SURVIVAL OF *RHIZOCTONIA SOLANI* KÜHN WITH SPECIAL REFERENCE TO ANTAGONISTIC SOIL MICROFLORA

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Survival of *Rhizoctonia solani* Kühn with special reference to antagonistic soil microflora" is a bona fide 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.

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College of Agriculture,
Vellayani, 25.4.1989

CERTIFICATE

Certified that this thesis entitled "Survival of *Rhizoctonia solani* Kühn with special reference to antagonistic soil microflora" is a record of research work done independently by Smt. G. Padmakumary, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to her.

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INTRODUCTION

1. INTRODUCTION

Sheath blight disease of rice incited by Rhizoctonia solani Kühn (Thanatephorus cucumeris) (Frank) Donk is one of the major diseases of rice. Its occurrence has been reported from many countries, in the East, South east and South Asia, South and North America and Africa (Ou, 1972).

The reduction in grain yield due to the severity of this disease has been estimated to vary from 5.2 to 50.0 per cent (Ou, 1972; Kannaiyan and Prasad, 1976).

R. solani is a soil inhabiting pathogenic root infecting fungus which has a wide host range. The extent and ability of soil-borne plant pathogens to survive saprophytically in the absence of their hosts depend on their competitive saprophytic ability. Competitive saprophytic ability of microorganisms in relation to biological control of diseases caused by soil-borne pathogens has been discussed by Garrett (1965) and Park (1965).

Management of diseases caused by soil-borne plant pathogens is much more complex than that of diseases caused by air-borne plant pathogens. The use of chemicals for the control of diseases caused by soil-borne plant pathogens poses many practical difficulties due to their predominantly subterranean habit. Along with the efforts to overcome

these difficulties, biological control of soil-borne plant pathogens has recently received renewed attention throughout the world. The interest in this method of control draws momentum from the growing public concern regarding the widespread use of hazardous chemicals for pest and disease control (Mulder, 1979).

Biological control of phytopathogenic fungi has been suggested as an alternative to chemical control (Cook, 1977; Deacon, 1976). The most commonly attempted method of achieving biological control of plant diseases is by modification of soil environment through organic amendments (Stover, 1962; Huber and Watson, 1970).

Another method of achieving biological control is the incorporation of selected antagonists to the soil and to establish them in the rhizosphere of crop plants. The application of chemicals in the soil influences the activity of many kinds of soil microorganisms. Hence a proper understanding of the effect of common plant protection chemicals on the sheath blight pathogen and on the antagonistic microorganisms is essential to make a judicious selection of the chemicals to control the pathogen.

Considering the above facts, experiments on the following aspects were carried out during the course of the present studies.

Determination of the ability of R. solani to colonise crop stubbles in competition with other soil microorganisms and their comparative ability to survive.

Assessment of the effect of various ecological and agronomical factors on the duration of survival of R. solani.

Isolation of microorganisms antagonistic to R. solani from soils of different regions of Kerala.

Determination of the various conditions favourable for the multiplication of antagonistic organisms.

Comparison of the antagonistic ability of different microorganisms against R. solani.

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REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1. Competitive saprophytic ability

Competitive saprophytic ability is the summation of physiological characteristics that make for success in competitive colonization of dead organic substrates (Garrett, 1950). Competitive saprophytic ability of a fungus in soil would depend not only on growth rate, production of antibiotics, toxins or antibiotics produced by other microorganisms, but also on other micro determinants of soil ecosystem including number and variety of antagonists exploiting a substrate (Garrett, 1956).

Sclerotia constitute the main means of survival of *Rhizoctonia solani* and they may survive for several months (Palo, 1926). They fall on the ground before harvest of the crop and infect the subsequent crop, in the following season (Ikata and Hitoni, 1930).

Park and Bertus (1932) from Sri Lanka tested the survival of sclerotia under various conditions and reported that at room temperature, on dry or moist soil the sclerotia survived for at least 130 days and for 224 days when submerged under three inches of water. They also found that the sclerotia began to loose their viability after exposure to direct sunlight for 183 hours during a period of 34 days

and were killed by 204 hours of exposure. The availability of susceptible host plant is more important for survival in soil than that of dead or living roots of non susceptible hosts. R. solani disappeared from heavily infested soil in less than four months in the absence of susceptible crops, but survived up to eight months in soils planted with susceptible crops (Sanford, 1952). Valdez (1955) reported that the mycelium of R. solani remained viable for more than a month in pieces of leaf sheath and in soil, and sclerotia for nine months in laboratory and six months in the field. Papavizas and Davey (1961) found that the saprophytic survival of R. solani decreased with prolonged incubation, but the fungus was recoverable from the colonized substrates even after 120 days in soil.

Soil temperature, moisture, organic matter, nutrient content and type of soil microflora are some of the factors which influence the survival ability of soil fungi (Menzies, 1963). Some strains of R. solani grew vigorously for some time and colonized the organic particles of the soil, while some isolates which formed many sclerotia in soil also soon died out indicating that the sclerotia production is not necessarily related to survival (Baker et al. 1967). Papavizas (1969) studied the survival of root infecting fungi in soil, and found that the survival of R. solani (measured by colonization of organic substrates) and ability

to cause damping off of radish in sterilized and unsterilized soils declined after the addition of maize meal sand inoculum 0.3 per cent than at 1.25 or 2.5 per cent. Naiki and Ui (1972) and Kannaiyan and Prasad (1978) reported the survival of sclerotia of R. solani in soil for more than 360 days and 390 days respectively. Freeman (1973) found that sclerotia of an isolate of R. solani survived for 26 months when submerged in unsterilized lake water. Roy (1976) observed that the sclerotia of Corticium sasakii on non sterilized cowdung, rice straw, and soil remained viable up to nine months with a considerable decrease after seven months. Lakshmanan (1979) reported the viability of R. solani on rice straw up to 180 days. Shokes and McCarter (1979) found that R. solani in infested cotton stem sections were recoverable in decling numbers up to 96 days and as sclerotia up to 85 days from irrigation ponds. Mustafee and Chattopadhyay (1983) reported that survivability of Sclerotium rolfsii and Macrophomina phaseolina increased with the quantity of host tissues.

Temperature is an important factor which influences the viability of sclerotia and severity of infection. The severity of infection caused by Corticium sasakii differed even within the same temperature range, on different plants like rice, maize, bean and broad bean (Hashioka, 1948). Nisikado and Hirata (1937) studied the longevity of

sclerotia in steamed rice straw under controlled environmental conditions, and found that the sclerotia remained viable for three years, at or below 20°C, 26 months at 25°C, 16 months at 30°C and six months at 35°C. In sterilized water the sclerotia were viable for three years at room temperature of 25°C, 22 months at 10°C, 12-13 months at 30°C and less than one month at 35°C. Sengupta and Roy (1971) found that saprophytic activity of _S._ (_Corticium_) _rolfsii_ in unsterilized soil was maximum at 20-30°C and 20-24 per cent moisture holding capacity. Mahendra Prabhath _et al._ (1974) conducted studies on the viability of _C. sasakii_ and found that at room temperature (28-32°C) the viability of sclerotia was completely lost after 100 days, but at lower temperature of 10°C they remained viable for more than 300 days. But under submerged condition the viability lost within 60-90 days. Papavizas (1977) reported that 75 per cent of sclerotia of _Macrophomina phaseolina_ survived for one year in moist soils at 26°C. Colonisation of _R. solani_ was found to be higher in soil maintained at dry condition than at submerged condition regardless of the soil origins (Rosalis and Mew, 1982).

Ilyas _et al._ (1976) reported that under _in vitro_ condition benomyl, thiram, thiobendazole, and captan were effective in reducing the viability of sclerotia of _M. phaseolina_. Anilkumar and Gowda (1984) tried eight

fungicides to study their effect on the saprophytic survival of Sclerotium rolfsii and found that bayleton, sicarol, and Vitavax were highly effective as a dry mix and soil drench in reducing saprophytic activity.

2.2. Effect of agronomical and ecological factors on the survival of *R. solani*

2.2.1. Effect of organic amendments

During the recent years many plant pathologists have bestowed their attention to the ecology of soil-borne plant pathogens, in soil incorporated with organic amendments, with a view to have better understanding of the process of biological control of plant diseases caused by them. Garrett (1956) defined biological control of plant diseases as any condition under which or practice whereby survival or activity of a pathogen is reduced through the agency of any other living organism except man himself, with the result that there is a reduction in the incidence of the disease caused by the pathogen. As such biological control of soil-borne plant pathogens is mainly based on the assumption that suitable modification of soil with organic materials can stimulate the activity of soil microbial population which in turn can be antagonistic to a given pathogen. The role of organic amendments in the suppression of soil-borne plant pathogens has been amply

emphasised by Stover (1962), Griffin (1964), Huber and Watson (1970), Linderman (1970) and Babu George (1981).

Many important diseases caused by soil-borne plant pathogens like wilt of pan (*Piper betle*) caused by *Sclerotium rolfsii* (Chowdhury, 1946), black scurf of potato caused by *Rhizoctonia solani* (Singh, 1968), sheath blight of rice caused by *Rhizoctonia solani* (Kannaiyan and Prasad, 1981 a and 1983) and root rot of soybean caused by *Macrophomina phaseolina* (Narasimmalu and Bhaskaran, 1987) are reported to be controlled by soil amendments.

2.2.1.1. Saw dust

Application of saw dust as a soil amendment has been attempted by many workers (Wood, 1951; Shetty, 1964; Kender and Eggert, 1966). Increased yield after saw dust application has been reported by Salmon (1953), and Hornsby and Phillips (1965). Toxicity of saw dust to germination (Newton, 1953; Waddington *et al.*, 1967) and plant growth (Hughes, 1949; Allison, 1965) is also reported. Mitchell and Alexander (1962) found an increase in the fungal population after the application of saw dust. But Smith and Ashworth (1965) observed a reduction in the population of soil saprophytes, viz., bacteria, and actinomycetes as a result of amending the soil with rice hull and saw dust.

Basu chaudhary (1967) after applying rye meal, corn meal, oat meal and wood shavings to the soil at the rate of 20 g/kg of soil found a gradual reduction in the development of scab of potato caused by Streptomyces scabies, but Latham and Watson (1967) failed to control onion root rot caused by Fusarium, Rhizoctonia and Pythium by the application of saw dust in soil. A reduction in black scurf of potatoes (R. solani) by the application of saw dust and fertilizers was reported by Singh (1968).

Khanna (1970) noticed a reduction in the population of fungi, bacteria and actinomycetes in saw dust amended soils, especially during summer. According to Gautam and Kolte (1979), saw dust was very effective in controlling wilt of sunflower caused by Sclerotium rolfsii. Krishnamoorthy and Bhaskaran (1987) while studying the effect of Farmyard manure, neem cake, saw dust, and fresh tamarind leaves for the control of damping off of tomatoes caused by Pythium indicum found that maximum seedling emergence was observed in neem cake amended plots followed by plots amended by saw dust. Further they found maximum population of Trichoderma viride and other soil microorganisms in the saw dust treated plots.

2.2.1.2. Oil cakes

Many attempts have been made to control plant diseases

by amending the soil with oil cakes. Singh (1968) and Singh *et al.* (1972) tried mustard (*Brassica juncea* L.), castor (*Ricinus communis* L.), margosa (*Azadirachta indica* A. Juss.), mahuva (*Bassia latifolia* Roxb.) and pea nut (*Arachis hypogaea* L.), oil cakes as soil amendments, against *R. solani*. The best control of the disease was noticed in mustard cake amended soil while mahuva cake enhanced the disease. Rajan and Menon (1975) reported that soil amended with punna cake, eluppa cake and rubber seed cake reduced the intensity of sheath blight of rice caused by *Corticium sasakii*. Rajan (1980) tried oil cakes of neem, marotti, rubber seed and punna against sheath blight disease of rice and observed that the intensity of the disease has been reduced in amended plots. Non edible oil cakes like mahuva cake, marotti cake, neem cake and punna cake were found to reduce significantly the intensity as well as incidence of sheath blight of rice caused by *R. solani*, punna cake, being the most effective (Rajan and Alexander, 1987). Further, stimulation of total fungal and bacterial population was also observed by them in rice plots amended with punna cake.

Mustard oil cake when applied to soil has been found to reduce the incidence of wilt of pan (*Piper betle*) caused by *Sclerotium rolfsii* (Chowdhury, 1946). Kauraw (1970)

obtained varying degrees of control of *Helminthosporium sativum*, *S. rolfsii* and *Fusarium* sp. when castor, margosa and groundnut cakes were used. Further, he observed that oil cake amendments caused increase in the population of fungi and actinomycetes, while a decrease in bacterial population during early stages of decomposition of the oil cakes in the rhizosphere of pea and pigeon pea. Wajidkhan *et al.* (1974) observed that application of ammonium sulphate and oil cakes of neem, groundnut and castor increased total population of fungi in the rhizosphere of egg plant, but adversely affected the pathogenic fungi such as *Colletotrichum* sp., *R. solani* and *Fusarium* sp. Gautam and Kolte (1979) observed that oil cakes of castor and neem reduced the root rot of sunflower caused by *Sclerotium rolfsii*. According to Narendra Singh and Singh (1983) soil amendments enhanced the activity of *Fusarium udum* and many other soil microflora. Narasimmalu and Bhaskaran (1987) while conducting studies on the control of root rot of soybean caused by *Macrophomina phaseolina* using neem leaves, saw dust, compost, and neem cake, found that the disease was reduced by neem cake applied at the rate of five tonnes per hectare. Further, they observed that neem cake treatment caused more increased population of fungi than the other organic amendments and control.

2.2.1.3. Crop residues

A substantial quantity of crop residue is annually incorporated to the field soil in normal cropping practices. The chemical nature and quantity of these residues vary according to crop rotation, and other cultural practices followed. The role of crop residues in controlling diseases has been explained by many workers. Blair (1943) observed that in the absence of a susceptible host both wheat straw and dried grass suppressed the growth of *R. solani* in fertile soil. In such a soil rapid assimilation of nitrogen and excessive carbon dioxide evolution by the cellulose decomposing microflora resulted in starvation and apparent inhibition of *Rhizoctonia* spp. Rouatt and Lochhead (1955) used residues of six species of crop plants as soil amendments and found not much changes in the bacterial population. Davey and Papavizas (1960) used dry residues of soybean, corn and oat as amendments and found an increase in the population of actinomycetes. A two fold increase in actinomycetes population was observed by Papavizas (1963) when cellulose powder, oat straw and soybean straw enriched with ammonium nitrate were used as soil amendments. Latham and Watson (1967) used 25 different types of leaves as soil amendments to control root rot of onion, caused by *Pythium* sp., *Fusarium* sp. and *Rhizoctonia* sp. and found that in the

amended soil these pathogens did not increase in proportion to other fungi. Loshakov and Gusev (1976) observed a slight reduction in the intensity of black scurf of potatoes caused by *R. solani* by the application of straw alone or in combination with mineral fertilizers. Swardt *et al.* (1978) observed a reduction in the saprophytic activity of *Rhizoctonia solani* in plots incorporated with crop residues of oat, wheat, lucerne, maize, cotton and soybean. Hakeem and Ghaffar (1977) obtained a reduction in the number of sclerotia of *Macrophomina phaseolina* in soil amended with wheat straw after a gap of 40 days.

2.2.1.4. Green manures

Green manuring has been demonstrated by several workers as a means of controlling diseases caused by soil-borne pathogens. Lochhead and Landerkin (1949) noticed an increased population of actinomycetes in the rhizosphere of potato grown in soil green manured with soybean. Naumann (1960) observed that green manuring with rape increased the number of soil bacteria, but the population of actinomycetes remained unchanged.

Papavizas and Davey (1960) reported successful control of *Rhizoctonia* disease of snap beans by green manuring. They also reported reduced prevalence of *R. solani* in amended soils. A reduction in the incidence of

Streptomyces scabies and R. solani in potatoes by green manuring was observed by Loshakov and Gusev (1976). They reported that in plots wherein mineral fertilizers and green manure were combined the tuber yield was 24 per cent more than that in plots with fertilizers alone. They suggested that the reduction in the disease intensity and increase in yield may be due to the development of soil microorganisms antagonistic to S. scabies and R. solani. Lakshmanan (1979) observed that addition of green leaves to the paddy fields has got beneficial influence in reducing the viability of sclerotia of R. solani. This study revealed that among the different green manures tried, neem leaves was more effective. Kannaiyan and Prasad (1981 a) studied the effect of green manures like glyricidia, neem, ipomoea, sesbania, daincha, sunnhemp, kolunchi, and croton on the saprophytic survival of R. solani in soil and found that all the green manures tested have significantly reduced the saprophytic activity of rice sheath blight pathogen as compared to control. Rajan and Alexander (1987) observed that the pots in which soils amended with glyricidia leaves had least incidence and intensity of sheath blight of rice as compared to untreated control. They also found that in amended pots the population of soil saprophytes viz., fungi, bacteria and actinomycetes increased.

2.2.1.5. Rice husk and coconut pith

Smith and Ashworth (1965) reported that when rice husk and oat straw were used as amendments the bacterial and actinomycetes population increased for 105 days and the population of R. solani was depressed. But Gautam and Kolte (1979) did not observe any consistent reduction in Sclerotium rolfsii of sunflower as a result of amending the soil with rice husk.

Coconut pith, incorporated alone or in combination with NPK has been found to reduce the intensity of sheath blight disease of rice (Rajan and Menon, 1975; Rajan, 1980).

2.2.2. Effect of fertilizers

There are encouraging reports stating that the application of inorganic fertilizers alters the survival of certain soil borne plant pathogens.

Miles and Thomas (1925) conducted investigations on the effect of varying quantities of nitrogen, potash, as well as balanced fertilizers, on the percentage of infection of potato by late blight caused by Phytophthora infestans and other diseases caused by R. solani and Colletotrichum tubifium and found that application of nitrogenous manure up to 3.5 cwt had no effect on disease incidence, but an excess quantity over this favours disease. Further trials

on this line showed that increased application of potash reduced the diseases.

Weinhold *et al.* (1969) found that when *R. solani* was grown on different media before being inoculated on cotton hypocotyls a direct relationship was observed between the C and N concentration in the medium and survival of the pathogens. Nelson (1970) studied the effect of NH_4Cl and NH_4Co_3 on the survival of *Poria weirii* in the field as well as in the laboratory and it was observed that survival was not significantly correlated with quantitative or qualitative levels of fungi or aerobic actinomycetes. They found that *P. weirii* survived for six months in only one of the 60 pots with either form of nitrogen whereas it was in 14 pots in the case of unfertilized soil. Kannaiyan and Prasad (1973) found that the soil amended with Potassium chloride suppressed the survival of musk melon wilt fungus. They also suggested that the depressing effect of potassium might be due to an increase in the number of antagonistic microorganisms. Shanmugam (1975) and Alagappan (1976) reported that soils amended with potassium chloride, potassium sulphate and potassium nitrate inhibited the survival of *R. bataticola*. Kannaiyan and Prasad (1981 b) found that K and PK have significantly reduced the survival of *R. solani*, and the soil treated with K reduced the survival period also to a considerable period compared to control. Huber and

Watson (1974) found that the population of soil pathogens like *Fusarium*, *Rhizoctonia* and *Aphanomyces* decreased by NO_3^--N and increased by NH_4^+-N.

Dahlsson (1975) reported that infection by *R. solani* is favoured by the application of heavy nitrogen. Mariappan and Viswanathan (1986) found that higher levels of N, viz. 120 and 240 kg/ha increased the disease incidence to 54.5 per cent and 63.3 per cent as against 45 and 80 kg/ha and higher levels of K recorded least percentage of disease index of 26.7 compared to 67.2 at 40 kg K/ha. They also found that sawdust applied along with NPK recorded least disease incidence of 35.5 per cent as against 73 per cent in untreated control.

Balakrishnan and Nair (1985) found that application of slow release nitrogen by utilising neem coated urea and an enhanced rate of potash application were found to have profound effect in reducing the severity of sheath blight and sheath rot of rice.

Gokulapalan *et al*. (1986) reported that the application of carbofuran at 1 kg ai/ha along with fungicide carboxin and 50 per cent more of K reduced the severity of sheath blight of rice and enhanced grain yield.

2.3. Antagonism of soil microorganisms

2.3.1. Antagonism of fungi

There are several reports on the presence of micro-organisms in soil antagonistic to plant pathogens (Weindling, 1932; 1934; Vlassova, 1940; Jaarsveld, 1942; Tisdale and Foster, 1948; Wood, 1951; Sanford, 1952). Among them there are many references on the fungal antagonism against *R. solani*. Weindling (1934) reported that *Aspergillus niger*, *Penicillium* spp., and *Fusarium lateritum* were parasitic on *R. solani*. The antagonistic activities of different species of *Aspergillus* has been observed by many scientists from different parts of the world. Important among them are *Aspergillus niger*, *A. parasiticus*, *A. tamari*, *A. terreus*, *A. flavus*, *A. fumigatus*, *A. buchensis* (Endo, 1935; Vasudeva and Sikka, 1941; Naim and El-Esawy, 1985; Roy, 1984; Gupta *et al.*, 1985).

Naim and El-Esawy (1965) suggested that biological control of *R. solani* might best be achieved by applying *A. terreus* at a soil temperature of 35°C and at a pH of 4 or less. Neweigy *et al.* (1982) stated that two species of *Aspergillus* and three species of *Trichoderma* were most effective against some pathogens attacking the faba bean cultivars, namely *Fusarium solani*, *Rhizoctonia solani* and *Sclerotium rolfsii*. Venkatasubbaiah and Safceulla (1984)

demonstrated that under glass house and field conditions seed treatment with Aspergillus niger reduced the incidence of collar rot of coffee seedlings.

Chaetomium spp. have been found to show antagonism against R. solani. Chaetomium globosum and C. cochlioides, C. gracile and an unidentified Chaetomium sp. were the species which showed significant antagonistic activity (Tveit and Moore, 1954; Harman et al., 1980; Sezgin et al., 1982; Jose Joseph and Susamma Philip, 1987).

Fusarium solani also has been reported to have antagonistic activities against R. solani (Yen et al., 1957; Lulu Das, 1986).

The role of Penicillium spp. in inhibiting the growth of R. solani was demonstrated by various workers. Boosalis (1956) reported parasitism of R. solani in unsterilized pea field by Penicillium vermiculatum Dong and exhibited internal parasitic mycelium in hyphae of R. solani by means of penetration pegs arising from hyphae in contact with host mycelium or from mycelium coiling around host hyphae.

According to Newhook (1957) Penicillium spp. gave complete control of tomato infected with Botrytis cinerea. Many species of Penicillium including Penicillium clavariaforme Bain, P. patulum, P. cyclopium Weslling, P. nigricans (Baon)

Thom and *P. oxalicum* Currie & Thom were also reported to have antagonistic activities against *R. solani*. (Wood, 1951; Chu and Wu, 1981; Chand and Logan, 1984; Gupta *et al*., 1985; Lulu Das, 1986).

Arjunan *et al*. (1987) found that *Penicillium* sp. was antagonistic to *Macrophomina phaseolina* causing root rot in pigeon pea.

Endo *et al*. (1973) observed the reduced incidence of *Corticium sasakii* the causal agent of sheath blight of rice by *Neurospora crassa* Shear and Dodge.

