available. Huber and Watson (1974) observed the same trend in various crop diseases. They have pointed out one example of rice disease in this context that the blast disease was favoured in presence of ammoniacal nitrogen, whereas it was suppressed with nitrate nitrogen and this was just reverse in the case of brown spot of rice, where nitrate nitrogen favoured the disease and ammoniacal nitrogen suppressed the disease. In the present study it was found that the severity of sheath rot disease could be minimised considerably by the application of ammonium sulphate as foliar spray in the last split than the foliar application of urea during same period. The possible reason for this phenomenon may be the direct toxic effect of free ammonium ions to the pathogen from the ammonium sulphate applied as foliar. Whereas in the case of urea, nitrogen available on the plant surface in amide form may not be toxic to the pathogen.

Henis and Chet (1967) reported the toxic effect of ammonia on germination of sclerotia of <u>Sclerotium</u> <u>rolfsii</u> Sacc. by increasing the ammonium content of sclerotial environment in crop plants. They have also discussed about the direct toxic effect of ammonia in <u>Phymatotrichum</u> root rot of cotton.

Eventhough the minimum disease index was observed in the present study in plots which received the organic manure alone it was found uneconomic with respect to both grain and straw yield.

Another notable observation of the present study was, even though a lower disease index was recorded for the nutrition schedules with ammonium sulphate, the higher yield was observed for the schedules with urea. The possible reason for the same may be the direct toxic effect of ammonium sulphate as discussed earlier which could have minimised the disease incidence whereas the increased yield by the foliar application of urea along with potash might have been resulted by the other physiological changes brought about by the latter in the host.

In a study conducted by Movsumov <u>et</u> <u>al</u>. (1975) with nitrate, ammoniacal and amide forms of nitrogen as foliar spray in rice, observed that the rate of transformation of inorganic nitrogen into amino acids in the plant was greater with urea (amide form of nitrogen). They also reported that foliar application of potash with urea could further increase the rate of transformation of nitrogen into amino acids. This may be the reason for the enhanced grain yield with urea as foliar application in presence of potash in the present study also. Similarly Raju et al. (1978) observed a five per cent increase in grain yield in rice by the foliar application of urea than applying the same in the soil. Debata and Murty (1983) revealed that foliar spray of nitrogen was the most effective one followed by potash and phosphorus with respect to yield. In general the maximum grain yield was recorded for the treatments with urea as nitrogen source. Again, in all these treatment schedules where the last split of urea and potash was applied as foliar spray could enhance the grain yield. It was also observed that the efficiency of these treatment schedules was further increased with the application of the fungicide, Carboxin. The same trend of increase in grain yield could be noticed in treatments with urea as nitrogen source where zinc and manganese were given as foliar spray at active tillering stage of the crop. This treatment schedule has recorded the maximum straw yield also.

Mahapatra and Gupta (1978) worked out the efficacy of foliar application of macro and micro nutrients to rice crop and they found that the average grain yield can be increased economically with the foliar application of such nutrients. Similarly Jadhav *et al.* (1983) found that four kg of zinc in the form of zinc sulphate given as foliar spray to rice crop in kharif season could increase the grain yield to 22 per cent.

The present observations that yield can be increased with foliar spray of micronutrients, Zn and Mn along with urea are in agreement with the observations of the earlier workers as discussed above.

SUMMARY

SUMMARY

Detailed investigations were carried out on symptomatology, epidemiology and control aspects of sheath rot disease of rice caused by *Sarocladium oryzae* Gams & Hawksworth (= *Acrocylindrium oryzae* Saw).

The sheath rot disease of rice is characterised by the initiation of purplish-brown oblong lesions on the sheath of the flag leaf. At maturity these lesions assumed larger in size, turned dark brown with grey-white centres and often covered the entire flag leaf sheath. In severely affected plants the panicles did not emerge and such panicles are choked inside the sheath itself. In the affected field different sizes of partially emerged panicles with discoloured and fully or partially chaffy grains could be noticed.

Artificial inoculation of rice plants with the pathogen showed that under sufficient humid conditions it took an average of five to eight days for initiation of symptoms which developed into typical symptoms in another ten to twelve days. A few isolates of the pathogen were obtained following standard techniques from naturally infected four rice varieties collected from three different localities. These isolates were brought into pure culture on potato dextrose agar. From the various isolates seven different isolates viz., S_1, S_2, S_3, S_4, S_5, S_6 and S_7 were selected based mainly on

symptomatological variations for further detailed study. Slide cultures of the selected isolates were prepared and their morphological characters were compared and recorded.

Mycelium was septate and profusely branched and colour varied from pinkish-white to orange-white or grey-brown. The hyphal thickness of various isolates measured on average 1.6 to 3.2 µm. Conidiophores were branched in one to three whorls and the main axis measured 9.5 to 63 x 3.2 µm. Conidia were single celled, hyaline, cylindrical in shape and borne singly or in bunch at the tip of each branch, which measured on the average 4.7 to 7.9 x 1.6 to 3.2 µm. However, no appreciable differences in the morphological characters were noticed between different isolates.

