ROLE OF THE RICE ROOT NEMATODE (HIRSCHMANNIELLA ORYZAE) IN THE INCIDENCE OF SHEATH BLIGHT DISEASE OF RICE IN KERALA

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Role of rice root nematode (*Hirschmanniella oryzae*) in the incidence of sheath blight disease of rice in Kerala" 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 to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

College of Agriculture,
Vellayani,
23rd March, 1981.

GOKULAPALAN, C.

CERTIFICATE

Certified that this thesis entitled "Role of rice root nematode (*Hirschmanniella oryzae*) in the incidence of sheath blight disease of rice in Kerala" is a record of research work done independently by Shri. C. GOKULAPALAN, 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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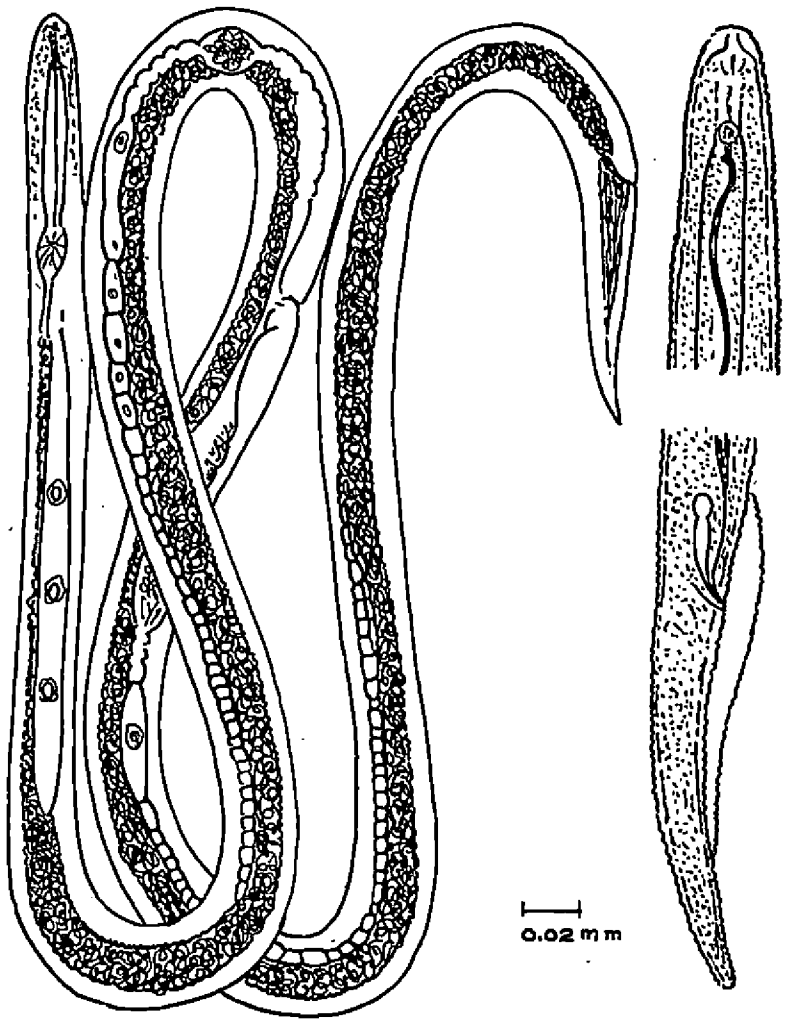
INTRODUCTION

INTRODUCTION

Sheath blight of rice caused by Rhizoctonia solani Kühn (fig.B) eventhough known to occur in Kerala only in recent years, is causing much damage to the crop and is often extremely difficult to control. The prevalence of this disease in Kerala was first observed during 1969 and since then it has been noted in all rice growing areas of the State, however, certain areas are known to be endemic for this disease. This disease is known to be widespread and a serious problem in Japan, where Kozaka (1970) has estimated that 30 to 40 per cent of the cultivated area under rice has been affected by this disease. In Kerala the studies of Mathai (1975) revealed a loss in yield by 25 per cent as a result of infection by this disease.

A survey conducted by an expert team of the Kerala Agricultural University, at the State Seed Farm, Adoor, Quilon District, where the sheath blight disease was found to be endemic from 1969 onwards, revealed the occurrence of heavy incidence of this disease and also high populations of the rice root nematode; Hirschmanniella oryzae (Soltwedel) Luc & Goodey (fig.A) (Anon., 1978c). This nematode was found to be present in all rice growing tracts of the State (Venkitesan and Charles, 1979).

The above information has prompted to take up a detailed study of the disease and its association with the



FEMALE MALE

FIG: A. *Hirschmanniella oryzae* (Solt wedel) Luc & goodey

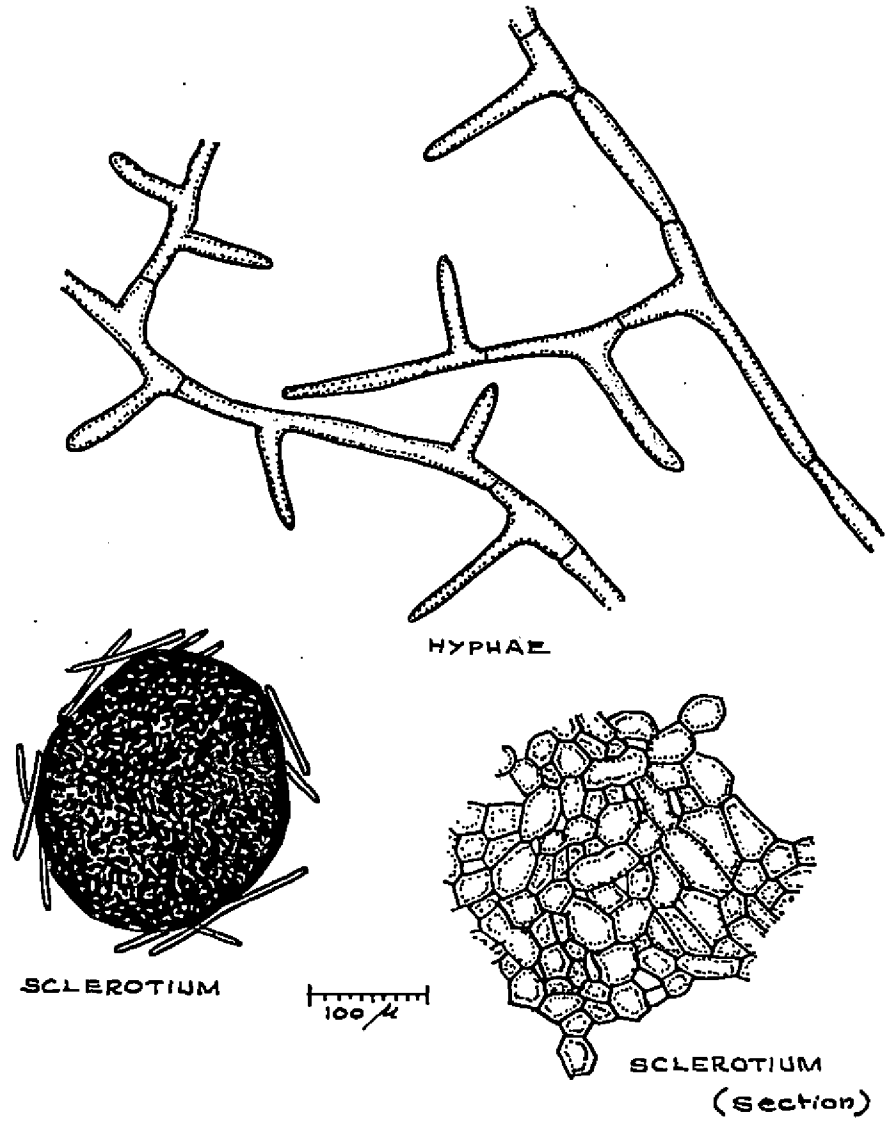


FIG. B *Rhizoctonia solani* Kühn

rice root nematode, Hirschmanniella oryzae. Along with these studies, as part of a continuous research programme of the Department of Plant Pathology, College of Agriculture, some of the epidemiological factors of the sheath blight disease also were taken up in the present study.

A detailed regular survey in and around the paddy fields at the College of Agriculture, Vellayani; Model Agronomic Research Station, Karamana; Rice Research Station, Kayamkulam; and State Seed Farm, Adoor, was conducted to detect collateral hosts for the organism and those found affected were recorded. Ten common rice varieties were screened under natural conditions at the State Seed Farm, Adoor for their comparitive resistance to the infection by sheath blight disease and infestation by the rice root nematode. A few of the R. solani isolates made from other crops were compared for their morphological characters and pathological reaction with the isolate from rice and for its genetic relationship by studying their anastomosis reaction. The role of rice root nematode in initiating the disease was assessed by artificial inoculation studies.

Effect of certain nematicides on R. solani was tested under laboratory condition. A field trial to study the effect of fungicides, mineral nutrients and nematicide on the sheath blight disease and rice root nematode was conducted at the State Seed Farm, Adoor. In vitro studies were also made to identify microorganisms antagonistic to R. solani.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Miyake (1910) first described a new disease of rice from Japan under the name oriental sheath blight and leaf spot and named the causal organism as a new species, Sclerotium irregulare. Subsequently the occurrence of this disease has been recorded from various rice growing countries of the world (Ou, 1972). Eventhough Butler (1918) mentioned about the occurrence of this disease in India, it was Paracer and Chahal (1963) who first described the sheath blight disease caused by Rhizoctonia solani Kuhn from Punjab in detail. The disease assumed serious proportions in the rice growing tracts of Kerala, in recent years (Mahendra Prabhath, 1971).

The causal organism

Following Miyake (1910), Matsumoto (1934) described sheath blight disease again from Japan in detail, and named the causal organism as Corticium sasakii (Shirai) Matsumoto. Ryker and Gooch (1938) studied cultures of the sheath blight fungus from China and from Philippines and considered them to be large sclerotial strains of Rhizoctonia solani. Talbot (1970) after a detailed comparative study concluded that Thanatephorus cucumeris (Frank)Donk was the perfect state of R. solani. He has treated T. cucumeris as a collective species that includes T. praticola (Kotila) Flentje, Corticium microsclerotia Weber, and also

C. sasakii (Shirai) Matsumoto.

Singh and Pavgi (1969) observed the initial symptoms as oval to irregular straw coloured lesions on the leaf tip and leaf sheath. These lesions enlarged, coalesced and covered almost the complete leaf lamina, giving the appearance of banded patches. Sclerotia developed on the infected leaves and leaf sheaths.

Duggar (1915) observed that in R. solani, young hyphal branches were inclined in the direction of growth and constricted at the point of union with the main hyphae. Palo (1926) noted that in certain cases the young branches arise at right angles to the main hyphae but later they bent towards the direction of growth of the main filaments. The morphological studies on the organism have revealed that in mature hyphae, branches arise at right and acute angles, near 45° to the main branch (Matz, 1921; Matsumoto, 1921; Palo, 1926). Frederiksen et al. (1938) observed that the size of sclerotia ranged from about one mm to several mm in diameter.

Anastomosis relationship of Rhizoctonia solani

The grouping of R. solani on the basis of hyphal anastomosis between different strains has gained much importance in the study of this soil borne plant pathogen. R. solani consists of a great number of isolates differing in various characteristics (Flentje et al., 1970). Capacity

for hyphal anastomosis between different isolates provides an indication of relationship within groups of isolates. Parmeter et al. (1969) reported that each anastomosis group has its general tendency in host range and pathogenicity. Earlier reports consist of anastomosis groups involving a few strains of R. solani (Matsumoto, 1921; Matsumoto et al., 1932; Matsumoto and Yamamoto, 1935; Schultz, 1937).

Richter and Schneider (1953) classified strains of R. solani into six groups based on their ability to anastomose each other. Parmeter et al. (1969) observed that most of the 138 isolates of R. solani they isolated and tested fell into four anastomosis groups. Since then several Japanese workers have conducted detailed studies on anastomosis grouping of R. solani, including the relationship of anastomosis grouping to pathological, ecological and morphological differentiation in R. solani (Ogoshi, 1972; 1975; Naiki and Kanoh, 1978; Kuninaga et al., 1978). Lakshmanan et al. (1979) reported from Kerala, India, the hyphal anastomosis between strains of R. solani from rice and cowpea. Tu and Chang (1978) grouped 264 isolates of R. solani from different crops from various regions in Taiwan on the basis of anastomosis. They identified five anastomosis groups, viz., TRAG 1 to 5.

Varietal reaction to sheath blight

Studies on varietal reaction of rice to sheath blight

have been made in most rice growing tracts of the world. Hashioka (1951) observed from Japan that rice varieties from India, Thailand, Burma, Europe and North America were more resistant than local varieties. Trials conducted at IRRI, Philippines using all available cultivated rice varieties to screen for resistance to sheath blight, revealed that only very few varieties were resistant to sheath blight (Anon., 1967). Of the 36 rice varieties screened against sheath blight in Kerala, no variety was found to be resistant to the disease (Mahendra Prabhath, 1971) but the varieties varied considerably in their reaction to infection.

Host range

Nakata and Kawamura (1939) gave an indication of the wide host range of the fungus Corticium sasakii from rice. Ryker (1938) reported Rhizoctonia (Corticium) solani on Bermuda grass, sugarcane, rice and other grasses in Louisiana. Atkins (1952) reported Corticium sasakii on various forage crops and Bermuda grass. Kozaka (1965) stated that plants of 128 species in 32 families may be infected by the sheath-blight fungus. Inoculation trials on seven grasses and one sedge plant with the sheath blight pathogen gave positive results (Kohli, 1966). Kamjaipai and Giatgong (1971) reported that all the 45 rice varieties, 10 grasses and a Cyperus sp. tested were susceptible to the fungus, Corticium sasakii, causing sheath blight of rice. Tsai (1970) observed that the host range of Pellicularia (Corticium)

sasakii on weeds comprised 11 families (Cyperaceae and Gramineae were the most important) and 20 species. Mahendra Prabhath (1971) reported that the sheath blight fungus can infect various hosts of different families, viz., Gramineae, Cyperaceae, Pontederiaceae, Zingiberaceae, Leguminosae, Solanaceae, Labiatae, Musaceae, Convolvulaceae and Araceae. Mahendra Prabhath et al. (1973) reported the susceptibility of Panicum repens L., Echinochloa colonum Link and Cyperus rotundus L. to the sheath blight fungus, R. solani under artificial inoculation tests. The sheath blight fungus was readily isolated from weed hosts and pathogenicity tests with all the isolates on rice proved successful (Roy, 1973). Saikia and Roy (1975) conducted inoculation trials with Corticium sasakii and infection was obtained on 60 different plants (both crop plants and weeds) belonging to 19 families. Nayak et al. (1979) reported that of the 20 weeds inoculated with the sheath blight pathogen 18 developed symptoms. The fungus was found to infect a number of Oryza species like O. perennis Moench em. Sampath, O. eichingeri A. Peter, O. granulata Nees et Arn.ex.Hook f., O. perreiri A. Camus and O. brachyantha A. Chev et Roehr.

Effect of mineral nutrition on sheath blight incidence

Increased incidence of fungal diseases in rice caused by heavy application of nitrogen fertilizers has been reported by several workers (Krishnaswami, 1952; Hashioka,

1956; Padwick, 1956; Loo et al., 1963). Application of potassic fertilizers has been reported to lower the incidence of fungal diseases in rice (Mariani, 1951; McNew, 1953; Corbetta, 1954; Otto, 1956). Potash deficiency associated with iron toxicity was reported to increase Helminthosporium leaf spot (Tanaka and Yoshida, 1970). Muneera (1973) observed that the sheath blight intensity was less at the lower level of nitrogenous fertilizer and that there was a significant reduction in the intensity of the disease with incremental doses of potash. Tanaka and Yoshida (1970) reported that manganese level is frequently low in highly weathered lateritic and degraded paddy soils, which is often accompanied by iron toxicity and a low level of bases including K, Ca or Mg. Plants growing in such soils were found to be deficient in Mn and such plants are reported to be susceptible to Helminthosporium leaf spot.

Chemical control of sheath blight

Chemical control of sheath blight of rice has been studied by different workers all over the world. Earlier, copper and mercury compounds were recommended (Hashioka and Saito, 1953; Yoshimura, 1954). Later, organo arsine compounds were reported to be more effective (Hashioka, 1956). Kozaka (1961) observed that organo arsine compounds are the most effective agents against the sheath blight disease. Several workers have reported the effectiveness

of Hinosan (O-ethyl S, S-diphenyl-dithiophosphate) in controlling the sheath blight disease of rice (Umeda, 1973; Yamaguchi, 1974; Mathai, 1975; Mukherjee, 1978; Kannaiyan and Prasad, 1979).

Hartzfield (1957) found that terrachlor (Pentachloro nitrobenzene) dust, W.P. and E.C. were effective against sclerotia forming fungi. Ko and Oda (1972) observed that the nature of control of R. solani by pentachloro nitrobenzene in soil appeared to result from growth suppression rather than destruction of the pathogen. Benlate (methyl 1-butyl carbamoyl-2-benzimidazole carbamate) was found to be effective in reducing the intensity of sheath blight disease (Muneera, 1973; Jagannmohan, 1977).

In vitro trials revealed the effectiveness of Vitavax (5,6-dihydro 2 methyl-1-4 oxathiin-3-carboxanilide) against the sheath blight organism (Mahendra Prabhath, 1971). Jagannmohan (1977) found that sheath blight intensity was reduced significantly at higher levels of potash with application of Vitavax (0.02 per cent). Lakshmanan et al. (1980) also observed effective control of sheath blight under field conditions with Vitavax.

El-Khadem et al. (1977) observed that three nematicides, aldicarb (2-methyl-2(methylthio) propional-dehyde O-methyl carbamoyl) oxime, fensulfothion (diethyl 4 (methyl sulphinyl) phenyl phosphorothioate) and phenamiphos

(O-ethyl-O(3-methyl-4-methyl thio-phenyl)-isopropyl amido-phosphate) at 1, 5 and 125 ppm were effective against R. solani.

Biological control

Biological control of R. solani has been attempted by various workers using different antagonistic micro-organisms. There are several reports on biological control of plant pathogenic organisms by antagonistic fungi (Weindling, 1932; 1934; Jaarsveld, 1942; Sanford, 1952). The earlier studies have shown that Trichoderma spp. were the predominant fungi which exerted significant antagonistic action on R. solani (Hino, 1935; Josifovic, 1967; Roy, 1977; Henis et al., 1978; Heder et al., 1979).

Endo (1935) observed that Aspergillus niger, A. parasiticus Speare and A. tamarii Kita were antagonistic to and weakened the pathogenicity of the sheath blight fungus, Hypochnus sasakii. Naim and El-Essawy (1965), Shukla and Dwivedi (1979) have also reported the antagonistic action of Aspergillus spp. against R. solani.

The inhibitory effect of Bacillus sp. on R. solani has been reported by many workers (Hino, 1935; Cordon and Haenseler, 1939; Michener and Snell, 1949; Dunleavy, 1952; Vasudeva and Chakravarthy, 1954; Olsen, 1965). In an experiment conducted at IRRI, Philippines, the antagonistic action of many bacterial isolates differing in colony

characters obtained from the irrigation water of rice fields and sclerotia of R. solani were studied. Many isolates especially those from sclerotia exhibited antagonism to the pathogen (Anon., 1978b).

Rice root nematode

Van Breda de Haan (1902) reported the rice root nematode for the first time from Indonesia. The rice root nematode is reported to be widely distributed in all rice growing regions of the world (Ou, 1972). The rice root nematode Hirschmanniella oryzae (Goltwedel) Luc & Goodey is reported to occur in most of the rice growing areas in Kerala, India (Venkitesan and Charles, 1979).

Rao (1970) evaluated the damages and losses due to nematode infestation in rice which included those caused by rice root nematode. Panda and Rao (1971) observed that rice seedlings inoculated with the rice root nematode at levels of 1000, 5000 and 10,000 per seedling showed reduction in tillering, earhead length, grain yield and root weight. Das and Rao (1971) reported that the maximum population of rice root nematode was at about the flowering stage of the crop. Results of a pot culture trial indicated that rice root nematode, at inoculum levels of 1000 to 5000 per plant caused considerable reduction in tillering, delayed flowering, chlorosis and reduction in grain yield of rice (Babatola and Bridge, 1979).

Fungus-nematode interaction

Plant diseases which are complex in nature, involving fungi and nematodes have been observed in various crops by different workers. Several workers have exhaustively reviewed the studies conducted on such complex plant diseases (Powell, 1963; 1971; Pitcher, 1963; Bergeson, 1972). In most of these fungus-nematode complex diseases, a root infecting fungal pathogen and the soil or root infesting nematode are observed to cause synergistic increase in disease severity. Only very scanty information is available at present with regard to fungus-nematode complex diseases involving an aerial fungal pathogen and nematode, infesting root and soil. A clear correlation was reported between the number of nematodes, Ditylenchus dipsaci (Kuhn) Filipjev in the soil before planting potatoes and the percentage of infection by Phoma solanicola Pr. & Delacr., suggesting that the nematodes weakened the plants for fungus attack (Hijink, 1963).

In several cases plant parasitic nematodes have been found to modify the host plant tissue in such a way that it becomes a better substrate for the fungus and thus promotes fungal growth and reproduction to the detriment of the host. Giebel (1973) reported biochemical association between infection of Heterodera rostochiensis Wollenweber and development of R. solani on potato. Agrawal et al.

(1974) found that the hyphal thickness and linear growth of Fusarium oxysporum f. sp. Zingiberi Trujillo were greater in media containing the extract of ginger roots galled by Meloidogyne incognita Chitwood, than in that of healthy roots indicating the presence of some growth promoting substance produced by the interaction of host and nematode. Van Gundy et al. (1977) reported that severe root rot of tomato caused by Meloidogyne incognita and R. solani was associated with nutrient mobilisation into gall tissue and root exudation. Sidhu and Webster (1977) observed the role of free amino acids which are abundant in nematode galled tissues in predisposing the plants to infection by the fungus, Fusarium oxysporum f. sp. lycopersici Sacc.

Jacobsen et al. (1979) observed that combined application of benomyl and carbofuran gave higher yields, reduced disease index and controlled the nematode infestation in the case of Verticillium wilt of potato involving the root knot nematode Meloidogyne hapla Chitwood.

Chemical treatment of soil with nematicides like D-D(Dichloropropane + Dichloropropene) or Ethylene dibromide or vapam (sodium methyl dithiocarbamate) resulted in low nematode population and higher grain yield in rice (Ichinohe, 1966, Iyatomi and Nishizawa, 1968). Chhabra and Dhaliwal (1978) have reported the effectiveness of three granular

nematicides, viz., carbofuran (2,3-dihydro-2, 2-dimethyl-7-benzofuranylmethyl carbamate), aldicarb and phorate (O-O-diethyl S-2(ethyl thio) ethyl phosphorodithioate) each at two kg ai per hectare in controlling the rice root nematode.

MATERIALS AND METHODS

MATERIALS AND METHODS

Isolation and culturing of the fungus

The isolate of Rhizoctonia solani used in the study was obtained from naturally infected rice plants collected from the rice fields at the State Seed Farm, Adoor. The sheath portions of infected plants showing characteristic symptoms of attack were cut into small bits, surface sterilised with 0.1 per cent mercuric chloride solution for two minutes and were repeatedly washed in three changes of sterile water. These were then planted over potato dextrose agar (PDA) in sterile petri dishes and incubated under laboratory conditions. The isolate was purified by repeated hyphal tip plating and the organism was maintained on PDA by sub-culturing periodically.