Among the many potentially antagonistic soil micro-organisms members of the genus *Trichoderma* have gained considerable importance. There are many reports on the effective application of *Trichoderma* spp. for the control of disease caused by *R. solani*. Weindling (1932) observed that damping off of citrus seedlings caused by *R. solani* can be reduced by inoculating *Trichoderma* spp. He suggested that this is due to the decreased activity of *R. solani* caused by the increased antagonistic activities of *Trichoderma* spp. Hino and Endo (1940) observed that *Trichoderma viride* Pers ex S.F. Gray can parasitise and destroy the sclerotia and mycelia of *Corticium solani* and *Sclerotinia sclerotiorum*. The antagonistic activity of *Trichoderma lignorum* on *Aspergillus niger*, *Macrophomina phaseoli* and *Corticium solani*

was reported by Vasudeva and Sikka (1941). They found that the hyphae of the pathogen undergo lysis on coming into contact with those of the antagonists.

Tisdale and Foster (1948) from a green house test observed that Trichoderma sp. can reduce the pathogenicity of R. solani. Evans and Gottlieb (1952) found that damping off of pea caused by R. solani was controlled in sterile and non sterile soil containing T. viride. The antagonistic effect of T. lignorum (T. viride) has been reported from different parts of the world (Jaarsveld, 1942; Fedorinchick, 1951; Josifovic, 1967; Naiki and Ui, 1972; Ferrera-Cerrato, 1976; Rosales and Mew, 1982; Mukhopadhyay, 1987).

Dennis and Webster (1971) recorded effective inhibition of mycelial growth, vacuolation of hyphae of R. solani by isolates of different species of Trichoderma. Infection of Phaseolus lunatus and pea was found to be reduced effectively when T. viride was either added to soil or inoculated into seedlings and roots prior to inoculation with R. solani (Mall, 1975). In vivo and in vitro study conducted by Sadowski (1970) showed that T. viride inhibited the development of R. solani on soils rich in humus.

Roy (1977) showed that when T. viride was incorporated in sterilized soil together with C. sasakii, sheath

blight of rice was slightly reduced. Hadar *et al.* (1979) reported that an isolate of *T. harzianum* effectively controlled damping off of bean, tomato and egg plant caused by *R. solani*. Elad *et al.* (1981) tested a wheat bran culture of *T. harzianum* against *R. solani* on cardamom fields infected by *R. solani* and a linear correlation was observed between the rate of application and degree of disease control. Bell *et al.* (1982) compared the *in vitro* interaction between seven isolates of *T. harzianum* and several pathogenic fungi and noted the one between *T. harzianum* and *R. solani* to be the most evident. The antagonistic action between *T. harzianum* and *R. solani* was also reported by Rosales and Mew (1982) and Lulu Das (1986).

Manian and Paulsamy (1987) reported that *T. aureoviride* was highly antagonistic to *R. solani* and found that its culture filtrate antagonised the mycelial growth and sclerotial initiation in *R. solani*. During the investigations on susceptibility of rice sheath blight pathogen (*R. solani*) to mycoparasites, Manibhushanrao *et al.* (1987) found that *Gliocladium virens* and *T. longibrachiatum* isolated from paddy fields of Kerala and Tamil Nadu were antagonistic to *R. solani*.

2.3.2. Antagonism of bacteria

A number of species of bacteria are reported to be

antagonistic to R. solani and many attempts have been made to use them for the control of diseases caused by this pathogen. Hino (1935) found that Bacterium lactis was antagonistic to R. solani. There are many reports on the antagonistic action of Bacillus subtilis on R. solani (Michener and Snell, 1949; Wood, 1951; Dunleavy, 1952; Lily et al., 1952; Vasudeva and Chakravarthy, 1954). Olsen (1965) found that B. subtilis survived at temperature of 140°-160°F and even 212°F for 30 minutes and was highly inhibitory to R. solani in culture. The Bacillus spp. usually used for biological control of root pathogens increased plant growth also (Broadbent et al., 1971; Merriman et al., 1974). Utkhede and Rahe (1979) studied the effect of four isolates of B. subtilis for the control of white rot of onion caused by Sclerotium cepivorum Berk. and observed that an isolate of B. subtilis provided significant and season long protection against white rot. Howell and Stipanovic (1979) found that a strain of Pseudomonas fluorescens was highly antagonistic to R. solani. They also reported that sclerotium formation by R. solani was reduced by B. subtilis. Neweigy et al. (1981) found that out of 93 bacterial isolates from rhizosphere of broadbeans infected by R. solani 20 were antagonistic. B. subtilis, B. badicus and B. cereus were reported to significantly enhance chlamydospore formation when sprayed on actively growing agar cultures of F. udum

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(Narendra Singh and Singh, 1983). The use of B. subtilis for the biological control of wilt pathogens has been reported by Podile and Dube (1985) and Podile et al. (1985). In a study conducted by Jharia and Khare (1986) it was found that two isolates of Bacillus spp. and three isolates of B. subtilis were highly antagonistic to R. solani in vitro and in vivo. Mew and Rosales (1986) found that when sclerotia of R. solani treated with suspension of non fluorescent and fluorescent bacteria and allowed to infect rice plants at tillering stage, the disease incidence was reduced compared with plants infected with sclerotia soaked in sterile distilled water. They also reported that the incidence of sheath blight was lower when the seeds were treated or the plants sprayed with bacterial suspension.

2.3.3. Antagonism between soil fungi

Kamoen (1960) reported that Chaetomium globosum was highly antagonistic to Aspergillus niger and Trichoderma viride. Chohan (1970) found that T. viride and Streptomyces sp. were highly antagonistic to A. niger.

Wu (1977) showed that A. clavatus reduced the growth of F. culmorum and R. solani. The inhibitory effect of T. viride against other fungi was reported by many workers. For example, Ferrera-Cerrato (1976) found that T. viride

parasitized on Rhizopus stolonifer and R. solani. Dohroo and Sharma (1984) reported its antagonism against Fusarium equiseti and Neweigy et al. (1982) and Kusum Mathur et al. (1988) observed its antagonism against F. solani.

Zakhi Alli (1980) observed that Aspergillus sp., Penicillium sp. and Trichoderma sp. were antagonistic to F. solani, and F. oxysporum. Lakshmi Ramakrishnan and Jeyarajan (1987) also found that the growth of F. solani was significantly inhibited by Aspergillus sp., Trichoderma sp., A. sydowii and T. viride. The antagonistic activity of Gliocladium virens, A. sulphinus and A. flavus against Penicillium patulum, Aspergillus sp., A. terreus and Chaetomium sp. was reported by Sezgin et al. (1982). Vajna (1983) observed the mutual parasitism between Trichoderma hamatum and T. pseudokoningi in a dual culture.

Raghunathan (1987) reported that the growth of A. flavus was inhibited by A. niger, A. sydowii and T. viride.

2.3.4. Antagonism between soil fungi and bacteria

There are a number of reports regarding the inhibitory effect of different bacteria against various fungi and bacteria. B. subtilis was antagonistic to Gliocladium virens (Lily et al., 1952), B. macerans to Fusarium roseum (Park, 1956), B. subtilis to Penicillium sp. (Cubeta et al., 1985).

B. subtilis to F. oxysporum f. sp. lycopersici and Rhizopus nigricans, (Podile and Dube, 1987) and to F. oxysporum f. sp. Udum and Fusarium sp. (Khot et al., 1988).

The antagonistic action of Pseudomonas spp. against fungi causing plant diseases was reported by Smith (1967) and that of Pseudomonas and Alcaligenes by Yuen et al. (1985).

Hubard et al. (1982) found that the treatment of squash bean with ascospores of Chaetomium globosum suppressed the growth of Pseudomonas sp.

2.3.5. Antagonism of actinomycetes

There are a number of actinomycetes which are reported to be antagonistic to R. solani. Among them the most striking effects shown by Streptomyces spp. and Actinomyces diasticus (Katz, 1953), Actinomycetes spp. (Yen et al., 1957) and S. griseus, S. hygrocopicus var. geldanus and S. noursci (Rothrock and Gottlieb, 1981). Rothrock and Gottlieb (1984) showed that R. solani was inhibited by Geldamycin, an antibiotic produced by S. hygrocopicus on nutrient media. Stimulation of Streptomyces spp. in the rhizosphere of wheat has been found to inhibit the growth of R. solani and S. rolfsii (Mohammed, 1985).

Ramakrishnan and Jeyarajan (1987) reported the antagonistic activities of *Streptomyces* spp. to *R. solani*. During the studies conducted by Arjunan *et al.* (1987) on the effects of organic amendments on *Macrophomina* root rot in pigeon pea, it was observed that *Streptomyces* spp. found in the amendment applied plots were antagonistic to the pathogen.

2.4. Effect of fungicides, insecticides and herbicides on *R. solani* and antagonistic organism

2.4.1. Effect of fungicides

The fungicidal control of sheath blight of rice has been attempted by different workers all over the world (Rosen, 1924; Hashioka and Saito, 1953; Hashioka, 1952; Kozaka, 1961). Sinclair (1960) reported that isolates of *R. solani* differed in their sensitivity to captan, PCNB and dichlone. Captan was effective against *R. solani* even at 100 ppm (Sen and Kapoor, 1975). But the studies conducted by Muneera (1973) and Mathai (1975) showed that captan and Dithane M-45 were most effective against *R. solani*. Sinha and Khare (1977) showed that captan and Difolatan at 3000 ppm were effective for controlling *Macrophomina phaseolina* and *Fusarium equiseti* on cowpea. Roy (1981) found that spraying with captafol and guazatine was less effective in reducing the incidence of sheath blight of rice

than other chemicals like carbendazim and edifenphos. Dash and Panda (1984) reported that captafol and carboxin at 200 ppm each were effective against the sheath blight pathogen *in vitro*.

Ashworth *et al.* (1964) found that for the control of *Aspergillus niger* associated with groundnut, captan and thiram (0.3 per cent) were very effective. Frank (1969) conducted laboratory and field trials and proved that three parts of 75 per cent captan + 1 part of 75 per cent PCNB at 3 g/kg seed gave effective control of *Aspergillus* and *Rhizopus* rot of groundnut seedlings. Harper (1964) showed that seed treatment with captan (0.2 per cent) controlled *Fusarium* sp. in peas. While studying the control of seed microflora on vegetables, Naseema (1981) found that captan was effective in controlling *R. stolonifer*, *Penicillium* sp. and *A. flavus* followed by Difolatan and Dithane M-45 was effective in checking the growth of *A. flavus*.

Agnihotri (1971) stated that the population of *Rhizoctonia* sp. and *Pythium* sp. was killed by the application of captan while the growth of saprophytic species of *Penicillium*, *Trichoderma* and *Fusarium* increased. Bacteria increased by the seventh day and subsequently declined to normal by the 38th day. Wainwright and Sowden (1977) found that the proportions of fungi and bacteria were selectively

increased by treatment with captan, benomyl and thiram.

Among four systemics and sixteen non systemics tested by using poisoned food technique, Sen and Kapoor (1975) reported that Bavistin, Dithane M-45, BAS 3050 F, Benlate, captan and R.H. 893 were effective against R. solani even at 100 ppm. Kataria and Grover (1977) observed the inhibitory effect of Bavistin on the mycelial growth of R. solani in Czapeks agar plates. Kannaiyan and Prasad (1979) stated that Bavistin, Kitazin, Hinosan, Benlate, Demosan and thiabendazole gave significant disease control against rice sheath blight. Kar and Narain (1986) found that carbendazim (0.15 per cent) was very effective in inhibiting the growth of A. niger, Sclerotium rolfsii and Fusarium sp. The inhibitory effect of Bavistin of 10 and 25 ppm on Fusarium sp. was also reported by Ghosh and Singh (1981). Delen and Yildiz (1982) found that out of the four isolates of R. solani, only one could grow on agar media containing 1.5 mg/ml carbendazim. Complete inhibition of mycelial growth of sheath blight pathogen in vitro by carbendazim, thiram, edifenphos and kitazin has been reported (Dash and Panda, 1984).

Borum and Sinclair (1968) while conducting studies on the effect of Vitavax against R. solani found that Vitavax was fungitoxic to R. solani at 1 ppm in vitro. Follen and

Diallo (1971) by screening eight fungicides against three fungi reported that Vitavax, Damosan and Benlate were most effective against R. solani. The effectiveness of Vitavax in inhibiting the growth of R. solani has been observed by many workers (Datta and Sharma, 1976; Jagan Mohan, 1977; Lakshmanan et al., 1980; Gokulapalan, 1981). Khanna and Chandra (1976) observed that Benlate was effective for the control of A. niger. Vidhyasekaran (1987) showed that carboxin and benomyl (0.1 per cent) inhibited the growth of F. oxysporum.

The superiority of Hinosan over other fungicides in controlling sheath blight of rice caused by R. solani has been observed by several workers (Mahendra Prabhath, 1971; Muneera, 1973; Yamaguchi, 1974; Mathai, 1975; Mukherjee, 1978; Rajan et al., 1979). But Varma and Menon (1977) reported that Hinosan was not as effective as Kitazin granules and Aureofungin Sol in reducing the disease intensity. Lakshmanan (1979) found that Hinosan was effective in reducing the disease intensity and per cent hill infection. Gokulapalan (1981) observed that Hinosan was effective but ranked third in efficiency in controlling the sheath blight pathogen. It was found that Hinosan at 100 ppm and above was very effective in inhibiting the growth of R. solani (Lulu Das, 1986).

Hashioka (1952) stated that spraying the field with Dithane Z-78 or Bordeaux mixture of Uspulun (Chlorophenyl mercury) at 0.5 per cent did not control *Hypochnus* (*Corticium*) *sasakii*. According to Hashioka and Saito (1953) zineb + Phygon was intermediate in efficiency while Copper dust and $CuSO_4$ were almost ineffective even at maximum concentrations tested against *R. solani*. Elsaid and Sinclair (1963) reported that *R. solani* from seedling cotton became tolerant to PCNB, captan, dichlone, maneb and thiram after seven serial transfers, on potato sucrose agar containing these fungicides. Tandon *et al*. (1976) found that treatment with Dithane M-45 gave 83 per cent control of *Fusarium semitectum*.

2.4.2. Effect of insecticides

There are reports on the efficacy of certain insecticides on diseases caused by *R. solani*.

Simkover and Shenefelt (1951) in their laboratory tests observed that crude BHC dust greatly inhibited mycelial growth of *R. solani* on agar slants. *In vitro* studies conducted with Sevin showed that at 125 ppm and 50 ppm it reduced the growth of *R. solani* (Hacskayle and Stewart, 1962; Naguib, 1968). Yamaguchi (1974) observed that Lebaycid was effective as dust than as granule formulation against sheath blight of rice. Tisserat *et al*. (1977) reported that linear growth of

R. solani was reduced on PDA amended with aldicarb. Lakshmanan and Nair (1980) conducted studies on the in vitro toxicity of granular insecticides against R. solani isolated from rice and observed that Sevidol (1000 ppm and 2000 ppm) and Thimet (2000 ppm) were highly inhibitory to the fungal growth and sclerotial formation. Lulu Das (1986) found that carbaryl (1000 ppm) was the most effective insecticide followed by BHC and malathion each at 750 ppm in inhibiting the radial growth of R. solani.

Bollen et al. (1954) found that BHC and DDT depressed fungal counts in several soil types. Under laboratory conditions they showed that BHC was more effective in quantitative and qualitative microbial response at 1000 ppm.

The fungitoxic properties of Thimet have also been reported by Erwin and Reynolds (1958). Naumann (1960) reported that parathion is rapidly decomposed by bacteria in soil and stimulated the increase in various physiological groups. Also he observed that even concentration of 0.05 per cent, significantly increased total bacterial count.

Swaminathan and Sullia (1969) showed that malathion influences the bacterial and actinomycetes population of the rhizosphere of groundnut, but ineffective on the fungal populations. In general, lower dosages of carbamate and organophosphorus insecticides enhance the actinomycete population. Stimulatory effects on actinomycetes have been

observed with insecticides like Temik, phorate, carbofuran, disulfoton, malathion, diazinon etc. (Sethunathan and Mac Rae, 1969; Swaminathan and Sullia, 1969; Mathur et al., 1976; Kandaswamy et al., 1975).

Roy et al. (1975) stated that treatments of rice soil with diazinon, carbofuran and endosulphan drastically reduced bacteria and actinomycetes population while carbofuran and endosulphan alone reduced fungal population drastically. According to Tu and Miles (1976) species of Bacillus, Pseudomonas and Streptomyces were inhibited by several chlorinated hydrocarbons and organophosphorus insecticides. Mathur et al. (1976) also found that application of carbofuran resulted in about 100 to 300 per cent increase in bacterial and actinomycetes population.

Purushothaman et al. (1976) found no inhibitory effect on the fungal and actinomycete population of rice field by the addition of carbofuran, diazinon, carbaryl + Lindane, quinalphos and Dursban.

2.4.3. Effect of herbicides

There are many reports on the effect of herbicides on soil-borne plant pathogens. Those groups of microbes which can use the herbicides applied in soil as food will increase in population, and those microbes for which herbicides proved to be toxic will decrease in number (Altman and

Campbell, 1977). Kurodani et al. (1959) found that the pathogenicity of Hypochnus (Corticium) sasakii on rice was increased by spraying with 2,4-D which also increased the size and number of spots found on plants. 2,4-D at 1000 ppm reduced the growth of R. solani by 80 per cent (Millikan and Fields, 1964). Tatsuyama and Jikihara (1970) found that 2,4-D, M.C.P.A. and simazine encouraged the development of aerial hyphae of R. solani. Sridhar et al. (1976) tried several herbicides in rice, in which benthiocarb treated plots recorded better weed control and least phytotoxicity and maximum yield. Varma et al. (1978) recorded that Avirosan 50 EC, Saturn, 50 EC, Machete 50 EC, and Rilof H 500 EC were highly inhibitory to the growth of Corticium sasakii. Dath and Swain (1979) studied the in vitro effect of butachlor, nitrofen and propanil at 25, 50, 100, 250 and 500 ppm on radial growth of R. solani and found that the growth of the fungus was completely suppressed at all concentrations of propanil followed by nitrofen and concluded that propanil and nitrofen have potentiality of suppressing the growth of sheath blight pathogen. Verma et al. (1979) pointed out that fluchloralin had no effect on R. bataticola but reduced the radial growth of mycelia of Fusarium oxysporum f. ciceri (padwick) Subran and Sclerotium rolfsii Sacc. Lakshmanan and Nair (1980) showed that 2,4-D did not inhibit the growth of R. solani but increased the number and size of sclerotia. They also found that Tok and Saturn at 125 ppm

significantly reduced the growth of R. solani. Lakshmi (1984) reported that only higher concentrations of pendimethalin (250 ppm) was effective in the inhibition of sclerotia formation of R. solani. It was also observed from field studies that grain yield in rice was increased in treatments with nitrofen 1.75 kg ai/ha and bentazone 1.5 kg ai/ha than that of control. Pendimethalin, dinitramine and butealin at 100 g/ml reduced mycelial growth of Fusarium oxysporum f. sp. vasinfectum, R. solani and Sclerotium rolfsii (Youssef et al., 1985). Tripathi and Vyas (1986) showed that collar rot of cowpea caused by Rhizoctonia bataticola was more in the fluchloralin amended pots as compared to that caused by Sclerotium rolfsii. Lulu Das (1986) from in vitro study found that bentazone at 1000 ppm was most effective in inhibiting the mycelial growth of R. solani followed by thiobencarb, butachlor, fluchloralin, nitrofen and 2,4-D sodium salt each at 1000 ppm. Under field condition it was found that propanil was the most effective herbicide followed by thiobencarb, pendimethalin and bentazone in reducing the intensity and incidence of sheath blight.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1. Isolation of the pathogen

Rhizoctonia solani Kühn causing sheath blight of rice was isolated from naturally infected rice plants collected from the Instructional Farm, College of Agriculture, Vellayani. For isolation of the pathogen, portions of the sheath showing fresh typical symptoms were cut into small bits, surface sterilized with 0.1 per cent mercuric chloride solution for one minute and washed in three changes of sterile distilled water. They were then plated on potato dextrose agar medium (PDA) in sterile petri dishes and incubated at room temperature (28±2°C). On the second day the fungal growth from the infected tissue was transferred to PDA slants. The isolate was purified by the hyphal tip method. The organism was maintained on PDA slants by subculturing periodically. This pure culture of the fungus was used throughout the study.

3.2. Estimation of competitive saprophytic ability of *R. solani*

Colonization of *R. solani* on rice straw in competition with other microorganisms in the soils of dry land and wet land paddy fields of Vellayani was assessed to determine the competitive saprophytic ability by the Cambridge method (Garrett, 1950).

3.2.1. Using the culture of R. solani in maize meal sand medium as inoculum

R. solani was grown for two weeks on sterilized maize meal sand medium. This medium was prepared in 1000 ml conical flasks each containing 95 g sand, 5 g maize meal and 35 ml distilled water. A series of dilutions 100:0 (T_1), 90:10 (T_2), 50:50 (T_3), 10:90 (T_4) and 0:100 (T_5) of the pure culture of the fungus with unsterilized soil (both dry and wet land) were made. Each inoculum dilution was filled in six 1000 ml conical flasks. In each flask 50 sterilized rice straw bits (2.5 cm long) were buried. In one set of three flasks inoculum and soil with the straw bits were maintained under dry condition and in another set of three flasks they were kept under submerged condition by pouring 250 ml water in each flask. This was done in the case of both dry land and wet land soils. All the flasks were kept under laboratory conditions at room temperature. After one month of incubation the infected straw bits were picked out from the conical flasks and washed with tap water to remove the adhering soil particles. They were then surface sterilized with 0.1 per cent mercuric chloride solution for one minute and washed with three changes of sterile distilled water. The percentage of straw bits colonized by the fungus was assessed by plating the surface sterilized straw bits on plain agar, and examined for the growth of the organism.

The pathogenicity of the colonized straw bits was assessed by inoculating them on paddy seedlings (Variety Triveni) at tillering stage, by placing the straw bits within the outer leaf sheath.

3.2.2. Using sclerotia of R. solani as inoculum

In this experiment sclerotia of R. solani were used as inoculum instead of the culture of the fungus on maize meal sand medium in the previous experiment. In each conical flask 300 g of the soil was taken. Approximately uniform sized sclerotia obtained from 15-day-old culture of R. solani on PDA were used as the inoculum. Mixture of soil and different numbers of sclerotia (100, 75, 50, 25 and 0) were taken in the conical flasks. Other details were the same as in the previous experiment.

3.3. Influence of moisture and soil type on saprophytic survival of R. solani in dry and wet land soils

3.3.1. In sterilized soil

Straw bits (2.5 cm in length) from rice plants (Variety - Triveni) were kept in 250 ml conical flasks and sterilized by autoclaving at 120°C for one hour. Each conical flask contained 100 straw bits. These straw bits were then inoculated with mycelial fragments of R. solani and incubated for two weeks at room temperature (28$\pm$2°C).