From a number of isolations tried with sheath rot affected specimens collected from the Cropping Systems Research Centre (C.S.R.C.), Karamana, it constantly yielded three other fungi also besides the causal organism, S.oryzae. From the detailed studies of their morphological characters, two of these associated fungi were identified as species of Fusarium (A_1 & A_2) and the other as Alternaria padwickii (Ganguly) M.B. Ellis (A_3).

The pathogenicity tests showed that all the isolates of S.oryzae (S_1 to S_7) can initiate the disease, but it varied in symptom development. The associated fungi (A_1, A_2 & A_3) individually and in combination with the most virulent isolate of S.oryzae, S_5, (the isolate from the rice variety Jyothi with typical sheath rot symptoms) were able to infect different rice varieties namely, Jaya, Pavizham, Jyothi and Triveni and produced varying type of sheath rot symptoms. Among the isolates of S.oryzae used, isolate (S_2) showed mild reaction to all the rice varieties, whereas, the isolate (S_5) showed the most virulent reaction on them. All the four rice varieties tested showed susceptible reaction to all isolates of S.oryzae, except the variety Pavizham which showed tolerant reaction to the isolate (S_6) only. The combined inoculation of the isolate (S_5) with the three associated fungi could hasten the initiation and development of sheath rot symptoms in all the rice varieties tested.

Studies on post infectional biochemical changes brought about by the pathogen on artificially inoculated four rice varieties showed that there was a gradual quantitative fall in the content of total soluble sugars in diseased plants irrespective of the variety. The maximum reduction of total soluble sugars due to infection was noticed in the variety Jyothi and the least reduction in Triveni. The infection by the pathogen also caused a general increase in the total phenolics level in the varieties, Jaya Jyothi and Triveni, with the exception in the variety Pavizham, where the total phenolics level was found to be decreased due to infection.

In this study observations were made on sheath rot incidence with respect to different crop management practices under field conditions.

The results showed that:

(i) Higher levels of nitrogen (above 80 kg/ha) and lower levels of potash (below 40 Kg/ha) caused a higher incidence of the disease irrespective of the cropping season.

(ii) Delayed planting upto two weeks, both in Kharif and Rabi seasons from the normal date constantly reduced the incidence of the disease.

(iii) Comparative performance of three varieties under varying agronomic practices also revealed that the disease incidence was less in Pavizham and Jaya, whereas Karthika showed maximum disease incidence.

(iv) The comparative performance of certain pre-release cultures and few promising new rice varieties under field conditions showed that Cul.4-4, Cul.1954, Cul.1907 and Cul.25331 were tolerant to the disease.

(v) Application of nitrogenous fertilisers with slow release nitrogen and nitrification inhibitors showed that, neem cake treated urea and gypsum coated urea minimised the disease incidence than free urea.

(vi) Spraying of the herbicide, Benthiocarb at the rate of 1.5 kg a.i/ha on 6th day of transplanting could minimise the disease than two hand weeding of the crop.

In vitro evaluation of three fungicide and one fungicidal mixture was done against five isolates of the pathogen viz., isolates S_1, S_3, S_4, S_5 and S_7. Inhibition on growth of the isolates was tested on solid medium by the poisoned food technique. The results showed that the fungicides, Bavistin and Carbistin (both Carbendazim formulations) at 500, 750 and 1000 ppm each could inhibit the complete growth of the isolates S_1, S_4, S_5 and S_1,S_3,S_4

respectively. Similarly Calixin-Bavistin mixture (at 50, 75 & 100 ppm each) was able to inhibit complete growth of the isolate (S_4), and this fungicidal mixture at 75 and 100 ppm each were found equally effective as Calixin alone at 750 and 1000 ppm respectively in checking the growth of the isolate (S_5)

A detailed field trial was conducted to evaluate the influence of various crop nutrition schedules on the incidence of the disease. The results revealed that various forms of nitrogen and their method of application could influence the incidence and intensity of the disease significantly.

Minimum disease index was noticed in plots receiving organic manure alone followed by application of urea as nitrogen source and 50 per cent increased potash as MOP in equal splits in soil. This was found on par with the treatment where nitrogen was applied as ammonium sulphate in the same manner. Nitrogen in the form of urea in two splits in soil and last split as foliar, was compared with the nitrogen source, ammonium sulphate, applied in the same manner, the least disease index was noticed for the latter nutrition schedule. This treatment schedule was able to minimise the disease to economic level without the use of fungicide.

Even though the least disease index was recorded for the treatment schedule with organic manure alone, it was found uneconomic with respect to both grain and straw yield.

Another notable observation of the present study was even though a lower disease index was recorded for the nutrition schedules with ammonium sulphate, the higher yield was recorded for the schedules with urea. In all these treatment schedules where the last split of urea and potash were applied as foliar spray it could enhance the grain yield. It was also observed that the efficiency of these treatment schedules could be further increased with the application of the fungicide Carboxin.