Survey of collateral hosts of R. solani in and around rice fields

Regular survey was conducted for detecting collateral hosts of R. solani on other common crops raised in rice fallows and also on weeds found in and around rice fields. The survey was conducted at the Instructional Farm, College of Agriculture, Vellayani; State Seed Farm, Adoor; Rice Research Station, Kayamkulam and Model Agronomic Research Station, Karamana. The causal organism was isolated from the following plants which gave positive results.

1. Sesamum indicum L. (Pedaliaceae)
2. Arachis hypogaea L. (Leguminosae)
3. Sesbania aculeata Pers. (Leguminosae)
4. Wild colocasia (Araceae)
5. Cyperus iria L. (Cyperaceae)
6. Fimbristylis miliacea Vahl. (Cyperaceae)
7. Aplude aristata L. (Panicoideae)
8. Monochoria vaginalis (Burm F.) Presl (Pontederiaceae)

Parts of plants showing characteristic symptoms of attack were cut into small bits and R. solani was isolated and purified into pure culture following the same methods described under isolation from rice. The identification of R. solani was done by observing characters such as hyphal branching, septation of hyphae and sclerotial characters. Pathogenicity studies were made by artificial inoculation on rice and also on their respective hosts.

Mass culturing of R. solani

R. solani was mass cultured on sterilised sand maize medium in 1000 ml Erlenmeyer flasks. Actively growing three day old culture bits were aseptically introduced into the flasks with sand maize medium and were incubated for twenty days.

Multiplication of rice root nematode (Hirschmanniella oryzae)

The roots of rice plants and soil from fields severely

infested with the rice root nematode were collected and the nematodes from these formed the original nucleus culture. This was multiplied on paddy seedlings grown in pots containing nematode free soil (Nemagon treated). Fresh seedlings were periodically planted in the same pots and the debris of the old plants were incorporated into the soil for favouring the multiplication of the nematode.

The roots of several wet land weeds from nematode infested soil were incubated according to a method described by Young (1954) to study the host range of the rice root nematode. The root systems were carefully washed free from soil and cut into lengths of five to ten cm and put into polythene bags. The roots of the following wetland weeds were included.

1. Cyperus iria L. (Cyperaceae)
2. Fimbristylis miliaceae Vahl. (Cyperaceae)
3. Echinochloa crusgalli (Linn.) P. Beauv. (Panicoideae)
4. Monochoria vaginalis (Burm.F.) Presl. (Pontederiaceae)

Morphological characters of four different isolates of R. solani and their pathogenicity reactions

A comparitive study of the morphological characters, ability to anastomose each other, and pathogenicity of four isolates of R. solani was carried out using standard laboratory techniques. The isolates used were:

1. Isolate from rice (A)
2. Isolate from sesamum (B)

3. Isolate from daincha (C)

4. Isolate from groundnut (D)

The morphological characters of the isolates were studied by growing them on PDA in nine cm petri dishes and incubated under laboratory conditions. After fifteen days, number of sclerotia formed, size of sclerotia and hyphal measurements were recorded.

Pathogenicity

The pathogenicity of all the isolates were proved on their respective hosts. Cross inoculation trials were conducted to study the pathogenicity of all the four isolates mentioned above. Plants were raised in earthen pots (22.5 cm diameter) and were artificially inoculated on aerial parts as well as at the collar region. The aerial inoculations were done by placing sclerotia or by sprays of mycelial suspension and covering with a polythene bag for 48 hours to maintain high humidity. Soil inoculation was done by placing culture bits containing sclerotia at the collar region of the plant and covering up with soil.

Anastomosis

The ability of the four isolates to anastomose each other was tested by the method described by Parmeter et al. (1969). Sterilised discs of cellophane were placed over solidified two per cent water agar in nine cm petri dishes. In each dish mycelial discs from actively growing culture

of the four isolates of the fungus on PDA were placed three cm apart over the cellophane. The dishes were then incubated at laboratory temperature (28±3°C) until the advancing hyphae came in contact and slightly overlapped. A two sq.cm portion of the area of contact of the growth was removed, stained with a dilute solution of cotton blue lactophenol, mounted on a glass slide and examined under the microscope for anastomosis of the isolates.

Screening of rice varieties against sheath blight and rice root nematode under field conditions

A field trial was conducted to screen ten rice varieties against sheath blight and rice root nematode at the State Seed Farm, Adoor. The details of the experiment are as follows.

Lay out:	Randomised block design
Variety:	Ten rice varieties: Triveni, Annapurna Rohini, Sabari, Bharati, IR-8, CO-25, Jaya, PTB-12, Jyothi.
Spacing:	15 cm x 10 cm
Gross plot size:	10 m x 4 m
Replication:	Three
Number of treatments:	Ten

Nursery:

Half a kg of seeds of each of the above mentioned rice varieties was sown on short strips of well ploughed

field. A prophylactic spraying with Ekalux (0.05 per cent) was given to prevent insect attack.

Main field:

The soil population in the plots was assessed before planting and was found to be uniform with 100 nematodes per 100 ml of soil. This was achieved by adding nematode infested rice roots to the plots. The soil population of the nematode was assayed following the modified method of Cobb's decanting and sieving technique (Christie and Perry, 1951).

In the main field after land preparation, three plots of the size 10 m x 4 m were taken and a basal dressing was made giving 45:45:45 NPK/ha in the form of urea, super-phosphate and muriate of potash. The seedlings of the rice varieties were planted, in five rows in each plot, each row consisting of 24 hills. In between each variety, two rows of the highly sheath blight susceptible rice variety, Jyothi was planted to ensure uniform disease incidence and spread. Twenty days after transplanting, the plants were top dressed with 45 kg of N/ha in the form of urea. The crop was sprayed with Sevin 50 W.P. (0.25 per cent) on the 20th day and with Metacid 50 E.C. (0.05 per cent) on the 45th day of planting against pest attack. At the earhead stage another spraying was also given with BHC 50 W.P. (0.25 per cent) against the earhead bug.

Observations

(a) Per cent hill infection

The observation was recorded 15 days before the harvest of each variety. The per cent of hills infected in each variety in each replication was recorded by examining all hills in each of the five rows leaving two hills on either ends as border rows.

(b) Disease intensity

The disease intensity was recorded 15 days before harvest of each variety. All hills in each of the five row replicates from each plot were scored and recorded the sheath blight intensity as per the "Standard Evaluation system for Rice Diseases" (Anon., 1976).

Grade	Description
1.	Lesions limited to lower ¼ of leaf sheaths.
3.	Lesions present on lower ½ of leaf sheaths.
5.	Lesions present on more than ½ of leaf sheaths.
7.	Lesions present on more than ¾ of leaf sheaths. Severe infection on lower leaves and slight infection on upper leaves (Flag and second leaf).
9.	Lesions reaching top of tillers; severe infection on all leaves.

(c) Population of rice-root nematode in roots

For each variety, one hill each of healthy and diseased plants were uprooted carefully from each replication

at the flowering stage of the crop. The nematodes were then extracted using the technique described earlier and were counted using stereoscopic binocular microscope (50X magnification).

Effect of rice-root nematode infestation on the intensity of sheath blight of rice

A pot culture experiment was conducted at the College of Agriculture, Vellayani to study the effect of rice root nematode on the intensity of sheath blight. Medium sized (22.5 cm diameter) earthen pots were filled with 5 l. of steam sterilised paddy field soil and used for the experiment. The details of the experiment were as follows:-

Lay out	- Completely randomised design
Variety	- Jyothi
Replication	- Five
Number of treatments	- 12

Treatments

1. F_1 - Soil inoculation with the fungus.
2. F_2 - Inoculation of plants with the fungus in between sheaths.
3. N_1 - Soil inoculation with ten nematodes per pot.
4. N_2 - Soil inoculation with 100 nematodes per pot.
5. N_3 - Soil inoculation with 1000 nematodes per pot.
6. N_1F_1 - Soil inoculation with ten nematodes per pot and the fungus.

7. N_1F_2 - Soil inoculation with ten nematodes per pot and inoculation of plants with fungus in between the sheath.

8. N_2F_1 - Soil inoculation with 100 nematodes per pot and the fungus.

9. N_2F_2 - Soil inoculation with 100 nematodes per pot and inoculation of plants with the fungus in between the sheath.

10. N_3F_1 - Soil inoculation with 1000 nematodes per pot and the fungus.

11. N_3F_2 - Soil inoculation with 1000 nematodes per pot and inoculation of plants with the fungus in between the sheath.

12. N_0F_0 - Control.

Method of inoculation of fungus and nematode

The soil inoculation of the fungus was done by mixing the pathogen cultured in sand maize medium with the soil near the collar region of the plants at the rate of five g/ plant. Sheath inoculation of the fungus was made by placing two or three mature sclerotia of the fungus from a 12 day old culture, in between the sheath of the rice plant and covering with a bit of moist cotton.

In the case of the nematode inoculum the soil containing the nematode culture was placed on a polythene sheet and mixed well to ensure uniform distribution. From

this bulk four samples of 200 g each were taken at random and the nematode population estimated. The nematodes were extracted from the soil following the modified method of Cobb's decanting and sieving technique (Christie and Perry, 1951) and counted.

A measured quantity of soil required to give the desired number of nematodes (10, 100 & 1000) was then incorporated into upper layers of sterilised soil to about 15 cm depth in the pots. The rice seedlings were then planted in the pots at the rate of two seedlings per pot.

Observations

(a) Disease intensity

The observation was made by scoring the plants according to the method described earlier. This was done at the boot leaf stage of the crop and fifteen days before the harvest of the crop.

(b) Soil and root population of the nematode

The soil and root population of the rice root nematode was estimated from each treatment as per the methods mentioned earlier.

(c) Plant characters

Observations on plant height, tiller count, panicle length, panicle weight and root weight were also recorded.

Fungistatic effect of nematicides on R. solani

The sensitivity of R. solani to four nematicides

was studied by adopting a modified method of poisoned food technique described by Lilly and Barnett (1951). The nematicides tested were the following.

1. Carbofuran (2,3 dihydro-2, 2-dimethyl 7-benzofuranyl methyl carbamate (Furadan)
2. Fensulfothion (O,Diethyl O-(P-(methyl sulfinyl) phenyl phosphorothioate) (Dasanit)
3. Aldicarb (3 methyl-2 methyl thio) propionaldehyde O-(methyl carbamoyl)-oxime) (Temik)
4. SMDC (sodium methyl dithiocarbamate) (Vapam).

The required concentrations of these nematicides 30, 60 and 120 ppm ai. each of carbofuran, fensulfothion and aldicarb and 1000, 2500 and 5000 ppm of SMDC were prepared by adding the appropriate quantities of the chemicals to the autoclaved (1.2 kg/cm^2 for 30 minutes) PDA cooled to 45°C. They were mixed thoroughly by gently shaking the flasks. Poisoned medium was poured aseptically into sterile petri dishes and a five mm mycelial disc of R. solani from a four day old culture was inoculated in the centre of each dish. In the case of control, non poisoned PDA was used and inoculated with the mycelial disc. For each treatment five replications were maintained. The mean diameter of the radial growth of the fungus was noted after three days. The number of sclerotia produced in each treatment was recorded after 15 days.

Field assay of fungicides, micronutrients, N:K ratio, and nematicidal treatment on the incidence and intensity of sheath blight of rice and the rice-root nematode.

A field experiment was laid out during the second crop season (September-October to December-January) at the State Seed Farm, Adoor, Quilon District to study the effects of selected fungicides, mineral nutrients and nematicide on the sheath blight disease of rice and the rice-root nematode. The details of the experiment were as follows.

Lay out:	Randomised block design
Variety:	Jyothi (a variety highly susceptible to sheath blight)
Spacing:	15 cm x 10 cm
Gross plot size:	1.8 x 2.4 m^2
Net plot size:	1.5 x 2.2 m^2
Replications:	Three
Number of treatment combinations:	8 x 2 = 16

Treatments

(i) Fungicides and mineral nutrients

1. T_1 - Zinc - Soil application of zinc sulphate @ 10 kg/ha.
2. T_2 - Manganese - Soil application of manganese sulphate @ 10 kg/ha.
3. T_3 - Fycop (Copper oxychloride 40 per cent W.P.)- 0.4 per cent.

4. T_4 - Hinosan - (O-ethyl S, S-diphenyl-dithio-phosphate)(E.C. 50 per cent) - 0.1 per cent.

5. T_5 - Brassicol - (Pentachloro nitrobenzene 75 per cent W.P.) - @ 30 kg/ha.

6. T_6 - Vitavax - (5,6, dihydro-2-methyl-4, 4, oxathiin 3-carboxanilide) 75 per cent W.P. 0.1 per cent.

7. T_7 - Nitrogen:potash at the ratio of 2:1.5

8. T_{10} - Control - Water spray

(ii) Nematicide

1. N_1 - a. Furadan flowable formulation with 40% carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methyl carbamate) - Seedling dip with solution of this formulation in water at 0.25 per cent ai.

b. Soil application - Furadan granules applied one month after transplanting @ 50 kg Furadan 3 G. per hectare.

2. N_0 - Control

Different treatment combinations

T_0N_0	T_2N_0	T_4N_0	T_6N_0
T_0N_1	T_2N_1	T_4N_1	T_6N_1
T_1N_0	T_3N_0	T_5N_0	T_7N_0
T_1N_1	T_3N_1	T_5N_1	T_7N_1

Nursery

The seedlings required for the experiment were raised in a wet nursery in an area of 100 sq.m. One month prior to seeding, the nursery area was treated with Nemagon (Dibromochloropropane) @ 3 ml/sq.m. to make it nematode free. Prophylactic spraying on seedlings on the 12th day with Ekalux (0.05 per cent) were given to prevent insect attack. Twenty one day old seedlings were used in all the experiments.

Main field

The crop was raised following the methods described in the Package of Practices Recommendations (Anon., 1978a). The main field was prepared well and laid out into different plots.

The soil population of rice root nematode in the plots was assessed before planting and was found to be uniform in all the plots with 100 nematodes per 100 ml of soil. This was achieved by adding nematode infested rice-roots to the plots. The soil population of the nematode was assayed following the method mentioned earlier.

Farm yard manure and lime were applied to the plots at the rate of five t/ha of cattle manure and 600 kg of lime per ha. Each plot was given a basal dressing of 60:45:30 NPK/ha except those plots which received the NK ratio of 2:1.5 as a treatment and those were given a basal dressing of 60:45:45 NPK per ha. in the form of urea, superphosphate

and muriate of potash respectively.

The mineral nutrients, zinc and manganese were applied to soil as zinc sulphate and manganese sulphate @ 10 kg/ha in the plots receiving the respective treatments one day before transplanting. The seedlings to be planted in plots receiving nematicidal treatment were dipped in a 0.2 per cent ai. solution of Furadan flowable formulation for twelve hours and planted. Thirty days after transplanting the soil application of Furadan 3 G. was made @ 50 kg/ha in those plots receiving the nematicidal treatment. Twenty five days after transplanting all plots excepting those with N-K ratio as a treatment were top dressed with 30 kg of nitrogen and 15 kg of potash per hectare. Those plots receiving NK ratio as a treatment were top dressed with 30 kg nitrogen and 22.5 kg of potash per hectare. The crop was sprayed with sevin 50 W.P.(0.25 per cent) on the 20th day and with Metacid 50 E.C. (0.05 per cent) on the 45th day of planting against pest attack. At the earhead stage of the crop, a spraying with BHC 50 W.P. (0.25 per cent) was given to ward off the rice bug.

Fungicidal application

Brassicol 75 per cent W.P. (30 kg/ha) was applied to soil in the plots receiving that treatment one week before transplanting. The rest of the three fungicides, (Fycop, Hinosan and Vitavax) were sprayed thrice. The first

spray was given during the active tillering phase, the second fifteen days after the first and the last, twenty days after the second spray so as to synchronise with the highly susceptible stages of growth phase (Kozaka, 1961; Mahendra Prabhath, 1971).

Observations

Different observations regarding sheath blight disease rice-root nematode infestation and plant characters were recorded as follows.

a. Sheath blight

(i) Per cent hill infection

The observation was recorded 15 days before harvest. The per cent hill infection was recorded by observing the incidence of sheath blight in alternate three rows of rice plants per plot leaving a single border row all around.

(ii) Disease intensity

As in the above case alternate three rows of rice plants were scored and recorded the sheath blight intensity as described earlier. The observation was made thrice, at the flowering stage, earhead stage and 15 days before the harvest of the crop.

(iii) Determination of R. solani propagules in soil

Soil samples were drawn from four different areas from each plot, collecting soil from the surface layers 15 days before harvest of the crop. These were pooled

together, mixed well and a sample of 100 g soil was drawn in each case. R. solani propagules in soil was determined quantitatively using a method described by Ko and Hora (1971).

A fixed quantity (30 g) of soil was moistened with sterile distilled water, compacted with a spatula, and evenly distributed in ten clumps on a plate of selective medium. Fifteen such plates were used for each designated amount of soil. The perimeters of soil clumps were examined microscopically with X10 objective, 24-48 hours after incubation at 30°C.

b. Rice root nematode

(i) Population of rice root nematode in soil

Soil samples were collected from four different parts from each plot after removing the surface soil and were thoroughly mixed together. From this pooled lot, a sample of 100 ml was drawn and used for the extraction of nematodes. Nematodes were extracted from soil samples following the modified Cobb's decanting and sieving technique (Christie and Perry, 1951) and the nematodes were counted.

(ii) Nematode population in root

One plant each was uprooted carefully without damaging the roots from each replication. These plant roots were then incubated as described earlier, and the nematode population assessed.

c. Plant characters

(i) Tillering

A sample of four hills selected (two x two hill square) at random from each plot was used for the study. The number of tillers of all the four hills were counted. These hills were marked and the effective tiller count was made prior to the harvest of the crop.

(ii) Plant height

The observation on plant height was made on one of the hills in the two x two hill unit mentioned above, in each plot. The distance from ground level to the tip of the panicle of mature rice plants was noted (Gomez, 1972).

(iii) Panicle length and number of grains per panicle

All panicles from a single hill were collected from each plot and the length was measured and recorded. The grains were separated and counted to get the number of grains per panicle.

(iv) Grain weight

From the grains harvested in bulk from each plot, 1000 grains were collected and the weight was recorded.

(v) Grain yield

The plot wise harvest of the crop was made on the 115th day and dried. The grain weight was then recorded.

Studies on microorganisms antagonistic to R. solani

Isolation of microorganisms were made from paddy

field soil and irrigation water by dilution plate method (Warcup, 1950) using Martin's Rose-Bengal Streptomycin agar medium for fungi and soil extract agar medium for bacteria. In addition to the above, bacteria of different colony types were isolated from field water and sclerotia of R. solani also.

The fungi were tested for their antagonism towards R. solani by the method adopted by Mathur and Sarbhoy (1978). A single sclerotium of R. solani was kept in the centre of each sterile petri dish containing 15 ml of sterilised PDA. Five mm mycelial discs out from fifteen day old culture of test organisms were placed at four different places in the petri dish. Five replications were maintained in each case. Petri plates inoculated with R. solani alone served as control. Linear growth of R. solani was recorded five days after incubation at 30°C. Percentage of inhibition was calculated by the formula

$$I = 100\ (C-T)/C$$

where I = inhibition

C = growth in control and

T = growth in treatment

Bacterial isolates obtained from several sources like field soil, irrigation water and sclerotia of R. solani were purified and maintained on nutrient agar medium.

Their reaction to gram staining, spore staining and colony characters were studied. They were tested to determine their antagonism to R. solani using a method described by Anon (1978b), which involves the culturing of the bacteria and R. solani in a single petri dish and observing the influence of the bacteria on the fungus.

To test the effect of specific bacterial isolates on survival of R. solani sclerotia, sclerotia from fifteen day old culture were ikept in bacterial suspensions in peptone-sucrose broth. Uninoculated broth tubes served as control. The sclerotia were removed from the bacterial suspensions after 5, 10, 20 and 25 days and tested for survival (Anon., 1978b).

RESULTS

RESULTS

Isolation of the fungus from rice and other host plants

The fungus Rhizoctonia solani was isolated from sheaths of naturally infected rice plants (Isolate A) collected from the State Seed Farm, Adoor. It was also isolated from the following three host plants observed during the survey.

1. Sesamum indicum L. (B)
2. Arachis hypogaea L.(D)
3. Sesbania aculeata L.(C)

The infected regions were cut into small bits, surfac sterilised in 0.1 per cent mercuric chloride solution for one minute and washed thoroughly three times in sterile distilled water. These bits were then transferred to PDA plates. The isolates were purified by repeated hyphal tip method and maintained on PDA slants. Pathogenicity of the isolates was established by artificial inoculation on their respective host plants.

Survey of collateral hosts of R. solani in and around rice fields

A number of common crops raised in rice fallows and common wetland weeds were frequently surveyed for attack by R. solani. The following plants were found to be

collateral hosts of R. solani.

1. Sesamum indicum L.
2. Arachis hypogaea L.
3. Sesbania aculeata Pers.
4. Wild colocasia
5. Cyperus iria L.
6. Fimbristylis miliaceae Vahl.
7. Apluda aristata L.
8. Monochoria vaginalis Burm F. Presl.