Soil samples were collected from dry land and wet land paddy fields of the Instructional Farm, College of Agriculture, Vellayani. Two sets of six conical flasks (1000 ml) each, were used in the experiment. In one set 300 g of dry land paddy field soil was taken in each conical flask and in the other set 300 g of wet land paddy field soil was taken. These soil samples were also autoclaved at 120°C for one hour. In the soil in each conical flask fifty inoculated straw bits were buried. The soil in one set of three flasks containing sterilized dry land paddy soil was kept under submerged condition by pouring 300 ml of sterilized water and that in the other set was kept in dry condition. Similarly the soil in one set of three flasks containing sterilized wet land paddy soil was kept under submerged condition and that in the other set under dry condition. All the flasks were kept at room temperature (28±2°C) throughout the period of experiment. Samples of straw bits were taken at fortnightly intervals for 16 weeks, and plated on plain agar, for assessing the saprophytic survival, on the basis of colonization of the straw bits by *R. solani*.

3.3.2. In unsterilized soil

In this experiment also sterilized straw bits inoculated with mycelial fragments of *R. solani* and incubated for two weeks at room temperature (28±2°C) were buried in lots of 50

in 300 g each of unsterilized soil, from wet land and dry land paddy fields, taken in 1000 ml conical flasks. The soil in one set of three flasks for each soil type was maintained under submerged condition and the other under dry condition.

Except the use of unsterilized soil, all the other details of this experiment were as in the previous one.

3.4. Effect of agronomical and ecological factors on the survival of *R. solani*

3.4.1. Effect of organic amendments

A pot experiment to find out the effect of organic amendments on the soil microbial population and survival of *R. solani* was laid out with the following treatments.

T_1 - Control
T_2 - Glyricidia leaves (*Glyricidia maculata* Stoud.)
T_3 - Clerodendron leaves (*Clerodendron indicum* L.)
T_4 - Eupatorium leaves (*Eupatorium odoratum* L.)
T_5 - Saw dust
T_6 - Coconut pith (*Cocos nucifera* L.)
T_7 - Neem cake (*Azadirachta indica* A. Juss.)
T_8 - Groundnut cake (*Arachis hypogaea* L.)
T_9 - Punna cake (*Callophyllum inophyllum* L.)
T_{10} - Fish waste

T_{11} - Paddy husk (Oryza sativa L.)

T_{12} - Groundnut shell (Arachis hypogaea L.)

Design - C.R.D.

Replication - 3

Total treatment combinations - 36

Earthen pots of 22 cm diameter were filled with 8 kg of soil collected from wet land paddy fields of Vellayani. The amendments were thoroughly incorporated in each pot at the rate of 19 g/pot. Green leaves were used in treatments where leaves were used as amendments. Rice straw bits (2.5 cm in length) of variety Triveni inoculated by keeping in the culture of R. solani in maize meal sand medium were buried in the soil at a depth of 7.5 cm at the rate of 200 numbers per pot. Two weeks after incorporation of amendments and inoculum, 20-day-old rice seedlings of variety 'Triveni' were transplanted in the pots at the rate of four hills per pot. The plants were maintained as per package of practice recommendations of Kerala Agricultural University (1986).

3.4.1.1. Variation in soil microbial population

Soil samples were collected at six stages from all the pots starting from before the incorporation of amendments, at fortnightly intervals, corresponding to before planting, tillering stage, maximum tillering stage, boot

leaf stage and two weeks before harvest for the estimation of microbial population. Martin's medium (Martin, 1950) (peptone dextrose agar with rose bengal and streptomycin) soil extract agar (Allen, 1957) and Kuster and William's medium (Kuster and Williams, 1964) were used for selective isolation of fungi, bacteria and actinomycetes from these soil samples (Appendix I).

The soil dilution plating (Timonin, 1940) was done for the isolation. From the soil samples collected, one g each was placed in 250 ml conical flasks containing 99 ml of sterile distilled water and the flasks were shaken by a mechanical shaker for 20 minutes. One ml of the suspension was pipetted from each flask while swirling and transferred to 99 ml of sterile water in 250 ml conical flasks. This dilution of 10^4 was used for estimating the population of fungi. After thorough shaking of the above dilution in a mechanical shaker for 20 minutes one ml was transferred to 99 ml of sterile water blank making the dilution of the suspension to 10^6 and used for estimating bacteria and actinomycetes. One ml of final dilution was transferred into sterile petri dish using sterile pipette. About 15 ml of the required medium, melted and cooled to 45°C, was dispensed into the petri dishes and rotated to ensure uniform spread of the suspension in the medium. Three replications were kept for each group of microorganism. The plates were then incubated at room temperature and quantitative estimation of microorganisms was made. Observations on fungi,

bacteria and actinomycetes were recorded after five, four and ten days, respectively, after plating.

3.4.1.2. Survival of *R. solani*

The straw bits were removed from each of the above treatment at different stages of growth of the crop starting from one month after the application of amendments. These were washed with several changes of distilled water, surface sterilized with 0.1 per cent mercuric chloride solution for one minute, washed well in sterile distilled water and plated in petri dishes containing plain agar. The development of *R. solani* was examined and the percentage of survival recorded.

3.4.1.3. Incidence and intensity of sheath blight

The incidence and intensity of sheath blight were recorded at maximum tillering stage and two weeks before harvest. Disease incidence was estimated by observing all the hills in each pot and recorded as percentage. The intensity (disease index) of the disease was assessed by scoring all the hills according to Standard Evaluation System for Rice Diseases (International Rice Research Institute, 1976) as follows.

Grade	Description
0	No incidence
1	Lesions limited to lower 1/4 of leaf sheath area

3	Lesions present in lower 1/2 of leaf sheath area
5	Lesions present on more than 1/2 of leaf sheath area. Slight infection on lower (3rd or 4th) leaves
7	Lesions present on more than 3/4 of leaf sheath. Severe infection on lower leaves and slight infection on upper leaves (flag and 2nd leaf)
9	Lesions reaching top of tillers, severe infection on all leaves and some plants killed

Disease index (DI) was calculated using the following formula

$$\text{Disease index} = \frac{\text{Sum of individual ratings} \times 100}{\text{Number of hills observed} \times 9}$$

Rice in each pot was harvested separately and the yield of grains was recorded after drying.

3.5. Laboratory trial on the effect of organic amendments on the survival of sclerotia of *R. solani*

A laboratory study was conducted to find out the effect of organic amendments on the survival of sclerotia of the sheath blight pathogen.

Design - C.R.D.
Treatments - 12
Replications - 3

Treatments

T_1 - Control

T_2 - Glyricidia leaves (Glyricidia maculata Steud.)

T_3 - Clerodendron leaves (Clerodendron indicum L.)

T_4 - Eupatorium leaves (Eupatorium odoratum L.)

T_5 - Saw dust

T_6 - Coconut pith (Cocos nucifera L.)

T_7 - Neem cake (Azadirachta indica A. Juss.)

T_8 - Groundnut cake (Arachis hypogaea L.)

T_9 - Punna cake (Callophyllum inophyllum L.)

T_{10} - Fish waste

T_{11} - Paddy husk (Oryza sativa L.)

T_{12} - Groundnut shell (Arachis hypogaea L.)

Soil collected from wet land paddy fields of the Instructional Farm, College of Agriculture, Vellayani was air dried and powdered. This soil was taken in 140 mm petri dishes at the rate of 100 g per petri dish. Green manures and oil cakes were added to the soil at the rate of 1 g for 100 g soil (equivalent to the field dose of 25 quintals/ha). All the other amendments were added at the rate of 4.33 g for 100 g soil (equivalent to the field dose of 10 tonnes/ha). Soil without any amendment was kept as the control. There were three replications for each treatment. Uniform sized sclerotia from 15-day-old PDA culture of R. solani were used

for the study at the rate of 150 sclerotia per petri dish. The sclerotia were embedded in the soil so that they were in complete contact with the soil. The petri dishes were incubated at room temperature. The moisture content of the soil was maintained at saturation level by adding sterile water periodically. The percentage of viable sclerotia in each treatment was assessed at monthly intervals for 12 months by plating the sclerotia on PDA. Ten sclerotia were taken from each petri dish. One month after incubation the qualitative and quantitative estimation of microorganisms in soil were done as per the method described under 3.4.1.1.

3.6. Effect of NPK fertilizers on the survival of *R. solani*

A pot experiment was conducted to study the effect of NPK fertilizers on the survival of *R. solani*.

Design - C.R.D.

Replication - 3

Treatments - 8

Treatments

T_1 - $N_0P_0K_0$ (control)
T_2 - $N_0P_0K_1$
T_3 - $N_0P_1K_0$
T_4 - $N_0P_1K_1$
T_5 - $N_1P_0K_0$
T_6 - $N_1P_0K_1$
T_7 - $N_1P_1K_0$
T_8 - $N_1P_1K_1$

N_0 - no nitrogen

N_1 - 70 kg N per hectare

P_0 - no phosphorus

P_1 - 35 kg P_2O_5 per hectare

K_0 - no potash

K_1 - 35 kg K_2O per hectare

Pots (22 cm diameter) were filled with soil collected from wet land paddy fields of Vellayani. The fertilizers at 70:35:35, N:P:K kg/ha were added to the pots as per the recommended level for short duration variety of rice (Kerala Agricultural University, 1982). Nitrogen was applied as ammonium sulphate (20 per cent N), phosphorus as superphosphate (16 per cent P_2O_5) and potassium as muriate of potash (60 per cent K_2O). A 15-day-old culture of R. solani grown on maize meal sand medium was added to the pots at 25 per cent (W/W) inoculum level. The soil was maintained in a semidry condition by maintaining 50 per cent moisture level. Soil samples were collected at 20 days interval for 400 days and the population of R. solani was determined by soil dilution plate method (Timonin, 1940) using selective medium for R. solani (Ko and Hora, 1971). The colonies were counted after four days of incubation.

3.7. Influence of soil moisture, temperature and pH on the survival of R. solani

The effect of soil moisture, temperature, and pH on

the survival of R. solani in the inoculum-soil mixture was studied in the laboratory.

3.7.1. Preparation of soil-inoculum mixture

Cambridge method (Garrett, 1963) was followed for the experiment. R. solani was grown for two weeks in sterilized maize meal sand medium. This medium was prepared in 1000 ml conical flasks, each containing 95 g sand, 5 g maize meal and 35 ml distilled water. A series of dilutions: 100:0 (I_1), 98:2 (I_2), 90:10 (I_3), 50:50 (I_4), 10:90 (I_5), 2:98 (I_6), 0:100 (I_7) of the pure culture of the fungus with field soil (w/w) (soil collected from the fields of Instructional Farm, Vellayani) were used for this study.

Survival of R. solani was estimated as follows. Each dilution was taken in a 1000 ml conical flask. Three replications were maintained for each treatment. Thirty straw bits (2.5 cm) in length) buried in each flask were incubated at room temperature. After one month of incubation the straw bits were picked out and washed with tap water to remove the adhering soil particles. They were then surface sterilized with 0.1 per cent mercuric chloride solution and washed well in sterile distilled water. The percentage of straw bits colonized by the fungus was assessed by plating the surface sterilized straw bits on plain agar.

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3.7.2. Soil moisture

Moisture of the soil-inoculum mixture at 10 (m_1), 15 (m_2), 25 (m_3), 35 (m_4) and 40 (m_5) per cent (oven dry basis) was maintained by the addition of sterile distilled water to the inoculum soil mixture.

3.7.3. Soil temperature

The temperature of the soil-inoculum mixture was maintained at 10±2°C (t_1), 15±2°C (t_2), 20±2°C (t_3), 30±2°C (t_4), and 40±2°C (t_5) by keeping it in a BOD incubator.

3.7.4. Soil pH

The reaction of the soil-inoculum mixture was maintained at pH values of 4(p_1), 5 (p_2), 6 (p_3), 7 (p_4) and 9 (p_5) by the addition of required volume of N/10 HCl for pH 4 to 6 and N/10 NaOH for pH 7 to 9.

3.8. Isolation of microorganisms from paddy fields of different parts of Kerala and testing their antagonism against *R. solani*.

3.8.1. Isolation of microorganisms

Isolation of microorganisms present in the soil samples collected from the following paddy growing areas of Kerala was carried out.

(a) Instructional Farm, College of Agriculture, Vellayani.

(b) Cropping Systems Research Centre, Karamana.

(c) Rice Research Station, Moncompu.

(d) Rice Research Station, Mannuthy.

(e) Rice Research Station, Pattambi.

The fungi, bacteria, and actinomycetes from the above soil samples were isolated by following the soil dilution and plate counts (Timonin, 1940) described under 3.4.1.1.

As soon as the growth appeared in the plates, the fungal colonies were transferred to potato-dextrose agar slants and the bacteria and actinomycetes to nutrient agar slants. The isolates of fungi, bacteria and actinomycetes were purified and maintained by periodical subculturing. Identity of fungi was confirmed from the Commonwealth Mycological Institute, Kew, Surrey, England and from Centre for Advanced Study in Botany, Madras.

The bacterial and actinomycete isolates were identified by the Microbiology Division, College of Veterinary Science, Kerala Agricultural University, Mannuthy, Trichur.

3.8.2. Antagonism of fungi to *R. solani*

The antagonistic reactions between *R. solani* and the 30 species of fungi isolated in the above experiment were studied *in vitro* by dual culture technique.

The test fungi were grown individually with *R. solani* on PDA in sterile petri dishes. Each pair of fungi was inoculated by placing 5 mm diameter culture discs on the medium 3 cm apart and five replications were kept for each combination. Colony development was observed and assessment made of the interaction between the organisms when growth pattern became stable. Interaction types were assigned according to the method adopted by Purkayastha and Bhattacharya (1982). Interaction types were grouped into the following four categories.

A - Homogeneous (free intermingling of hyphae)

B - Over growth (*R. solani* over grown by test organism)

C - Cessation of growth at line of contact

D - Aversion (a clear zone of inhibition)

3.8.2.1. Interactions between fungi antagonistic to *R. solani*

The interactions, if any, in all the 91 combinations between the 14 species of fungi which showed significant antagonistic reactions with *R. solani* in the above experiment were also studied as under 3.8.2.

3.8.3. Antagonism of bacteria to *R. solani*

The eleven bacterial isolates from soils of different

regions were individually tested for their ability to inhibit the growth of *R. solani in vitro* by following the method described by Olsen and Baker (1968). Bacterial culture was streaked on one edge of a 90 mm petri dish, 3 cm away from the periphery and 5 mm diameter culture disc of *R. solani* was placed on the opposite side of the petri dish. The fungus - bacteria dual culture was replicated three times and incubated at room temperature. After three days of incubation, zones of inhibition were measured (in mm) from the edge of the growth of *R. solani* to the margin of each bacterial colony.

3.8.3.1. Interactions between bacteria antagonistic to *R. solani*

The interactions between the eight isolates of bacteria which showed antagonistic reactions with *R. solani* in the above experiment were studied following the method of Utkhede and Rahe (1983). The test organisms were streaked on either sides of 90 mm petri dishes containing nutrient agar medium. The paired cultures were examined after incubation at room temperature for 72 h and the type of interaction noted.

The bacterial isolates showing antagonistic action on *R. solani* in the *in vitro* tests were used for pot culture and field experiments to study their effect on the incidence

of sheath blight and on the survival of *R. solani*.

3.8.4. Interactions between fungi and bacteria antagonistic to *R. solani*

The interactions between 14 isolates of fungi and nine isolates of bacteria antagonistic to *R. solani* were studied following the method of Olsen and Baker (1968). The test bacteria were streaked on either sides of the centrally placed fungal culture disc of 5 mm diameter on PDA in 90 mm petri dishes. The paired cultures were examined after incubation at room temperature for 72 h and the type of interaction noted.

3.8.5. Antagonism of actinomycetes to *R. solani*

Five isolates of actinomycetes obtained from soils of different regions were individually tested for their ability to inhibit the growth of *R. solani* by following the method described under 3.8.3.

3.8.6. Effect of antagonistic bacteria on the survival of *R. solani*

Twenty uniform sized sclerotia of *R. solani* were kept in 10 ml of bacterial suspension at room temperature for different periods (ten minutes, one week, two weeks, four weeks and six weeks). Sclerotia kept in sterile distilled water served as control. The bacterial isolates for sclerotial

treatment were grown on nutrient agar medium for 24 h at room temperature. The bacterial suspension prepared were then diluted to a concentration of 1×10^8 colony forming units (cfu) per ml. The percentage of survival was assessed by plating the sclerotia recovered from bacterial suspension on PDA after surface sterilization. The details of the treatments are as follows.

Treatments : 9

Replication : 3

T_1. *Bacillus* sp.

T_2. *Bacillus subtilis*

T_3. *Rothia* sp.

T_4. *Chromobacterium* sp.

T_5. *Propionibacterium* sp.

T_6. *Pseudomonas* sp.

T_7. *Alcaligenes* sp.

T_8. *Corynebacterium* sp.

T_9. Control

3.8.6.1. Effect of antagonistic bacteria on sheath blight of rice caused by *R. solani*

Soils collected from paddy fields of Vellayani were sterilized and filled in 26 cm earthen pots. The fertilizers were incorporated according to package of practices recommendations (Kerala Agricultural University, 1986). Rice seedlings

(variety "Triveni") were planted in the pots at the rate of three hills per pot. At tillering stage the bacterial suspensions (1 x 10^8 cfu/ml) were sprayed on the rice plants at the sheath region and on the leaves. Sterile distilled water spray served as control. After this sclerotia of *R. solani* were inoculated on the sheath region. One week after inoculation the disease incidence and intensity were recorded. The details of the experiment were as follows.

Design : CRD

Treatments : 9

Replication : 3

T_1. *Bacillus* sp.

T_2. *Bacillus subtilis*

T_3. *Rothia* sp.

T_4. *Chromobacterium* sp.

T_5. *Propionibacterium* sp.

T_6. *Pseudomonas* sp.

T_7. *Alcaligenes* sp.

T_8. *Corynebacterium* sp.

T_9. Control

3.9. *In vitro* effect of plant protection chemicals on antagonistic fungi and *R. solani*

Eighteen plant protection chemicals were tested for their *in vitro* effect on antagonistic fungi and *R. solani*

3.9.1. Fungicides

Generic name	Trade name	Chemical name	*Concentration (ppm)	Treatment No.
1.Captafol	Difolatan	1,2,3,6 - tetrahydro-N-(1,1,2,2-tetrachloro ethylthio) phthalimide	2000	T_1
			3000	T_2
			4000	T_3
2.Carbendazim	Bavistin	Methyl benzimidazol-2-ylcarbamate	500	T_4
			1000	T_5
			2000	T_6
3.Carboxin	Vitavax	5,6-dihydro-2-methyl-1, 4-Oxathin-3-carboxanilide	500	T_7
			1000	T_8
			2000	T_9
4.Dithane M-45	Mancozeb	Manganese-zinc ethylene bis (dithiocarbamate)	3000	T_{10}
			4000	T_{11}
			5000	T_{12}
5.Edifenphos	Hinosan	O-ethyl S,S-diphenyl phosphorodithioate	500	T_{13}
			1000	T_{14}
			2000	T_{15}
6.Ziram	Cuman	Zinc dimethyl dithiocarbamate	3000	T_{16}
			4000	T_{17}
			5000	T_{18}

* Concentrations of the commercial product

3.9.2. Insecticides

Generic name	Trade name	Chemical name	Concentration (ppm)	Treatment No.
1. Carbaryl	Sevin 50 EC	1-naphthyl methyl carbamate	3500	T_1
			4000	T_2
			4500	T_3
2. Fenthion	Lebaycid 1000	O,O-dimethyl O-4-methylthio-m-tolyl phosphorothioate	500	T_4
			1000	T_5
			1500	T_6
3. Methyl parathion	Metacid 50 EC	O,O-dimethyl O-4-nitrophenyl phosphorothioate	500	T_7
			1000	T_8
			1500	T_9
4. Hexachloro hexane	HCH 10% D	1,2,3,4,5,6-hexachloro cyclohexane	1500	T_{10}
			2000	T_{11}
			2500	T_{12}
5. Carbofuran	Furadan 3 G	2,3-dihydro-2,2-dimethyl benzofuran-7-yl methyl carbamate	1000	T_{13}
			1500	T_{14}
			2000	T_{15}
6. Phorate	Thimet 10 G	O,O-diethyl S-ethylthiomethyl phosphoro dithioate	2000	T_{16}
			2500	T_{17}
			3000	T_{18}

3.9.3. Herbicides

Generic name	Trade name	Chemical name	Concentration (ppm)	Treatment No.
1. Bentazone	Basagran	3-isopropyl-2,1,3-benzothia diazin-4-one 2,2-dioxide	2500	T_1
			3000	T_2
			3500	T_3
2. Thiobencarb	Saturn	S-4-Chlorobenzyl diethyl thiocarbamate	2500	T_4
			3000	T_5
			3500	T_6
3. Nitrofen	Tok E25	2,4-dichlorophenyl-4-nitrophenyl ether	2000	T_7
			2500	T_8
			3000	T_9
4. Pendimathalin	Stomp	N(1-ethylpropyl)-2,6-dinitro-3,4-Xylidine	2000	T_{10}
			2500	T_{11}
			3000	T_{12}
5. Propanil	Stam F34	3',4'-dichloro propionanilide	3000	T_{13}
			3500	T_{14}
			4000	T_{15}
6. 2,4-D Sodium salt	Fernoxone	(2,4-dichloro-phenoxy) acetic acid	1500	T_{16}
			2000	T_{17}
			2500	T_{18}

The chemicals were tested against the following antagonistic fungi.

1. *Aspergillus flavus*
2. *Aspergillus niger*
3. *Chaetomium globosum*
4. *Fusarium semitectum*
5. *Fusarium solani*
6. *Gliocladium virens*
7. *Neurospora crassa*
8. *Penicillium citrinum*
9. *Penicillium oxalicum*
10. *Penicillium wortmanii*
11. *Rhizopus oryzae*
12. *Rhizoctonia solani*
13. *Rhizopus stolonifer*
14. *Trichoderma harzianum*
15. *Trichoderma viride*

Poisoned food technique of Zentmyer (1955) was employed for the study.

Stock solutions of the chemicals were prepared and the appropriate quantity of each was added separately to 50 ml of sterilized potato dextrose agar medium, so as to get the required concentrations of the chemicals. The

poisoned medium was dispensed in 90 mm sterile petri dishes at the rate of 15 ml per dish. After solidification, mycelial disc (5 mm diameter) from an actively growing culture of the respective fungus was cut out by a sterile cork borer and placed at the centre of each petri dish. Non poisoned PDA plates inoculated with mycelial discs served as control. Three replications were maintained for each treatment. The plates were incubated at room temperature. The colony diameter was measured in treatments when the fungal growth covered the plate in the control. The per cent inhibition over control was calculated by the following formula:

$$I = \frac{C-T}{C} \times 100$$

C = Radial growth in control

T = Radial growth in treatments

I = Per cent inhibition

3.10. Effect of antagonistic fungi and plant protection chemicals on survival of *R. solani* and intensity of sheath blight of rice

A pot culture experiment was laid out at the College of Agriculture, Vellayani to assess the effect of antagonistic fungi and plant protection chemicals, individually and in combination on the intensity of sheath blight disease of rice.