The same trend of increase in grain yield could be noticed in treatmentswith urea as nitrogen source and where zinc and manganese were applied as foliar spray at active tillering stage of the crop. This treatment schedule has recorded the maximum straw yield also.

REFERENCES

REFERENCES

Agnihothrudu, V. (1973). Acrocylindrium oryzae Sawada, Sheath rot on paddy. Kavaka 1: 69-71.

Alagarsamy, G., Velusamy, M., Rajagopalan, S. and Palanisamy, S. (1985). Effect of slow release nitrogen fertilizers on stem borer and sheath rot incidence and on rice grain yield. I.R.R.N. 10 (4): 19.

Allen, P.J. (1942). Changes in the metabolism of wheat leaves induced by infection with powdery mildew. Am. J. Bot. 29: 425-435.

Altman, J. and Campbell, C.L. (1977). Effects of herbicides on plant diseases. Ann. Rev. Phytopathol. 15: 361-385.

Amin, K.S. (1976 a). Sources of resistance to Acrocylindrium oryzae, sheath rot of rice. Pl. Dis. Reptr. 60: 72-73.

Amin, K.S. (1976 b). Standard Assessment of Diseases of Rice. AICRIP, India pp.14.

Amin, K.S., Sharma, B.D. and Das, C.R. (1974). Occurrence in India of sheath rot of rice caused by Acrocylindrium. Pl. Dis. Reptr. 58: 358-360.

* Anonymous (1962). Studies on plant diseases. Progr. Rep. Crop. Improv. Prog. 2: 289-295.

Anonymous (1982). Package of Practices Recommendations. Kerala Agricultural University, Vellanikkara. pp.199.

Anonymous (1983 a). Research Report (1982-'83). Kerala Agricultural University, pp.548.

Anonymous (1983 b). Confirmatory trials on the control of sheath rot disease of rice (Vellayani). Annual Report (1982-'83). Kerala Agricultural University, pp.112.

Asada, Y. (1957). Studies on the susceptibility of akiochi (autumn decline) Rice plant to Helminthosporium blight. Phytopathol. Soc. Japan, Ann. 22: 103-106.

Attabhanyo, A. and Rush, M.C. (1973). Sheath rot of rice in Louisiana (Abstr. 0246) Proc. 2nd Int. Cong. Plant Pathol. Minneapolis, Minn. pp.5-12.

Balakrishnan, B. (1981). Symptomatology Etiology and control of sheath rot disease of rice caused by Acrocylindrium oryzae. M.Sc.(Ag.) Thesis, Kerala Agricultural University, pp.97.

Balakrishnan, B. and Nair, M.C.(1982). Chemical control of sheath rot disease of rice in Kerala. Indian J. Mycol. and Pl. Pathol. 12: 129-130.

Balakrishnan, B. and Nair, M.C.(1983). Observations on the post infectional changes of rice plants infected by the sheath rot fungus Acrocylindrium oryzae Saw. Agric. Res. J. Kerala 21: 73-74.

Balakrishnan, B. and Nair, M.C.(1986). Effect of N:K nutrition, time of planting and therapeutic application of fungicides in the management of sheath blight and sheath rot diseases of rice. Abstract of National Seminar on Plant Protection in Field Crops pp.41; paper presented in the National Seminar at the Central Plant Protection Training Institute, Hyderabad during January 1986.

Balakrishnan, B. and Rajan, K.M.(1981). Disease reaction of Advanced Rice cultures. I.R.R.N. 6(6): 13.

Chakravarty, D.K. and Biswas, S.(1978). Estimation of yield loss in rice affected by sheath rot. Pl. Dis. Reptr. 62: 226-231.

Chakrabarti, D.K. and Sen, C.(1978). Effect of foliar application of herbicides on the conidial germination and growth of Helminthosporium oryzae causing brown spot of paddy. Oryza 15: 201-203.

Chaudhuri, S.R. and Purkayastha, R.P.(1980). Experimental observations on Rice sheath rot disease. I.R.R.N. 5(4): 13-14.

Chen, M.J.(1957). Studies on sheath rot of rice plant. J. Agric. Res. Taiwan 6: 84-102.

Chien, C.C.(1981). Studies on the sheath rot disease and its relation to the sterility of rice plants. Pl. Prot. Bull. Taiwan (80) 22(1): 31-39.

Chien, C.C. and Chu, C.L.(1970). Studies on the effect of fertilizers to rice disease. J. Agric. Res. Taiwan 19: 62-71.

Chien, C.C. and Huang, C.H.(1979). The relation between sheath rot and sterility of rice plant. J. Agric. Res. China 28(1): 7-16.

Chien, C.C. and Thseng, F.M.(1982). Rice variety and age in relation to the susceptibility to sheath rot. J. Agric. Res. China 31(2): 155-161.