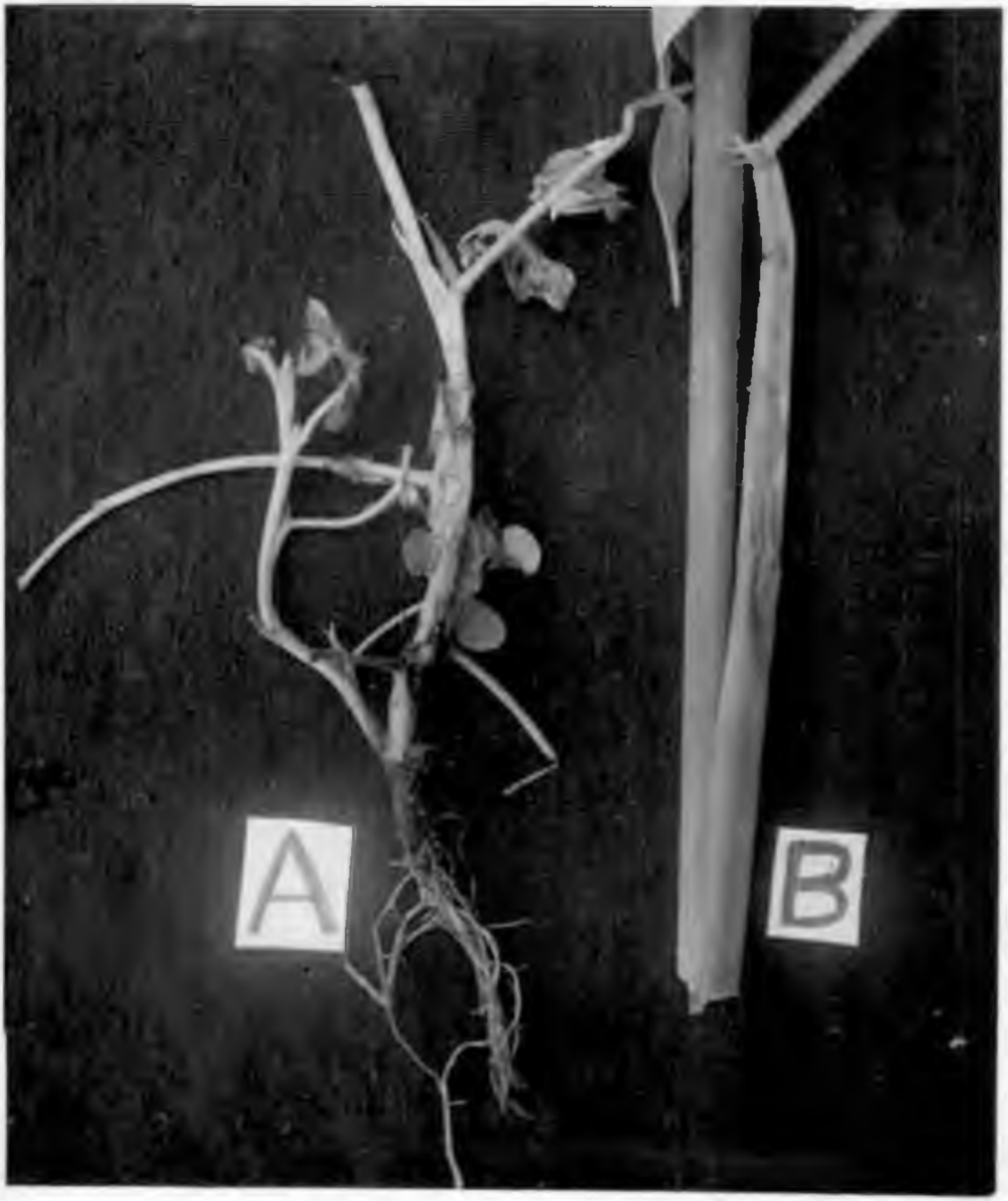
Symptoms

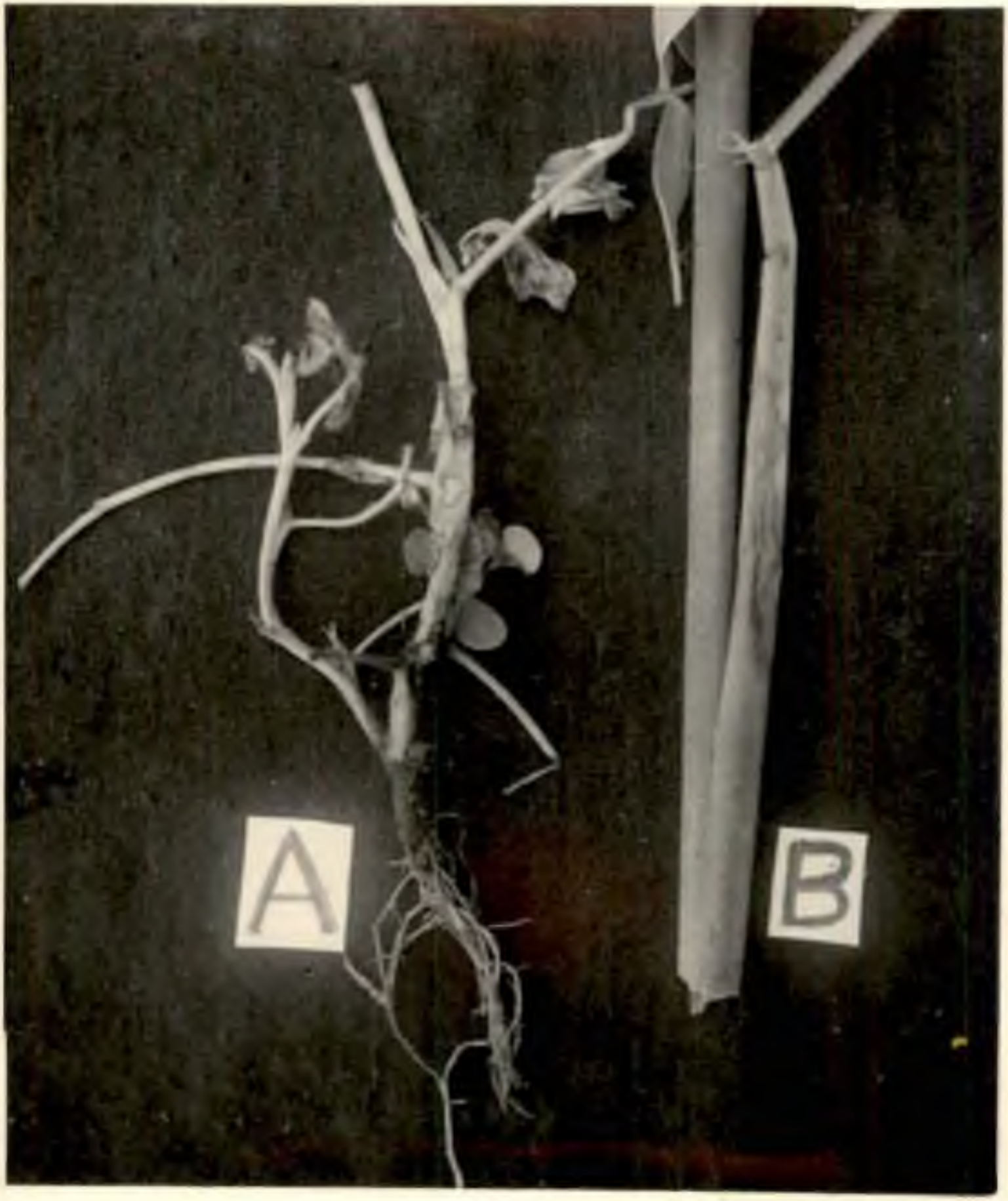
On sesamum, R. solani was found to produce severe collar rot symptoms in nature. Severely infected plants were found to wilt and die. The fungus produced leaf and stem blight in groundnut (Plate 1a & 1b). The severely infected leaves were shed prematurely. On Sesbania aculeata, the fungus produced severe collar rot symptoms at all stages of growth of the plants (Plate 2).

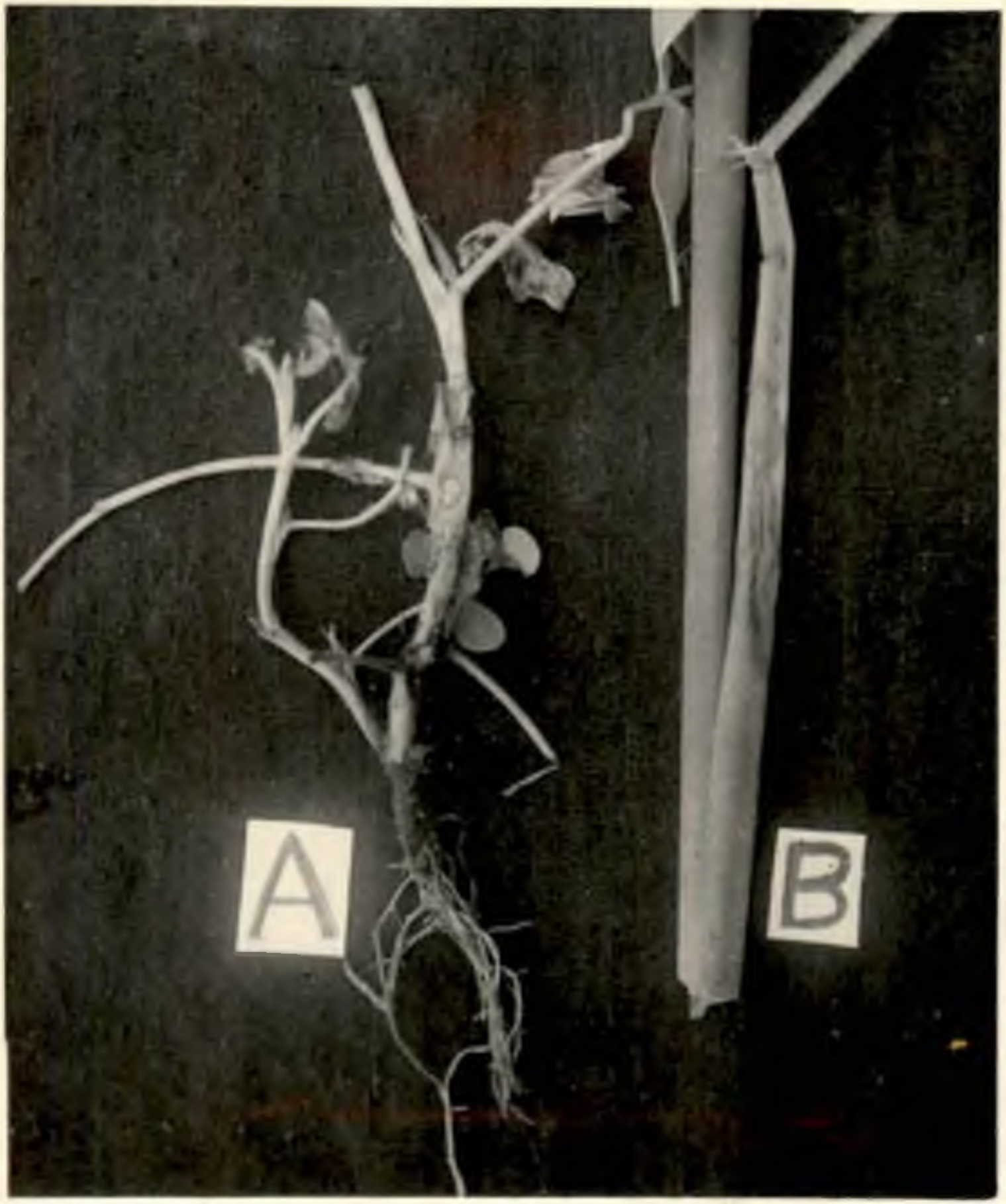
Wild colocasia plants growing in and around rice fields were found to develop typical sheath blight symptoms on the petiole on infection by R. solani (Plate 3). On Cyperus iria and Fimbristylis miliaceae, R. solani caused leaf blight symptoms. The fungus produced dark coloured lesions on the leaf sheath and leaves of Apluda aristata (Plate 4). Infection by R. solani produced typical sheath blight symptoms on the petioles of Monochoria vaginalis.

Plate 1a. Symptoms produced by R. solani on groundnut leaf (A) and rice sheath (B).

Plate 1b. Symptoms produced by R. solani on groundnut stem (A) and rice sheath (B).


A
B


A
B


A
B

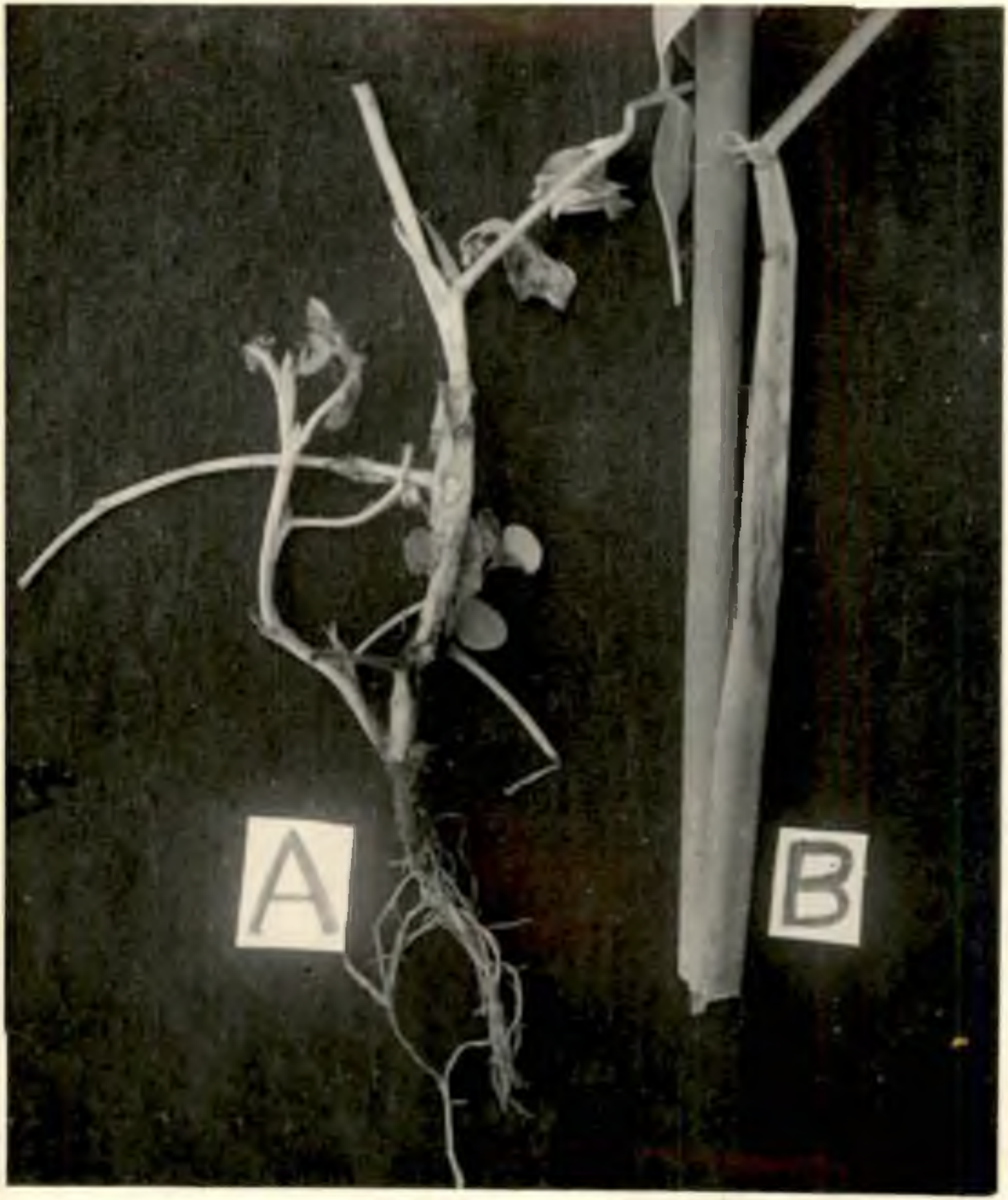

A
B

Plate 2. Collar rot symptoms produced by R. solani on daincha.

Plate 3. Lesions produced by R. solani on rice sheath (A) and colocasia petiole (B).

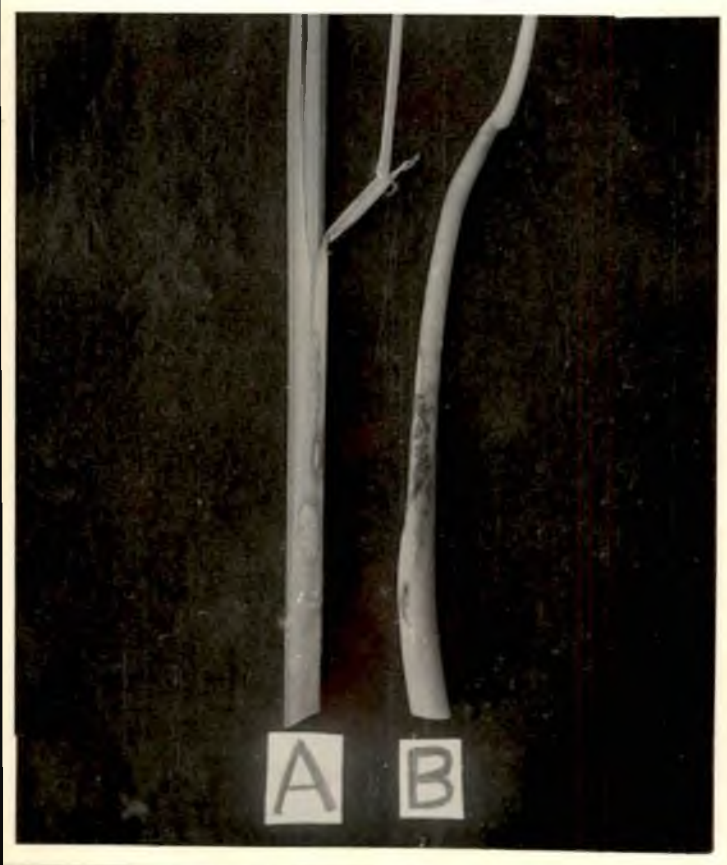

A
B

Plate 4. Symptoms on *Apluda aristata* (B) produced by *R. solani* in comparison with sheath blight in rice (A).


A
B

Weed hosts of rice root nematode

The following weeds found in and around rice fields were found to harbour the rice root nematode in their root systems.

1. Cyperus iria
2. Fimbristylis miliaceae
3. Echinochloa crusgalli
4. Monochoria vaginalis

Morphological characters of four isolates of R. solani

The morphological characters of the four isolates of R. solani are presented in Table 1, Plate 5. Hyphae of isolate B (sesamum) were slightly thinner than those of other isolates. The sclerotia of isolate B were smaller when compared with those of the other isolates.

Pathogenicity of four isolates of R. solani

The pathogenic reaction of the isolates was studied by cross inoculation trials. Host plants were artificially inoculated on the aerial parts and at the collar region with each isolate. The observations are given below.

I. Aerial inoculation

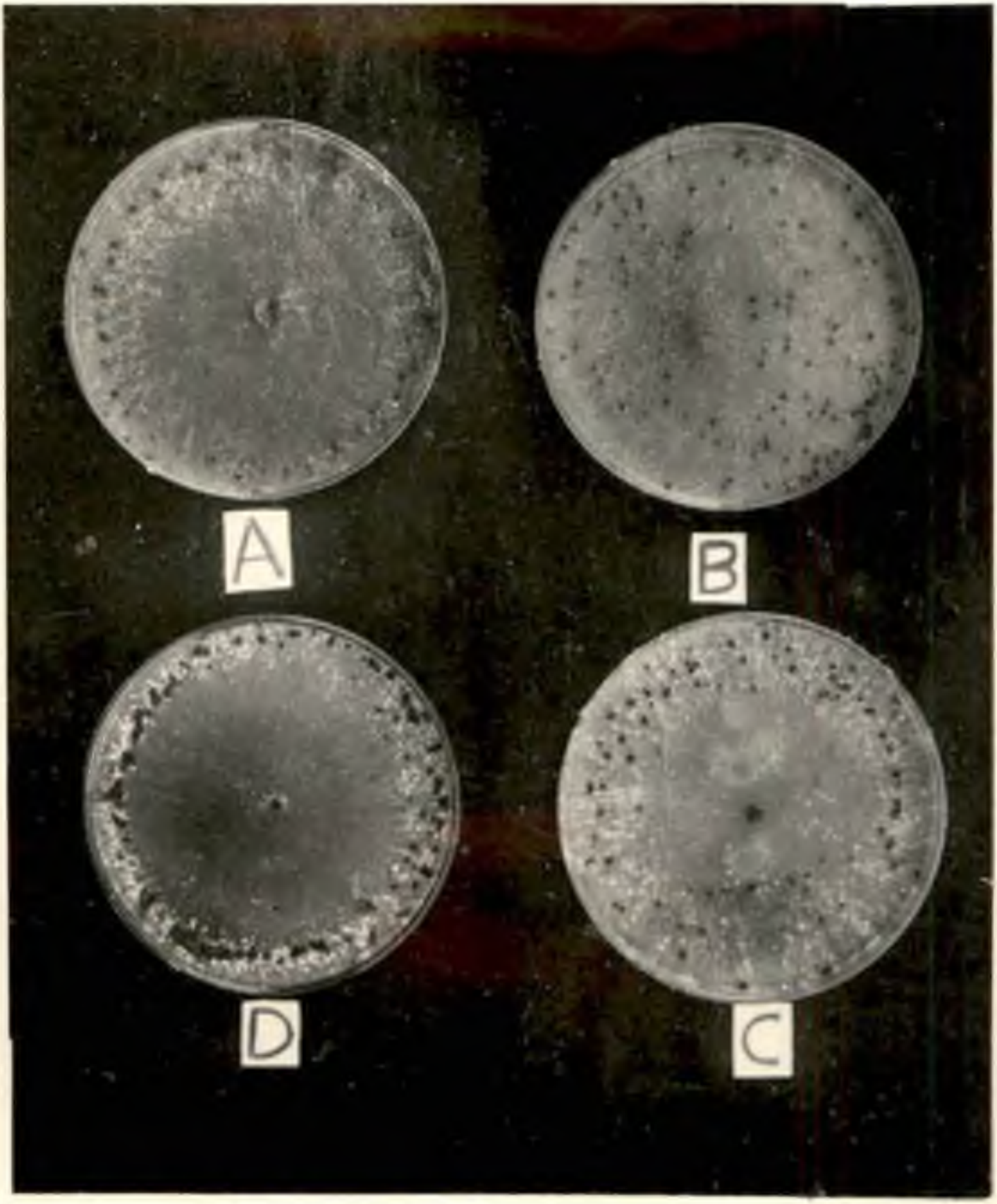
i) Oryza sativa (Plate 6)

Isolate A: Within seven days of inoculation, typical sheath blight lesions with greyish white centre and pale brown margin were produced.

Table 1. Comparative morphological characters of four isolates of *R. solani*.

Characters	Isolate A - Rice		Isolate B - Sesamum		Isolate C - Daincha		Isolate D - Ground nut	
	Range (in µm)	Average (in µm)	Range (in µm)	Average (in µm)	Range (in µm)	Average (in µm)	Range (in µm)	Average (in µm)
Hyphal thickness	5.37 - 8.95	7.23	3.58 - 7.16	5.37	6.265 - 10.74	8.34	5.37 - 7.16	6.98
Sclerotia Length	153 - 272	208.42	115.6 - 146.2	135.32	108.8 - 265.2	177.8	136 - 224.64	182.24
Breadth	148.2 - 221	178.16	102 - 136	124.44	102 - 197.2	148.07	108.8 - 190.4	144.16
Number of sclerotia per plate (90 mm diameter)	109		121		154		131	

Plate 5. Growth of four R. solani isolates on PDA - fifteen days after inoculation.


A
B
D
C

Isolate B: No symptoms were produced.

Isolate C: Typical sheath blight symptoms produced within seven days of inoculation.

Isolate D: Typical sheath blight symptoms produced within five days of inoculation.

ii) Sesamum indicum

Isolate A: Mild leaf blight symptoms were developed, but plants recovered completely within 14 days.

Isolate B: Severe leaf and stem blight and collar rot symptoms were developed. Plants wilted and died within ten days of inoculation.

Isolate C: No symptoms were produced

Isolate D: No symptoms were produced

iii) Sesbania aculeata (Plate 7)

Isolate A: Severe leaf blight symptoms leading to shedding of leaves were observed within seven days of inoculation.

Isolate B: No symptoms were produced

Isolate C: Leaf blight symptoms appeared within seven days of inoculation.