Design - Factorial CRD for factors A and B

Replications - 3

Treatments - 10 x 3 x 3

Factor A - Antagonistic fungi

Factor B - Fungicide, insecticide and herbicide

Factor A

A_1 - *Aspergillus niger*

A_2 - *A. flavus*

A_3 - *Fusarium semitectum*

A_4 - *F. solani*

A_5 - *Penicillium wortmanii*

A_6 - *P. citrinum*

A_7 - *Rhizopus stolonifer*

A_8 - *Trichoderma viride*

A_9 - *T. harzianum*

A_{10} - Control

Factor B

B_1 - Carboxin 0.05% spray

B_2 - Carbofuran 0.75 kg ai/ha

B_3 - Bentazone 1.75 kg ai/ha

B_4 - Control

3.10.1. Survival of *R. solani*

Pots of 26 cm diameter were filled with sterilized wet land soil. Antagonistic organisms grown in maize meal sand medium were incorporated into the soil at the rate of 100 g/pot. After one week 50 numbers of sheath blight infected rice sheath bits of variety 'Triveni' were buried in the soil. Twenty one day-old 'Triveni' seedlings were transplanted. Fertilizers were applied according to the Package of practice recommendations (Kerala Agricultural University, 1982). Fungicide, insecticide and herbicide treatments were given 20 days after transplanting. At maximum tillering stage the buried sheath bits were removed from the pots, washed, surface sterilized and plated on plain agar to assess per cent colonization.

3.10.2. Intensity of sheath blight

The intensity of sheath blight disease was recorded at maximum tillering stage.

3.11. Field evaluation of plant protection chemicals and antagonistic microorganisms on soil microflora and sheath blight of rice

Field experiments were laid out during the second crop season (Mundakan) of 1982-83 and first crop season (Virippu) of 1983-84 at the Cropping System Research Centre,

Karamana, Trivandrum, to study the effect of certain fungicides, insecticides, herbicides and antagonistic organisms on the incidence and intensity of sheath blight disease. The details of the experiment were as follows.

1. Design - 2^4 Factorial experiment in RBD
2. Replication - 4
3. Plot size - 4.0 m x 4.5 m
4. Spacing - 15 cm x 10 cm
5. Number of treatments - 17 (16+1)
6. Variety - Triveni

Factors: a_1 - Carboxin

a_2 - Edifenphos

b_1 - Bentazone

b_2 - Thiobencarb

c_1 - Carbofuran

c_2 - Phorate

d_1 - *Trichoderma viride*

d_2 - *Bacillus subtilis*

Treatment combinations

T_1	$a_1b_1c_1d_1$	T_5	$a_1b_2c_1d_1$
T_2	$a_1b_1c_1d_2$	T_6	$a_1b_2c_1d_2$
T_3	$a_1b_1c_2d_1$	T_7	$a_1b_2c_2d_1$
T_4	$a_1b_1c_2d_2$	T_8	$a_1b_2c_2d_2$

T_9	$a_2b_1c_1d_1$	T_{13}	$a_2b_2c_1d_1$
T_{10}	$a_2b_1c_1d_2$	T_{14}	$a_2b_2c_1d_2$
T_{11}	$a_2b_1c_2d_1$	T_{15}	$a_2b_2c_2d_1$
T_{12}	$a_2b_1c_2d_2$	T_{16}	$a_2b_2c_2d_2$
		T_{17}	$a_0b_0c_0d_0$ - Control

3.11.1. Nursery

The seedlings were raised in a wet nursery as per the Package of practice recommendations (Kerala Agricultural University, 1982).

3.11.2. Main field

The crop was raised following the Package of practices recommendations (Kerala Agricultural University, 1982). The fertilizer recommendations for the high yielding short duration rice varieties (70:35:35 NPK/ha) were followed. Nitrogen was applied in two equal doses, first half as basal dressing and second at active tillering stage. Full dose of P was applied as basal dressing at the time of field preparation. Potash was applied in two split doses, first half as basal dressing and second at panicle initiation stage.

3.11.2.1. Application of fungicides

The fungicides were sprayed at a concentration of

0.1 per cent (commercial product) during active tillering stage and at boot leaf stage so as to synchronise with the highly suspectible stages of growth (Kozaka, 1961; Mahendra Prabhath, 1971).

3.11.2.2. Application of insecticides

Carbofuran (Furadan) 0.75 kg ai/ha and phorate (Thimet) 1.25 kg ai/ha were applied on 15th day after transplanting.

3.11.2.3. Application of herbicides

Bentazone (Basagran) 1.75 kg ai/ha and thiobencarb (Saturn) 1.75 kg ai/ha were applied on 25th day after transplanting.

3.11.2.4. Application of antagonistic organisms

The spore suspension of *Trichoderma viride* (25 spores/microscopic field) and suspension of *Bacillus subtilis* (10^8 cfu/ml) were sprayed on the plants at the sheath region at the tillering stage.

3.11.2.5. Effect of treatments on soil microflora

Soil dilution plate count was done for the estimation of soil microflora at tillering stage (pre treatment), boot leaf stage and 10 days before harvest by the procedure

described under 3.4.1.1.

3.11.2.6. Incidence of sheath blight

Observations on the incidence of disease were recorded at tillering stage, boot leaf stage and 10 days before harvest. The disease incidence was recorded by selecting three rows at random from each plot and examining all the hills in the rows, leaving two hills in the border.

3.11.2.7. Disease intensity

The intensity of the disease was also recorded at tillering stage (pre treatment), boot leaf stage and 10 days before harvest from the random squares selected. The intensity was scored as per the 'Standard evaluation system for rice diseases' (International Rice Research Institute, 1976).

Score	Description
0	- No incidence of disease
1	- Lesions limited to lower 1/4th of leaf sheath area
3	- Lesions present in lower 1/2 of leaf sheath
5	- Lesions present on more than 1/2 of leaf sheath area, slight infection on lower (3rd or 4th) leaves
7	- Lesions present on more than 3/4 of leaf sheath. Severe infection on lower leaves and slight infection on upper leaves (flag and 2nd leaf)

9 - Lesions reaching top of the tillers, severe infection on all leaves and some plants killed

Disease index was calculated based on the following formula,

$$\frac{\text{Total numerical ratings} \times 100}{\text{Total number of hills observed} \times 9}$$

3.11.2.8. Harvest

The crop was harvested on 110th day. The dry weights of grain and straw were recorded.

RESULTS

4. RESULTS

4.1. Estimation of competitive saprophytic ability of *R. solani* in dry land soil

4.1.1. Using culture of *R. solani* as inoculum

In the case of dry land soil kept under dry condition, the percentage of colonization was found to decrease significantly with the decrease in the inoculum level, the values of T_1 and T_5 being 93.90 and 11.00, respectively. Under submerged condition also there was a general trend of decrease in the percentage of colonization, as the inoculum content decreased. But, the differences between T_1 (100:0) and T_2 (90:10) and T_3 (50:50) and T_4 (10:90) were not statistically significant (table 1).

The percentage infectivity of the colonized straw bits, when assessed by inoculating on paddy seedlings, was also found to show a decrease with the decrease in the percentage of colonization (table 1, fig. 1). In dry land soil at dry condition the percentage of infectivity decreased from 92.71 (T_1) to 21.30 (T_5) and at submerged condition the values were 81.65 and 2.51, respectively. The differences in the percentage of infectivity between all the treatments were statistically significant.

Table 1. Competitive saprophytic ability of *R. solani* in dry land soil (using culture)

Treatment	Inoculum: field soil	Dry		Submerged	
		Percentage of colonization	Percentage of infectivity	Percentage of colonization	Percentage of infectivity
T_1	100:0	93.90 (75.70)	92.71 (74.28)	66.80 (54.78)	81.65 (64.63)
T_2	90:10	82.00 (64.92)	80.90 (64.10)	60.40 (50.97)	71.00 (57.37)
T_3	50:50	66.80 (54.78)	61.40 (51.54)	45.00 (42.12)	56.85 (48.86)
T_4	10:90	36.60 (37.22)	24.60 (29.72)	36.60 (37.22)	26.00 (30.65)
T_5	0:100	11.00 (20.23)	21.30 (27.49)	5.20 (13.16)	2.51 (9.05)
CD (0.05)		5.31	6.12	5.36	6.31

Figures in parenthesis indicate transformed values

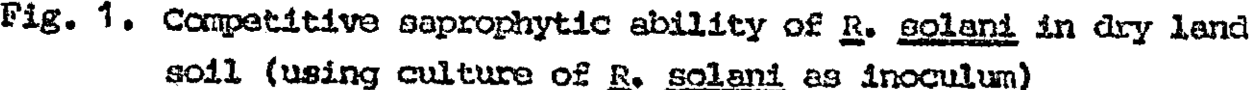


Fig. 1. Competitive saprophytic ability of R. solani in dry land soil (using culture of R. solani as inoculum)

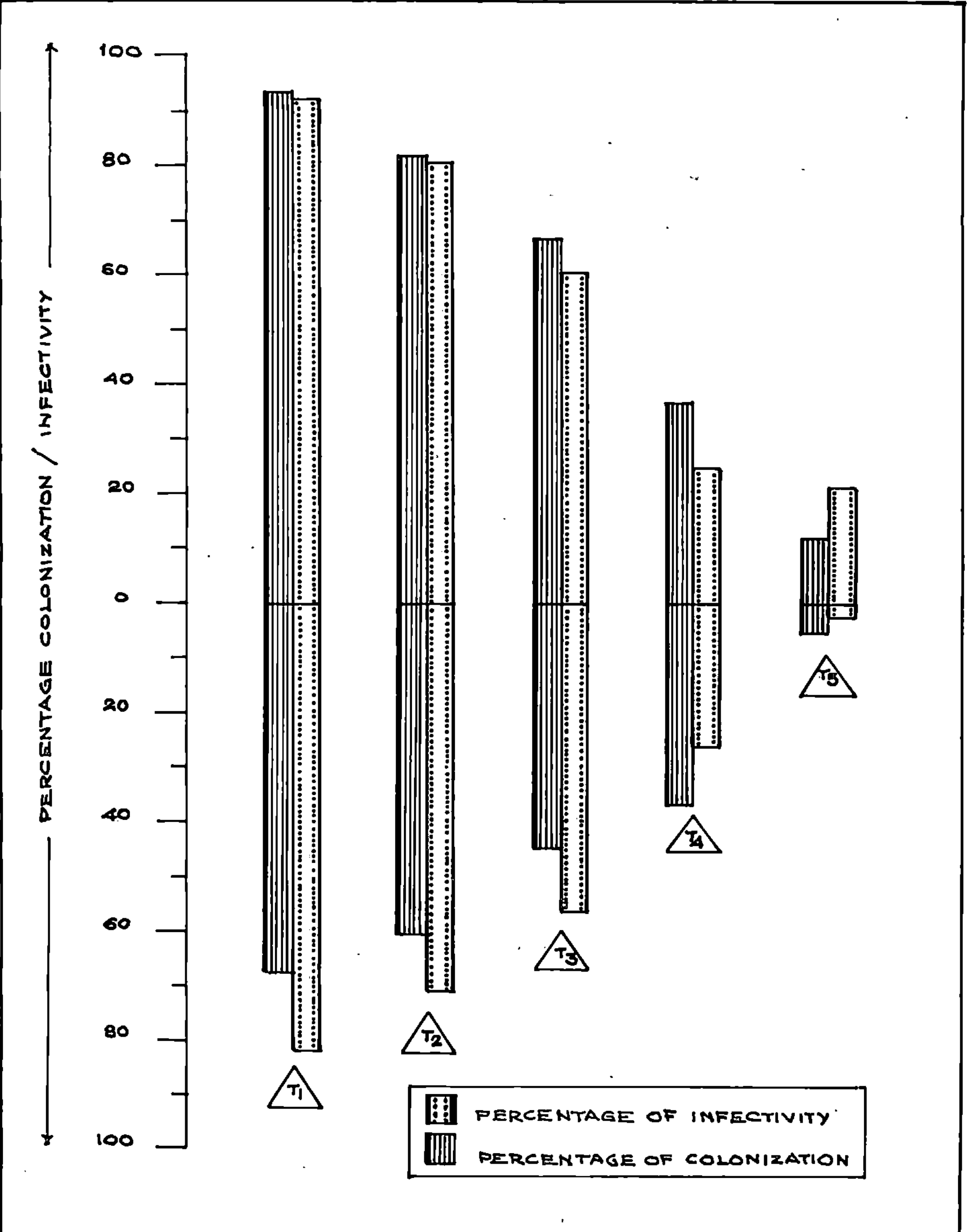


FIG: 1.

4.1.2. Using sclerotia of *R. solani* as inoculum

In dry land soil, kept under dry condition, the percentage of colonization was found to increase significantly with increase in inoculum ie. sclerotial numbers (table 2, fig. 2). The values of T_1 and T_5 being zero and 76.12, respectively. In dry land soil kept under submerged condition also there was a general trend of increase in percentage of colonization with an increase in inoculum content. The differences in the percentage of colonization between all the treatments were statistically significant.

The percentage of infectivity was also found to increase with increase in inoculum (sclerotial numbers) under dry condition. But under submerged condition there was no significant difference between T_1 and T_2. The percentages of infectivity in all the other treatments were significantly different.

4.2. Estimation of competitive saprophytic ability of *R. solani* in wet land soil

4.2.1. Using culture of *R. solani* as inoculum

In wet land soil also the percentage of colonization was found to decrease with the decrease in inoculum level under dry condition and also under submerged condition. Under dry condition, no significant difference in

Table 2. Competitive saprophytic ability of *R. solani* in dry land soil (using sclerotia)

Treatment	Number of sclerotia	Dry		Submerged	
		Percentage of colonization	Percentage of infectivity	Percentage of colonization	Percentage of infectivity
T_1	0	0	0	0	0
T_2	25	18.81 (25.72)	14.30 (22.23)	17.30 (24.57)	0
T_3	50	30.53 (33.49)	21.71 (27.73)	20.05 (26.56)	10.00 (18.38)
T_4	75	61.85 (51.75)	25.02 (29.99)	24.73 (29.78)	12.71 (20.85)
T_5	100	76.12 (60.68)	31.05 (33.83)	31.30 (34.04)	15.71 (23.31)
CD (0.05)		7.31	1.52	1.64	0.55

Figures in parenthesis indicate transformed values

Fig. 2. Competitive saprophytic ability of R. solani in dry land soil (using sclerotia of R. solani as inoculum)

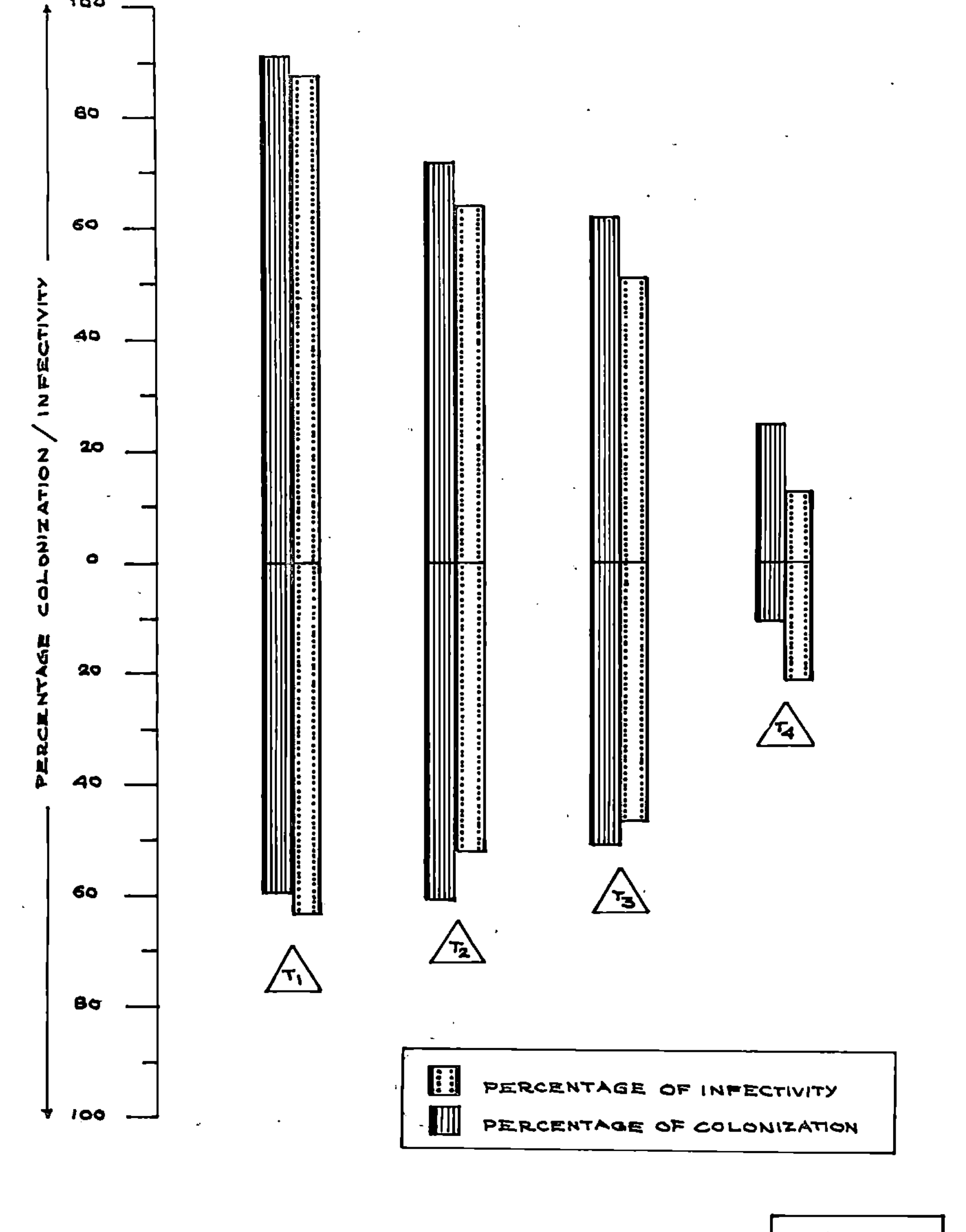


FIG: 2.

the percentage of colonization was observed when inoculum and field soil ratio were 90:10 and 50:50 (T_2 and T_3). The decrease in the percentage of colonization was from 90.90 in T_1 to zero in T_5. Similarly under submerged condition, the percentage of colonization in the treatments T_1 (100:0) and T_2 (90:10) were not significantly different. But T_2 (90:10), T_3 (50:50) and T_4 (10:90) were significantly different. In submerged condition the decrease in the percentage of colonization was from 57.40 in T_1 to zero in T_5 (table 3).

The percentage of infectivity also decreased with the decrease in inoculum level under both dry and submerged conditions. Under dry condition the differences between the percentage of infectivity in all the treatments were significantly different. The decrease in percentage of infectivity was from 87.40 in T_1 to zero in T_5. Under submerged condition there was no significant difference between the percentages of infectivity in treatments T_1 and T_2 and T_2 and T_3. The differences between all the other treatments were significant. The decrease in the percentage of infectivity was from 63.30 in T_1 to zero in T_5 (table 3, fig. 3).

4.2.2. Using sclerotia of *R. solani* as inoculum

In wet land soil the percentage of colonization was

Table 3. Competitive saprophytic ability of *R. solani* in wet land soil (using culture)

Treatment	Inoculum: field soil	Dry		Submerged	
		Percentage of colonization	Percentage of infectivity	Percentage of colonization	Percentage of infectivity
T_1	100:0	90.90 (72.41)	87.40 (69.26)	57.40 (50.38)	63.30 (52.68)
T_2	90:10	71.30 (57.64)	64.10 (53.20)	60.70 (51.18)	52.10 (46.16)
T_3	50:50	61.90 (51.95)	50.70 (45.38)	50.70 (45.38)	46.70 (43.08)
T_4	10:90	24.60 (29.72)	12.60 (20.76)	10.90 (19.34)	21.70 (27.78)
T_5	0:100	0.00	0.00	0.00	0.00
CD (0.05)		6.22	5.42	5.58	12.74

Figures in parenthesis indicate transformed values

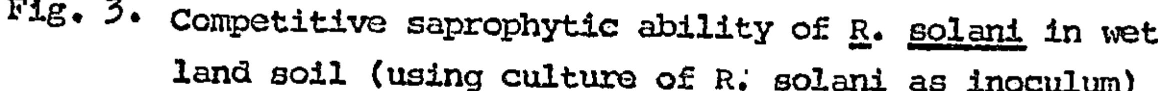


Fig. 3. Competitive saprophytic ability of *R. solani* in wet land soil (using culture of *R. solani* as inoculum)

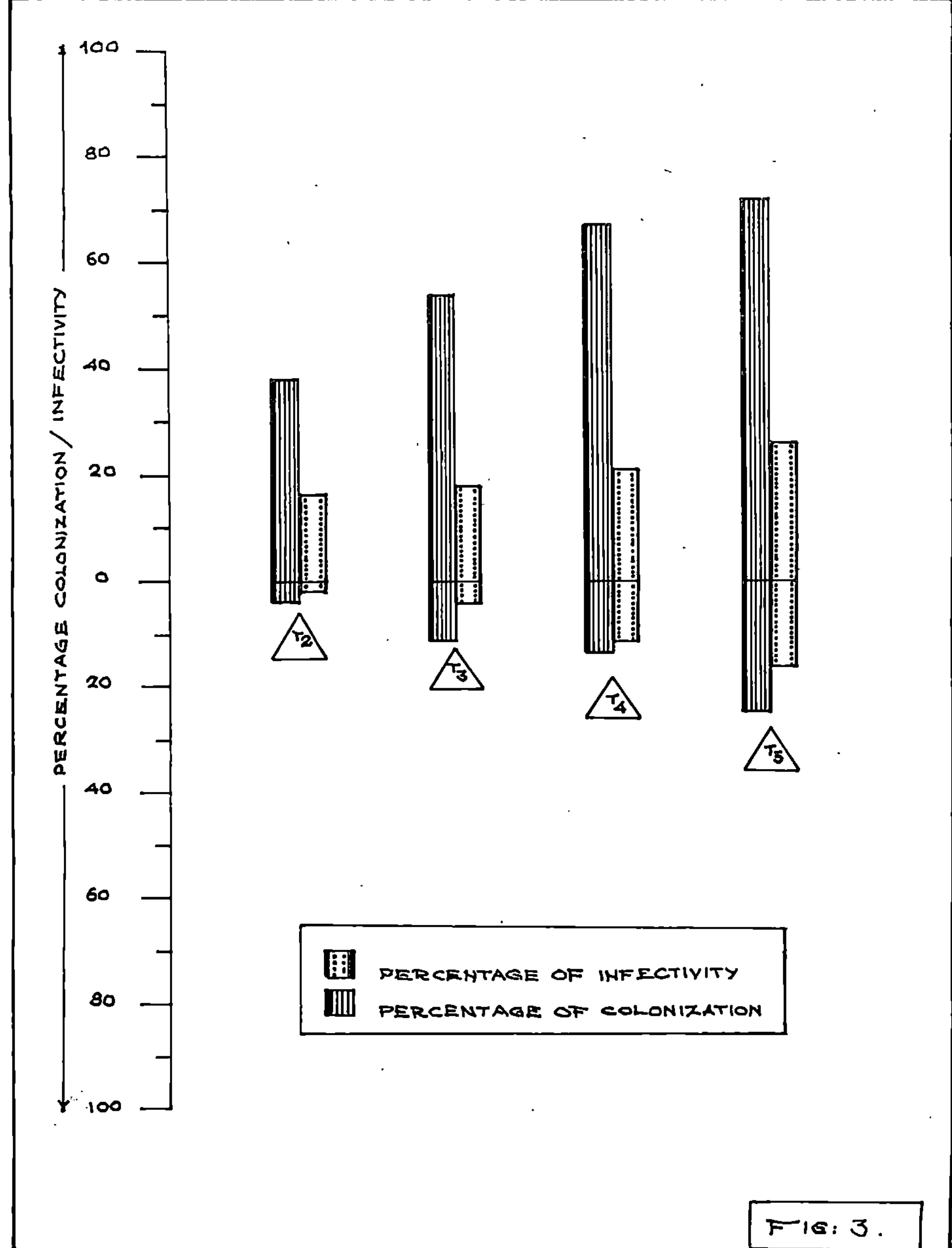


FIG: 3.

found to increase with increase in inoculum level under dry and submerged conditions. Under dry condition the percentage colonization between different treatments was significantly different. But under submerged condition, no significant difference between percentage of colonization was observed between T_2 and T_3.