Chinnaswamy, R., Nair, M.C. and Menon, M.R. (1977). Comparative efficacy of fungicides in sheath rot control. Paper presented on the Golden Jubilee Symposium on Rice Research Station, Pattambi. Abstract of papers, December 1977, Kerala Agricultural University pp. 41-42.

Datta, K.S. and Purkayastha, R.P.(1978). Germination behaviour of Acrocylindrium oryzae causing the sheath rot disease of rice. Indian Phytopath. 31: 89-91.

Dayal, R. and Joshi, M.M.(1968). Post infection changes in the sugar content of leaf-spot infected Barley. Indian Phytopath. 21: 221.

Debata, A. and Murty, K.S.(1983). Effect of foliar application of nitrogen, phosphorus and potassium salts on flag leaf senescence in Rice. Agl. Sc. Digest. 3(1): 23-26.

* Dubois, M., Gilles, K., Hamilton, J.K., Rebers, P.A. and Smith, F.(1951). A colorimetric method for the determination of sugars. Nature London

Estrada, B.A., Sanchez, L.M. and Crill, P.(1979). Evaluation of screening methods for sheath rot resistance of rice. Pl. Dis. Reptr. 3: 908-911.

Estrada, B.A., Torres, C.Q. and Bonman, J.M. (1984). Effect of sheath rot on some yield components. I.R.R.N. 9(2): 14.

Farkas, G.L. and Kiraly, Z. (1962). Role of phenolic compounds of interest in the physiology of plant disease resistance. Phytopath. Z. 44: 105-150.

Gams, W. and Hawksworth, D.L. (1975). The identity of Acrocylindrium oryzae Sawada., and a similar fungus causing sheath rot of rice. Kavaka 3: 56-61.

George, B. (1981). The role of organic amendments on the control of sheath blight of rice. M.Sc.(Ag.) Thesis, Kerala Agricultural University, pp.79.

Henis, Y. and Chet, I. (1967). Mode of action of ammonia on Sclerotium rolfsii. Phytopathology 57: 425-427.

Henis, Y. and Katan, J. (1975). Effect of organic amendments and soil reaction on soil-borne plant diseases In: Bruehl G.W. (ed.) Biology and control of soil-borne plant diseases. Am. Phytopathol. Soc., St. Paul Minn., pp.100-106.

Horsfall, J.G. and Dimond, A.E. (1957). Interactions of tissue sugar, growth substances and disease susceptibility. Z. Pflanzenkrankh Pflanzenschutz 57: 1207-1211.

Hsieh, S.P.Y., Liang, W.L. and Chang, S.Y. (1977). Etiological studies on the sterility of rice plants. I. Association of sheath rot fungus Acrocylindrium oryzae Sawada, with sterile rice plant. Pl. Prot. Bull. Taiwan 19(1): 30-36.

Huber, D.M. and Watson, R.D. (1974). Nitrogen form and plant disease. Annu. Rev. Phytopathol. 12: 139-165.

Inman, R.E. (1962). Disease development, disease intensity and carbohydrate levels in rusted bean plants. Phytopathology 52: 1207-1211.

Jadhav, B.B., Pati, V.H. and Kadrekar, S.B. (1983). Effects of soil and foliar application of zinc on rice. J. Maharastra Agl. Universities. 8(3): 227-228.

Jaganmohan, K.P.(1977). Studies on the control of sheath blight of rice caused by Corticium sasakii (Shirai) Matsumoto. M.Sc.(Ag.) Thesis, Kerala Agricultural University, pp.55.

Jayachandran Nair, K.(1975). Epidemiology of Blast disease of Rice. Doctoral Thesis submitted to Orissa University of Agriculture and Technology., Bhubaneswar. pp.174-175.

Kang, M.S. and Rattan, G.S.(1983). Sheath rot in Punjab, India. I.R.R.N. 8(3): 7-8.

Kannaiyan, S. (1979). Chemical control of sheath rot disease of rice. I.R.R.N. 4(3): 14-15.

Katan, J. and Eshel, Y.(1973). Interaction between herbicides and plant pathogens. Residue Reviews 45: 145-147.

Kataria, H.R. and Grover, R.K.(1977). Comparison of fungicides for the control of Rhizoctonia solani causing damping off of mung bean (Phaseolus aureus). Indian Phytopath. 30: 151.

Kozaka, T.(1970). Pellicularia sheath blight of rice plants and its control. Jap. agric. Res. Quart. 5: 12-16.

Lakshmanan, P.(1984). Effective control of sheath rot of paddy. I.R.R.N. 9(5): 14.

Lakshmanan, P. and Nair, M.C.(1980). In vitro effect of certain herbicides on Rhizoctonia solani. Pesticides (14): 30-31.

Lakshmy, T.R.(1984). Evaluation of various herbicides on the control of sheath blight disease (Rhizoctonia solani Kuhn) on rice. M.Sc.(Ag.) Thesis, Kerala Agricultural University, pp.108.