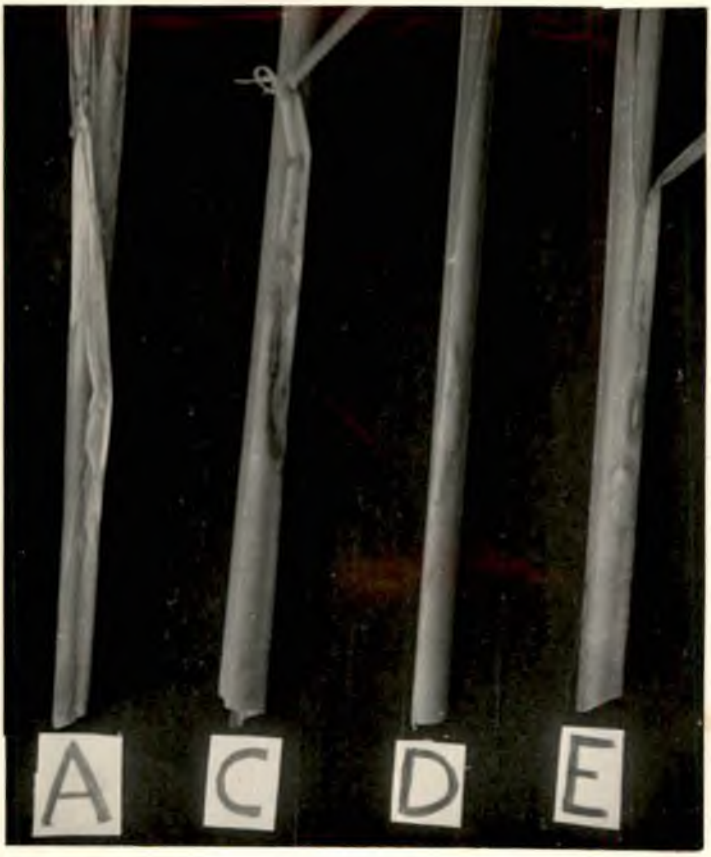
Isolate D: Leaf blight symptoms appeared within seven days of inoculation.

iv) Arachis hypogaea (Plate 8a & 8b)

Isolate A: Severe leaf and stem blight with sheath blight symptoms were produced on them. The leaves were covered with lesions having a grey centre and dark brown margin and were shed prematurely.

Plate 6. Symptoms produced on rice by the R. solani isolates - seven days after aerial inoculation (Isolate A & E - rice, Isolate C - daincha, Isolate D - groundnut).

Plate 7. Collar rot symptoms produced by R. solani isolates on daincha (Isolate A - rice, Isolate C - daincha, Isolate D - groundnut).


A
C
D
E

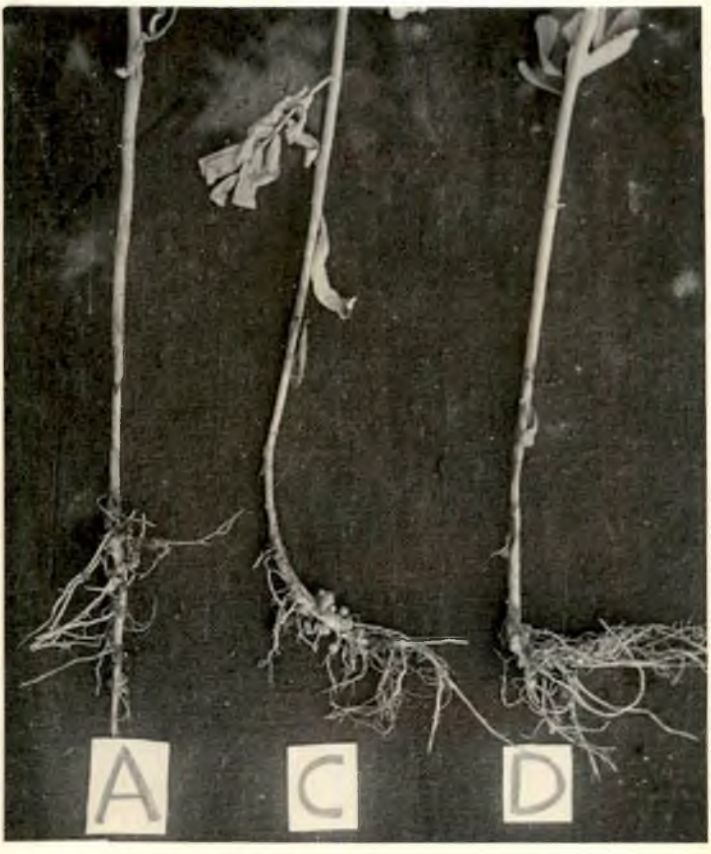

A
C
D

Plate 8a. Leaf blight symptoms produced by R. solani isolates, A, C and D on groundnut - five days after aerial inoculation. (Isolate A - rice, Isolate C - daincha, Isolate D - groundnut).

Plate 8b. Leaf and stem blight symptoms produced by R. solani isolates, A, C and D on groundnut - five days after aerial inoculation (Isolate A - rice, Isolate C - daincha, Isolate D - groundnut).

Isolate B: No symptoms were produced.

Isolate C: Leaf blight symptoms were produced within five days of inoculation.

Isolate D: Severe leaf and stem blight symptoms were produced five days after inoculation.

II. Soil inoculation

i) Oryza sativa - Isolate A, B & C produced typical sheath blight lesions on the basal portion of the plants within ten days of inoculation.

Isolate B: No symptoms were produced

ii) Sesamum indicum - Except the isolate B no other isolate produced any symptoms. Isolate B caused severe collar rot symptoms and plants wilted within ten days of inoculation.

iii) Sesbania aculeata - All isolates except isolate B, caused severe collar rot symptoms within ten days of inoculation. Isolate B failed to cause any symptoms.

iv) Arachis hypogaea - No symptoms were produced by any of the isolates.

Anastomosis

The ability of the four isolates to anastomose each other was studied and the observations are presented in Table 2, Fig. 1a & 1b. Isolate A was capable to anastomose with isolates C and D. Isolate B failed to anastomose with either A, C or D.

Table 2. Anastomosis between the four isolates of *R. solani*.

Isolates	Observation
A x B	-
A x C	+
A x D	+
B x C	-
B x D	-
C x D	+

\+ Anastomosis occurred

\- No anastomosis

A - Rice B - Sesamum C - Daincha

D - Groundnut

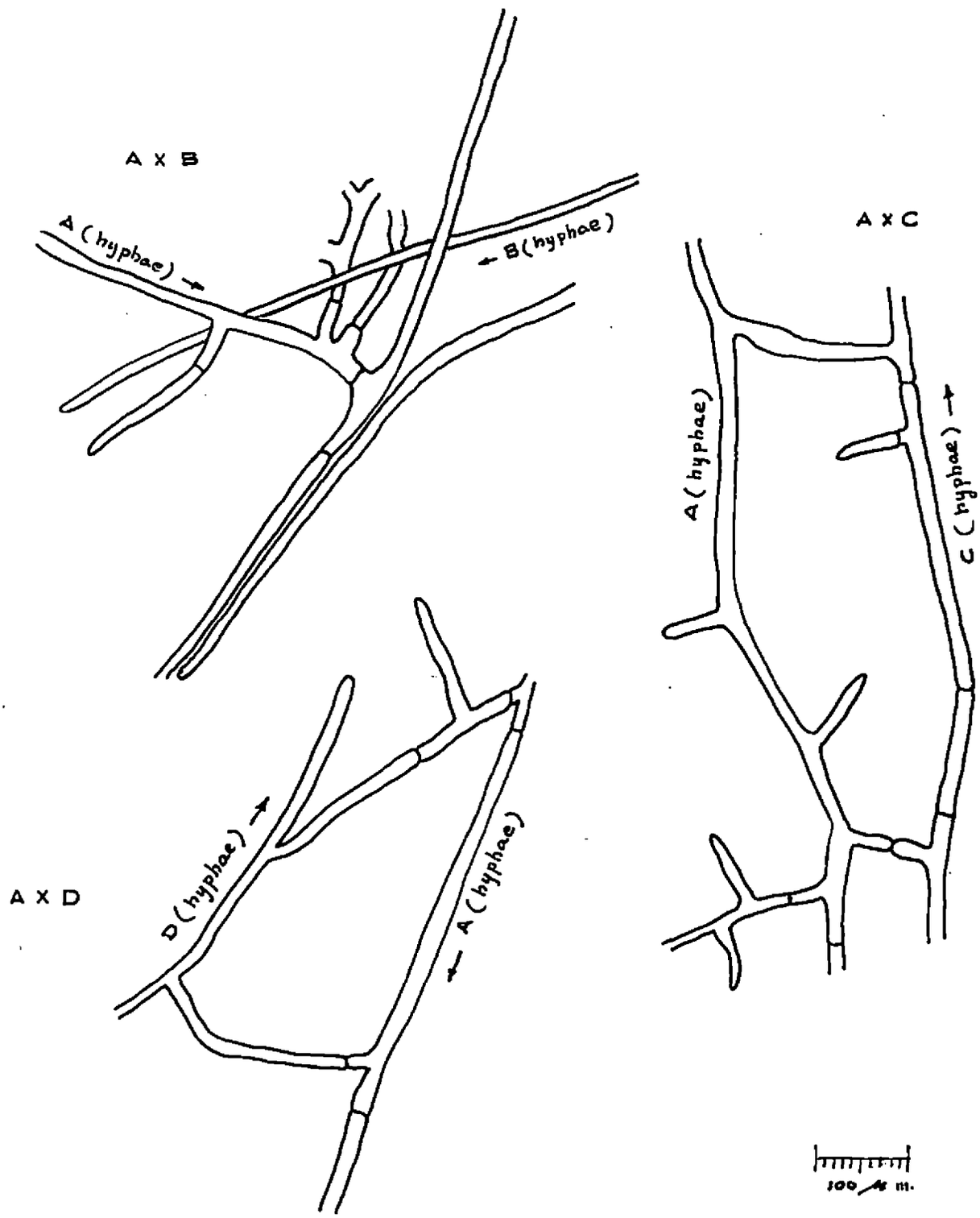


FIG: 1a. ANASTOMOSIS

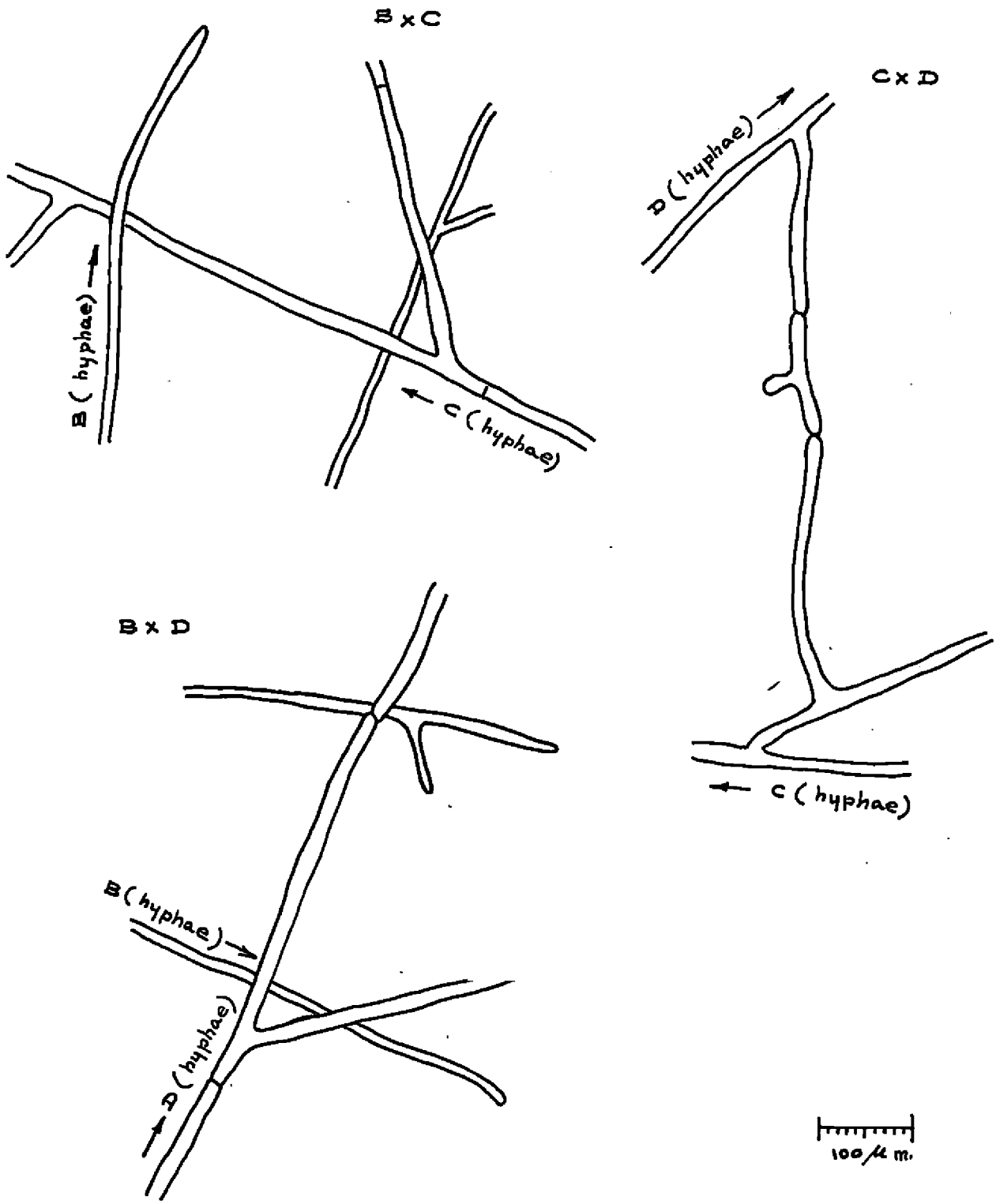


FIG. 1 b. ANASTOMOSIS

Reaction of different rice varieties to sheath blight disease and infestation by rice root nematode

(a) Sheath blight: Observations on the reactions of the ten different rice varieties to sheath blight intensity are recorded in Table 3. The degree of susceptibility to sheath blight varied with the different varieties. Bharati and Rohini showed significantly lower levels of intensity of disease followed by Sabari, CO-25, IR-8, Annapurna and Jaya (Fig.2). Varieties Triveni, Ptb-12 and Jyothi showed maximum disease intensity which ranged from 4.56 to 6.73.

(b) Per cent hill infection: Observations regarding per cent hill infection are presented in Table 4, Fig.3. The per cent hill infection ranged from 57.18 to 78.32 in the different varieties of rice. Bharati and Sabari followed by Rohini recorded significantly lower per cent hill infection by sheath blight than the rest of the varieties. Varieties CO-25 and IR-8 were on par and showed lower per cent hill infection than Triveni, Annapurna and Jaya. Varieties Ptb-12 and Jyothi were observed to have the maximum hill infection.

(c) Rice root nematode infestation: The observations on nematode population in roots of healthy and diseased rice plants of the different varieties are presented in Table 5 (Fig.4).

(i) On diseased plant roots: Nematode population in roots of diseased plants of rice varieties Ptb-12 and Annapurna were found to be significantly lesser than that of the other

Table 3. Reaction of different rice varieties to sheath blight.

Rice variety	Disease index
Bharati	1.34
Rohini	1.77
Sabari	2.04
CO-25	2.77
IR-8	3.27
Annapurna	3.29
Jaya	3.37
Triveni	4.56
PTB-12	5.06
Jyothi	6.73
C.D.	0.536

Table 4. Per cent hill infection by sheath blight in different rice varieties.
(Mean value after angular transformation)

Rice variety	Per cent hill infection
Bharati	57.18
Sabari	58.09
Rohini	59.93
CO-25	69.44
IR-8	70.31
Triveni	72.34
Annapurna	72.56
Jaya	73.66
PTB-12	76.68
Jyothi	78.32
C.D.	1.371

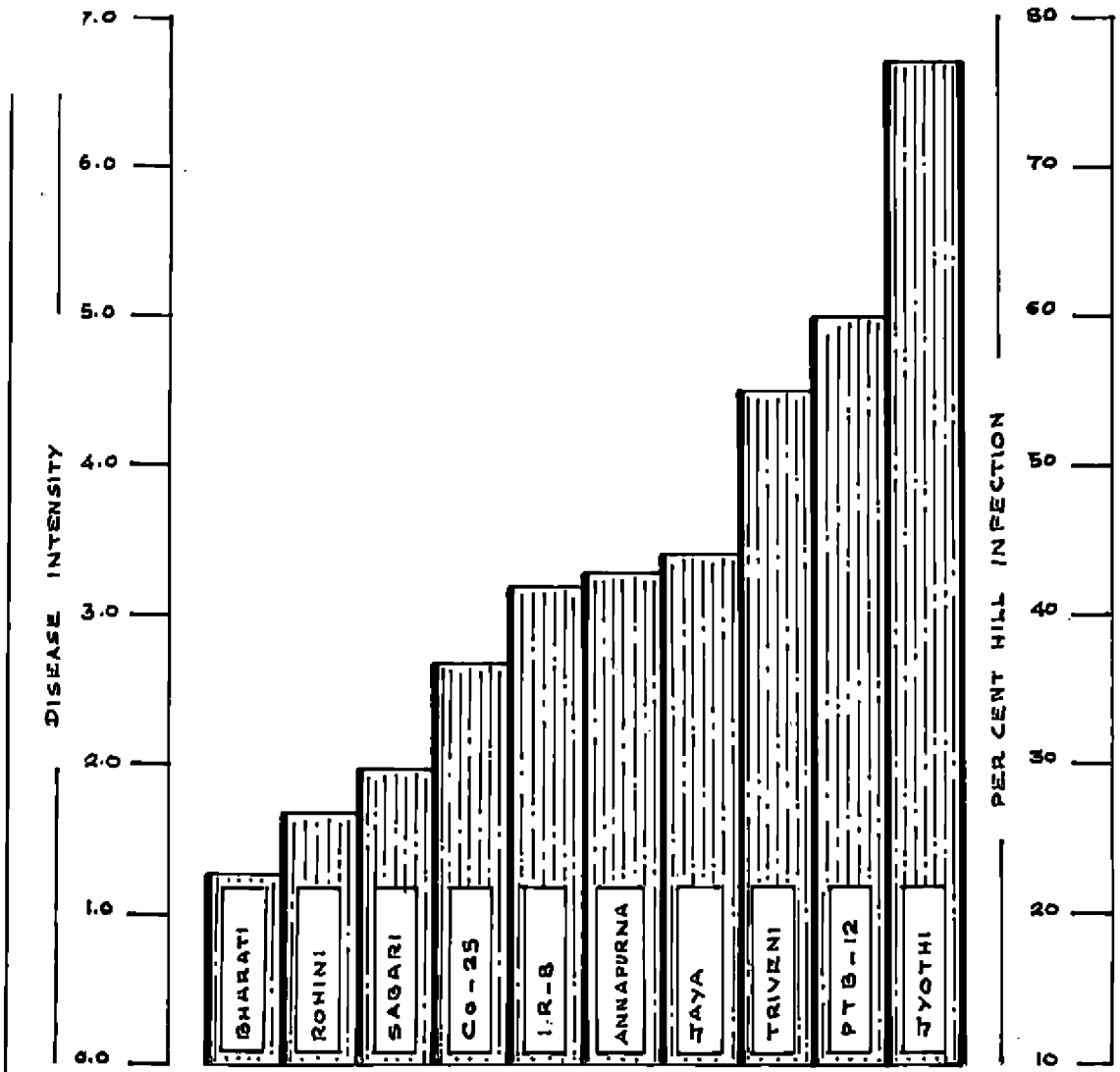


FIG: 2 REACTION OF DIFFERENT RICE VARIETIES TO SHEATH BLIGHT

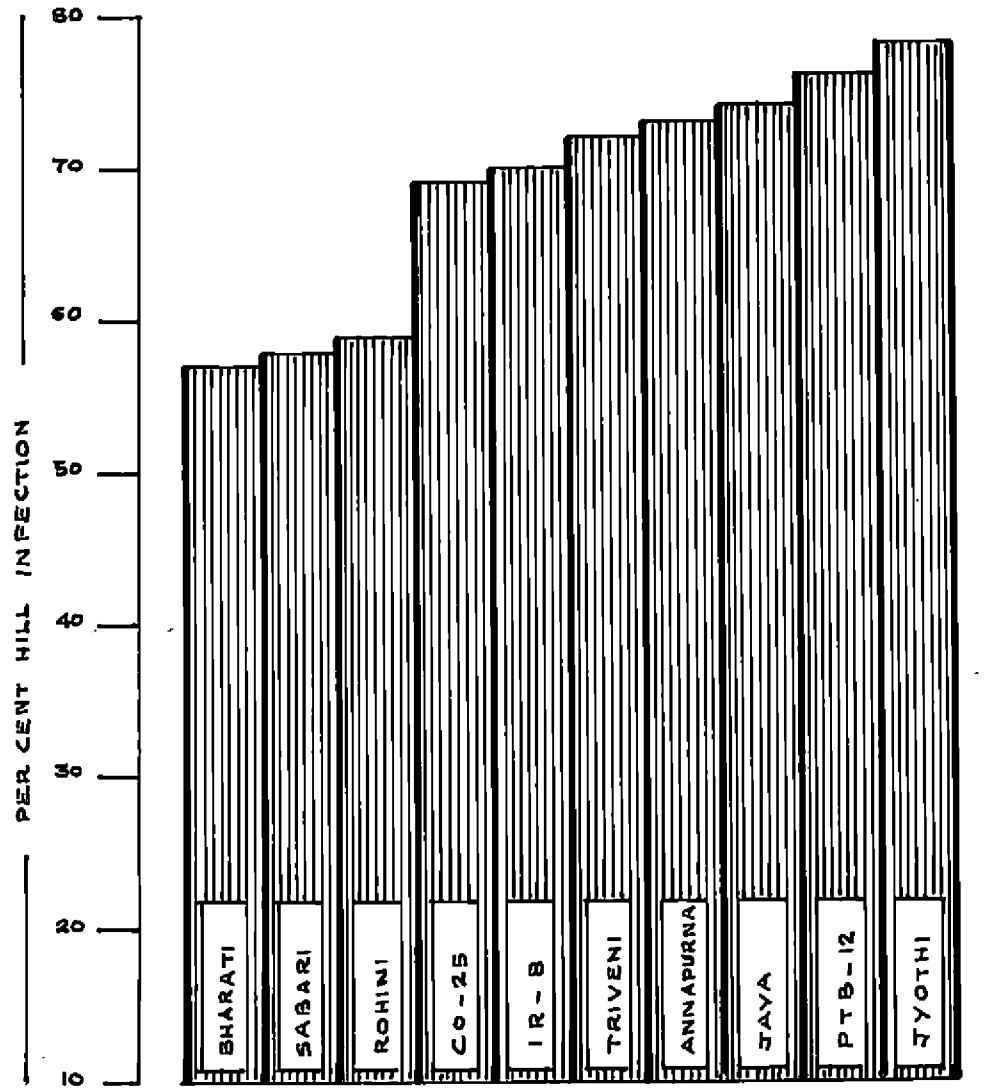


FIG: 3 PER CENT HILL INFECTION BY SHEATH BLIGHT ON DIFFERENT RICE VARIETIES

Table 5. Population of Hirschmanniella oryzae in roots of different rice varieties.