The percentage of infectivity was also found to increase with increase in inoculum both under dry and submerged conditions. But under submerged condition the percentage of infectivity was not significantly different between T_2 and T_3. The percentages of infectivity in all the other treatments were significantly different (table 4, fig. 4).

4.3. Influence of moisture and soil type on the saprophytic survival of _R_. _solani_

4.3.1. Dry land soil

In sterilized dry land soil under dry condition there was a gradual decline in the survival with an increase in the incubation period. The percentages of colonization by _R_. _solani_ in straw bits in all the fortnightly observations up to the 16th week of incubation were significantly different. The survival was maximum in T_1 with 97.40 per cent colonization after two weeks of incubation. After 16th week (T_8) the survival was only 20.10 per cent. In sterilized

Table 4. Competitive saprophytic ability of *R. solani* in wet land soil (using sclerotia)

Treatment	Number of sclerotia	Dry		Submerged	
		Percentage of colonization	Percentage of infectivity	Percentage of colonization	Percentage of infectivity
T_1	0	0.00	0.00	0.00	0.00
T_2	25	37.91 (38.05)	16.00 (23.58)	4.10 (11.72)	2.00 (8.13)
T_3	50	54.00 (47.31)	17.71 (24.85)	11.30 (19.66)	4.03 (11.48)
T_4	75	67.43 (55.18)	21.00 (27.27)	13.91 (21.94)	12.30 (20.49)
T_5	100	71.92 (58.06)	25.31 (30.22)	24.72 (29.78)	16.31 (23.82)
CD (0.05)		3.79	0.74	8.24	2.34

Figures in parenthesis indicate transformed values

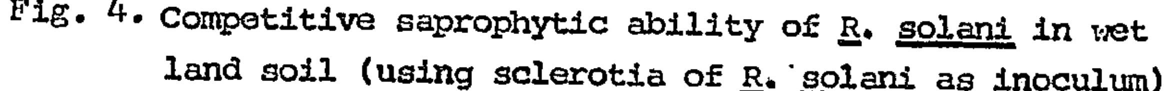


Fig. 4. Competitive saprophytic ability of *R. solani* in wet land soil (using sclerotia of *R. solani* as inoculum)

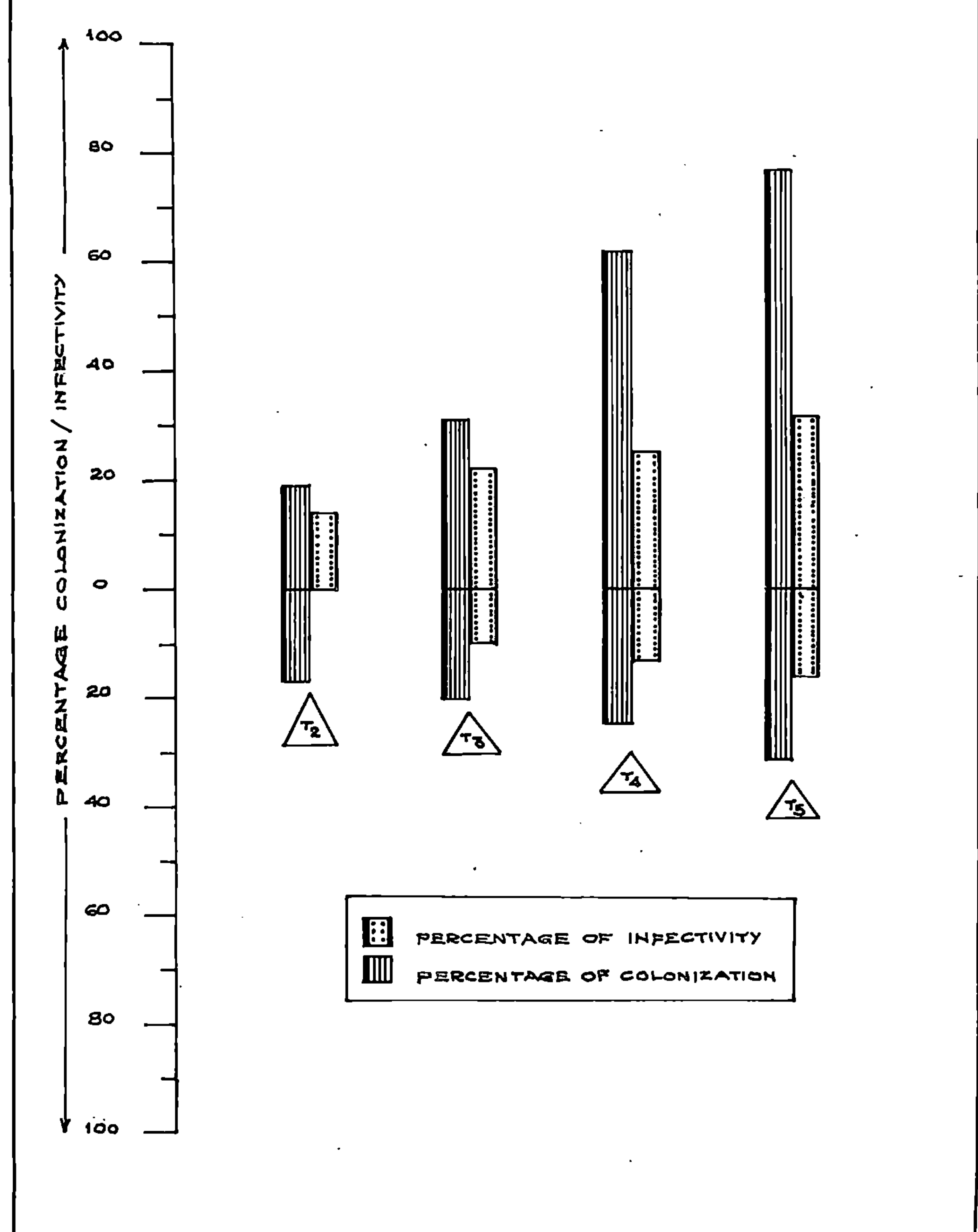


FIG. 4.

dry land soil under submerged condition also there was a gradual decrease in the survival of R. solani from 95.40 in T_1 to 10.00 in T_8 (table 5).

In the unsterilized dry land soil also there was a general decline in the survival of R. solani with the increase in the incubation period. In soil kept at dry condition the percentage of colonization ranged from 58.30 to 1.60 from second week to 16th week. The differences in the percentages of colonization between all the observations from second week to 12th week were statistically significant. In the submerged condition the percentages of colonization ranged from 46.00 in the second week to zero in the 16th week. But the differences between the observations in the second and fourth week and fourth and sixth week were not significant. Similarly there was no difference between the observations in T_4 and T_5 and T_6 and T_7.

4.3.2. Wet land soil

In wet land sterilized and unsterilized soils under dry and submerged conditions also the percentage of colonization of R. solani was found to decrease with increase in incubation period.

In sterilized wet land soil under both dry and submerged conditions there was very high percentage of colonization during the second week. Then there was a gradual

Table 5. Influence of moisture and soil type on the saprophytic survival of *R. solani* in dry land soil

Treatment	Incubation period (weeks)	Sterilized		Unsterilized	
		Percentage of colonization under dry condition	Percentage of colonization under submerged condition	Percentage of colonization under dry condition	Percentage of colonization under submerged condition
T_1	2	97.40 (80.73)	95.40 (77.58)	58.30 (49.99)	46.00 (42.70)
T_2	4	95.40 (77.58)	90.70 (72.23)	54.00 (47.30)	46.60 (43.09)
T_3	6	88.10 (69.77)	70.00 (56.79)	48.10 (43.85)	40.00 (39.23)
T_4	8	80.70 (63.92)	52.00 (46.14)	40.00 (39.23)	20.70 (27.03)
T_5	10	70.00 (56.80)	48.70 (44.24)	22.60 (28.41)	20.70 (27.03)
T_6	12	60.70 (51.16)	37.60 (37.85)	2.60 (9.27)	0.90 (5.51)
T_7	14	53.30 (46.91)	32.60 (34.86)	1.60 (7.33)	0.90 (5.51)
T_8	16	20.10 (26.55)	10.00 (18.38)	1.60 (7.33)	0.00
CD (0.05)		2.44	2.24	2.24	4.30

Figures in parenthesis indicate transformed values

decline in survival, with the increase in incubation period. Under dry condition the decrease was from 95.3 per cent to 2.2 per cent and in the submerged condition it ranged from 54.0 per cent to 0.1 per cent.

In unsterilized wet land soil under dry and submerged conditions there was a gradual decline in survival from second week to 16th week of incubation. Under dry condition it was from 63.3 per cent to 0.1 per cent and in the submerged condition from 54.1 to 0.1 (table 6). The decrease in the percentage of colonization under dry condition in the 14th and 16th weeks was not significant.

The statistical relationship worked out between percentage of colonization and level of inoculum showed that the estimates of coefficient of determination of the fitted model were relatively high indicating the adequacy of fitted relationship. The amount of variation expressed by the equation ranged from 67 to 97 per cent. The correlation coefficient between per cent colonization and inoculum level ranged from 0.91 to 0.96 and were statistically significant. The regression coefficient which indicated the rate of change of colonization per unit change in inoculum level varied between 0.489 in dry land soil kept under dry condition to 0.719 in dry land soil kept under submerged condition. Similarly the rate of change of percentage of

Table 6. Influence of moisture and soil type on the saprophytic survival of *R. solani* in wet land soil

Treatment	Incubation period (weeks)	Sterilized		Unsterilized	
		Percentage of colonization under dry condition	Percentage of colonization under submerged condition	Percentage of colonization under dry condition	Percentage of colonization under submerged condition
T_1	2	95.30 (77.58)	94.10 (75.95)	63.30 (52.73)	54.00 (47.29)
T_2	4	88.60 (70.34)	89.30 (70.95)	57.30 (49.22)	42.70 (40.78)
T_3	6	83.40 (65.96)	80.70 (63.96)	42.00 (40.39)	24.00 (29.32)
T_4	8	74.00 (59.34)	60.70 (51.14)	26.00 (30.66)	16.00 (23.55)
T_5	10	27.40 (31.82)	24.00 (29.33)	11.30 (19.66)	8.60 (17.10)
T_6	12	14.00 (21.97)	13.40 (21.37)	6.60 (14.93)	4.60 (12.41)
T_7	14	8.60 (17.09)	5.20 (13.17)	0.90 (5.42)	4.60 (12.41)
T_8	16	2.20 (8.47)	0.10 (2.10)	0.10 (2.10)	0.10 (2.10)
CD (0.05)		2.69	3.58	3.79	2.87

Figures in parenthesis indicate transformed values

colonization per unit change in inoculum level varied between 0.575 in wet land soil kept under submerged condition to 0.646 in wet land soil kept under dry condition. The rate of change in percentage colonization per unit change in inoculum level was more in dry condition than in submerged condition (table 7).

A definite simple linear relationship was observed between recovery percentage and incubation period, in all the conditions tested. Significant correlation was observed in all the cases and average regression coefficients were highly significant. The values of coefficient of determination ranged from 88 to 96 per cent (table 8).

4.4. Effect of agronomical and ecological factors on the survival of *R. solani*

4.4.1. Effect of organic amendments

The data on the population of fungi, bacteria and actinomycetes were obtained from the pot culture experiment with 12 treatments. The observations were recorded six times at fortnightly intervals starting from just before the incorporation of amendments. The data showed wide variations and hence logarithmic transformations were applied to analyse the data.

There was no significant difference in the microbial population among the different treatments prior to the

Table 7. Relation between percentage of colonization and level of inoculum of *R. solani*

Sl. No.	Soil	Condition	Regression equation	r^2	r
1	Dry	Dry	Y = 22.245 + 0.719X	0.93	0.96**
2	"	Submerged	Y = 18.328 + 0.489X	0.82	0.91**
3	Wet	Dry	Y = 21.699 + 0.646X	0.92	0.96**
4	"	Submerged	Y = 12.679 + 0.575X	0.85	0.92**

** Significant at 0.01 level

Y = Per cent colonization

X = Inoculum level

r^2 = Coefficient of determination

r = The correlation coefficient

Table 8. Relationship between percentage of colonization and incubation period

Sl. No.	Soil condition	Regression equation	r^2	r
1.	Dry land dry (unsterilized)	Y = 72.273 - 4.845X	0.94	0.97**
2.	Dry land submerged (unsterilized)	Y = 57.690 - 3.956X	0.93	0.96**
3.	Dry land dry (sterilized)	Y = 115.880 - 5.025X	0.90	0.95**
4.	Dry land submerged (sterilized)	Y = 107.536 - 5.879X	0.96	0.98**
5.	Wet land dry (unsterilized)	Y = 75.143 + 5.678X	0.96	0.98**
6.	Wet land submerged (unsterilized)	Y = 57.524 - 4.506X	0.93	0.96**
7.	Wet land dry (sterilized)	Y = 117.726 - 7.613X	0.88	0.94**
8.	Wet land submerged (sterilized)	Y = 116.416 - 7.736X	0.90	0.95**

** Significant at 0.01 level

application of amendments whereas, significant differences were obtained afterwards.

4.4.1.1. Effect on fungal population

At planting stage, i.e., two weeks after the application of organic amendments, maximum population of fungi, i.e., 31.48 millions, was observed in T_8 (groundnut cake) and the minimum of 11.61 millions in T_{12} (groundnut shell) which was statistically on par with control (table 9, fig. 5). At tillering stage also a similar trend was observed. However, effects of T_7 (neem cake), T_8 (groundnut cake) and T_{11} (paddy husk) were on par. All the other treatments were statistically different. At maximum tillering stage, maximum population of fungi, i.e., 54.83 millions was recorded in T_7 and minimum in T_{12}. T_7 and T_{11} were on par. At boot leaf stage among the treatments maximum population of fungi i.e., 75.34 millions was recorded in T_8 and minimum in T_{12}. The effect of T_{12} was not significant. Two weeks before harvest the maximum population of fungi, i.e., 74.47 millions was recorded in T_6 (coconut pith) and minimum in T_{12} (groundnut shell). T_6 (coconut pith) and T_5 (saw dust) were on par.

Pooled analysis of the data showed that in general the treatments were effective in enhancing the population of soil fungi. Among the treated plots maximum population

of fungi was recorded in T_8 (groundnut cake) and minimum in T_{12} (groundnut shell) (table 9).

4.4.1.2. Effect on bacterial population

Fish waste (T_{10}) was found to support maximum soil bacterial population at all the stages of plant growth (table 10). In general T_3 and T_4 did not exert considerable influence on the soil bacterial population. At maximum tillering stage T_6 (coconut pith) recorded the minimum population.

Pooled analysis of the data showed that maximum population of bacteria was in T_{10} and minimum in T_4. The effects of T_3 and T_4 were on par (table 10, fig. 6).

4.4.1.3. Effect on actinomycetes population

At planting stage maximum actinomycete population i.e., 13.49 millions was recorded in T_9 (punna cake) and minimum in T_4. The effects of T_6 (coconut pith) and T_9 were on par (table 11, fig. 7). At tillering stage the maximum population of 20.23 millions was observed in T_2 (Glyricidia leaves) and minimum in T_3 (Clerodendron leaves). The effects of T_6 and T_9 were on par. The effect of T_3 was not significant. At maximum tillering stage highest population of actinomycetes i.e., 24.43 millions was recorded in T_2 and the minimum of 10.30 millions in T_{12} (groundnut shell).

Table 9. Effect of organic amendments on the population of fungi (10^6/g of soil)

Treatments	Before incorporation of amendment	Planting stage	Tillering stage	Maximum tillering stage	Boot leaf stage	Before harvest	Pooled analysis
T_1	9.10 (0.959)	13.03 (1.115)	14.89 (1.173)	25.41 (1.405)	25.70 (1.410)	27.42 (1.438)	20.33 (1.308)
T_2	9.14 (0.961)	22.75 (1.357)	28.64 (1.457)	37.15 (1.570)	49.09 (1.691)	67.61 (1.830)	38.11 (1.581)
T_3	9.12 (0.960)	15.45 (1.189)	22.96 (1.361)	26.67 (1.426)	32.14 (1.507)	33.57 (1.526)	34.83 (1.542)
T_4	9.10 (0.959)	16.67 (1.222)	20.75 (1.317)	25.47 (1.406)	26.67 (1.426)	27.54 (1.440)	23.01 (1.362)
T_5	9.10 (0.959)	26.92 (1.430)	31.33 (1.496)	38.46 (1.585)	42.29 (1.656)	72.61 (1.861)	40.27 (1.605)
T_6	8.53 (0.931)	25.76 (1.411)	28.64 (1.457)	33.50 (1.525)	71.78 (1.856)	74.47 (1.872)	42.07 (1.624)
T_7	9.10 (0.959)	24.49 (1.389)	33.88 (1.530)	54.83 (1.739)	66.22 (1.821)	63.10 (1.800)	45.27 (1.655)
T_8	9.09 (0.958)	31.48 (1.498)	35.58 (1.551)	51.17 (1.709)	61.38 (1.788)	61.24 (1.787)	46.34 (1.661)
T_9	9.10 (0.959)	22.70 (1.356)	30.76 (1.488)	44.87 (1.652)	75.34 (1.877)	71.45 (1.854)	44.16 (1.645)
T_{10}	9.12 (0.960)	24.66 (1.392)	25.35 (1.404)	30.69 (1.487)	48.31 (1.684)	52.24 (1.718)	34.43 (1.537)
T_{11}	9.08 (0.958)	24.10 (1.382)	34.91 (1.543)	53.95 (1.732)	46.24 (1.665)	51.40 (1.711)	40.36 (1.606)
T_{12}	9.12 (0.960)	11.61 (1.065)	16.00 (1.204)	21.18 (1.326)	25.94 (1.414)	28.64 (1.457)	19.63 (1.293)
CD(0.05)	-	0.05	0.02	0.02	0.03	0.02	0.03

Figures in parenthesis indicate transformed values

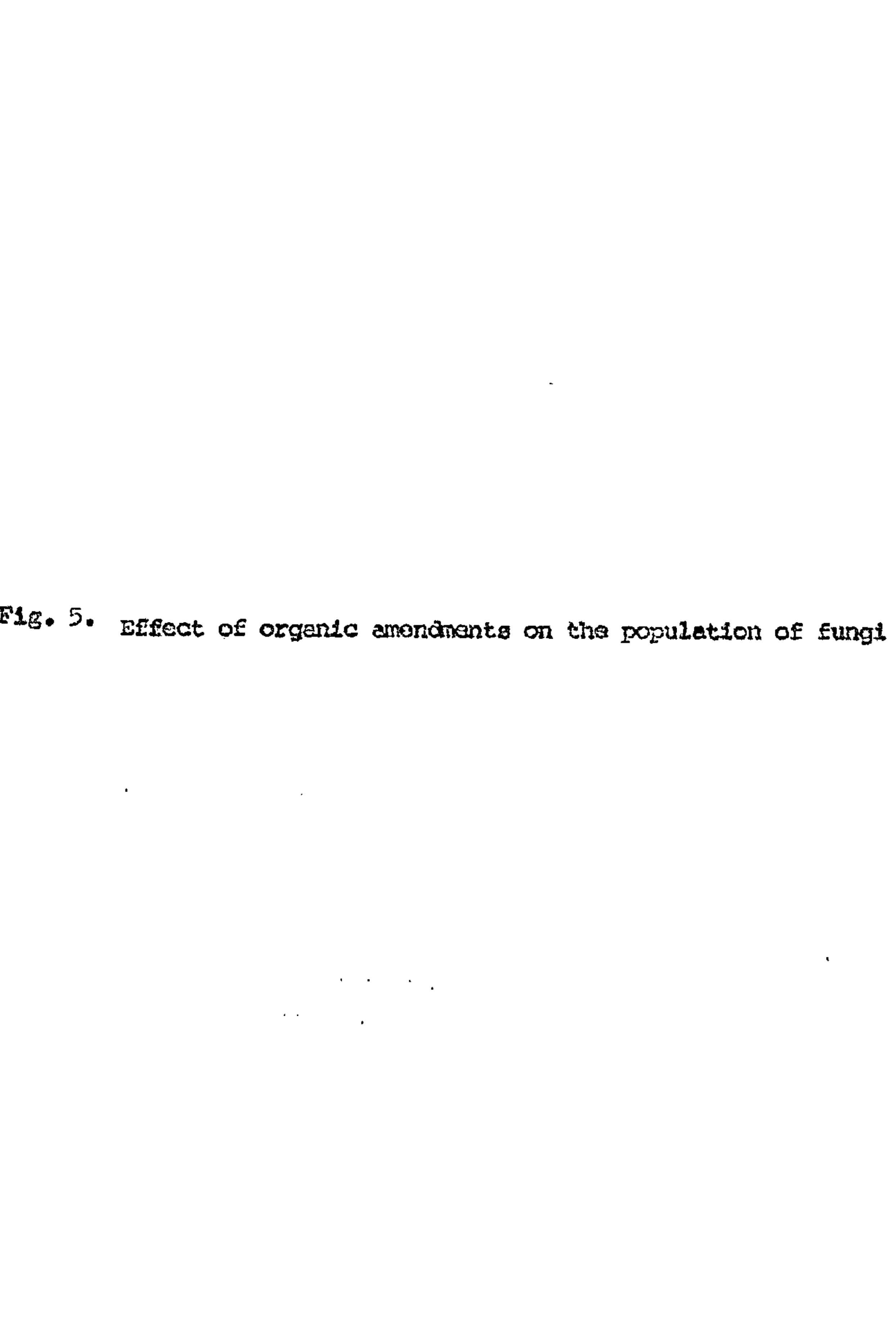


Fig. 5. Effect of organic amendments on the population of fungi

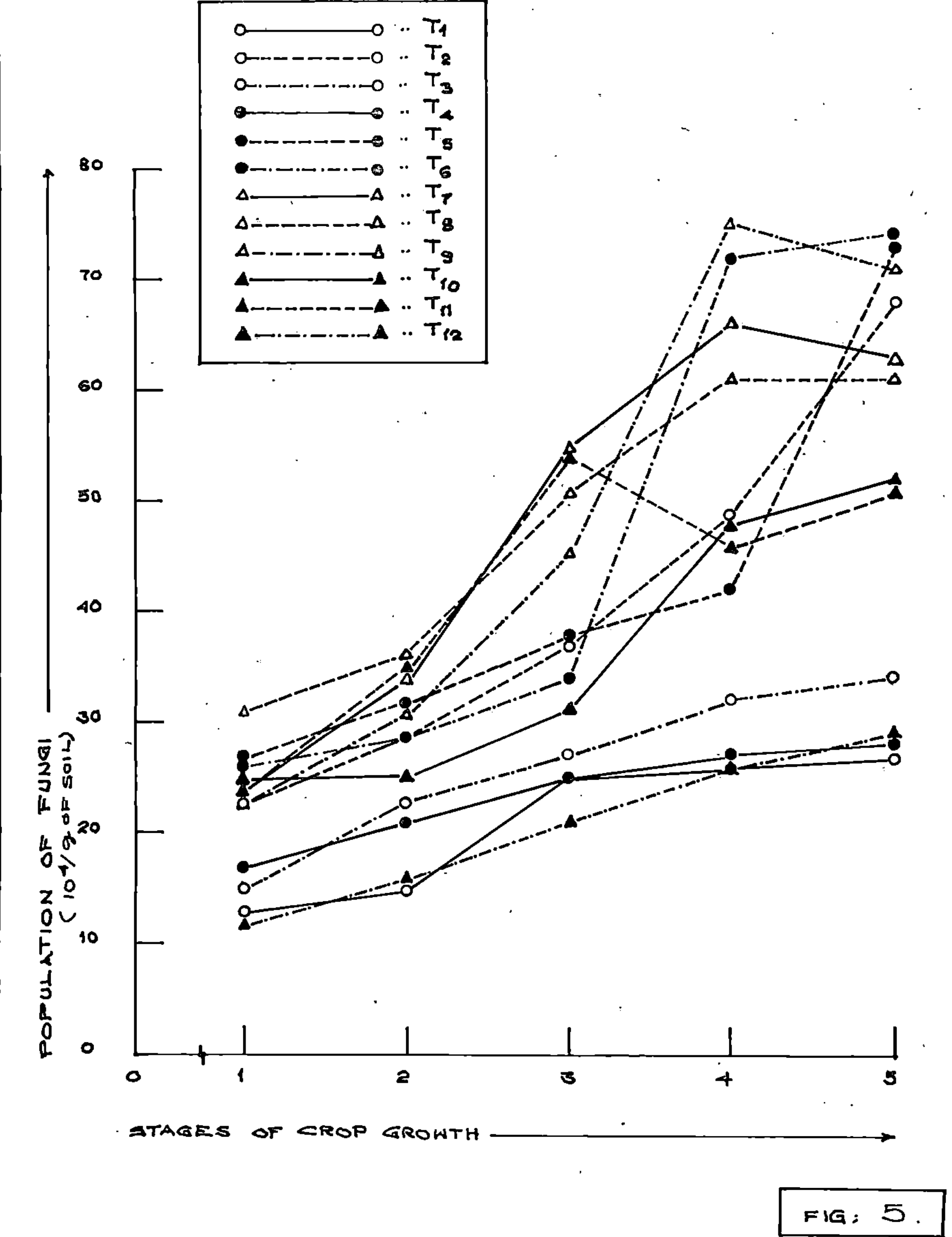


FIG: 5.