Lin, T.F.(1978). Indica Rice varietal improvement for major diseases and insects resistance. J. Agril. Assoc. China N.S. 102: 86-95.

Loo, C.P., Choun, C.Q. and Lee, D.C.(1963). Studies on Rhizoctonia blight of rice. Acta. Phytophylac. Sin. 2: 431-440.

Mahapatra, I.C. and Gupta, S.K.(1978). Foliar application of macro and micro nutrients on rice. Indian J. Agron. 23: 369-371.

Misra, A.K. and Mathur, S.C.(1985). Sheath rot incidence in cultivars grown at different nitrogen levels. I.R.R.N. 8(2): 5-6.

Mohan, R. and Subramanian, C.L.(1979). Yield loss due to sheath rot disease of rice caused by Acrocylindrium oryzae Sawada. Madras Agric. J. 66:195.

Mohan, R. and Subramanian, C.L.(1981). Sheath rot of rice - a seed-borne disease. MACCO Agl. Digest. 5(9): 7.

* Movsunov, S.R., Akhundov, M.K. and Akperov, A.K. (1975). Effect of mineral fertilizers on the rate of uptake and on the metabolism of nitrogen in rice plants. Agrokhimiya. (1): 67-69.

Mukerjee, N., Singh, B.D. and Rahman, F.(1981). Testing of indigenous germ plasm of rice against sheath rot by artificial inoculation. Indian Phytopath. 34: 287-290.

Muneera, V.K.(1973). Studies on the control of sheath blight of Rice. M.Sc.(Ag.) Thesis, Kerala Agricultural University, pp.66.

Nair, R.(1976). Incidence of sheath rot in rice - a potential problem for Sambalpur, Orissa. I.R.R.N. 1(1): 19.

Nair, M.C., Rema Devi, L., Balakrishnan, B., Lakshmy, C.R. and Madhavan Nair, K.P.(1986). Effect of herbicides in the incidence of sheath blight disease of rice. Paper presented in the National Seminar held at T.N.A.U. Coimbatore during January 1986 under the auspicious of Society of Mycology and Plant Pathology.

Nair, M.C. and Sathyarajan, P.K.(1975). Sheath rot of rice. Agric.Res. J. Kerala 13: 105-106.

Ngala, G.N. (1983). Sarocladium attenuatum as one of the causes of rice grain spotting in Nigeria. Pl. Pathol. 32: 289-293.

Ou, S.H.(1963). Report to the Govt. of Thailand on Blast and other diseases of rice. Rev. Appl. Mycol. 43: 354-355.

Ou,S.H.(1972). Rice diseases Commonwealth Mycol. Institute, Kew, England, pp.274-275.

Padwick, G.W.(1956). Diseases and pests of rice in Japan. Outlook on Agric. 1, 20-25.

Perrenoud, S.(1977). Potassium and Plant Health. IPI Research Topics No. 3: pp.218.

Prabakaran, J., Ragunathan, V. and Prasad, N.N.(1974). Occurrence of sheath rot disease of rice caused by Acrocylindrium oryzae Sawada. Annamalai Univ. Agric. Res. Ann. 5: 182-183.

Purkayastha, R.P., Ghosal, A. and Biswas, S.(1983). Production of momilactone associated with resistance of rice cultivars to sheath rot disease. Curr. Sci. 52: 131-132.

Ragunathan,V. and Vijayaraghavan, C.(1976). Effect of certain fungicides on the in vitro growth and enzymatic activities of A.oryzae Sawada. Madras agric. J. 63: 396-399.

Raina, G.L. and Gurjit Singh (1980). Sheath rot out break in the Punjab. I.R.R.N. 5(1): 16.

Rajan, K.M. (1980). Soil amendments in plant disease control. I.R.R.N. 5(4): 15.

Raju, C.A. and Singh, R.A.(1981). Studies on sheath rot of rice II: Chemical control. Pesticides 15(3): 26-28.

Raju, J.S.N., Sreedharan, C. and Sasidhar, V.K.(1978). Efficiency of foliar vs soil application of nitrogen on growth and yield of summer paddy. Agl. Res. J. Kerala 16: 237-239.

Reddy, B.J.S., Chary, M.P. and Reddy, S.M.(1984). Evaluation of different fungicides in the control of sheath rot of rice caused by Acrocylindrium oryzae. Indian J. Mycol.& Pl. Pathol. 13 105.

Reddy, P.R. and Sridhar, R.(1976). Influence of potassium nutrition and bacterial blight disease on phenol, soluble carbohydrates and amino acid contents in rice leaves. Indian Potash J. 1: 13.

Riddell, R.W.(1950). Slide cultures. Mycologia 42: 265-270.

* Sawada, K.(1922). Descriptive catalogue of Formosan Fungi.II. Rep. Govt. Res. Inst. Dept. Agric. Formosa 2: 135.