Rice variety	Nematodes in 10 g root sample	
	Healthy	Diseased
PTB-12	3.45	4.195
Annapurna	2.83	4.280
Triveni	4.04	4.320
Jaya	3.50	5.030
Bharati	3.81	5.370
Sabari	3.44	5.550
Rohini	4.98	5.650
CO-25	4.56	5.810
IR-8	4.18	6.080
Jyothi	3.46	6.220
C.D.	0.445	0.853

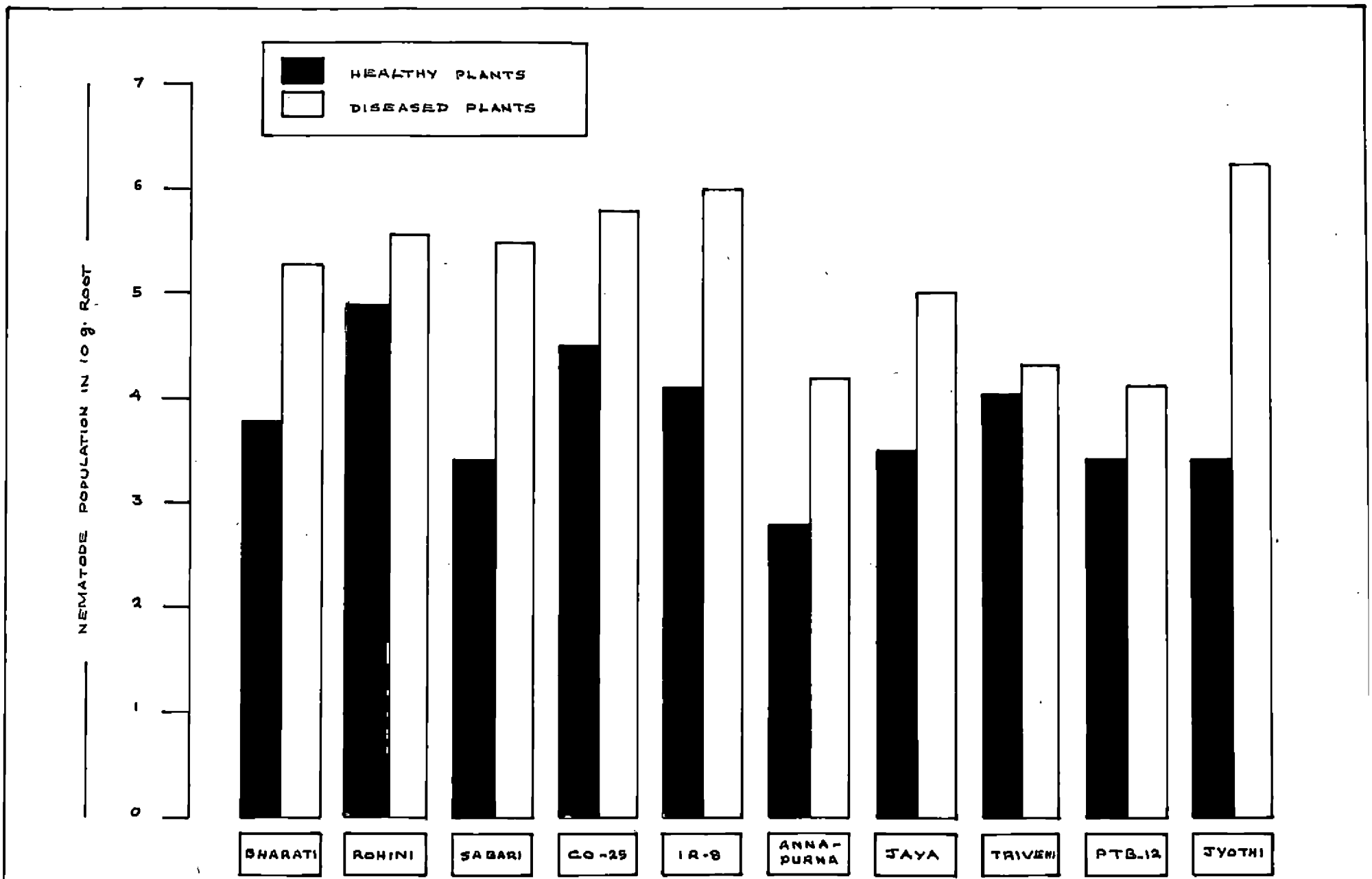


FIG: 4 REACTION OF DIFFERENT RICE VARIETIES TO RICE ROOT NEMATODE INFESTATION

varieties. This was followed by varieties Triveni, Jaya and Bharati which were on par. The maximum nematode population was noted in diseased plant roots of the varieties Sabari, Rohini, CO-25, IR-8 and Jyothi.

(ii) On healthy plant roots: Healthy plant roots of the rice variety Annapurna was found to harbour a significantly lesser population of the rice root nematode when compared with the rest of the varieties. Ptb-12, Jyothi, Jaya and Bharati were on par with lesser nematode population than IR-8 and Triveni. The highest nematode counts were observed in roots of rice varieties Triveni and CO-25.

Effect of rice root nematode on sheath blight incidence

The effects of different inoculation methods on sheath blight incidence using R. solani and the nematode (Hirschmanniella oryzae) on rice plants are presented in Plates 9 to 13.

a. Effect on disease intensity

Observations on disease intensity were made twice, once at boot leaf stage and again fifteen days before harvest and results are presented in Tables 6 and 7.

At the boot leaf stage of the crop, maximum disease intensity was observed in plants receiving the highest nematode inoculum (N_3-1000) along with sheath inoculation of the fungus. The intensity of disease was significantly greater than in other treatments. The sheath inoculation

Plate 9. N_2 - Symptoms on rice plants inoculated artificially with 100 nematodes (H. oryzae) per pot.

N_0F_0 - Uninoculated control

Plate 10. N_3 - Symptoms on rice plants inoculated artificially with 1000 nematodes (H. oryzae) per pot.

N_0F_0 - Uninoculated control


NF
oo
N


NF
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N.

Table 6. Effect of combined inoculation of rice with R. solani and H. oryzae on the intensity of sheath blight. (First observation at boot leaf stage)

Level of nematode inoculum		Fungal inoculation: Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	0.0	0.60	2.60	1.07
N_1	(10)	0.0	0.60	1.80	0.80
N_2	(100)	0.0	0.80	2.40	1.07
N_3	(1000)	0.0	1.40	4.00	1.80
Mean (F)		0.0	0.85	2.70	

C.D. for comparison of N means = 0.442
" " F means = 0.380
" " NF means = 0.770

Table 7. Effect of combined inoculation of rice with R. solani and H. oryzae on intensity of sheath blight. (2nd observation fifteen days before harvest)

Level of nematode inoculum		Fungal inoculation: Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	0.0	1.00	4.20	1.73
N_1	(10)	0.0	1.50	4.00	1.83
N_2	(100)	0.0	2.10	4.00	2.03
N_3	(1000)	0.0	2.80	6.50	3.10
Mean (F)		0.0	1.85	4.675	

C.D. for comparison of N means = 0.612
" " F means = 0.530
" " NF means = 1.061

Plate 11. F_2 - Symptoms on rice plants inoculated artificially with R. solani (Sheath inoculation).

N_0F_0 - Uninoculated control


NF
F

of the fungus was found to cause significantly more disease intensity than soil inoculation. The interaction between the fungus and nematode was also found to be significant in increasing the disease intensity.

Fifteen days before the harvest of the crop, the interaction between the fungus and nematode was found to be significant in increasing disease severity. Maximum disease severity was observed in plants receiving the highest nematode inoculum (1000) along with sheath inoculation of the fungus. Sheath inoculation of the fungus was found to cause significantly more disease than soil inoculation. The inoculation of plants with lower levels of nematode (0, 10, & 100) had no significant effect on disease intensity.

b. Effect on tiller count

Observations on tiller production were recorded two times (15 days and 30 days after planting) and are presented in Tables 8 and 9.

From the first observation it was found that the effects of nematode and fungus and their interaction was significant on tiller production. All the three nematode levels (10, 100 and 1000) were found to decrease tiller production significantly. Inoculation of soil with the fungus R. solani also was observed to decrease tiller production when compared with the control. Of the various treatment combinations the highest nematode inoculum (1000) along with soil or sheath inoculation of the fungus was

Table 8. Effect of combined inoculation of rice with R. solani and H. oryzae on tillering (15 days after planting). (Mean values after square root transformation)

Level of ne nematode inoculum		Fungal inoculation: Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	2.65	2.21	2.50	2.45
N_1	(10)	2.23	2.16	2.29	2.23
N_2	(100)	2.07	2.14	2.21	2.14
N_3	(1000)	1.86	2.12	2.18	2.08
Mean (F)		2.20	2.16	2.32	

C.D. for comparison of N means = 0.089
" " F means = 0.077
" " NF means = 0.154

Table 9. Effect of combined inoculation of rice with R. solani and H. oryzae on tillering (30 days after planting).

Level of nematode inoculum		Fungal inoculation: Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	3.32	2.87	3.28	3.16
N_1	(10)	3.11	3.05	2.96	3.04
N_2	(100)	2.99	2.99	2.89	2.96
N_3	(1000)	2.52	2.44	2.37	2.44
Mean (F)		2.98	2.84	2.88	

C.D. for comparison of N means = 0.244
" " F means = 0.211
" " NF means = 0.423

Plate 12. N_3F_1 - Symptoms on rice plants inoculated artificially with 1000 nematodes (H.oryzae) per pot and R. solani (Soil inoculation).

Plate 13. N_3F_2 - Symptoms on rice plants inoculated artificially with 1000 nematodes (H. oryzae) per pot and R. solani (Sheath inoculation)


NF
NF


NF
NF

found to reduce tillering significantly.

During the second observation, it was found that only the highest nematode level (1000) showed significant effect on tiller production as compared with the control. The effect of N_2 (100) and N_1 (10) levels of nematode on tiller production was on par. As the level of nematode was increased, there was a proportionate reduction in the number of tillers formed. The effect of fungus inoculation on tiller production was not significant.

c. Effect on plant height

The observations on the effect of fungus-nematode inoculation on plant height are presented in Table 10. The plant height was affected significantly by inoculation of the nematode at the highest level (1000). The effect of fungus inoculation was not significant with respect to plant height. The interaction of the treatments was significant but the effect of nematode inoculation alone was highly significant in reducing the plant height.

d. Effect on panicle length

The observations on panicle length are presented in Table 11. The effect of inoculation of plants with the fungus and nematode separately and their interaction was found to be significant on panicle length. The highest nematode level (1000) by itself was found to reduce the panicle length significantly. The nematode levels N_3 (1000)

Table 10. Effect of combined inoculation of rice with R. solani and H. oryzae on plant height.
(Mean values of plant height in cm)

Level of nematode inoculum		Fungal inoculation			
		Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	95.42	88.10	83.40	85.63
N_1	(10)	81.70	85.58	83.16	83.47
N_2	(100)	83.26	82.44	86.64	84.45
N_3	(1000)	76.04	78.40	79.88	78.44
Mean (F)		86.09	83.38	86.27	

C.D. for comparison of N means = 5.156
" " F means = 4.465
" " NF means = 8.931

Table 11. Effect of combined inoculation of rice with R. solani and H. oryzae on panicle length.
(Mean values of panicle length in cm)

Level of nematode inoculum		Fungal inoculation			
		Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	26.12	20.62	20.84	22.53
N_1	(10)	23.64	20.20	21.02	21.62
N_2	(100)	20.38	20.02	21.24	20.55
N_3	(1000)	19.54	19.72	18.90	19.39
Mean (F)		22.42	20.14	20.50	

C.D. for comparison of N means = 0.964
" " F means = 0.835
" " NF means = 1.670

and N_2 (100) exerted significant reduction in panicle length with either type of fungal inoculation.

e. Effect on panicle weight

The observations on panicle weight are presented in Table 12. The fungus and the nematode separately and their interaction had a significant effect on panicle weight. The maximum significant reduction in panicle weight was observed when the plants were inoculated by the fungus combined with a high population of nematode (1000). However the method of inoculation of the fungus had no effect on panicle weight. It was also observed that nematode inoculation by itself had significant effect in reducing the panicle weight.

f. Effect on root weight

The observations on root weight are presented in Table 13. The nematode inoculation was found to have a significant effect on root weight. The effect of interaction between nematode and fungus on root weight was also significant. The high nematode level (1000) significantly reduced root weight. The higher levels of nematode inoculum (100 & 1000) along with sheath inoculation of the fungus, were found to cause significant reduction in root weight.

g. Population of nematode in root and soil

The observation on root and soil population of the nematode are presented in Tables 14 and 15. The soil and root population of the nematode was found to be significantly

Table 12. Effect of combined inoculation of rice with R. solani and H. oryzae on panicle weight.
(Mean values of panicle weight in g)

Level of nematode inoculum		Fungal inoculation: Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	5.24	3.30	3.06	3.87
N_1	(10)	4.56	2.98	2.66	3.33
N_2	(100)	4.06	2.94	2.96	3.32
N_3	(1000)	2.64	1.96	1.58	2.06
Mean (F)		4.13	2.75	2.57	

C.D. for comparison of N means = 0.369
" " F means = 0.319
" " NF means = 0.639

Table 13. Effect of combined inoculation of rice with R. solani and H. oryzae on root weight.
(Mean values of root weight in g)

Level of nematode inoculum		Fungal inoculation: Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	39.74	30.88	42.92	37.51
N_1	(10)	27.32	26.10	29.18	34.20
N_2	(100)	38.94	32.90	21.26	31.03
N_3	(1000)	34.98	31.22	20.58	28.93
Mean (F)		32.44	30.28	28.49	

C.D. for comparison of N means = 7.065
" " F means = 6.119
" " NF means = 12.238

Table 14. Effect of combined inoculation of rice with R. solani and H. oryzae on root population of nematode. (Mean values after square root transformation)

Level of nematode inoculum		Fungal inoculation: Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	0	0	0	0
N_1	(10)	17.34	16.30	17.16	16.93
N_2	(100)	17.28	20.08	25.78	21.05
N_3	(1000)	25.16	27.99	30.68	27.94
Mean (F)		14.95	16.09	18.41	

C.D. for comparison of N means = 0.178
" " F means = 0.155
" " NF means = 0.309

Table 15. Effect of combined inoculation of rice with R. solani and H. oryzae on soil population of nematode. (Mean values after square root transformation)

Level of nematode inoculum		Fungal inoculation: Not inoculated (F_0)	Soil inoculation (F_1)	Sheath inoculation (F_2)	Mean (N)
N_0	(0)	0	0	0	0
N_1	(10)	17.43	18.21	16.85	17.497
N_2	(100)	25.99	21.78	28.65	25.473
N_3	(1000)	76.76	78.50	83.19	79.483
Mean (F)		30.045	29.623	32.173	

C.D. for comparison of N means = 0.1428
" " F means = 0.1236
" " NF means = 0.2473

higher when the nematode inoculation was combined with fungus inoculation. Sheath inoculation of the fungus was found to increase nematode population significantly in the case of the higher nematode levels (100, 1000) when compared with soil inoculation.

Effect of four different nematicides on radial growth and sclerotia formation of R. solani

a. Effect on radial growth

SMDC showed complete inhibition of growth of the fungus followed by aldicarb which was significantly superior to carbofuran and fensulfothion. SMDC, even at the lowest concentration was significantly superior in inhibiting sclerotial germination and growth of the fungus to other nematicides at their highest concentrations. Aldicarb, fensulfothion and carbofuran at 120 ppm was found to be significantly superior to the lower levels of 60 and 30 ppm in reducing the radial growth of the fungus (Table 16, Plate 14).

b. Effect on sclerotia formation

As growth was completely supprossed at all levels of SMDC, no sclerotia were formed. The number of sclerotia formed at 120 ppm of carbofuran, aldicarb and fensulfothion was significantly reduced than the lower levels and control. No significant difference in their effect was observed among carbofuran, fensulfothion and aldicarb on sclerotia

Table 16. Effect of different nematicides on radial growth of R. solani.

Nematicide	Conc. in ppm	Growth in mm	Mean
Carbofuran	30	70.6	
	60	30.0	40.0
	120	19.4	
Fensulfothion	30	74.8	
	60	32.8	41.93
	120	18.2	
Aldicarb	30	70.2	
	60	30.6	37.53
	120	11.8	
EMDC	1000	-	
	2500	-	
	5000	-	
Control	-	90.0	

C.D. for comparison between nematicides = 3.11

" " concentrations = 5.38

Plate 14. Effect of four nematicides on radial growth of *R. solani*.

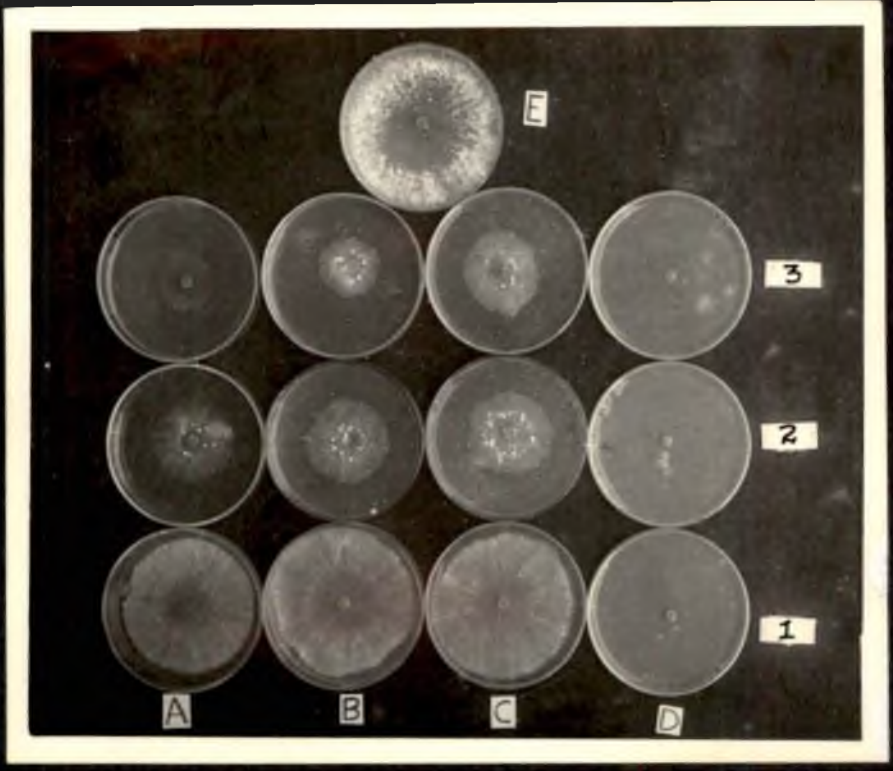


Plate 14.	Concentration in ppm		
	1	2	3
A. Carbofuran	30	60	120
B. Fensulfothion	30	60	120
C. Aldicarb	30	60	120
D. Vapam	1000	2500	5000

formation (Table 17).

Effect of different fungicides, mineral nutrients and nematicides on the incidence of sheath blight and on the population of Rhizoctonia solani and rice root nematode under field conditions.

a. Effect on disease intensity

Intensity of sheath blight incidence was recorded at three stages of plant growth i.e. boot leaf stage, ear head stage and fifteen days before harvest. The observations are presented in Tables 18a, b & c; Fig. 5 and Fig. 6. At the boot leaf stage it was found that all the treatments ($T_1 - T_7$) were effective in reducing the disease intensity. However, there was no significant effect for nematicide application. The effect of interaction between the various treatments and nematicide application also was not significant. Fycop, Hinosan and Vitavax sprays were significantly superior to the rest of the treatments.

The observations made at ear head stage are given in Table 18b. The results showed the same trend as in the previous observation. Vitavax (T_6) was found to be significantly superior over Hinosan (T_4) but to be on par with Fycop (T_3). All the other treatments showed significant effect in reducing the disease intensity as compared with the control. Application of nematicide also showed significant effect in reducing the disease intensity. However the interaction between the treatments was not significant.

Table 17. Effect of different nematicides on sclerotia formation by R. solani.

Nematicide	Conc.in ppm	No. of sclerotia	Mean
Carbofuran	30	5.76	
	60	4.89	4.84
	120	3.83	
Fensulfothion	30	7.66	
	60	6.45	6.35
	120	4.95	
Aldicarb	30	5.95	
	60	4.66	4.59
	120	3.15	
SMDC	1000	-	
	2500	-	-
	5000	-	
Control	-	11.98	-

C.D. for comparison between nematicides = 2.81

" " concentrations = 4.87

Table 18a. Effect of different fungicides, mineral nutrients and nematicides on the intensity of sheath blight. (Boot leaf stage)

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	1.870	2.260	2.067
T_2	Manganese	1.649	1.277	1.463
T_3	Fycop	0.954	0.340	0.670
T_4	Hinosan	0.697	0.540	0.607
T_5	PCNB	1.480	2.230	1.854
T_6	Vitavax	0.596	0.477	0.536
T_7	N:K ratio	1.247	1.930	1.590
T_0	Control	2.910	2.570	2.744
Mean (N)		1.430	1.426	

C.D. for comparison of T means = 0.8010
" " N means = 0.3910
" " TN means = 1.1072

Table 18b. Effect of different fungicides, mineral nutrients and nematicides on the intensity of sheath blight. (Earhead stage).

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	3.296	4.430	3.863
T_2	Manganese	2.900	3.480	3.190
T_3	Fycop	1.283	1.693	1.488
T_4	Hinosan	1.640	2.166	1.903
T_5	PCNB	2.543	3.466	3.004
T_6	Vitavax	0.846	1.786	1.316
T_7	N:K ratio	3.263	4.440	3.851
T_0	Control	4.293	5.286	4.789
Mean (N)		2.511	3.340	

C.D. for comparison of T means = 0.5709
" " N means = 0.2851
" " TN means = 0.8074

The final observation made fifteen days before the harvest of the crop is presented in Table 18c. The results show a similar trend in the effect of Fycop, Hinosan and Vitavax. The effects of Vitavax (T_6) and Fycop (T_3) were significantly superior to all other treatments; however, Hinosan (T_4) was on par with Fycop (T_3). All the treatments showed significant effect in reducing disease intensity over the control. Fungicidal application as spray combined with nematicidal treatments have revealed a profound and significant effect over other treatments and control.

b. Per cent hill infection

The observations on the effect of different treatments on per cent hill infection is presented in Table 19. Fycop (T_3) was significantly superior in reducing the per cent hill infection over all the other treatments (Fig.7). It was followed by Vitavax (T_6) which was also superior to the rest of the treatments. The effect of Hinosan spray (T_4) was on par with the soil application of Brassicol (T_5). All the treatments were significantly effective in reducing hill infection as compared with the control. The nematicidal treatment was found to reduce the per cent hill infection significantly over the control. The interaction between the different treatments and nematicidal application was found to be highly significant. Among the treatment combinations Fycop with nematicide was found to be

Table 18c. Effect of different fungicides, mineral nutrients and of nematicide on sheath blight intensity at the time of harvest.