Table 10. Effect of organic amendments on the population of bacteria (10^6/g of soil)

Treatment	Before incorporation of amendment	Planting stage	Tillering stage	Maximum tillering stage	Boot leaf stage	Before harvest	Pooled analysis
T_1	10.59 (1.025)	13.46 (1.129)	20.80 (1.318)	28.71 (1.458)	24.55 (1.390)	25.18 (1.401	21.83 (1.33)
T_2	10.74 (1.031)	19.50 (1.290)	27.23 (1.435)	79.43 (1.900)	40.36 (1.606)	34.75 (1.541)	35.81 (1.55)
T_3	10.69 (1.029)	15.07 (1.178)	24.72 (1.393)	48.08 (1.682)	25.23 (1.402)	20.37 (1.309)	24.99 (1.39)
T_4	10.59 (1.025)	13.96 (1.145)	24.72 (1.393)	45.92 (1.662)	21.04 (1.323)	23.82 (1.377)	23.99 (1.38)
T_5	10.59 (1.025)	16.18 (1.209)	27.42 (1.438)	42.17 (1.625)	29.04 (1.463)	43.45 (1.638)	29.85 (1.47)
T_6	10.54 (1.023)	14.69 (1.167)	28.05 (1.448)	38.82 (1.589)	33.04 (1.519)	45.81 (1.661)	29.99 (1.47)
T_7	10.59 (1.025)	15.31 (1.185)	25.00 (1.398)	80.35 (1.905)	66.99 (1.826)	73.45 (1.866)	43.25 (1.63)
T_8	10.57 (1.024)	20.80 (1.318)	31.19 (1.494)	74.13 (1.870)	74.13 (1.870)	69.98 (1.845)	47.75 (1.67)
T_9	10.57 (1.024)	24.15 (1.383)	32.43 (1.511)	84.72 (1.928)	76.21 (1.882)	51.17 (1.709)	47.97 (1.68)
T_{10}	10.59 (1.025)	28.38 (1.453)	34.04 (1.532)	92.90 (1.968)	85.90 (1.934)	90.16 (1.955)	57.94 (1.76)
T_{11}	10.59 (1.025)	15.07 (1.178)	28.91 (1.461)	87.70 (1.943)	33.04 (1.519)	37.24 (1.571)	34.20 (1.53)
T_{12}	10.54 (1.023)	26.30 (1.420)	31.99 (1.505)	78.89 (1.897)	61.94 (1.792)	67.76 (1.831)	48.80 (1.68)
CD (0.05)	-	0.03	0.03	0.02	0.02	0.03	0.14

Figures in parenthesis indicate transformed values

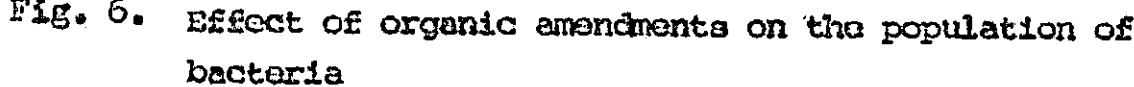


Fig. 6. Effect of organic amendments on the population of bacteria

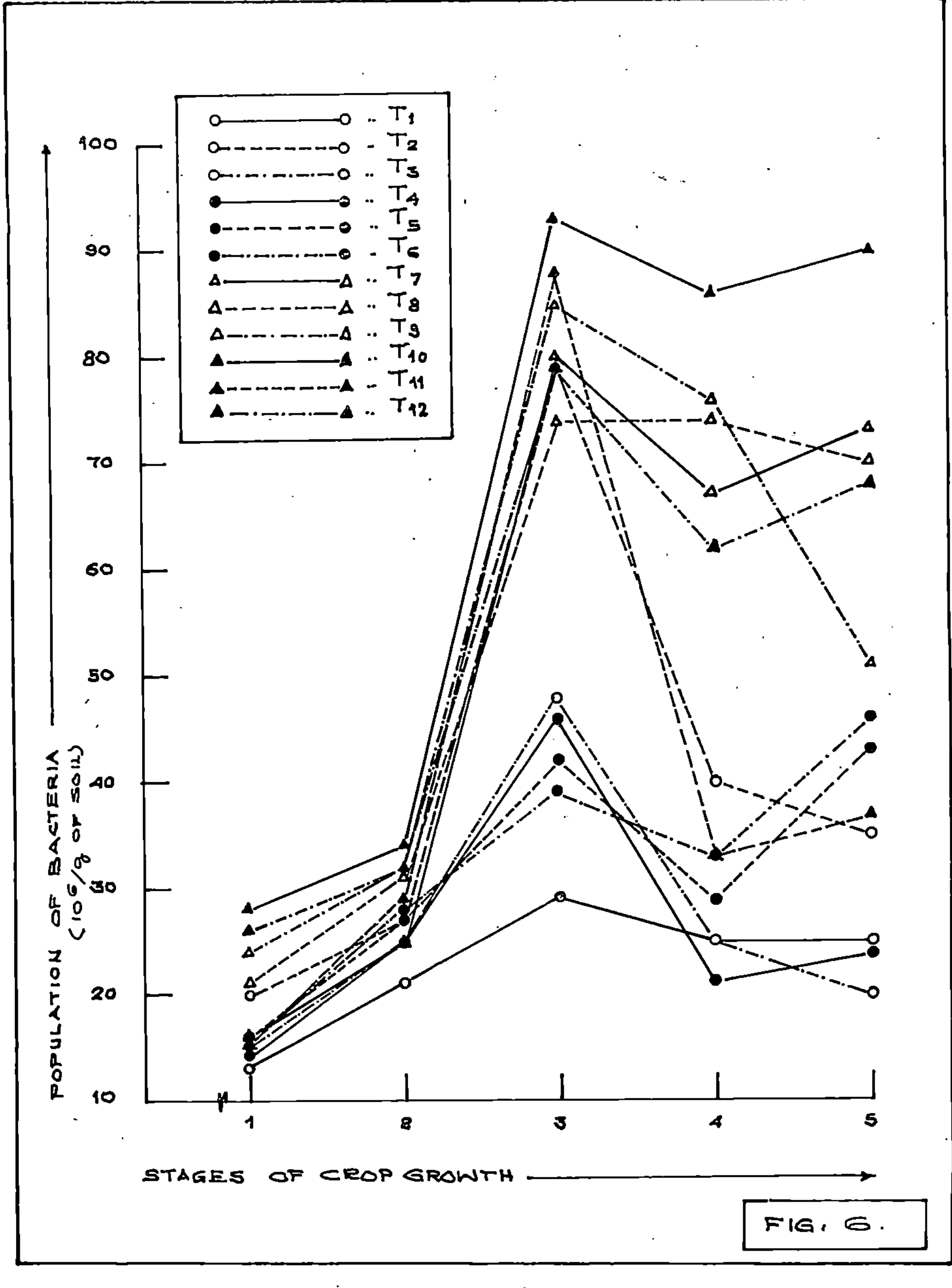


FIG. 6.

The effects of T_7 (neem cake), T_{10} (fish waste), T_9 (punna cake) and T_{11} (paddy husk) were on par. At boot leaf stage the maximum population of actinomycetes i.e., 30.27 millions was recorded in T_{11} and minimum in T_{12}. Two weeks before harvest the maximum population of 31.26 millions was recorded in T_{11} (paddy husk) and minimum in T_5. The effects of T_{11}, T_2, T_3 and T_4 (Eupatorium leaves) were on par.

Pooled analysis of the data showed that maximum population was in T_{11} (paddy husk) and minimum in T_{12} (groundnut shell) (table 11 and fig. 7).

4.4.1.4. Effect on the survival of R. solani

At the tillering stage percentage of survival of R. solani was significantly low in treated pots and in control (T_1), it was 91.40 per cent (table 12, fig. 8). The lowest percentage of survival was in T_5 (saw dust), i.e., 34.00 per cent, which was on par with T_{11} (paddy husk). T_7 (neem cake), T_4 (eupatorium leaves) and T_3 (clerodendron leaves) were on par. At maximum tillering stage also, in all the treated pots percentage of survival was less compared to control. T_5 (saw dust) recorded the lowest percentage of survival of 28.70. There was no significant difference between T_8 (groundnut cake), T_{10} (fish waste) and T_7 (neem cake). At boot leaf stage the lowest percentage of survival, i.e. 25.30 was in T_{11}, while in control it was

Table 11. Effect of organic amendments on the population of Actinomycetes (10^6/g of soil)

Treatments	Before incorporation of amendment	Planting stage	Tillering stage	Maximum tillering stage	Boot leaf stage	Before harvest	Pooled analysis
T_1	7.53 (0.877)	7.99 (0.903)	10.23 (1.010)	13.65 (1.135)	15.78 (1.198)	17.58 (1.245)	12.63 (1.098)
T_2	7.43 (0.871)	8.59 (0.934)	20.23 (1.306)	24.43 (1.388)	27.80 (1.444)	28.44 (1.454)	20.18 (1.305)
T_3	7.46 (0.873)	7.88 (0.897)	10.09 (1.004)	14.32 (1.156)	15.10 (1.179)	14.69 (1.167)	12.05 (1.081)
T_4	7.55 (0.878)	7.76 (0.890)	11.43 (1.058)	16.29 (1.212)	17.91 (1.253)	14.72 (1.168)	13.06 (1.116)
T_5	7.43 (0.871)	10.00 (1.000)	14.00 (1.146)	14.69 (1.167)	18.71 (1.272)	11.38 (1.056)	13.43 (1.128)
T_6	7.43 (0.871)	12.50 (1.097)	18.97 (1.278)	21.93 (1.341)	25.23 (1.402)	24.49 (1.389)	20.00 (1.301)
T_7	7.44 (0.872)	11.09 (1.045)	16.07 (1.206)	15.81 (1.199)	20.28 (1.307)	24.72 (1.393)	16.98 (1.230)
T_8	7.48 (0.874)	10.30 (1.013)	16.48 (1.217)	18.28 (1.262)	26.42 (1.422)	21.83 (1.339)	17.82 (1.251)
T_9	7.53 (0.877)	13.49 (1.130)	18.88 (1.276)	20.80 (1.318)	25.47 (1.406)	21.63 (1.335)	18.75 (1.273)
T_{10}	7.53 (0.877)	9.81 (0.992)	13.37 (1.126)	15.56 (1.192)	16.71 (1.223)	17.34 (1.239)	14.26 (1.154)
T_{11}	7.51 (0.876)	11.17 (1.048)	16.37 (1.214)	20.89 (1.320)	30.27 (1.481)	31.26 (1.495)	20.46 (1.311)
T_{12}	7.51 (0.876)	9.33 (0.970)	15.38 (1.187)	10.30 (1.013)	9.20 (0.964)	16.33 (1.213)	11.72 (1.069)
CD (0.05)	-	0.334	0.04	0.03	0.03	0.05	0.31

Figures in parentheses indicate transformed values

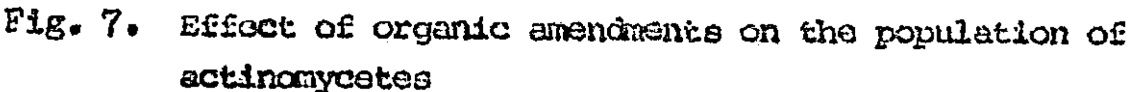


Fig. 7. Effect of organic amendments on the population of actinomycetes

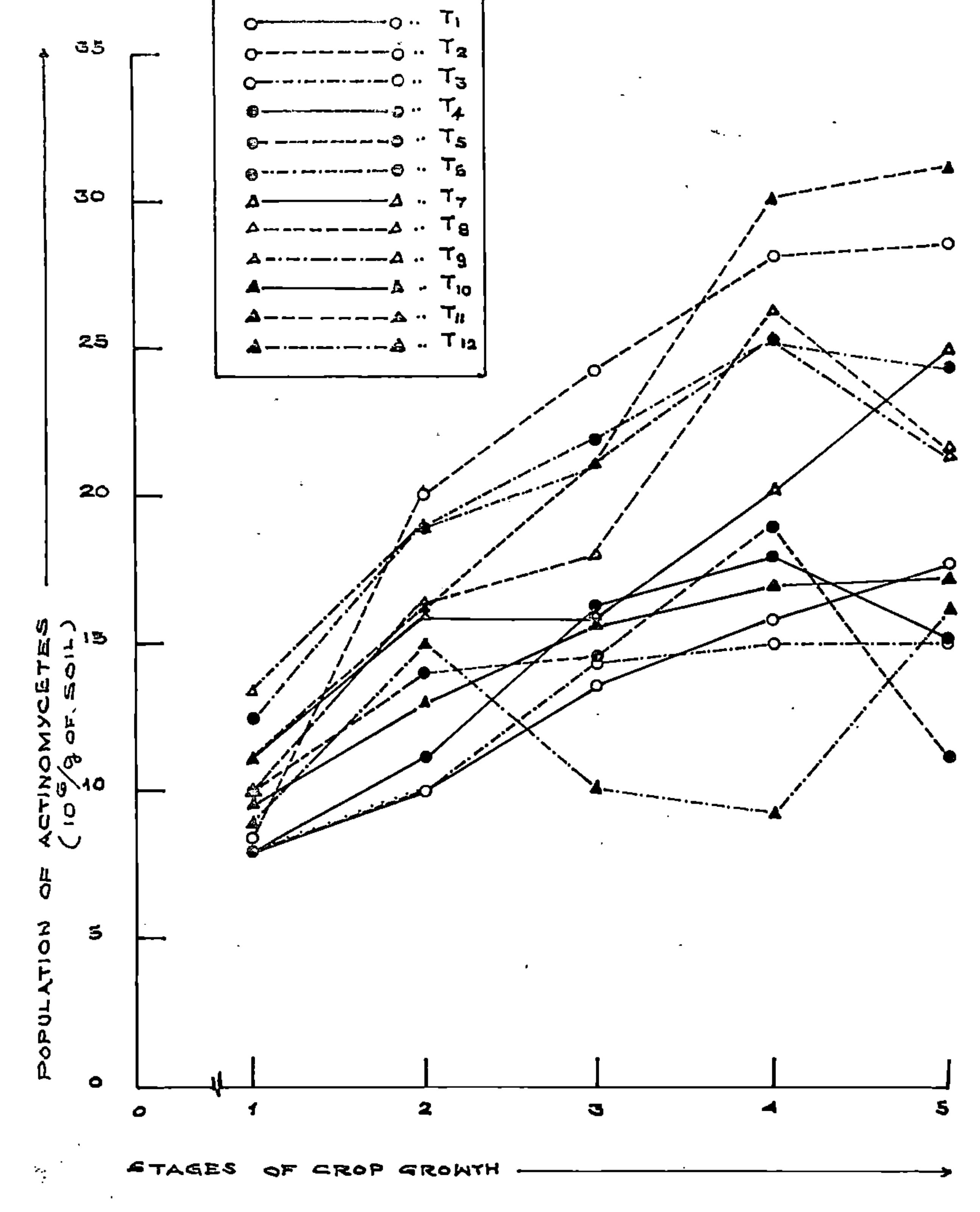


FIG: 7.

92.90 per cent. Two weeks before harvest all the treatments recorded lesser percentage of survival of R. solani than control. The minimum survival of 25.30 per cent was recorded in T_{11} (paddy husk) and the maximum of 66.70 per cent was in T_4 (eupatorium leaves).

Pooled analysis of the data showed that T_{11} (paddy husk) recorded lowest survival percentage of 29.08. T_3 (clerodendron leaves) with 63.3 per cent and T_4 (eupatorium leaves) with 61.20 per cent survival were on par and these treatments recorded the maximum survival percentage among the amendments (table 12, fig. 8).

4.4.1.5. Effect of organic amendments on incidence of sheath blight

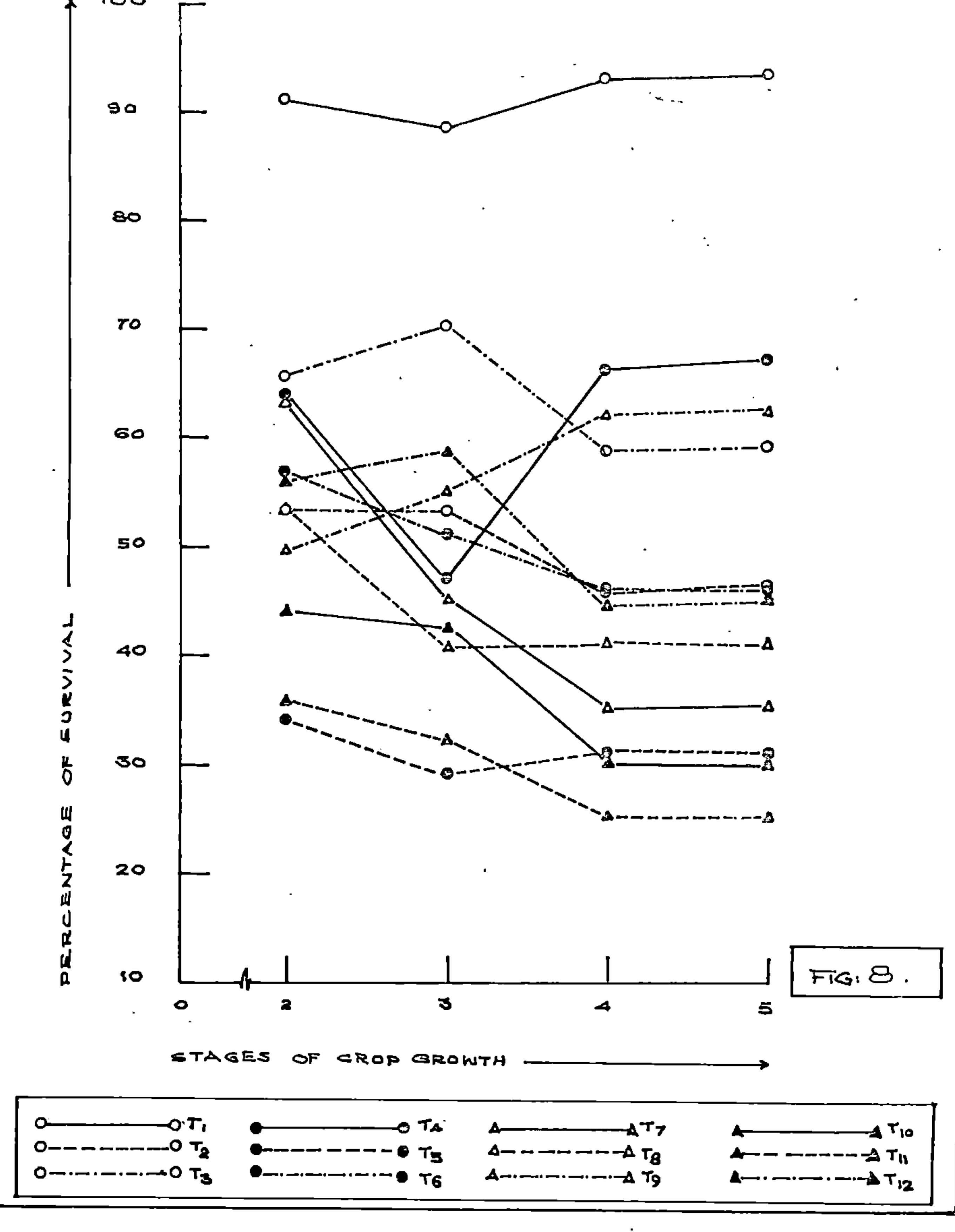
At maximum tillering stage all the treatments showed less incidence of disease as compared to control (table 13). The disease incidence in T_{11} (paddy husk) and T_{12} (groundnut shell) were 24.90 and 25.20 per cent respectively and these treatments were superior to all the other treatments. Two weeks before harvest all the treatments, except T_3 (clerodendron leaves) with 76.70 per cent and T_4 (eupatorium leaves) with 78.60 per cent incidence, were found to reduce the disease incidence significantly. T_{12} (groundnut shell) recorded the least incidence of 27.40 per cent. There was no significant difference among the effects of T_7 (neem cake), T_9 (punna cake),

Table 12. Effect of organic amendments on the survival of *R. solani* (percentage of colonization)

Treatments	Tillering stage	Maximum tillering stage	Boot leaf stage	Before harvest
T_1	91.40(72.90)	88.70(70.38)	92.90(74.53)	92.90(74.53)
T_2	53.30(46.91)	53.30(46.91)	45.60(42.51)	45.70(42.51)
T_3	65.40(54.14)	70.00(56.80)	58.70(49.99)	58.70(49.99)
T_4	64.00(53.13)	47.00(43.28)	66.60(54.74)	66.70(54.74)
T_5	34.00(35.65)	28.70(32.37)	31.30(34.04)	31.30(34.04)
T_6	57.30(49.22)	50.70(45.38)	46.30(42.89)	46.30(42.89)
T_7	63.30(52.74)	44.60(41.93)	35.30(36.46)	35.30(36.46)
T_8	53.00(46.72)	40.60(39.62)	41.35(40.01)	41.30(40.01)
T_9	49.70(44.81)	54.70(47.68)	62.00(51.95)	62.00(51.95)
T_{10}	44.30(41.74)	42.70(40.78)	30.00(33.20)	30.00(33.20)
T_{11}	36.30(37.05)	32.60(34.84)	25.30(30.22)	25.30(30.22)
T_{12}	56.00(48.45)	58.70(49.99)	44.70(41.93)	44.70(41.93)
CD (0.05)	2.57	2.64	2.70	2.70

Figures in parenthesis indicate transformed values

Fig. 8. Effect of organic amendments on the survival of *R. solani*



PERCENTAGE OF SURVIVAL
100
90
80
70
60
50
40
30
20
10
0
2
3
4
5
STAGES OF CROP GROWTH
FIG: 8.
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12

T_{10} (fish waste) and T_{11} (paddy husk).