Sen, B. and Kapoor, I.J. (1975). Control of Rhizoctonia collar rot of cauliflower. Pesticides 9(2): 36.

Shajahan, A.K.M., Ahmed, H.U. and Miah, S.A.(1983). Sheath blotch of rice in Bangladesh. I.R.R.N. 8(2): 12.

Shajahan, A.K.M., Harahap, Z. and Rush, M.C.(1974). Sheath rot of rice caused by Acrocylindrium oryzae in Louisiana. Pl. Dis. Reptr. 61: 307-310.

Singh, R.A. and Raju, C.A.(1981). Studies on sheathr rot of rice. I.R.R.N. 6(2): 11-12.

* Sridhar, R.(1972). Carbohydrate metabolism of rice plants as influenced by nitrogen ffertilization and the blast disease development. Riso. 21: 269-273.

Sridhar, R. and Ou, S.H.(1974). Biochemical changes associated with the development of resistant and susceptible types of rice plant tissues. Phytopath.Z. 79: 222-223.

Srinivasan, S.(1980). Yield loss caused by sheath rot. I.R.R.N. 5(2): 4.

Srinivasan, S. (1981). Seasonal incidence of sheath rot in Thanjavur Delta, India. I.R.R.N. 6(5): 16.

Subramanian, C.L. and Ramakrishnan, G.(1975). Varietal reaction to the sheath rot of rice (Acrocylindrium oryzae Saw.). Curr. Sci. 44: 405-406.

Sung, J.M., Lee, S.C. and Park, J.S.(1982). Sheath rot disease of rice seedling caused by Gaeumannomyces graminis var. tritici in Korea. Korean J. Mycol. 10: 177-180.

* Suzuki, H.(1965). Nature of resistance to blast. In the Rice Blast Disease. Proc. Symp. at IRRI, July 1963. Baltimore, Maryland, John Hopkins Press. pp.271-301.

Swain, T. and Hills, W.E.(1959). The phenolic constituents of Prunus domestica I. The quantitative analysis of phenolic constituents. J. Sci. Food Agric. 10: 63-68.

* Tasugi, H. and Ikeda, Y.(1956). Studies on the sheath rot of rice plant caused by Acrocylindrium oryzae Saw. Bull. nat. Inst. Agric. Sci. Tokyo Ser C. 6: 151-166.

* Tomiyama, K.(1963). Physiology and biochemistry of diseases resistance of plants. Ann.Rev. Phytopathol. 1:295-324.

Tschen, J. and Wen, F.S.(1980). Physiological studies on etiology of the sterility of rice plants. Pl. Prot. Bull. Taiwan 22(1): 57-62.

Vasavan, M.G., Rajan, K.M. and Thomas, M.J.(1980). Herbicides in plant disease control. I.R.R.N. 5(4): 18.

Vidhyasekaran, P., Ranganathan, K., Rajamanickam, B. and Radhakrishnan, J.(1984). Quality of rice grains from sheath rot affected plants. I.R.R.N. 9(1): 19.

* Walker, J.C. and Stahmann, M.A.(1955). Chemical nature of disease resistance in plants. Ann. Rev. Plant Physiol. 6: 351-366.

* Zachos, D.G., Panogo Poulos, C.G. and Markis, S.A.(1963). Fungicide test on the control of the damping off of cotton seedlings caused by Rhizoctonia solani Kuhn. Annls. Inst. Phytopath. Benaki N.S. 5: 108-116.

Zentmeyer, G.A.(1955). A laboratory method for testing soil fungicide with Phytophthora cinnamomi as test organism. Phytopathology 45: 398-404.

* Zhuge, G.H. and Lapis, D.B. (1985). Studies on rice sheath rot.1. Pathogenicity of the pathogen and the factors affecting the disease. Acta Phytopathologica Sinica 15(1): 1-8.

* Original not seen.

APPENDICES

APPENDIX I

Composition of potato dextrose agar medium

Peeled and sliced potato	200 g
Dextrose	20 g
Agar agar	20 g
Distilled water	1000 ml

Source : Source book of laboratory exercises in Plant Pathology, source book committee of the American Phytopathological Society, pp. 366-368.

APPENDIX II

Analysis of variance table

Effect of continuous cropping and manuring in sheath rot disease incidence

Source	S.S.	df	M.S.S.	F
Year	4300.6656	2	2150.3328	101.0058*
Treatment	1076.2998	17	63.3118	2.9739*
N	486.2998	2	243.1499	11.4213*
P	151.6912	2	75.8456	3.5626*
NP	104.2754	4	26.0688	1.2245
K	10.4720	1	10.4720	1
NK	0.8657	2	0.4329	1
PK	77.6988	2	38.8494	1.8248
NPK	144.9979	4	36.2490	1.7027
Year X Treatment	933.5732	34	27.4580	1.3785
Pooled error	3047.4999	153	19.9183	..

Year X Treatment = Not significant

Combined E.M.S. = 21.2892

* Significant at five per cent level of significance.