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	4.633	6.293	5.463
T_2	Manganese	4.353	5.236	4.795
T_3	Fycop	1.746	2.566	2.157
T_4	Hinosan	1.923	3.753	2.840
T_5	PCNB	4.310	5.583	4.950
T_6	Vitavax	1.410	2.626	2.018
T_7	N:K ratio	5.060	5.486	5.773
T_0	Control	5.706	7.740	6.723
Mean (N)		3.463	5.035	

C.D. for comparing T means = 0.8010
" " N means = 0.4007
" " TN means = 1.1312

Table 19. Effect of different fungicides, mineral nutrients and nematicide on per cent hill infection (Ear head stage).
(Mean value after angular transformation)

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	63.45	68.29	65.87
T_2	Manganese	67.22	69.56	68.40
T_3	Fycop	48.93	55.52	52.23
T_4	Hinosan	57.66	61.49	59.58
T_5	PCNB	57.02	64.52	60.78
T_6	Vitavax	51.56	61.17	56.37
T_7	N:K ratio	64.94	68.87	66.91
T_0	Control	70.28	76.13	73.21
Mean (N)		60.14	65.90	

C.D. for comparing T means = 1.788
" " N means = 0.894
" " TN means = 2.530

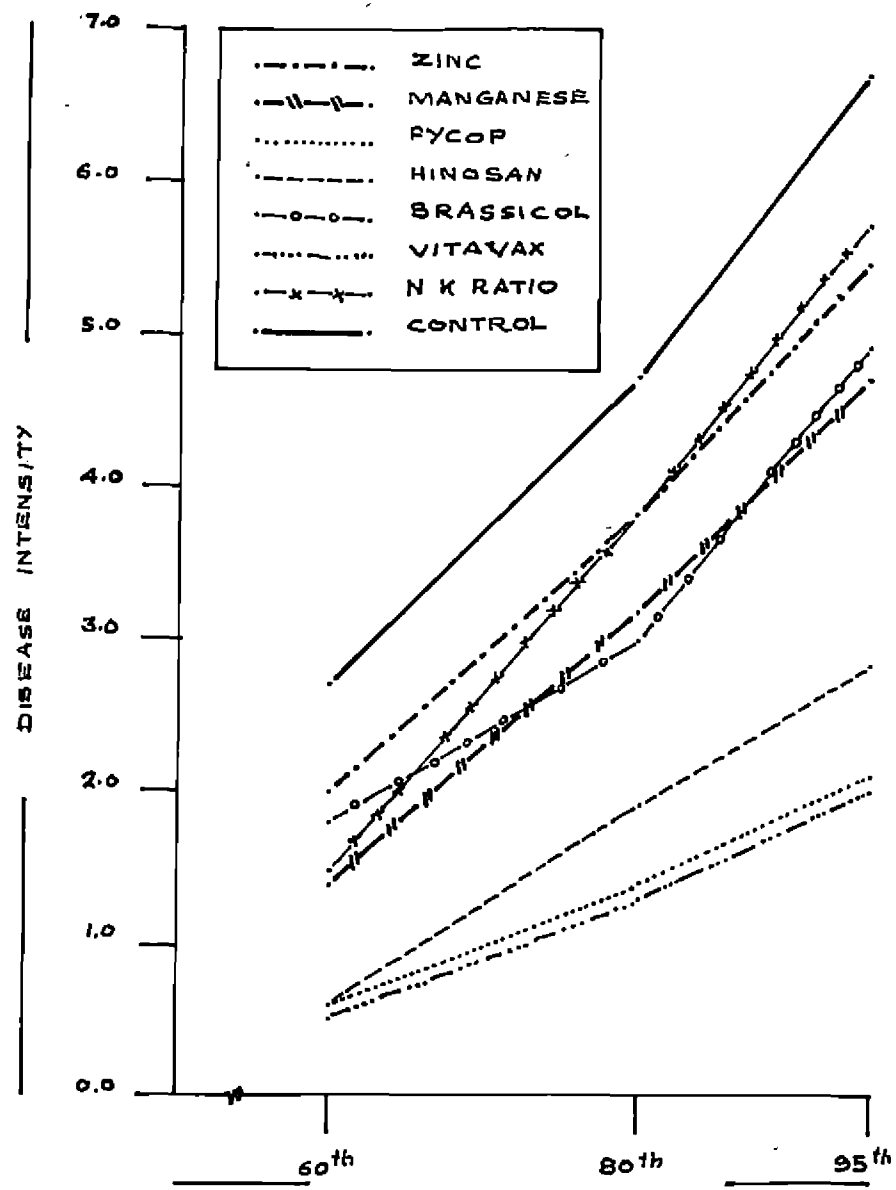


FIG: 5 EFFECT OF FUNGICIDES AND MINERAL NUTRIENTS ON INTENSITY OF SHEATH BLIGHT

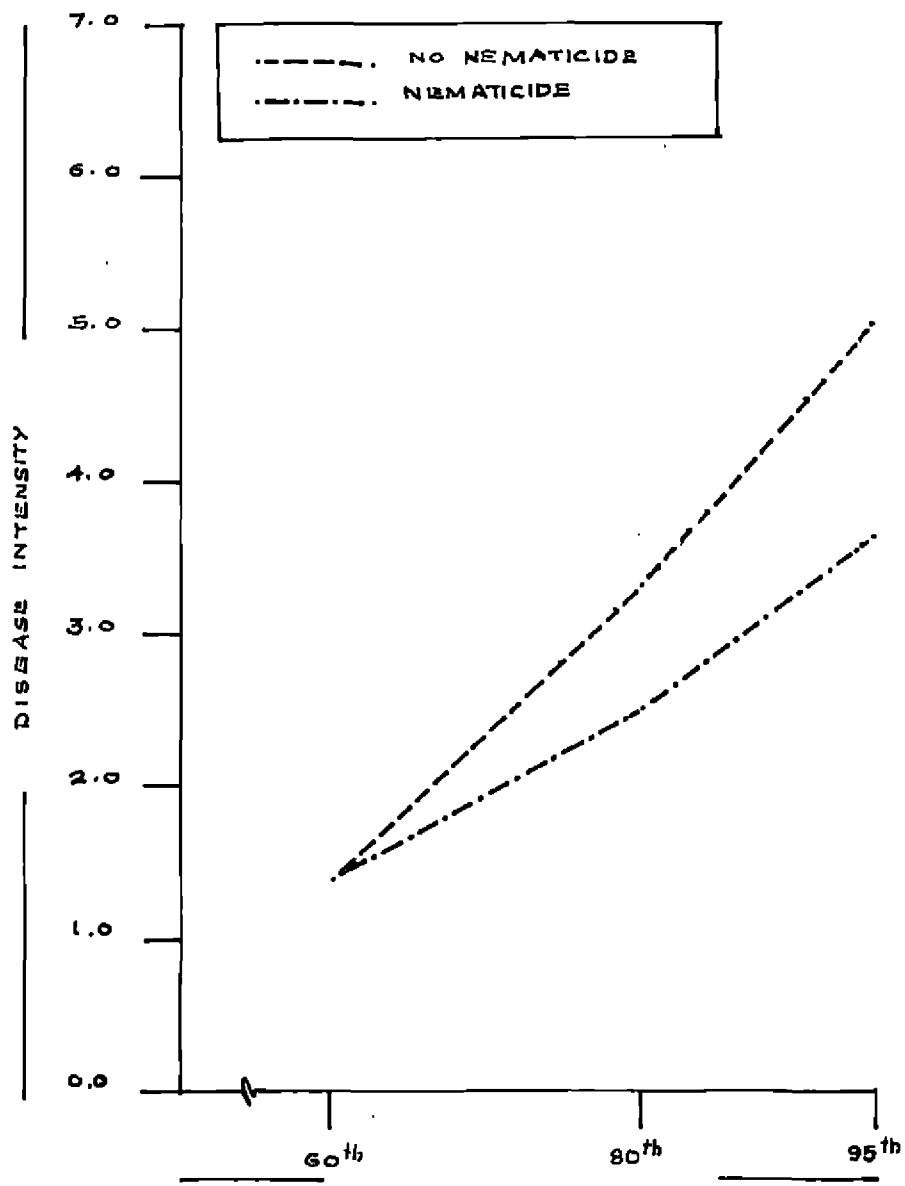


FIG: 6 EFFECT OF NEMATICIDE APPLICATION ON INTENSITY OF SHEATH BLIGHT

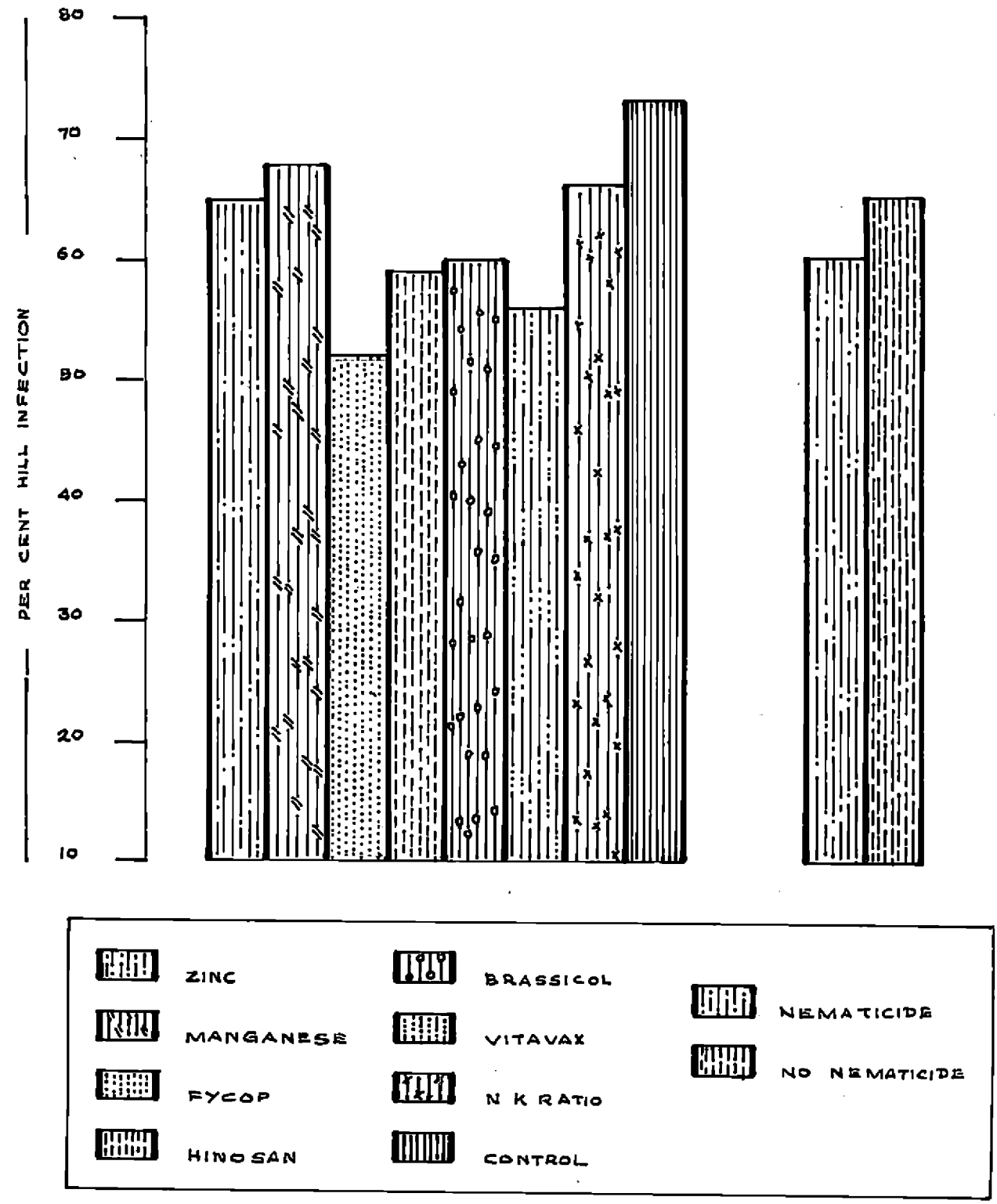


FIG: 7 EFFECT OF FUNGICIDES, MINERAL NUTRIENTS & NEMATICIDE ON PER CENT HILL INFECTION

significantly superior over the rest of the treatments in reducing the per cent hill infection and it was followed by Vitavax sprays with nematicidal treatment.

c. Effect on grain yield

The grain yield of the crop was influenced by the application of fungicides, mineral nutrients and nematicidal treatment is given in Table 20. It was found that Vitavax (T_6) was significantly superior to the rest of the treatments in increasing grain yield followed by Fycop (T_3) and Hinosan (T_4) which were on par. Effect of soil application of Brassicol (T_5) and an N:K ratio of 2:1.5 was found to be on par. All treatments significantly increased the grain yield as compared with the control. The interaction between the different treatments and nematicidal application was found to be highly significant in increasing the grain yield. Among the treatment combinations Vitavax with nematicide was found to be significantly superior to the rest of the treatments in increasing grain yield followed by Fycop with nematicide and Hinosan with nematicide.

d. Effect on tillering

The observations on effective tiller production in plots receiving different treatments are presented in Table 21. Treatment with Fycop (T_3) was found to increase effective tiller production significantly over other treatments, except Vitavax (T_6). Of the rest of the treatments

Table 20. Effect of different fungicides, mineral nutrients and nematicide on yield (kg/ha).

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	3645.83	4320.98	3983.41
T_2	Manganese	3819.44	4417.44	4118.44
T_3	Fycop	4456.01	5169.75	4813.88
T_4	Hinosan	4513.89	4976.85	4745.37
T_5	PCNB	4089.50	4648.92	4369.21
T_6	Vitavax	4841.82	5652.01	5247.91
T_7	N:K ratio	3819.44	4706.79	4263.11
T_0	Control	3298.81	3993.05	3646.83
Mean (N)		4060.56	4736.72	

C.D. for comparison of T means = 239.618
" " N means = 119.810
" " TN means = 338.875

Table 21. Influence of different fungicides, mineral nutrients, nematicide on effective tiller production.
(Mean values after square root transformation)

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	2.43	2.28	2.35
T_2	Manganese	2.46	2.31	2.38
T_3	Fycop	2.83	2.59	2.71
T_4	Hinosan	2.42	2.36	2.39
T_5	PCNB	2.62	2.32	2.47
T_6	Vitavax	2.75	2.49	2.62
T_7	N:K ratio	2.41	2.44	2.43
T_0	Control	2.40	2.40	2.30
Mean (N)		2.54	2.40	

C.D. for comparison of T means = 0.155
" " N means = 0.077
" " TN means = 0.219

Brassicol (T_5) alone was significant over the control. The nematicidal treatment was found to increase effective tiller production significantly as compared with the control. The interaction between the different treatments and nematicide application was not significant.

e. Plant height

The observations on plant height are presented in Table 22. A significant increase in plant height was observed in all treatments except treatment T_7 (N:K ratio) which was on par with the control. Spraying the plants with Fycop and application of zinc to soil in combination with nematicide treatment were observed to be better in increasing plant height. The nematicidal treatment was found to increase plant height significantly over untreated control. The interaction between the different factors and nematicide application was not significant.

f. Effect on number of grains per panicle

The observations regarding the number of grains per panicle are recorded in Table 23. The fungicides Vitavax (T_6), Hinosan (T_4), Fycop (T_3), Brassicol (T_5) and an N:K ratio of 2:1.5 (T_7) were found to increase the number of grains per panicle significantly. Zinc (T_1) and Manganese (T_2) soil application were found to be on par with the control. Among the nutrients tried the effect of N and K was superior to zinc and mongenese. The nematicidal

Table 22. Effect of different fungicides, mineral nutrients and nematicide on plant height.

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	92.83	79.33	86.08
T_2	Manganese	83.50	84.00	83.75
T_3	Fycop	89.06	84.80	86.95
T_4	Hinosan	86.66	80.16	83.42
T_5	PCNB	88.00	81.16	84.58
T_6	Vitavax	88.00	81.33	84.67
T_7	N:K ratio	84.00	75.66	80.83
T_0	Control	82.16	79.50	78.83
Mean (N)		86.80	80.50	

C.D. for comparison of T means = 4.231
" " N means = 2.114
" " TN means = 5.952

Table 23. Influence of different fungicides, mineral nutrients and nematicide on grains per panicle.
(Mean value after square root transformation)

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	9.932	8.318	9.125
T_2	Manganese	9.241	9.716	9.499
T_3	Fycop	10.181	9.741	10.137
T_4	Hinosan	10.283	9.501	10.162
T_5	PCNB	10.437	9.498	9.967
T_6	Vitavax	11.127	8.757	10.427
T_7	N:K ratio	9.806	9.766	9.978
T_0	Control	9.970	6.638	8.304
Mean (N)		10.150	9.200	

C.D. for comparison of T means = 1.2169
" " N means = 0.6084
" " TN means = 1.7209

treatment was also found to increase the number of grains per panicle significantly. The interaction between the different treatments and nematicidal application was significant. Among the treatment combinations, T_3N_1, T_6N_1, T_5N_1 and T_4N_1 were found to be on par and significantly superior to the rest of the treatment combinations.

g. Effect on weight of grains

The observations on weight of thousand grains from different treatments are presented in Table 24. It was found that Vitavax (T_6) was significantly superior to the rest of the treatments in increasing grain weight followed closely by Hinosan (T_4). Brassicol (T_5) and Fycop (T_3) were found to be on par but superior to T_7 (N:K ratio) while zinc (T_1) and manganese (T_2) were on par with the control. In this case the same trend as in the previous case was observed. The systemic fungicides were effective in increasing the grain weight as compared to other treatments.

The nematicidal application was found to increase grain weight significantly over the control. The interaction between the different treatments and nematicidal application was not significant.

h. Population of nematode in soil

Observations on the soil population of rice root nematode before the harvest of the crop are presented in

Table 25. The fungicides and mineral nutrients did not exert any influence on the soil population of rice root nematode. The nematicidal treatment was found to reduce the soil population of the nematode significantly over the control. The interaction between different treatments and nematicidal application was also not significant.

i. Population of nematode in rice roots

The observations on the population of the nematode in rice roots are recorded in Table 26. The different fungicides and mineral nutrients did not significantly alter the population of nematode in rice roots. The nematicidal treatment was found to reduce the root population of nematodes significantly as compared with the control. The interaction between the various treatments was found to be sigaificant. All treatment combinations with nematicide application (N_1) were found to be significantly superior to those without nematicide (N_0) in reducing the population of nematodes in the rice roots.

j. Population of R. solani in soil

The observations on soil population of R. solani are recorded in Table 27. Application of Brassicol (T_5) to soil was significantly superior to the rest of the treatments in reducing R. solani propagules in soil followed by Vitavex (T_6), Hinosan (T_4) and Fycop (T_3) which were on par. Soil application of manganese (T_2) was superior to that with

Table 24. Effect of different fungicides, mineral nutrients and nematicide on grain weight.

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	24.97	23.03	24.00
T_2	Manganese	23.87	23.10	23.48
T_3	Fycop	30.23	27.20	26.71
T_4	Hinosan	29.33	29.27	29.30
T_5	PCNB	28.23	26.93	27.58
T_6	Vitavax	33.20	29.97	31.58
T_7	N:K ratio	25.63	24.43	25.03
T_0	Control	23.87	21.67	22.77
Mean (N)		27.42	25.70	

C.D. for comparison of T means = 1.442
" " N means = 0.721
" " TN means = 2.039

Table 25. Influence of different fungicides, mineral nutrients and nematicide on nematode population in soil (100 g) before harvest of the crop.
(Mean values after square root transformation)

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	7.978	12.457	10.210
T_2	Manganese	5.313	11.218	8.220
T_3	Fycop	6.676	11.970	9.322
T_4	Hinosan	7.248	13.157	10.517
T_5	PCNB	7.545	12.632	10.088
T_6	Vitavax	8.748	12.739	10.743
T_7	N:K ratio	6.045	10.188	8.116
T_0	Control	7.847	12.910	10.378
Mean (N)		7.216	12.163	

C.D. for comparison of T means = 2.2562
" " N means = 1.1281
" " TN means = 3.1908

Table 26. Effect of different fungicides, nematicides and mineral nutrients on root population of nematodes in 10 g root.
(Mean values after square root transformation)

		Nematicide (N_1)	No nematicide (N_0)	Mean (F)
T_1	Zinc	3.55	5.54	4.53
T_2	Manganese	3.01	5.80	4.40
T_3	Fycop	3.06	5.02	4.04
T_4	Hinosan	3.14	5.07	4.11
T_5	PCNB	3.37	5.54	4.46
T_6	Vitavax	3.21	5.37	4.29
T_7	N:K ratio	3.12	5.77	4.45
T_0	Control	3.61	6.07	4.84
Mean (N)		3.26	5.52	

C.D. for comparison of T means = 0.865
" " N means = 0.432
" " TN means = 1.223

Table 27. Effect of different fungicides, mineral nutrients and nematicide on R. solani propagules in soil (30 g soil/plot).
(Mean values after square root transformation)

		Nematicide (N_1)	No nematicide (N_0)	Mean(F)
T_1	Zinc	4.318	4.320	4.32
T_2	Manganese	4.039	4.079	4.06
T_3	Fycop	2.940	3.410	3.18
T_4	Hinosan	2.936	3.265	3.10
T_5	PCNB	2.641	2.816	3.73
T_6	Vitavax	2.817	3.255	3.04
T_7	N:K ratio	4.162	4.507	4.34
T_0	Control	4.200	4.570	4.39
Mean (N)		3.507	3.778	

C.D. for comparison of T means = 0.2506
" " N means = 0.1253
" " TN means = 0.3544

zinc (T_1) and an N:K ratio of 2:1.5 (T_7) which were on par with the control. The nematicidal treatment was found to reduce the soil population of R. solani significantly when compared with the control. The interaction between the various treatments and nematicide application was not significant.

Studies on microorganisms antagonistic to R. solani

Isolation of microorganisms were carried out from sources like paddy field soil, irrigation water and sclerotia of R. solani and their antagonistic effect on R. solani was studied.

a. Fungi

Fungi isolated from different sources include

Trichoderma viride Pers. ex Fr.

Aspergillus niger Van Tiegh.

Aspergillus flavus Link.

Rhizopus sp.