4.4.1.6. Effect of organic amendments on intensity of sheath blight

In general all the amendments reduced the disease intensity both at maximum tillering stage and two weeks before harvest. However, T_3 and T_4 were on par with T_1 (control) two weeks before harvest. Disease intensity at maximum tillering stage was highest in T_1 and it was on par with T_3 and T_4. The disease intensity at this stage was the least in T_{11} with a disease index of 1.03 which was on par T_5, T_6, T_{10} and T_{12}. At two weeks before harvest all the amendments gave significantly lower disease intensity compared to the control. At this stage also T_{11} gave the least disease intensity of 0.96 which was significantly superior to all other treatments (table 13).

4.4.1.7. Effect of organic amendments on yield

The general trend of the effect of organic amendments on the yield of rice grains was also similar to that observed in the case of incidence and intensity of sheath blight. Maximum yield, i.e., 51.65 g per pot was from T_{11} (paddy husk) and minimum of 33.88 g was from T_4 (eupatorium leaves) which was on par with T_1 (control). T_{10} (fish waste) and T_{12} (groundnut shell) were on par with T_{11}. There was

Table 13. Effect of organic amendments on incidence and intensity of sheath blight and yield of grains

Treatment	Disease incidence (%)		Disease intensity		Yield/pot (g)
	Maximum tillering stage	Before harvest	Maximum tillering stage	Before harvest	
T_1	79.40(63.02)	80.10(63.49)	5.56	6.95	34.62
T_2	36.20(36.99)	57.00(49.02)	2.03	2.08	47.45
T_3	71.80(57.92)	76.70(61.68)	5.19	4.99	36.09
T_4	66.60(54.70)	78.00(62.05)	5.03	4.70	33.88
T_5	42.20(40.50)	49.30(44.59)	1.52	2.17	37.22
T_6	39.80(39.11)	47.10(43.34)	1.44	2.52	48.56
T_7	28.20(32.07)	33.90(35.63)	2.11	1.89	44.19
T_8	39.80(39.10)	41.50(40.09)	3.14	3.18	48.10
T_9	30.30(34.43)	33.80(35.57)	2.16	1.92	46.73
T_{10}	28.60(32.30)	32.70(34.89)	1.22	1.78	51.24
T_{11}	24.90(29.91)	30.70(33.62)	1.03	0.96	51.65
T_{12}	25.20(30.22)	27.40(31.53)	1.29	1.55	50.54
CD (0.05)	1.23	2.07	0.76	0.32	2.30

Figures in parenthesis indicate transformed values

no significant difference in yield from T_2 (glyricidia leaves), T_6 (coconut pith), T_8 (groundnut cake) and T_9 (punna cake) (table 13).

4.5. Laboratory trial on the effect of organic amendments on the survival of sclerotia of *R. solani*

The study was conducted in the laboratory to find out the effect of soil amendments on the survival of sclerotia. The observation recorded was percentage of germination of sclerotia. Analysis of variance was done after angular transformation and the results are presented (table 14).

Pooled analysis showed that minimum survival of sclerotia of 20.10 per cent was in T_{10} (fish waste) and maximum of 62.41 per cent in T_1 (control). T_9 (punna cake) with 61.30 per cent survival was on par with T_1 (control). There was no significant difference between the effects of T_4 (eupatorium leaves), T_3 (clerodendron leaves) and T_{12} (groundnut shell).

4.5.1. Effect of organic amendments on the population of microorganisms

T_{10} (fish waste) treated pots recorded maximum number of total microorganisms and antagonistic organisms like *Trichoderma harzianum*, *Penicillium* sp. and *Rhizopus stolonifer*

Table 14. Effect of organic amendments on the survival of *R. solani*

Treatments	Period of incubation (months)												
	1	2	3	4	5	6	7	8	9	10	11	12	Pooled
1. T_1	93.10 (74.73)	90.00 (71.55)	84.70 (67.01)	80.00 (63.41)	71.70 (57.84)	70.40 (57.03)	53.30 (46.89)	47.30 (43.45)	44.00 (41.54)	34.80 (36.22)	33.80 (35.61)	26.60 (31.06)	62.41 (52.19)
2. T_2	83.00 (65.64)	79.80 (63.29)	61.00 (51.32)	50.00 (46.32)	46.00 (42.68)	41.00 (39.80)	31.10 (33.85)	26.30 (30.21)	19.70 (26.31)	6.50 (14.75)	0.00 (0.00)	0.00 (0.00)	32.20 (34.56)
3. T_3	86.30 (68.28)	78.30 (62.24)	72.60 (55.44)	66.70 (54.76)	56.70 (48.83)	53.30 (46.90)	36.10 (37.10)	31.60 (34.22)	27.00 (31.28)	21.30 (27.48)	18.20 (25.28)	10.00 (18.41)	46.10 (42.77)
4. T_4	85.40 (68.52)	80.00 (63.41)	76.30 (60.87)	64.30 (53.32)	54.60 (47.66)	45.10 (45.17)	38.30 (38.23)	31.70 (34.23)	23.30 (28.84)	20.70 (27.03)	16.80 (24.21)	8.20 (16.68)	47.10 (43.35)
5. T_5	76.30 (60.80)	71.30 (57.61)	62.60 (52.32)	51.60 (45.84)	44.00 (41.54)	40.30 (39.41)	30.10 (33.27)	34.10 (31.71)	23.30 (28.84)	20.00 (26.55)	11.80 (17.41)	3.80 (11.47)	36.60 (37.25)
6. T_6	80.00 (63.40)	76.30 (60.79)	58.60 (50.56)	49.00 (44.41)	43.60 (41.34)	37.30 (37.64)	29.20 (32.70)	22.60 (27.95)	18.00 (25.09)	13.30 (21.33)	0.83 (5.83)	0.00 (0.00)	33.00 (35.03)
7. T_7	80.00 (63.41)	72.20 (58.20)	55.60 (48.24)	43.00 (41.25)	38.30 (38.23)	33.60 (35.45)	28.30 (32.13)	24.30 (29.54)	16.16 (24.04)	13.00 (21.14)	0.30 (13.16)	0.00 (0.00)	30.80 (33.72)
8. T_8	78.40 (62.47)	75.20 (60.12)	57.00 (49.00)	50.60 (45.37)	41.60 (40.18)	36.60 (37.34)	30.20 (33.30)	21.60 (27.72)	15.70 (23.30)	3.20 (10.34)	0.00 (0.00)	0.00 (0.00)	28.80 (32.44)
9. T_9	92.00 (74.04)	86.70 (68.58)	83.40 (65.93)	76.60 (61.10)	72.70 (58.47)	64.40 (53.33)	61.00 (51.33)	52.30 (46.32)	45.30 (42.30)	36.00 (36.35)	28.50 (32.32)	22.30 (28.17)	61.30 (51.55)
10. T_{10}	73.60 (59.06)	62.00 (51.93)	55.00 (47.86)	32.30 (34.63)	27.60 (31.71)	24.70 (29.77)	20.30 (26.79)	17.00 (24.32)	5.68 (18.51)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.10 (26.66)
11. T_{11}	80.10 (63.52)	66.00 (54.32)	52.00 (46.13)	45.30 (42.30)	42.00 (40.38)	37.30 (37.64)	32.30 (34.68)	25.60 (31.06)	20.70 (27.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	27.20 (31.42)
12. T_{12}	86.00 (68.02)	81.00 (64.71)	71.30 (57.61)	64.00 (53.11)	60.30 (50.14)	54.30 (47.47)	43.60 (41.34)	37.30 (37.64)	37.60 (38.82)	27.60 (31.73)	19.00 (25.83)	6.40 (14.69)	48.70 (44.23)
CD (0.05)	4.89	5.70	2.65	3.16	3.07	2.99	4.99	3.69	3.92	3.36	4.88	3.22	3.63

Figures in parenthesis indicate transformed values

followed by groundnut cake and paddy husk. In control pots of the total and antagonistic organisms were very less (table 15).

4.6. Effect of NPK fertilizers on the survival of *R. solani*

The population of *R. solani* showed an increase upto 100 days of incubation and thereafter it decreased gradually (table 16, fig. 9). In general up to 140 days maximum population of *R. solani* was recorded in $n_1p_0k_0$. Control pots recorded maximum population of *R. solani* during most of the observations. From 140 days to 320 days maximum population was recorded in $n_1p_1k_0$ except at 180 days of incubation. At 20 and 40 days of incubation the populations in $n_1p_0k_0$ and $n_1p_1k_1$ were on par.

Minimum population of *R. solani* was observed in $n_0p_1k_1$ except after 40, 60, 140 and 260 days of incubation, where minimum population of *R. solani* was observed in $n_0p_0k_1$. After 340 days the population of *R. solani* was observed only in control plots.

4.7. Influence of soil moisture, temperature and pH on the survival of *R. solani*

4.7.1 Soil moisture

In general, the survival of *R. solani* was low at 10 per cent moisture level. But it increased considerably

Table 15. Effect of organic amendments on the population of microorganisms

Treatments	Microorganisms isolated		Antagonistic organism isolated
T_1 Control	Fungi	3.1×10^4	*Aspergillus niger*
	Bacteria	2.6×10^6	-
	Actinomycetes	5.1×10^6	-
T_2 Glyricidia leaves	Fungi	5.4×10^4	*Aspergillus flavus*. *Fusarium solani*
	Bacteria	3.8×10^6	
	Actinomycetes	5.5×10^6	
T_3 Clerodendron leaves	Fungi	3.1×10^4	*Aspergillus nidulans*
	Bacteria	4.4×10^6	
	Actinomycetes	4.3×10^6	
T_4 Eupatorium leaves	Fungi	2.8×10^6	
	Bacteria	4.4×10^6	
	Actinomycetes	4.8×10^6	
T_5 Saw dust	Fungi	6.4×10^4	*A. niger* *A. terreus* *Penicillium citrinum*
	Bacteria	5.1×10^6	*Bacillus* sp. *Rothia* sp.
	Actinomycetes	6.3×10^6	*Streptomyces* sp.
T_6 Coconut pith	Fungi	4.1×10^4	*A. flavus*
	Bacteria	3.8×10^6	*Bacillus* sp.
	Actinomycetes	7.1×10^6	*Streptomyces* sp.

Table 15 continued.

Treatments	Microorganisms isolated		Antagonistic organism isolated
T_7 Neemcake	F	4.3×10^4	Panicillium citrinum
	B	3.2×10^6	Penicillium wortmanii
	A	6.8×10^6	Bacillus sp.
T_8 Groundnut cake	F	3.2×10^4	A. niger, A. flavus, Penicillium sp.
	B	4.3×10^6	Bacillus sp.
	A	5.5×10^6	Streptomyces sp.
T_9 Punna cake	F	3.2×10^4	A. paradoxus, A. niger, A. terreus
	B	5.1×10^6	
	A	6.2×10^6	
T_{10} Fish waste	F	6.2×10^4	A. nidulans, A. flavus, A. niger
	B	5.2×10^6	Bacillus sp., Chromobacterium sp.
	A	6.7×10^6	
T_{11} Paddy husk	F	6.8×10^4	Trichoderma harzianum, Penicillium sp., Rhizopus stolonifer
	B	4.1×10^6	Rothia sp.
	A	2.1×10^6	Streptomyces sp.
T_{12} Groundnot shell	F	2.2×10^4	Aspergillus niger
	B	1.1×10^6	
	A	1.2×10^6	

F - Fungi

B - Bacteria

A - Actinomycetes

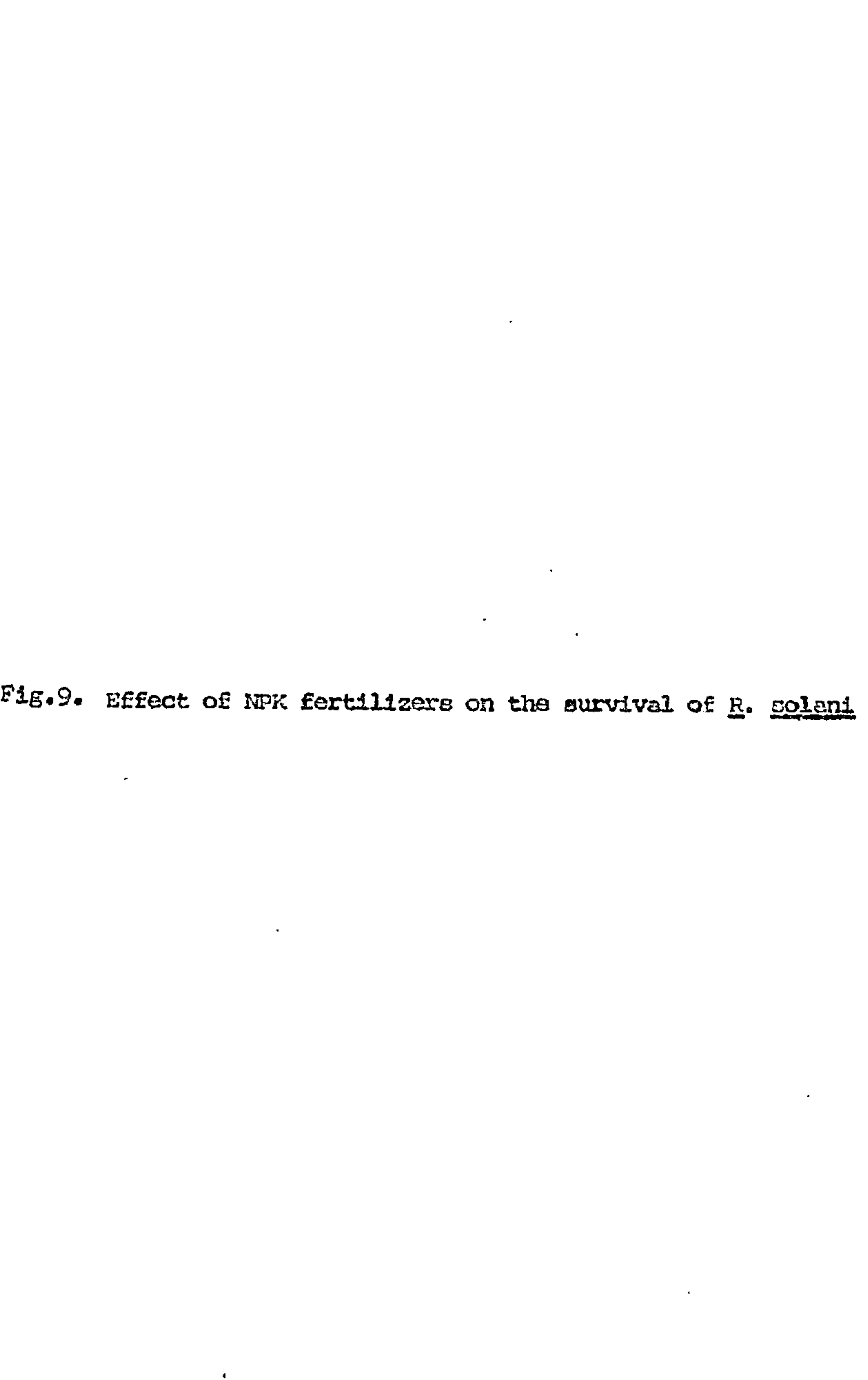


Fig.9. Effect of NPK fertilizers on the survival of *R. solani*

Table 16. Effect of NPK fertilizers on the survival of *R. solani*
(Population 10^4/g soil)

Treatments	Periods of incubation in days									
	20	40	60	80	100	120	140	160	180	200
1. $n_0p_0k_0$	3.73 (2.18)	3.81 (2.19)	3.93 (2.22)	3.99 (2.23)	2.85 (1.96)	2.65 (1.91)	2.55 (1.88)	2.35 (1.83)	2.28 (1.81)	2.13 (1.
2. $n_0p_0k_1$	1.68 (1.65)	1.78 (1.67)	1.81 (1.68)	1.94 (1.72)	1.99 (1.73)	1.63 (1.62)	1.53 (1.59)	1.33 (1.53)	1.10 (1.45)	0.99 (1.
3. $n_0p_1k_0$	2.11 (1.76)	2.21 (1.79)	2.33 (1.83)	2.48 (1.87)	2.57 (1.89)	1.88 (1.69)	1.75 (1.66)	1.53 (1.59)	1.31 (1.58)	1.28 (1.
4. $n_0p_1k_1$	1.62 (1.62)	1.82 (1.68)	1.78 (1.67)	1.88 (1.69)	1.77 (1.66)	1.62 (1.62)	1.57 (1.60)	1.41 (1.55)	1.31 (1.52)	1.22 (1.
5. $n_1p_0k_0$	2.31 (1.82)	2.38 (1.84)	2.44 (1.85)	3.55 (2.13)	3.78 (2.19)	3.88 (2.21)	2.38 (1.92)	2.19 (1.79)	2.20 (1.79)	1.71 (1.
6. $n_1p_0k_1$	1.75 (1.65)	1.89 (1.69)	1.99 (1.73)	2.02 (1.74)	2.10 (1.76)	2.00(1.73)	1.85 (1.68)	1.76 (1.66)	1.71 (1.65)	1.62 (1.
7. $n_1p_1k_0$	1.75 (1.66)	1.89 (1.69)	1.99 (1.73)	2.56 (1.89)	2.68 (1.92)	2.77 (1.94)	2.68 (1.82)	2.57 (1.89)	2.11 (1.76)	1.98 (1.
8. $n_1p_1k_1$	2.32 (1.82)	2.41 (1.85)	2.62 (1.91)	2.71 (1.93)	2.83 (1.96)	2.13 (1.77)	1.81 (1.68)	1.74 (1.66)	1.41 (1.55)	1.34 (1.

Treatments	Periods of incubation in days									
	220	240	260	280	300	320	340	360	380	400
1. $n_0p_0k_0$	1.99 (1.73)	1.87 (1.69)	1.65 (1.62)	1.63 (1.62)	1.43 (1.55)	1.15 (1.47)	0.93 (1.39)	0.63 (1.28)	0.24 (1.11)	0.11 (1.
2. $n_0p_0k_1$	0.99 (1.41)	0.73 (1.32)	0.31 (1.14)	0.22 (1.10)	0.08 (1.04)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.
3. $n_0p_1k_0$	1.15 (1.47)	0.89 (1.37)	0.76 (1.33)	0.71 (1.31)	0.64 (1.28)	0.47 (1.21)	0.41 (1.19)	0.00 (1.00)	0.00 (1.00)	0.00 (1.
4. $n_0p_1k_1$	0.91 (1.38)	0.79 (1.34)	0.51 (1.23)	0.21 (1.09)	0.09 (1.04)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.
5. $n_1p_0k_0$	1.11 (1.45)	1.00 (1.42)	0.88 (1.37)	0.55 (1.24)	0.38 (1.17)	0.08 (1.04)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.
6. $n_1p_0k_1$	1.38 (1.54)	1.13 (1.46)	0.99 (1.41)	0.81 (1.35)	0.67 (1.29)	0.52 (1.23)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.
7. $n_1p_1k_0$	1.91 (1.70)	1.68 (1.64)	1.54 (1.59)	1.31 (1.52)	1.23 (1.49)	0.99 (1.41)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.
8. $n_1p_1k_1$	1.17 (1.47)	1.11 (1.45)	0.94 (1.39)	0.71 (1.31)	1.14 (1.46)	1.14 (1.46)	0.66 (1.28)	0.00 (1.00)	0.00 (1.00)	0.00 (1