APPENDIX III

Analysis of variance table

Crop technology for optimum production under resource constraints and their effect on sheath rot incidence

Source	S.S.	df	M.S.S.	F
Season	13191.0888	2	6595.5444	108.4899*
Treatments	553.1789	15	36.8786	1
D x P	345.3914	3	115.1305	1.8938
D	321.1709	1	321.1709	5.2829*
P	10.7826	1	10.7826	1
DP	13.4387	1	13.4387	1
F x W	75.4414	3	25.1471	1
F	63.4892	1	63.4892	1.0443
W	11.8068	1	11.8068	1
FW	0.1454	1	0.1454	1
DP x FW	132.3461	9	14.7051	1
DF	0.9352	1	0.9352	1
DW	13.4366	1	13.4366	1
DFW	0.0929	1	0.0929	1
PF	6.8781	1	6.8781	1
PW	46.2012	1	46.2012	1
PFW	40.8225	1	40.8225	1
DPF	13.0646	1	13.0646	1
DPW	2.4907	1	2.4907	1
DPFW	8.4236	1	8.4236	1
Season x Treatment	1823.8236	30	60.7941	2.9226*
Pooled error	2808.2295	135	20.8017	..

* Significant at five per cent level of significance.

APPENDIX IV

Analysis of variance table

Effect of date of planting (D), different levels of fertilizers (F) and varieties (V) on sheath rot incidence

Source	S.S.	df	M.S.S.	F.
Season	681.5106	1	681.5106	12.9197*
Treatments	8468.2512	23	368.1848	6.9798*
D	4100.5091	1	4100.5091	77.7351*
F	3370.8105	3	1123.6035	21.3006*
DF	240.0687	3	80.0229	1.5170
V	646.2257	2	323.1129	6.1254*
DV	15.0009	3	5.0003	1
FV	85.8539	6	14.3090	1
DFV	9.7824	6	1.6304	1
Season x Treatment	1213.2451	23	52.7498	1.7744*
Pooled error	4102.5054	138	29.7283	..

* Significant at five per cent level of significance

APPENDIX V

Analysis of variance table

Effect of different sources and levels of fertilizers on sheath rot incidence

Source	S.S.	df	M.S.S.	F
Season	41.4217	1	41.4217	3.1985 N.S.
Treatments	112.4208	11	10.2201	1
L	47.2738	2	23.6369	1.8252
S	38.5830	3	12.8610	1
L x S	26.5640	6	4.4273	1
Season x Treatment	146.9004	11	13.3546	1.0393 N.S.
Pooled error	565.3780	44	12.8495	..

Season x Treatment = Not significant

Combined E.M.S. = 12.9505

C.D. = N.S. for L, S and L x S

APPENDIX VI

Analysis of variance table
Weed control studies in crop sequence

Source	S.S.	df	M.S.S.	F.
Replication	16.4533	3	5.4844	1.1380 N.S.
Treatment	53.1361	8	6.6420	1.3782 N.S.
Error	115.6607	24	4.8192	..

APPENDIX VII

Analysis of variance table

Varietal reaction to sheath rot incidence

Source	S.S.	df	M.S.S.	F
Replication	635.5593	2	317.7797	9.9740*
Varieties	3340.2613	25	133.6105	4.1935*
Error	1593.0493	50	31.8610	..

* Significant at five per cent level of significance

APPENDIX VIII

Analysis of variance table

In vitro effect of common fungicides on isolate, S_1 (as percentage inhibition of radial growth over control)

Source	S.S.	df	M.S.S.	F
Treatments	4747.3684	11	431.5790	74.0772*
Error	139.7880	24	5.8245	..

* Significant at five per cent level of significance

APPENDIX IX

Analysis of variance table

In vitro effect of common fungicides on isolate, S_3 (as percentage inhibition of radial growth over control)

Source	S.S.	df	M.S.S.	F
Treatments	7637.9245	11	694.3568	123.3316*
Error	135.1197	24	5.6300	..

* Significant at five per cent level of significance

APPENDIX X

Analysis of variance table

In vitro effect of common fungicides on isolate, S_4 (as percentage inhibition of radial growth over control)

Source	S.S.	df	M.S.S.	F
Treatments	4578.2542	11	416.2049	333.4708*
Error	29.9533	24	1.2481	..

* Significant at five per cent level of significance

APPENDIX XI

Analysis of variance table

In vitro effect of common fungicides on isolate, S_5 (as percentage inhibition of radial growth over control)

Source	S.S.	df	M.S.S.	F
Treatments	3473.1728	11	315.7430	83.2963*
Error	90.9741	24	3.7906	..

* Significant at five per cent level of significance

APPENDIX XXI

Analysis of variance table

In vitro effect of common fungicides on isolate, S_7 (as percentage inhibition of radial growth over control)

Source	S.S.	df	M.S.S.	F
Treatments	2082.3459	11	169.3042	26.2711*
Error	172.9396	24	7.2058	..