When these fungi were tested to determine their antagonistic action on R. solani, Aspergillus niger and Trichoderma viride exhibited maximum antagonism followed by Rhizopus sp. and Aspergillus flavus (Table 28, Plate 15).

b. Bacteria

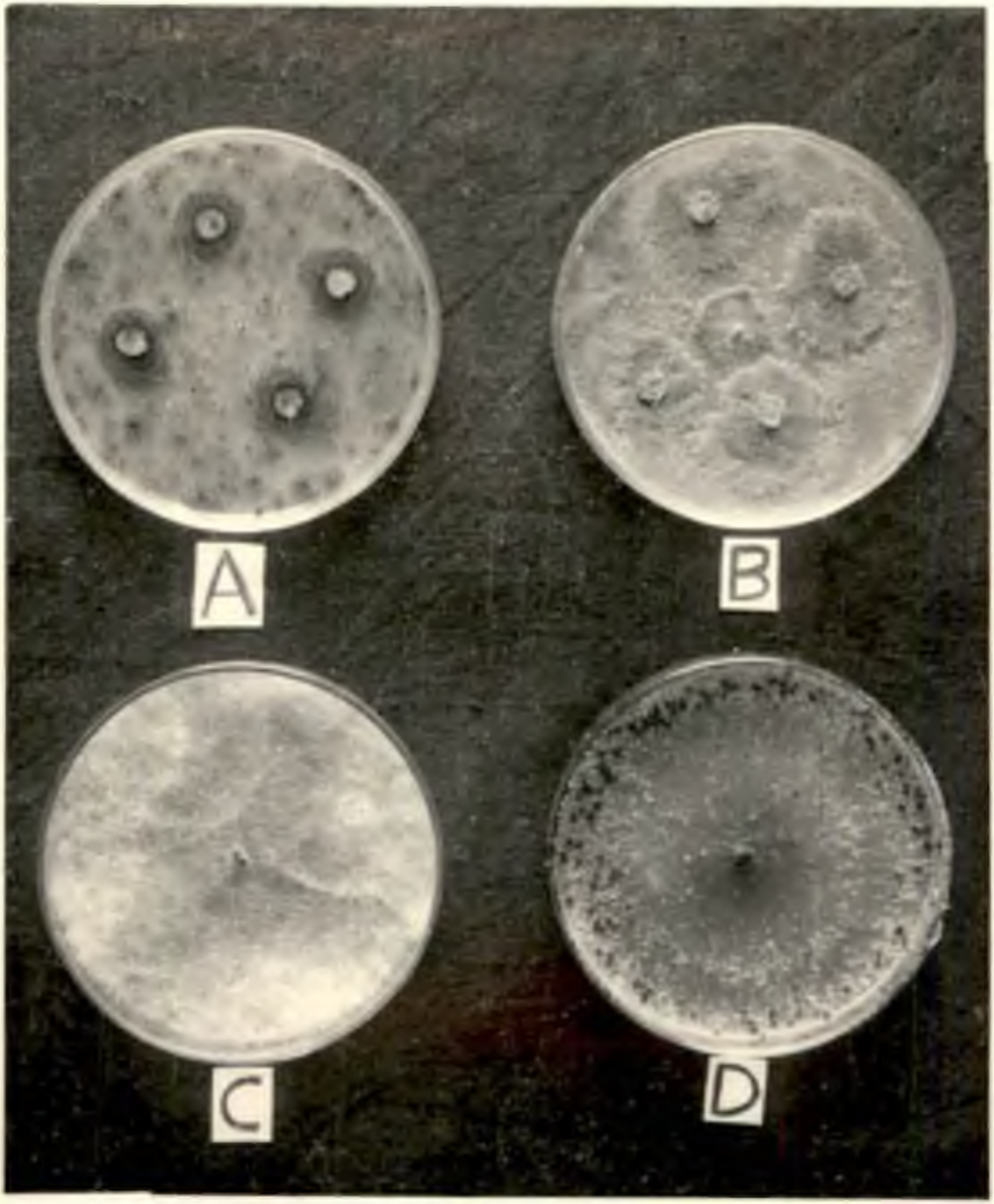
Four bacterial isolates (B_1, B_2, B_3 & B_4) differing in certain characters (Table 29) were obtained from

Table 28. Antagonism of four fungi towards R. solani in culture.

(Average of 5 replications)

Test fungi	Diameter of R. solani colony in mm	Percentage inhibition
Trichoderma sp.	4.24	95.27
Aspergillus flavus	61.75	31.38
Aspergillus niger	3.25	96.38
Rhizopus sp.	15.00	85.55

Plate 15. Antagonism of three fungi against R. solani - after seven days of incubation under room temperature.


A
B
C
D

irrigation water and sclerotia of R. solani. These were tested in vitro to determine their antagonistic action against R. solani. Isolates B_1 and B_4 exhibited strong antagonistic action (Plate 16).

From an experiment to test the sclerotial survival in the suspensions of the above bacterial isolates, it was revealed that the sclerotial germination of R. solani was completely inhibited after ten days immersion in the suspensions of isolates B_1 & B_4 (Table 30). In the controls maintained, the sclerotia showed 100 per cent viability.

Table 29. Characters of bacterial isolates showing antagonism against R. solani.

Bacterial isolate	Source	Gram staining	Spore staining	Colony character
B_1	Sclerotia	Gram-ve	Non sporulating	Entire edge, elevated with depressed centre
B_2	Field water	Gram-ve	Non sporulating	Entire edge, smooth elevated colony
B_3	Sclerotia	Gram+ve	Sporulating	Lobate edge, spreading colony
B_4	Sclerotia	Gram+ve	Sporulating	Lobate edge, spreading colony

Table 30. Antagonistic effect of different bacterial isolates on the germination of R. solani sclerotia.

	Percentage inhibition of sclerotial germination after immersion in bacterial suspension for			
Isolate	5 days	10 days	20 days	25 days
B_1	0	100	100	100
B_2	0	0	100	100
B_3	0	0	80	100
B_4	0	100	100	100
No bacteria	0	0	0	0

Plate 16. Antagonism of four bacterial isolates against *R. solani* after seven days of incubation under room temperature.

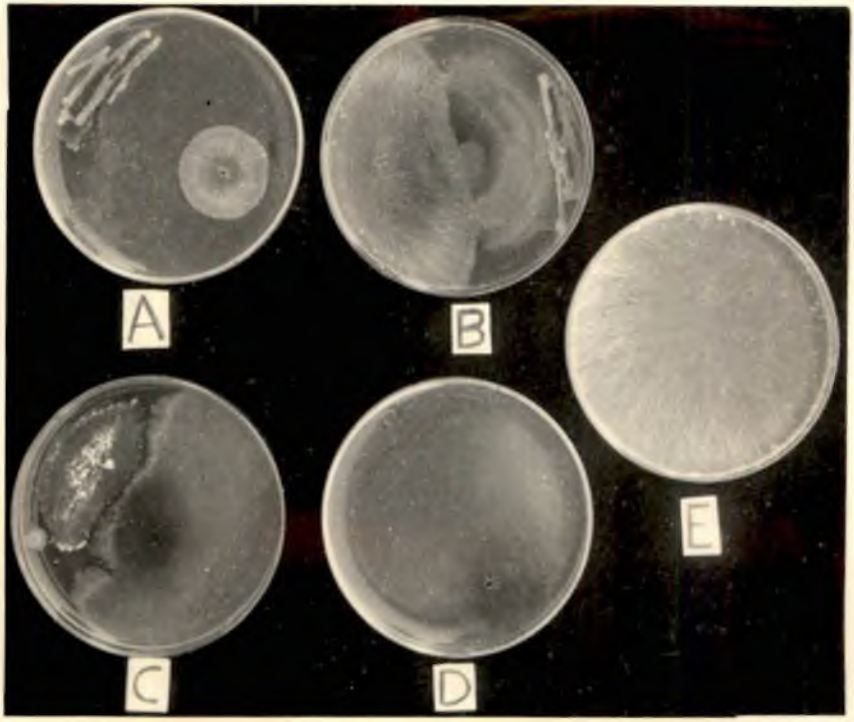


Plate 16

A. Isolate B_1

B. Isolate B_2

C. Isolate B_3

D. Isolate B_4

E. Control

DISCUSSION

DISCUSSION

The incidence of sheath blight of rice has been observed in endemic proportions in most of the important rice growing areas of Kerala during the past few years. The infestation of rice by the rice root nematode is also widely prevalent in the rice growing areas of the State (Venkitesan and Charles, 1979). The preliminary observational trials conducted at the State Seed Farm, Adoor have shown that the incidence of sheath blight was severe in areas severely infested by the rice root nematode. The nematode infestation was found to be quite serious so as to weaken the plants and thus render the crop more susceptible to the disease (Anon., 1978c). The present investigations were undertaken to make a critical assessment of the role of rice root nematode on the incidence of sheath blight of rice. Aspects like host range and pathogenicity of R. solani, effect of different nematicides on R. solani and antagonistic effect of other microorganisms to the sheath blight fungus were also included in the present study.

The wide host range of R. solani includes species of different crop plants, wild species of Oryza and many weeds commonly found in and around rice fields. In the present study besides rice, R. solani was found to infect a number of common weeds and crops raised in rice fallows.

Of the eight host plants listed out in the present studies Apluda aristata is a new record for this fungus in India. The fungus was found to produce dark coloured lesions on the slender sheath and leaves of the host plant (Plate 4.).

The present observation of sheath blight symptoms due to infection by R. solani on Monochoria vaginalis is also the first record of infection by R. solani under natural conditions. However, Mahendra Prabhath et al. (1973) and Kannaiyan and Prasad (1980) have recorded this weed as a host for R. solani from rice under artificial inoculation.

The fungus was found to produce severe collar rot symptoms on Sesamum indicum. R. solani has been reported to cause a serious root disease of Sesamum indicum resulting in wilt of the plants and a black discolouration of the collar region (Rhind, 1924, 1926).

On groundnut the fungus was found to produce severe leaf and stem blight. Reddy and Rao (1978) reported in detail the host parasite relations in damping off of groundnut caused by R. solani, first reported by Gadd and Bertus (1926). However, on groundnut it has not so far been recorded to cause leaf and stem blight (Plate 1a & 1b).

R. solani was found to produce collar rot symptoms on Sesbania aculeata grown as a green manure crop in rice fields. Gadd and Bertus (1926) observed damping off

symptoms caused by the fungus on Sesbania aculeata from Sri Lanka. However, this is the first record of this fungus on this crop in India (Plate 2).

On wild colocasia, typical sheath blight symptoms were observed on the fleshy petiole (Plate 3). Briton-Jones (1925) observed that a species of Rhizoctonia causing sore shin of cotton could infect species of Colocasia in nature. A root rot disease of Colocasia antiquorum caused by R. solani was reported by Auchinleck (1934).

R. solani was observed to infect Cyperus iria in nature causing leaf blight symptoms. Tsai (1970) observed that twenty weed species belonging to families, Gramineae and Cyperaceae were infected by R. solani. Nayak et al. (1979) reported that the fungus could infect Cyperus iria under artificial conditions.

On the weed plant, Fimbristylis miliaceae the fungus was found to produce blight symptoms on the leaves. The natural occurrence of the fungus on this weed has been reported by Roy (1975).

R. solani isolate from rice (A) was compared for its morphological characters pathogenic reaction and genetic relationship with the following three other isolates of R. solani obtained from other host plants during the survey.

1. Sesamum indicum (Isolate B)
2. Sesbania aculeata (Isolate C)
3. Arachis hypogaea (Isolate D)

The isolate from sesamum (B) was slightly different in its morphological characters from other isolates while all the other isolates compared well with each other.

The results on the pathogenic reaction revealed that isolates from rice, daincha and groundnut could cross infect each other causing typical leaf and stem blight and collar rot on their respective host plants. Rice plants inoculated with isolate (C) or (D) developed typical sheath blight symptoms (Plate 6). On groundnut, the symptoms observed were leaf and stem blight (Plates 8a & 8b) while in daincha collar rot symptoms were seen (Plate 7). Isolate (B) from sesamum which differed morphologically from the other three isolates failed to cross infect rice, daincha or groundnut.

The genetic relationship between the different isolates was studied by observing hyphal anastomosis between them. Hyphae of isolate (A), isolate (C) and isolate (D) were found to anastomose freely with each other (Fig. 1a & 1b). The ability of these isolates to anastomose with each other establishes the genetic relationship between them. The sesamum isolate (B) failed to anastomose with any of the other three isolates, indicating that it is genetically different from the other isolates.

Earlier workers have observed that isolates of R. solani falling in one anastomosis group agree with respect to their morphological characters also (Schultz,

1937; Richter and Schneider, 1953). Parmeter et al. (1969) reported that each anastomosis group has its general tendency in host range and pathogenicity. Ogoshi (1975) pointed out the pathological, ecological and morphological differentiation in R. solani and suggested that this differentiation can be seen in anastomosis groups too.

O'Neill et al. (1977) observed that the increased incidence of sheath blight of rice in South East Louisiana was due to the cultivation of soybean as a rotation crop with rice. Lakshmanan et al. (1979) suggested that the cultivation of cowpea as a fallow crop in rice fields may aggravate the problem of sheath blight of rice in Kerala. In the present study groundnut raised in rice fallows and daincha grown as a green manure crop were found to be infected by R. solani. Hence it is possible that raising daincha or groundnut in rice fields may aggravate the problem of sheath blight in rice and may develop into a major threat to groundnut cultivation also, in the State. In the light of the fact that R.solani has a wide host range, selection of crops to be raised during the fallow period in rice fields should be done with utmost care, considering the severe endemic nature of sheath blight in the State.

The results on reaction of rice varieties to sheath blight intensity and per cent hill infection (Tables 3 and 4) revealed that all the ten rice varieties tested were

susceptible to sheath blight. However, the degree of susceptibility varied considerably. Rice varieties Bharati, Sabari and Rohini recorded lesser intensity of disease and per cent hill infection when compared with the rest. With respect to nematode infestation, the nematode population of diseased plant roots were found to be significantly higher than that present in healthy plant roots (Fig. 5). These results indicate a positive relationship between the nematode population and intensity of sheath blight incidence. The rice varieties Annapurna and Ptb-12 harboured least nematode population when compared with the rest of the varieties. The results of the present investigations revealed that none of the rice varieties tested, showed resistance to the sheath blight pathogen or to the infestation by the rice root nematode.

Varietal screening trials conducted by earlier workers also have shown that none of the rice varieties tested was completely resistant to sheath blight eventhough they varied in their reaction to the disease (Hashioka, 1951; Chang, 1962; Anon., 1967; Mahendra Prabhath, 1971).

Observations regarding intensity of sheath blight were made at the boot leaf stage and fifteen days prior to the harvest of the crop in plants artificially inoculated with R. solani and the rice root nematode. The fungus and nematode were found to interact significantly to increase

disease intensity at both stages. Incorporation of high populations (1000 nematodes/5 l. of soil) of the nematode along with sheath inoculation of the fungus was found to produce maximum intensity of sheath blight. This suggests a possible role of the nematode in rendering the rice plants more susceptible to attack by R. solani thus enhancing the disease intensity.

Interactions between nematode infestation and fungal infection in vascular diseases are well documented (Bergeson, 1972). There are few reports of their interaction in other types of plant diseases also. Hijink (1963) observed a clear correlation between the nematode population of Ditylenchus dipsaci in soil before planting potatoes and the percentage of plants infected by Phoma solanicola. Agarwal and Goswami (1974) observed a significant synergistic effect when root knot nematode infestation preceded infection by Macrophomina phaseoli (Maubl) Ashby in soybean plants. Abu-Elamayen et al. (1978) observed that the severity of damping off in tomato seedlings was increased by infestation with the root knot nematode, Meloidogyne javanica (Treub) Chitwood.

Several plant characters like tiller count, plant height, panicle length and panicle weight were observed after artificial inoculations with the sheath blight fungus and different levels of the rice root nematode to study their

effect on plant growth. Data collected on tiller production revealed that during the early stages all the nematode inoculum levels (10, 100 and 1000) used, resulted in considerable reduction in tillering while during the later stages only the highest nematode inoculum level (1000) caused a depressing effect on tillering. Plant height was found to be decreased significantly by the highest nematode inoculum level. As the fungus was found to have no effect on plant height it can be assumed that reduction in plant height is a condition brought about by nematode infestation alone. The length of panicle was found to be reduced considerably due to the interaction between higher levels of nematode inoculum (100 and 1000) and fungus inoculation. A high nematode level was found to reduce panicle length considerably. From the results on root weight (Table 13) it can be understood that a high nematode inoculum level (1000) along with sheath inoculation of the fungus considerably decreases root weight. This can be attributed to the destruction of the root tissues by the actively feeding endoparasitic nematodes.

Mathur and Prasad (1972) observed that even an inoculum of 100 Hirschmanniella oryzae per plant significantly reduced the growth of rice plants. Ibrahim and Rezk (1978) observed that a combined infection of Meloidogyne javanica and Pyricularia oryzae Cav. reduced the growth of rice

plants more than either pathogen alone. Babatola and Bridge (1979) observed decrease in root weight at medium (1000) and high (5000) inoculum levels of the rice root nematode and that at a population of 1000 nematodes per plant, significant reduction was brought about in plant growth and yield as observed in the present study.

In general sheath blight incidence was found to be higher in plants artificially inoculated by R. solani within the leaf sheath (Tables 6 and 7). It was also found that the nematode populations both in the plant roots as well as in the soil were much higher in plants severely infected by sheath blight (Tables 14 and 15). This clearly indicates a synergistic relationship between the fungus and the nematode wherein one favours the multiplication of the other. Jacobsen et al. (1979) observed increased populations of Meloidogyne hapla on potato plants infected with Verticillium albo-atrum Reinke & Berth, and suggested a synergistic effect of the pathogens in increasing the disease severity.

Of the four nematicides tested in vitro for their effect on R. solani, SMDC (Vapam) was found to inhibit sclerotial germination at all the three concentrations tried. Carbofuran, fensulfothion and aldicarb at their highest concentration had a significant inhibitory effect on radial growth and sclerotial formation. Similar results have been obtained by El-Khaden et al. (1977) who observed that phenamiphos followed by fensulfothion were effective against

R. solani. Lakshmanan (1979) observed that aldicarb and Sevidol were effective in reducing radial growth and number of sclerotia of R. solani, isolated from rice.

The results of the field experiment with different fungicides indicate the superiority of Vitavax and Fycop in reducing disease intensity at the three stages at which observations were made. With regard to per cent hill infection, the copper fungicide, Fycop was found to be highly effective followed by Vitavax. The effects of Hinosan and soil application of PCNB were found to be on par.

Edgington and Barron (1967) reported Vitavax to be an effective fungicide against Basidiomycetes fungi. More over in vitro trials have shown that Vitavax is highly effective against R. solani (Follin and Diallo, 1971; Mahendra Prabhath, 1971; El-Sawah et al., 1977). Lakshmanan et al. (1980) observed effective control of sheath blight under field conditions with Vitavax. The effectiveness of Hinosan in the control of sheath blight has been reported from IRRI, Philippines (Anon., 1973) and by Muneera (1973) and Mathai (1975). Earlier reports reveal that copper fungicides were recommended for sheath blight disease (Hashioka and Saito, 1953; Yoshimura, 1954). Kozaka (1961) observed that common inorganic copper fungicides have remarkable preventive and good residual action against sheath blight. The present study revealed that Fycop,

a copper oxychloride preparation at 0.4 per cent is highly effective in reducing disease intensity and per cent hill infection. The effectiveness may be owing to its application thrice during the trial as with Vitavax and Hinosan.

The yield of grain was found to increase significantly by fungicidal sprays when compared with the rest of the treatments. Vitavax was most effective in increasing grain yield followed by Fycop and Hinosan. This may be attributed to the low incidence and intensity of sheath blight in plots receiving these treatments.

The results reveal that Vitavax and Fycop increased effective tiller production, plant height, number of grains per panicle and grain weight, significantly followed by Hinosan. The soil application of PCNB was most effective in reducing the soil population of R. solani followed by sprays of Vitavax, Fycop and Hinosan.

Hartzfield (1957) reported the efficacy of terrachlor (PCNB) in controlling sclerotia forming fungi. Ko and Oda (1972) observed that PCNB suppresses the growth of R. solani in soil rather than destroy the pathogen. This nature of action attributed to PCNB may be the reason for its low efficiency in controlling sheath blight.

The results of the field experiment indicate that the intensity of disease and per cent hill infection were reduced significantly by the application of zinc, manganese and an N:K ratio of 2:1.5 when compared with the control. The grain

yield was found to be increased significantly by the application of mineral nutrients. Effective enhancement in plant height was brought about by the application of mineral nutrients. An N:K ratio of 2:1.5 was found to have a significant effect on the number of grains per panicle and grain weight. The application of mineral nutrients was found to have no influence on effective tiller production, nematode infestation and R. solani population in soil.

Earlier reports indicate the role of K in imparting resistance to rice plants against various diseases (Mariani, 1951; McNew, 1953; Corbetta, 1954; Otto, 1956; Muneera, 1973; Jagan Mohan, 1977). Noguchi and Sugawara (1952), Jacob and Vezhull (1958) and Ignatieff and Page (1959) have also reported increase in yields in rice due to potash application. The increased application of potash tried in the present study can be attributed to have imparted resistance to disease and thereby increased grain yield.

Tanaka and Yoshida (1970) reported that rice plants growing in Mn deficient soils were more susceptible to Helminthosporium leaf spot. Castro (1977) observed that next to N and P, Zn is the most important nutritional factor limiting the growth of wetland rice.

The results of the field experiment indicate that the nematicide seedling dip before planting was found to have no effect on the intensity of disease at early stages.

The soil application of carbofuran one month after planting was found to reduce disease intensity. Nematicide application to soil was found to reduce per cent hill infection and the R. solani population in soil. The root and soil population of the rice root nematode was reduced significantly by nematicide application. This may be attributed to have an indirect effect in reducing the per cent hill infection. The nematicidal treatment was found to increase grain yield significantly. Other traits like effective tiller production, number of grains per panicle were also found to be enhanced significantly by nematicide application.

Mathur and Prasad (1972) observed that loss in yield caused by rice root nematode was 70 per cent in the weight of grain. Several workers have observed the effectiveness of carbofuran in controlling the rice root nematode (Muthukrishnan et al., 1977; Rao, 1975; Chhabra and Dhaliwal, 1978).

The interactional effect between the fungicides, mineral nutrients and nematicide was found to be significant in reducing the per cent hill infection and increasing the grain yield and the number of grains per panicle. The data on per cent hill infection and grain yield clearly indicate that the effect of fungicides and mineral nutrients is enhanced when they are used along with the nematicide.

Meagher et al. (1978) observed that soil application of the nematicide aldicarb increased the yield of wheat by 33 per cent in a trial to study the effect of Heterodera avenae Wollenweber and R. solani on the growth and yield of wheat. In the case of Verticillium wilt of potato involving the root knot nematode, Meloidogyne hapla, combined application of benomyl and carbofuran was found to give higher yields, lesser disease index and lower nematode population (Jacobsen et al., 1979).

The grain yield was maximum in the case of spray application of fungicides like Vitavax and Fycop along with nematicide application. The results indicate that the substantial suppression of disease and the nematode by the application of fungicides along with a nematicide has resulted in higher crop yields.

The studies on microorganisms antagonistic to R. solani revealed that Trichoderma viride and Aspergillus niger showed a high degree of antagonism to R. solani in culture as indicated in Table 28. A lesser degree of antagonism was exhibited by Aspergillus flavus and Rhizopus sp. All the above mentioned four fungi were found to restrict the radial growth of R. solani considerably.

Earlier reports clearly indicate the antagonistic action of Trichoderma viride towards R. solani (Ogura and Akai, 1965; Naiki and Ui, 1972; Roy, 1977). Nain and

El-Essawy (1965) reported the antagonism of Aspergillus terreus Thom. and Aspergillus flavus towards R. solani. But the antagonistic action of A. niger against R. solani observed in the present study is the first record of this organism as antagonistic against R. solani.

It was also found that two bacterial isolates (B_1 and B_4) showed considerable antagonistic action towards R. solani in culture.

The results of the present study indicate the ability of these two bacterial isolates to inhibit the sclerotial germination of R. solani after immersion for ten days in the bacterial suspension.

Olsen (1965) observed the antagonistic effect of Bacillus subtilis Cohn em. Prazm. on R. solani which he attributed to the ability of the bacteria to colonise on R. solani and lyse the hyphal tissues. At trials conducted at IRRI, Philippines, several bacterial isolates from sclerotia of R. solani were found to have strong antagonistic action towards R. solani (Anon., 1978b). The probable use of such bacterial isolates to reduce sclerotial survival and infection by R. solani under field conditions needs further investigation.

SUMMARY

SUMMARY

The sheath blight pathogen of rice, Rhizoctonia solani was isolated from leaf sheaths of infected rice plants and brought into pure culture. The pathogenicity of R. solani isolate was established following Koch's postulates.

An original nucleus culture of the rice root nematode Hirschmanniella oryzae was obtained from roots of rice plants and soil from fields severely infested with the rice root nematode. This was multiplied on rice seedlings grown in nematode free soil.

Surveys conducted in rice fields at Instructional Farm, College of Agriculture, Vellayani; Model Agronomic Research Station, Karamana; State Seed Farm, Adoor, and Rice Research Station, Kayamkulam, revealed that besides rice, R. solani could infect a number of common weeds and crops raised in rice fallows. R. solani caused aerial leaf and stem blight of groundnut, which is the first record of this fungus to cause aerial blight on adult groundnut plants. On Sesbania aculeata (daincha) the fungus produced severe collar rot. This is the first record of this fungus on this crop in India. The occurrence of R. solani under natural conditions on the weeds, Apluda aristata and Monochoria vaginalis are also new host records for this fungus.

The R. solani isolates from rice, daincha and

groundnut had similar morphological characters while the isolate from sesamum differed slightly from these in its morphological characters. The results on pathogenic reaction revealed that isolates from rice, daincha and groundnut could cross infect their respective host plants. The sesamum isolate (B) which differed morphologically from the other three isolates failed to cross infect rice, daincha, or groundnut. Hyphae of isolates from rice (A) and daincha (C) and groundnut (D) were found to anastomose freely with each other which establishes the genetic relationship between these isolates. The sesamum isolate (B) failed to anastomose with any of the other three isolates indicating that it is genetically different from the other isolates.

Of the ten rice varieties tested none exhibited resistance to the sheath blight or rice root nematode. However, the degree of susceptibility to both the disease and nematode infestation was found to vary. Comparatively low intensity of disease was noted in varieties Bharati, Sabari and Rohini. Nematode infestation was observed to be higher in roots of rice plants severely affected by sheath blight irrespective of the variety, when compared with the healthy plants, indicating a positive relationship between nematode infestation and disease incidence.

Pot culture experiments involving R. solani and varying levels of rice root nematode inoculum revealed a possible role of the rice root nematode in rendering the

rice plants more susceptible to sheath blight. High nematode populations (1000 nematodes/5 l soil) along with sheath inoculation of the fungus was found to produce maximum intensity of sheath blight. Tiller production, plant height and root weight were found to be reduced significantly at the highest nematode inoculum level. The length of panicles were considerably reduced by the interaction between higher levels of nematode inoculum and fungus inoculation. Nematode population, both in the plant roots as well as in the soil were much higher in plants severely infected by sheath blight. This indicates a synergistic relationship between the fungus and the nematode wherein one favours the multiplication of the other.

Among the nematicides tested, SMDC (Vapam) was found to inhibit sclerotial germination of R. solani at all the three concentrations tried. Carbofuran (Furadan), Fensulfothion (Dasanit) and Aldicarb (Temik) at their highest concentration of 120 ppm had a significant inhibitory effect on radial growth and sclerotial formation.

Field evaluation of fungicides, mineral nutrients and nematicides revealed that combined application of fungicides Vitavax (0.1%) or Fycop (0.4%) along with the nematicide Carbofuran (Furadan 3 G @ 50 kg/ha) significantly reduced the disease intensity and nematode infestation and considerably increased the grain yield. Vitavax and Fycop,

were found to be highly effective in reducing disease intensity followed by Hinosan. Other agronomic traits like effective tiller production, plant height, number of grains per panicle and grain weight were considerably enhanced by the application of Vitavax or Fycop. The soil application of mineral nutrients, zinc or manganese or the N:K ratio of 2:1.5 was found to reduce the disease intensity and per cent hill infection and increase grain yield over the control. The nematicidal treatment caused significant reduction in soil and root population of nematode and increased grain yield significantly. The combined effect of nematicides and fungicides was found to be significantly superior to their individual effects in reducing per cent hill infection and increasing grain yield.

Of the several fungi screened for their antagonistic action towards the sheath blight pathogen, Trichoderma viride and Aspergillus niger exhibited maximum antagonism towards R. solani in culture. Aspergillus flavus and Rhizopus sp. exhibited antagonism towards R. solani to a lesser degree. All the four antagonistic fungi were found to inhibit radial growth of R. solani. This is the first record of the antagonistic action of Aspergillus niger towards the sheath blight fungus R. solani in culture.

Of the four bacterial isolates screened for their antagonism towards the sheath blight fungus, two isolates

(B_1 & B_4) obtained from the sclerotia of R. solani exhibited strong antagonistic action against the fungus in culture. Sclerotial germination was completely inhibited after immersion for ten days in bacterial suspension of isolates B_1 and B_4. However the feasibility of using these antagonists against R. solani under field conditions needs further investigations.

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APPENDICES

APPENDIX I

Potato dextrose agar

Peeled potato	-	250.0 g
Dextrose	-	20.0 g
Agar	-	15.0 g
Water	-	1000 ml
pH	-	6.0 to 6.5

APPENDIX II

Sand maize media

Maize meal	-	5.0 g
Washed white sand	-	95.0 g
Water	-	35.0 ml

APPENDIX III

Selective medium

Dipotassium phosphate	-	1.0 g
Magnesium sulphate	-	0.5 g
Potassium chloride	-	0.5 g
Sodium nitrate	-	0.2 g
Gallic acid	-	0.4 g
Ferrous sulphate	-	10.0 mg
Dexon	-	90.0 mg
Chloramphenicol	-	50.0 mg
Streptomycin	-	50.0 mg
Agar	-	20.0 g
Distilled water	-	1000 ml

APPENDIX IV

Martins' rose bengal streptomycin agar

Dextrose	-	10.0 g
Peptone	-	5.0 g
Potassium dihydrogen phosphate	-	1.0 g
Magnesium sulphate	-	0.5 g
Rose bengal	-	(1 part in 30,000 parts of the medium)
Agar	-	20.0 g
Streptomycin	-	30.0 mg
Distilled water	-	1000 ml

APPENDIX V

Soil extract agar

Soil extract	-	100.0 ml
Glucose	-	1.0 g
Dipotassium phosphate	-	0.5 g
Agar	-	15.0 g
Water	-	900.0 ml
pH	-	7.0 to 7.2

APPENDIX VI

Nutrient Agar

Peptone	-	10.0 g
Beef extract	-	5.0 g
Agar	-	20.0 g
Distilled water	-	1000 ml
pH	-	7.0

APPENDIX VII

Peptone-sucrose broth

Peptone	-	10.0 g
Sucrose	-	5.0 g
Distilled water	-	1000 ml

APPENDIX VIII

Analysis of variance table

(Reaction of different rice varieties to sheath blight)

Source	S.S.	df	M.S.	F calculated	F at 0.05
Total	90.380	35			
Block	0.020	2	0.010	0.099	3.44
Treatment	88.150	11	8.010	79.79*	2.27
Error	2.209	22	1.004	1.00	

C.D. for comparison of treatment means = 0.536

*Significant at 0.05 level

APPENDIX IX

Analysis of variance table - angular transformation

(Per cent hill infection by sheath blight in different rice varieties)

Source	S.S.	df	M.S.	F calculated	F at 0.05
Total	1853.270	35			
Block	1.492	2	0.746	1.46	3.44
Treatment	1837.470	11	167.040	256.80*	2.27
Error	14.310	22	0.500	1.00	

C.D. for comparison of treatment means = 1.37

*Significant at 0.05 level

APPENDIX X

Analysis of variance table. Square root transformation.

(Population of *H. oryzae* in healthy plant roots of different rice varieties)

Source	S.S.	df	M.S.	F calculated	F at 0.05
Total	24.397	35			
Block	0.497	2	0.248	0.979	3.44
Treatment	18.30	11	1.660	6.550*	2.27
Error	5.59	22	0.254		

C.D. for comparison of treatment means = 0.853

*Significant at 0.05 level

APPENDIX XI

Analysis of variance table. Square root transformation.

(Population of *H. oryzae* in diseased plant roots of different rice varieties)

Source	S.S.	df	M.S.	F calculated	F at 0.05
Total	20.735	35			
Block	0.213	2	0.106	1.540	3.44
Treatment	19.004	11	1.727	25.057*	2.27
Error	1.516	22	0.068		

C.D. for comparison of treatment means = 0.445

*Significant at 0.05 level

APPENDIX XII

Analysis of variance table

(Effect of combined inoculation of rice with R. solani and H. oryzae on the intensity of sheath blight, Observation-1)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	108.98	59			
N	8.32	3	2.77	7.56*	2.808
F	76.23	2	38.12	103.95*	3.198
NF	6.83	6	1.14	3.11*	2.304
Error	17.60	48	3.67		

C.D. for comparison of N means = 0.442
" " F means = 0.380
" " NF means = 0.770

*Significant at 0.05 level

APPENDIX XIII

Analysis of variance table

(Effect of combined inoculation of rice with R. solani and H. oryzae on intensity of sheath blight - Observation 2)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	286.91	59			
N	17.81	3	5.93	8.43*	2.808
F	221.72	2	110.86	157.44*	3.198
NF	13.58	6	2.26	3.21*	2.304
Error	33.80	48	0.70		

C.D. for comparison of N means = 0.610
" " F means = 0.530
" " NF means = 1.060

*Significant at 0.05 level

APPENDIX XIV

Analysis of variance table · Square root transformation

(Effect of combined inoculation of rice with R. solani and H.oryzae on tillering - Observation 1)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	2.890	59			
N	1.195	3	0.398	26.59*	2.808
F	0.268	2	0.130	8.94*	3.198
NF	0.705	6	0.117	7.85*	2.304
Error	0.720	48	0.014		

C.D. for comparison of N means = 0.089
" " F means = 0.077
" " NF means = 0.150

*Significant at 0.05 level

APPENDIX XV

Analysis of variance table · Square root transformation

(Effect of combined inoculation of rice with R. solani and H. oryzae on tillering - Observation 2)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	10.63	59			
N	4.47	3	1.490	13.200*	2.808
F	0.23	2	0.110	1.067	3.198
NF	0.54	6	0.089	0.80	2.304
Error	5.38	48	1.120		

C.D. for comparison of N means = 0.24
" " F means = 0.21
" " NF means = 0.42

*Significant at 0.05 level

APPENDIX XVI

Analysis of variance table

(Effect of combined inoculation of rice with R. solani and and H. oryzae on plant height)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	3720.53	59			
N	251.25	3	83.75	3.68*	2.808
F	105.19	2	52.59	1.06	3.198
NF	971.21	6	161.86	3.25*	2.304
Error	2392.87	48	49.85		

C.D. for comparison of N means = 5.160
" " F means = 4.470
" " NF means = 8.930

*Significant at 0.05 level

APPENDIX XVII

Analysis of variance table

(Effect of combined inoculation of rice with R. solani and H. oryzae on panicle length)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	301.596	59			
N	82.820	3	27.600	15.83*	2.808
F	60.096	2	30.048	17.22*	3.198
NF	74.940	6	12.490	7.16*	2.304
Error	83.740	48	1.740		

C.D. for comparison of N means = 0.96
" " F means = 0.84
" " NF means = 1.67

*Significant at 0.05 level

APPENDIX XVIII

Analysis of variance table

(Effect of combined inoculation of rice with *R. solani* and *H. oryzae* on panicle weight)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	71.93	59			
N	26.46	3	8.820	34.52*	2.808
P	29.14	2	14.570	57.02*	3.198
NP	3.47	6	0.578	2.26	2.304
Error	12.26	48	0.260		

C.D. for comparison of N means = 0.57
" " P means = 0.32
" " NP means = 0.64

*Significant at 0.05 level

APPENDIX XIX

Analysis of variance table

(Effect of combined inoculation of rice with *R. solani* and *H. oryzae* on root weight)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	7985.55	59			
N	1374.15	3	458.05	4.89*	2.808
P	161.42	2	80.70	0.86	3.198
NP	1956.43	6	326.07	3.48*	2.304
Error	4493.55	48	93.62		

C.D. for comparison of N means = 7.07
" " P means = 6.12
" " NP means = 12.24

*Significant at 0.05 level

APPENDIX XX

Analysis of variance table. Square root transformation

(Effect of combined inoculation of rice with R. solani and H. oryzae on root population of nematode)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	293.917	59			
N	254.440	3	84.810	141.350*	2.808
F	4.972	2	2.486	4.143*	3.198
NF	5.703	6	0.9505	1.584	2.304
Error	28.802	48	0.600		

C.D. for comparison of N means = 0.178
" " F means = 0.154
" " NF means = 0.309

*Significant at 0.05 level

APPENDIX XXI

Analysis of variance table. Square root transformation

(Effect of combined inoculation of rice with R. solani and H. oryzae on soil population of nematode)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	2142.256	59			
N	2114.474	3	704.820	1840.260*	2.808
F	3.111	2	1.557	4.065*	3.198
NF	6.295	6	1.049	2.739*	2.304
Error	18.376	48	0.383		

C.D. for comparison of N means = 0.1428
" " F means = 0.1236
" " NF means = 0.2473

*Significant at 0.05 level

APPENDIX XXII

Analysis of variance table Square root transformation

(Effect of different nematicides on radial growth of R. solani)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	25622.58	44			
(N)Nematicide	145.91	2	72.96	4.030*	3.266
(L)Level	22417.37	2	12358.68	682.800*	3.266
(NxL) Nematicide x Level	107.68	4	26.92	1.487	2.642
Error	651.60	35	18.10		

C.D. for comparison of N means = 3.11
" " L means = 2.11
" " NL means = 5.38

*Significant at 0.05 level

APPENDIX XXIII

Analysis of variance table Square root transformation

(Effect of different nematicides on sclerotia formation by R.solani)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	79.590	44			
(N) Nematicide	27.330	2	13.660	92.35*	3.266
(L) Level	45.630	2	22.820	154.24*	3.266
(NxL) Nematicide x Level	1.299	4	0.325	2.19	2.642
Error	5.320	36	0.147		

C.D. for comparison of N means = 2.81
" " L means = 2.80
" " NL means = 4.87

*Significant at 0.05 level

APPENDIX XXIV

Analysis of variance table

(Effect of different fungicides, mineral nutrients and nematicides on intensity of sheath blight - boot leaf stage)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	46.7970	47			
Block	4.3516	2	2.7580	4.92*	3.32
T	26.3434	7	3.7633	8.516*	2.34
N	0.0058	1	0.0058	0.013	4.17
T x N	2.8366	7	0.4052	0.916	2.34
Error	13.2596	30	0.4419		

C.D. for comparison of T means = 0.8010
" " N means = 0.3910
" " TN means = 0.1072

*Significant at 0.05 level

APPENDIX XXV

Analysis of variance table

(Effect of different fungicides, mineral nutrients and nematicide on the intensity of sheath blight - earhead stage)

Source	S.S.	df	M.S.	F calculated	F. at 0.05 level
Total	83.2300	47			
Block	0.9976	2	0.4989	2.12	3.32
T	65.9412	7	9.4200	40.08*	2.34
N	8.3300	1	8.3300	35.44*	4.17
T x N	0.8900	7	0.1200	0.51	2.34
Error	7.0700	30	0.2350		

C.D. for comparison of T means = 0.5709
" " N means = 0.2851
" " TN means = 6.8074

*Significant at 0.05 level

APPENDIX XXVI

Analysis of variance table

(Effect of different fungicides, mineral nutrients and of nematicide on sheath blight intensity at the time of harvest)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	174.41	47			
Block	3.44	2	1.72	3.72	3.32
T	131.90	7	18.84	40.84*	2.34
N	23.28	1	23.28	50.46*	4.17
T x N	1.95	7	0.28	0.606	2.34
Error	13.84	30	0.46		

C.D. for comparing T means = 6.8010
" " N means = 0.4007
" " TN means = 1.1312

APPENDIX XXVII

Analysis of variance table
Angular transformation

(Effect of different fungicides, mineral nutrients and nematicide on per cent hill infection - ear head stage)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	2498.12	47			
Block	2.71	2	1.350	5.92	3.32
T	1999.68	7	285.670	125.11*	2.34
N	370.75	1	370.760	162.38*	4.17
T x N	56.47	7	8.067	3.53*	2.34
Error	68.49	30	2.280		

C.D. for comparing T means = 1.788
" " N means = 0.894
" " TN means = 2.530

*Significant at 0.05% level

APPENDIX XXVIII

Analysis of variance table
(Effect of different fungicides, mineral nutrients and nematicide on grain yield (kg/ha)

Source	S.S.	df	M.S.	F calculated	F at 0.0 level
Total	18051285.690	47			
Block	55676.001	2	27838.000	0.673	3.32
T	10044882.170	7	1434983.167	34.668*	2.34
N	4426483.286	1	426483.283	106.940*	4.17
T x N	2282510.334	7	326672.904	7.877*	2.34
Error	1241733.903	30	41391.130		

C.D. for comparing T means = 239.618
" " N means = 119.810
" " TN means = 338.874

*Significant at 0.05 level

APPENDIX XXIX

Analysis of variance table - Square root transformation
(Effect of different fungicides, mineral nutrients, nematicide on effective tiller production)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	1.630	47			
Block	0.051	2	0.025	1.461	3.32
T	0.678	7	0.097	5.670*	2.34
N	0.237	1	0.237	13.850*	4.17
T x N	0.153	7	0.022	1.284	2.34
Error	0.512	30	1.707		

C.D. for comparing T means = 0.155
" " N means = 0.077
" " TN means = 0.219

*Significant at 0.05 level

APPENDIX XXX

Analysis of variance table

(Effect of different fungicides, mineral nutrients and nematicide on plant height)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	1354.43	47			
Block	2.37	2	1.185	0.09	3.32
T	298.52	7	42.65	3.34*	2.34
N	472.51	1	472.51	37.0*	4.17
T x N	198.60	7	28.29	2.22	2.34
Error	383.03	30	12.77		

C.D. for comparison of T means = 4.231
" " N means = 2.114
" " TN means = 5.952

*Significant at 0.05 level

APPENDIX XXXI

Analysis of variance table

(Effect of different fungicides, mineral nutrients and nematicide on grains per panicle)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	89.245	47			
Block	5.172	2	2.586	2.370	3.32
T	19.908	7	2.844	2.612*	2.34
N	10.828	1	10.828	9.945*	4.17
T x N	20.672	7	2.953	2.745	2.34
Error	32.660	30	1.038		

C.D. for comparison of T means = 0.1216
" " N means = 0.6080
" " TN means = 1.7200

*Significant at 0.05 level

APPENDIX XXXII

Analysis of variance table

(Effect of different fungicides, mineral nutrients and nematicide on grain weight)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	522.84	47			
Block	1.96	2	0.98	0.64	3.32
T	427.08	7	61.01	39.88*	2.34
N	35.36	1	35.36	23.12*	4.17
T x N	12.57	7	1.80	1.17	2.34
Error	45.89	30	1.53		

C.D. for comparison of T means = 1.442
" " N means = 0.721
" " TN means = 2.639

*Significant at 0.05 level

APPENDIX XXXIII

Analysis of variance table
Square root transformation

(Effect of different fungicides, mineral nutrients and nematicide on nematode population in soil (100 g) before harvest of the crop)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	465.003	47			
Block	3.780	2	1.890	0.505	3.32
T	42.485	7	6.069	1.621	2.34
N	293.609	1	293.609	78.440*	4.17
T x N	3.840	7	0.548	0.146	2.34
Error	112.286	30	3.742		

C.D. for comparison of T means = 2.2562
" " N means = 1.1281
" " TN means = 3.1908

*Significant at 0.05 level

APPENDIX XXXIV

Analysis of variance table - Square root transformation
(Effect of different fungicides, nematicides and mineral nutrients on root population of nematodes in 10 g root)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	83.835	47			
Block	2.440	2	1.22	2.28	3.32
T	2.660	7	0.38	0.38	2.34
N	61.590	1	61.59	115.28*	4.17
T x N	1.120	7	0.16	2.99*	2.34
Error	16.020	30	0.53		

C.D. for comparison of T means = 0.865
" " N means = 0.432
" " TN means = 1.223

*Significant at 0.05 level

APPENDIX XXXV

Analysis of variance table - Square root transformation

Effect of different fungicides, mineral nutrients and nematicide on R. solani propagules in soil (30 g soil/plot)

Source	S.S.	df	M.S.	F calculated	F at 0.05 level
Total	23.058	47			
Block	0.210	2	0.1052	2.278	3.32
T	20.251	7	2.8930	62.649*	2.34
N	0.881	1	0.8812	19.080*	4.17
T x N	0.329	7	4.7050	1.019	2.34
Error	1.385	30	0.0460		

C.D. for comparison of T means = 0.2506
" " N means = 0.1253
" " TN means = 0.3544

*Significant at 0.05 level

ROLE OF THE RICE ROOT NEMATODE (HIRSCHMANNIELLA ORYZAE) IN THE INCIDENCE OF SHEATH BLIGHT DISEASE OF RICE IN KERALA

BY

GOKULAPALAN C.

ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILMENT OF

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KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT PATHOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, TRIVANDRUM

1981

ABSTRACT

Rhizoctonia solani, causing sheath blight of rice was found to infect a number of common weeds and crops raised in rice fallows in Kerala. The fungus was found to produce leaf and stem blight in groundnut plants. This is the first report of this fungus causing aerial blight symptoms in adult groundnut plants. On Sesbania aculeata (daincha), the fungus produced severe collar rot, this being the first record of this fungus on this crop in India. The occurrence of R. solani under natural conditions on the weeds, Aplida aristata and Monochoria vaginalis are reported for the first time.

R. solani isolates from rice, daincha and groundnut were found to be morphologically similar while the sesamum isolate differed slightly. Anastomosis studies revealed that isolates of R. solani from rice, daincha and groundnut were genetically related while the sesamum isolate was genetically different. The isolates from rice, daincha and groundnut could cross infect their respective host plants while the sesamum isolate failed to infect rice, daincha or groundnut.

All the ten rice varieties tested were found to be susceptible to sheath blight disease and the rice root nematode. A higher nematode population was noticed in the roots of plants severely affected by sheath blight of each variety when compared with that in healthy plant roots.

Pot culture experiments involving R. solani and varying levels of the rice root nematode inoculum revealed a possible role of the rice root nematode in rendering the rice plants more susceptible to the sheath blight disease. High nematode populations (1000 nematodes/5 l soil) along with sheath inoculation of the fungus was found to produce maximum intensity of sheath blight.

Of the four nematicides tested in the laboratory, SMDC (Vapam) was found to inhibit sclerotial germination of R. solani at all the three concentrations tried. Carbofuran (Furadan), Fensulfothion (Dasanit) and Aldicarb (Temik) caused significant reduction in radial growth and sclerotial formation at the highest concentration of 120 ppm.

Field evaluation of fungicides, mineral nutrients and nematicides revealed that combined application of fungicides Vitavax (0.1%) or Fycop(0.4%) along with the nematicide Carbofuran (Furadan 3 G @ 50 kg/ha) significantly reduced the disease intensity and nematode infestation and considerably increased the grain yield. The fungicides, Vitavax and Fycop were found to be highly effective in reducing disease intensity followed by Hinosan. The possibility of the combined application of fungicides and nematicides to control the sheath blight disease in nematode infested tracts is indicated.

Of the several fungi screened for their antagonism against R. solani in culture, Trichoderma viride and

Aspergillus niger were found to exhibit maximum antagonism followed by Aspergillus flavus and Rhizopus sp. The bacterial isolates B1 and B4 isolated from sclerotia of R. solani exhibited strong antagonism against the sheath blight fungus in culture. Sclerotial germination of the fungus was inhibited after immersion in a suspension of the bacterial isolates B1 & B4 for ten days. The feasibility of using these antagonistic microorganisms against R. solani under field conditions needs further investigations.