* Significant at five per cent level of significance

APPENDIX XLII

Analysis of variance table

Effect of various crop nutrition schedules with and without fungicide (Carboxin) on the incidence of sheath rot of rice

Source	S.S.	df	M.S.S.	F
Replication	0.5049	2	0.2525	0.0770
N	49.0354	6	8.1726	2.4951*
F	9.5593	1	9.5593	2.9173
N x F	51.6772	6	8.6129	2.6295*
Error	85.1611	26	3.2754	..

* Significant at five per cent level of significance

APPENDIX XIV

Analysis of variance table

Effect of various crop nutrition schedules with and without fungicide (Carboxin) on grain yield of rice

Source	S.S.	df	M.S.S.	F
Replication	5302.08	2	2651.04	9.6177*
M	149116.37	6	24852.73	90.1637*
F	1068.08	1	1068.08	3.8749
M x F	3108.04	6	518.01	1.8793
Error	7166.70	26	275.64	..

* Significant at five per cent level of significance

APPENDIX XV

Analysis of variance table

Effect of various crop nutrition schedules with and without fungicide (Carboxin) on straw yield of rice

Source	S.S.	df	M.S.S.	F
Replication	78536.09	2	39268.05	30.6724*
M	354651.46	6	59108.60	46.1700*
F	4441.37	1	4441.37	3.4692
M x F	2876.31	6	479.39	0.3745
Error	33286.11	26	1280.24	..

* Significant at five per cent level of significance

ABSTRACT

Studies on symptomatology, epidemiology and control aspects of sheath rot disease of rice caused by *Sarocladium oryzae* Gams & Hawksworth (= *Acrocylindrium oryzae* Saw.) were done in detail.

The disease initiated as purplish-brown oblong lesions on the sheath of the flag leaf. At maturity lesions enlarged in size with grey-white centres and often covered the entire flag leaf sheath. Panicles often did not emerge but choked inside the affected sheath itself.

Artificial inoculation studies showed that under sufficient humid conditions the pathogen took an average five to eight days for initiation and 15 to 20 days for the complete development of the disease in rice plants. The pathogen was isolated from four naturally infected rice varieties, collected from three different localities. From the various isolates seven different cultures (isolates viz., S_1, S_2, S_3, S_4, S_5, S_6 & S_7) were selected based mainly on symptomatological variations and their comparative morphological characters were studied in detail. No appreciable differences were noticed in the morphological characters between isolates.

During the investigation, three other associated fungi also were obtained which were found constantly associated with the disease besides the original causal organism, S.oryzae. From the detailed morphological studies these associated fungi were identified as Fusarium spp.(A_1) and (A_2) and the third one Alternaria padwickii (Gangaly) M.B. Ellis (A_3).

Pathogenicity tests conducted with different rice varieties showed that all the isolates of S.oryzae (S_1 to S_7) and associated fungi (A_1, A_2 and A_3) individually and the combinations of associated fungi with the most virulent isolate S_5 (isolate obtained from rice variety Jyothi) of S.oryzae were able to produce varying type of sheath rot symptoms. The combined inoculation resulted in hastened disease initiation and symptom development in all the four rice varieties tested.

Studies on biochemical changes in artificially inoculated rice varieties with Sarocladium oryzae showed that there was a gradual quantitative fall in the total soluble sugars and a gradual increase of total phenolic levels in diseased plants. An exception to this was noticed in the variety Pavizham where the infection caused a decrease in the total phenolic content.

Observations made in the field on the incidence of various crop management practices on the incidence of the disease showed that the practices like balanced fertiliser application, slight changes in date of planting, use of resistant/tolerant varieties, use of slow release nitrogen etc., could minimise the incidence of the disease economically. It was also noticed that the herbicides, Benthiocarb, given as spray on 6th day after transplanting was also effective in checking the disease.

In vitro evaluation of fungicides revealed that Bavistin and Carbistin the two Carbendazim products used could completely inhibit the growth of majority of the isolates of the pathogen tested. Among the other fungicides, Calixin-Bavistin mixture, was found to be very effective in inhibiting the growth of most of the isolates tested.

In this study a detailed field trial was done to evaluate various crop nutrition schedules on the incidence of the disease. The results showed that among the various crop nutrition schedules tried, the treatment with organic manure alone coupled with fungicidal spray could record the least disease index. Regarding the other nitrogen sources used, namely, urea and ammonium sulphate both were equally effective by soil application. But as foliar application along with MOP, ammonium sulphate was found most effective treatment which was able to minimise the disease at economic level even in the absence of fungicidal application. Application of fungicide alone, was found insignificant with respect to disease incidence.

Regarding grain and straw yield, in general the treatment schedules with urea showed increasing response than ammonium sulphate. The results also indicated in general, the efficiency of various crop nutrition schedules both in minimising the incidence of the disease as well as in increasing the yield.