CD (0.05) = 0.084

Figures in parenthesis indicate transformed values

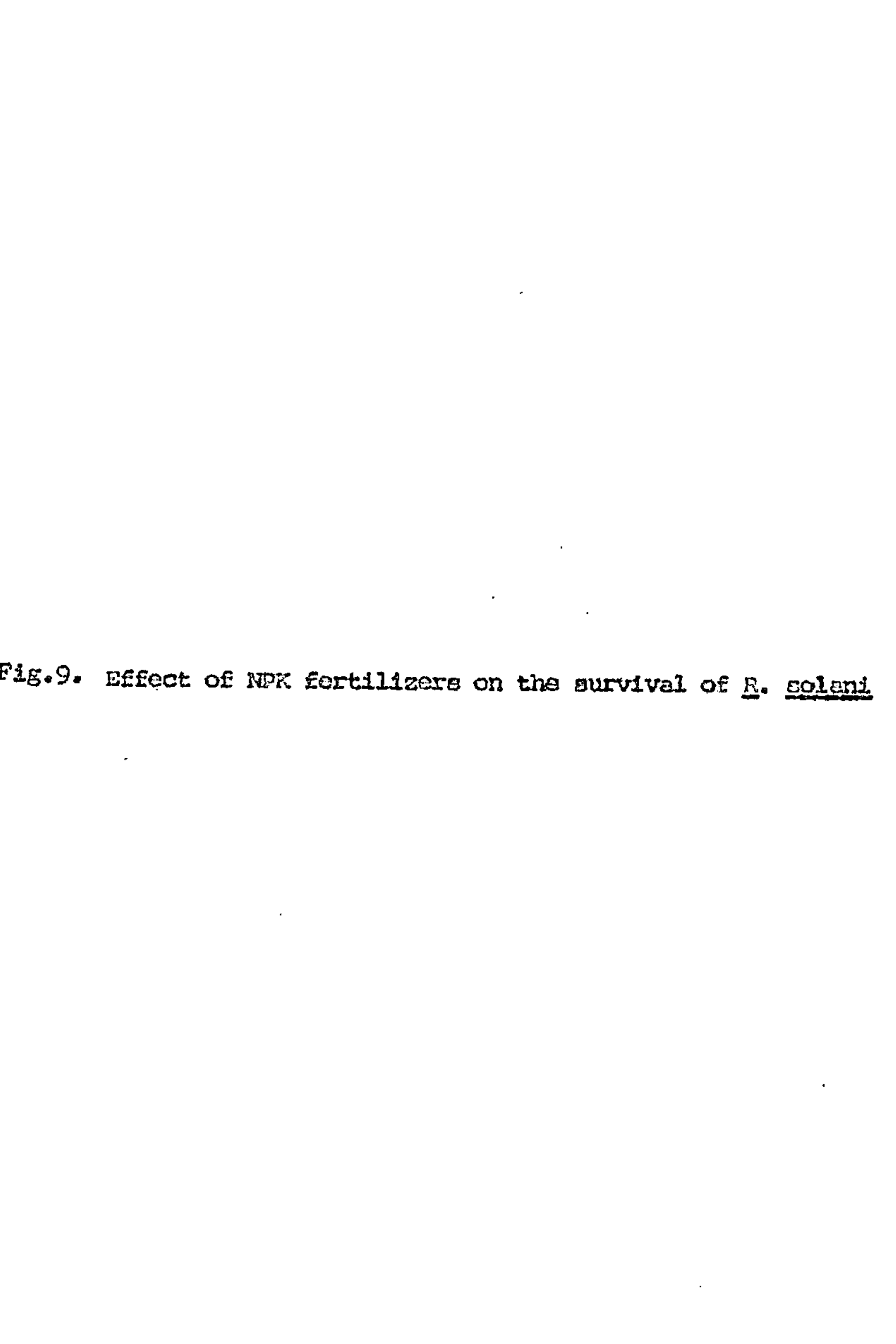


Fig.9. Effect of NPK fertilizers on the survival of *R. solani*

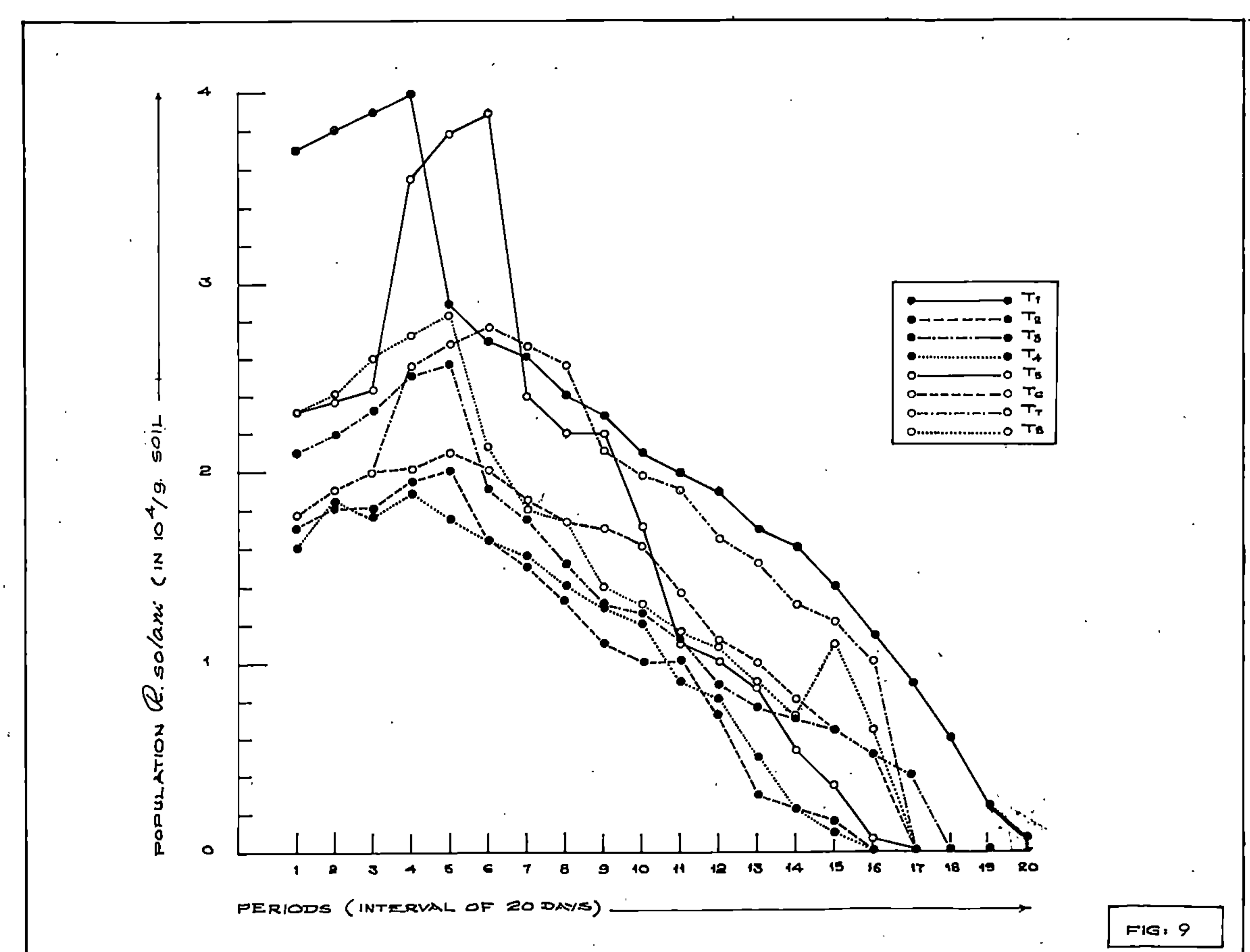


FIG: 9

at 15 per cent moisture level and thereafter it showed a decreasing trend (table 17). In I_1 (100 per cent inoculum) 100 per cent survival was recorded in all the levels of moisture except 45 per cent (m_5), which showed 94 per cent survival. In I_2 at 10 per cent moisture level the survival was 98.4 per cent and at 15 and 25 per cent moisture level there was 100 per cent survival. There was a reduction in survival corresponding to increase in moisture level from 25 to 45 per cent. In all the moisture levels the survival of R. solani was found to decrease corresponding to the decrease in the inoculum in the soil mixture.

4.7.2. Soil temperature

Significant differences were observed in the survival percentage of R. solani when various dilutions of inoculum: soil mixtures were kept at different temperatures (table 18).

In general, there was 100 per cent survival in I_1, I_2, I_3 up to t_4. At all temperatures as the inoculum level decreased there was a corresponding reduction in the percentage of survival of R. solani. The most favourable temperature for the survival of the fungus was between 20°C and 30°C.

4.7.3. Soil pH

The pH also was found to have significant influence

Table 17. Effect of moisture on survival of *R. solani*

Treatments Inoculum: field soil	Moisture percentage					
	10 (m_1)	15 (m_2)	25 (m_3)	35 (m_4)	45 (m_5)	Mean
I_1. 100:0	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	94.00 (75.82)	99.75 (87.16)
I_2. 98:2	98.40 (82.63)	100.00 (90.00)	100.00 (90.00)	96.10 (78.64)	87.70 (69.47)	98.10 (82.15)
I_3. 90:10	91.60 (73.19)	100.00 (90.00)	96.14 (78.64)	91.02 (72.53)	82.38 (65.15)	94.10 (75.91)
I_4. 50:50	84.47 (66.77)	97.59 (81.03)	84.47 (66.76)	88.67 (70.30)	73.02 (58.69)	86.80 (68.71)
I_5. 2:98	80.00 (63.41)	91.02 (72.53)	80.34 (63.65)	71.67 (57.82)	64.37 (53.33)	78.20 (62.15)
I_6. 10:90	79.01 (62.71)	83.05 (65.66)	75.33 (60.19)	48.33 (44.02)	50.00 (44.98)	67.90 (55.51)
I_7. 0:100	26.63 (31.06)	50.33 (45.17)	52.67 (46.51)	38.32 (38.23)	25.00 (29.98)	38.20 (38.19)
Mean	84.90 (67.11)	94.44 (76.34)	89.20 (70.81)	81.50 (64.50)	70.00 (56.77)	

CD (0.05) for inoculum (I) - 1.169
for moisture (m) - 0.987
for I x m - 2.613

Figures in parentheses indicate transformed values

Table 18. Effect of temperature on the survival of *R. solani*

Treatments	Inoculum: Field soil	Temperature					
		10±2°C (t_1)	15±2°C (t_2)	20±2°C (t_3)	30±2°C (t_4)	40±2°C (t_5)	Mean
I_1.	100:0	100.0 (90.00)	100.0 (90.00)	100.0 (90.00)	100.0 (90.00)	65.0 (53.74)	98.4 (82.74)
I_2.	98:2	100.0 (90.00)	100.0 (90.00)	100.0 (90.00)	100.0 (90.00)	37.9 (37.98)	96.6 (79.59)
I_3.	90:10	100.0 (90.00)	92.7 (74.25)	100.0 (90.00)	100.0 (90.00)	37.9 (38.02)	94.5 (76.47)
I_4.	50:50	46.0 (42.68)	83.5 (50.20)	100.0 (90.00)	100.0 (90.00)	32.0 (34.43)	81.8 (64.72)
I_5.	10:90	25.8 (30.55)	78.0 (62.01)	100.0 (90.00)	95.3 (77.48)	19.9 (26.48)	70.8 (57.30)
I_6.	2:98	15.0 (22.75)	65.7 (53.13)	83.8 (65.31)	82.0 (64.89)	9.9 (18.37)	50.2 (45.05)
I_7.	0:100	3.6 (11.01)	60.1 (50.03)	72.0 (58.55)	68.0 (55.54)	9.9 (18.37)	39.2 (38.76)
	Mean	65.1 (53.85)	87.8 (69.54)	98.1 (82.04)	96.4 (79.70)	28.9 (32.58)	

CD (0.05) Temperature (t) - 1.739
" Treatments (I) - 2.057
" t x I - 4.600

Figures in parentheses indicate transformed values

on the survival of R. solani (table 19). The survival of the fungus was found to increase with the increase in pH. In I_1, I_2, I_3 and I_4, 100 per cent survival was observed at pH 7 and 9 (p_4 and p_5). When the average effect of pH was considered maximum survival of 96.70 per cent was recorded at pH 7, which was on par with the survival at pH 9.

4.8. Isolation of microorganisms from paddy fields of different parts of Kerala and testing their antagonism against R. solani

4.8.1. Isolation of microorganisms

The following microorganisms were isolated from five different locations, namely, Vellayani, Karamana, Moncompu, Mannuthy and Pattambi as mentioned under 3.8.1 (table 20).

4.8.2. Antagonism of fungi to R. solani

Thirty species of fungi isolated from different locations were tested for their antagonistic reactions against R. solani and the types of interaction were grouped into four categories as mentioned under 3.8.2. Chaetomium globosum and Penicillium wortmanii showed 'C' (cessation of growth at line of contact) and 'D' (a clear zone of inhibition) types of antagonism respectively. Among the remaining fungi 12 species showed 'B' (over growth) type of antagonism, while the other 16 species did not exhibit any

Table 19. Effect of soil pH on the survival of *R. solani*

Treatments	Inoculum: field soil	pH 4 (p_1)	pH 5 (p_2)	pH 6 (p_3)	pH 7 (p_4)	pH 9 (p_5)	Mean
I_1.	100:0	34.90 (36.22)	95.10 (77.33)	95.30 (77.47)	100.00 (90.00)	100.00 (90.00)	92.60 (74.18)
I_2.	98:2	29.90 (33.15)	90.40 (71.92)	96.70 (79.52)	100.00 (90.00)	100.00 (90.00)	91.40 (72.92)
I_3.	90:10	25.80 (30.54)	81.40 (64.40)	90.40 (71.92)	100.00 (90.00)	100.00 (90.00)	87.60 (69.38)
I_4.	50:50	15.70 (23.24)	78.40 (62.25)	90.10 (71.59)	100.00 (90.00)	100.00 (90.00)	85.30 (67.43)
I_5.	2:98	9.60 (18.04)	56.00 (48.42)	75.10 (60.06)	90.40 (71.92)	90.40 (71.92)	65.60 (54.07)
I_6.	10:90	5.90 (14.04)	37.90 (37.98)	40.00 (39.19)	87.60 (69.35)	82.00 (64.89)	50.21 (45.09)
I_7.	0:100	0.0	23.90 (29.27)	34.00 (35.63)	67.10 (54.99)	70.10 (56.81)	33.50 (35.34)
	Mean	14.20 (22.18)	68.60 (55.92)	78.30 (62.20)	96.70 (79.46)	95.70 (79.09)	

CD (0.05) for treatments inoculum (I) - 2.652
" for pH (p) - 2.242
" for I x P - 5.931

Figures in parentheses indicate transformed values

Table 10. Microorganisms isolated from different locations

Location	Fungi	Bacteria	Actinomycetes
Vellayani	*Aspergillus flavus* Link.	*Alcaligenes* sp.	*Streptomyces* sp.1
	A. japonicus Saito	*Bacillus* sp.	*Streptomyces* sp.2
	A. niger Van Tiegh	*Bacillus subtilis*	*Streptomyces* sp.3
	A. paradoxus Fennell & Raper	*Chromobacterium* sp.	
	Chaetomium globosum Kunze & Schm	*Propionibacterium* sp.	
	Cladosporium cladosporioides (Fres.) de Vries	*Pseudomonas* sp.	
	Curvularia lunata (Wakker) Boedijn	*Rothia* sp.	
	Diplodia sp.	*Xanthomonas* sp.	
	Fusarium solani (Mart) Sacc		
	Mucor hiemalis Wehmeyer		
	Neurospora crass Shear & Dodge		
	Papulospora byssina Hotson		
	Penicillium citrinum Thom		
	P. italicum Wehmeyer		
	P. oxalicum Currie & Thom		
	Periconia sp.		
	Pestalotiopsis sp.		
	Trichoderma harzianum Rifai		
	T. viride Pers ex Fr.		
Karamana	*Aspergillus flavus* Link	*Alcaligenes* sp.	
	A. fumigatus Fres	*Bacillus* sp.	
	A. nidulans (Eidam) Wingate	*Bacillus subtilis*	
	A. niger Van Tiegh	*Corynebacterium* sp.	
	A. paradoxus Fennell & Raper	*Pseudomonas* sp.	
	Chaetomium sp.	*Rothia* sp.	
	Fusarium semitectum Berk & Rav		
	Penicillium italicum Wehmeyer		
	P. oxalicum Currie & Thom		
	P. purpurogenum Stoll		
	Pestalotiopsis sp. ~~Went & Geerlings~~		
	Rhizopus oryzae Went & Geerlings		
	R. stolonifer Ehrarb ex Fr. Lind		
	Trichoderma viride Pers ex Fr.		

Location	Fungi	Bacteria	Actinomycetes
		Acinetobacter sp.	
3.Moncompu	Aspergillus flavus Link.	Bacillus sp.	
	A. japonicus Saito	Bacillus subtilis	
	A. niger Van Tiegh	Propionibacterium sp.	
	A. terrus Thom	Rothia sp.	
	Diplodia sp.		
	Fusarium solani (Mart) Sacc		
	Gliocladium virens Miller, Giddens & Foster		
	Papulospora byssina Hotson		
	Penicillium sp.		
	Penicillium italicum Wehmeyer		
	P. wortmanii Kloecker		
	Pestalotiopsis sp.		
	Pestalotia bicolor Ell. & Ev.		
	Scopulariopsis brevicaulis (Sacc.) Bain		
	Trichoderma viride Pers. ex Fr.		
4. Mannuthy	Aspergillus flavus Link.	Acaligenes sp.	Streptomyces sp.
	A. fumigatus Fres.	Bacillus sp.	Streptomyces sp.
	A. japonicus Saito	Pseudomonas sp.	
	A. nidulans (Eidam) Wingate	Rothia sp.	
	A. niger Van Tiegh		
	Diplodia sp.		
	Fusarium semitectum Berk & Rav		
	Penicillium citrinum Thom		
	P. italicum Wehmeyer		
	P. oxalicum Currie & Thom		
	Rhizopus stolonifer Ehrarb ex Fr. Lind		
	Trichoderma viride Pers ex Fr.		

Location	Fungi	Bacteria	Actinomycetes
5. Pattambi	*Aspergillus flavus* Link.	*Acinetobacter* sp.	
	A. nidulans (Eidam) Wingate	*Alcaligenes* sp.	
	A. paradoxus Fennell & Raper	*Bacillus subtilis*	
	A. terreus Thom.	*Chromobacterium* sp.	
	Botryodiplodia theobromae Pat.	*Pseudomonas* sp..	
	Chaetomium globosum Kunze & Schm	*Rothia* sp.	
	Diplodia sp.		
	Fusarium sp.		
	Fusarium solani (Mart) Sacc		
	F. oxysporium Schlecht.		
	Penicillium citrinum Thom		
	P. italicum Wehmeyer		
	P. oxalicum Currie & Thom		
	Pestalotiopsis sp.		

antagonism (table 21, plate 1, A-I).

4.8.3. Interactions between fungi antagonistic to *R. solani*

The interactions, if any, between the 14 species of fungi antagonistic to *R. solani* have been noted and the data are presented (table 22, plate 2, A-I). Among the various antagonistic fungi *Aspergillus niger* was inhibitory to 11 other fungi tested. Only with *Penicillium oxalicum* and *P. wortmanii*, *A. niger* did not have any antagonistic activity. In general, *Trichoderma harzianum* and *T. viride* were without much interaction with other antagonistic fungi.

4.8.4. Antagonism of bacteria to *R. solani*

Eleven species of bacteria isolated from different locations were tested for their antagonistic reactions against *R. solani*. All the bacterial isolates, except *Xanthomonas* sp. and *Acinetobacter* sp., were found to exhibit antagonism against *R. solani*. (table 23, plate 3. A-D)

4.8.5. Interactions between bacteria antagonistic to *R. solani*

Interactions between the nine bacterial isolates antagonistic to *R. solani* were studied and the data are presented (table 24, plate 4 A-C).

Table 21. Antagonism of fungi to *R. solani*

Sl. No.	Fungi	Type of interaction
1.	*Aspergillus flavus* Link.	B
2.	*A. fumigatus* Fres.	A
3.	*A. japonicus* Saito.	A
4.	*A. nidulans* (Eidam) Wingate	A
5.	*A. niger* Van Tiegh	B
6.	*A. paradoxus* Fennell & Raper	A
7.	*A. terreus* Thom.	A
8.	*Chaetomium* sp.	A
9.	*C. globosum* Kunze & Schm	C
10.	*Curvularia lunata* (Wakker) Boedijn	A
11.	*Diplodia* sp.	A
12.	*Fusarium oxysporum* Schlecht	A
13.	*F. semitectum* Berk & Rav.	B
14.	*F. solani* (Mart) Sacc	B
15.	*Gliocladium virens* Miller, Giddens and Faster	B
16.	*Mucor hiemalis* Wehmeyer	A
17.	*Neurospora crassa* Shear & Dodge	B
18.	*Papulospora byssina* Hotson	A
19.	*Penicillium citrinum* Thom.	B
20.	*P. italicum* Wehmeyer	A
21.	*P. oxalicum* Currie & Thom.	B
22.	*Penicillium purpurogenum* Stoll.	A
23.	*P. wortmanii* Kloecker	D
24.	*Periconia* sp.	A
25.	*Pestalotiopsis* sp.	A
26.	*Rhizopus oryzae* Went & Geerlings	B
27.	*Rhizopus stolonifer* (Ehrarb ex Fr.) Lind	B
28.	*Scopulariopsis brevicaulis* (Sacc) Bain	A
29.	*Trichoderma harzianum* Rifai	B
30.	*T. viride* Pers. ex Fr.	B

A – Homogeneous (free intermingling of hyphae)

B – Over growth (*R. solani* over grown by test organism)

C – Cessation of growth at line of contact

D – Aversion (A clear zone of inhibition)

Plate 1. Antagonism of fungi to *Rhizoctonia solani*

A.

0. *Aspergillus flavus*

1. *Aspergillus flavus* x *Rhizoctonia solani*

2. *Rhizoctonia solani*

B.

0. *Aspergillus niger*

1. *Aspergillus niger* x *Rhizoctonia solani*

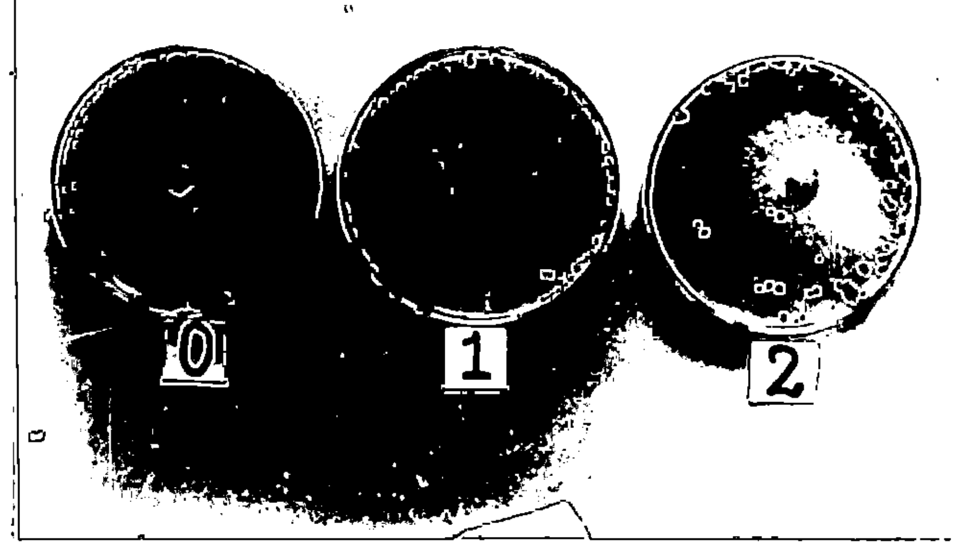
2. *Rhizoctonia solani*

C.

1. *Fusarium solani* x *Rhizoctonia solani*

2. *Fusarium solani*

3. *Rhizoctonia solani*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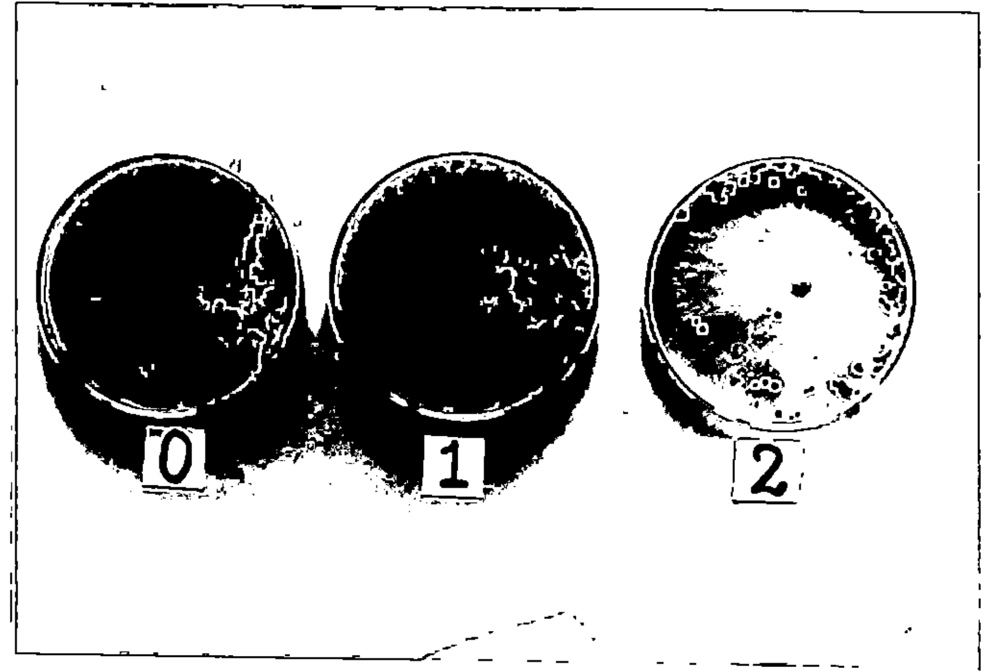

0
1
2

1
2
3

Plate 1 continued

D.

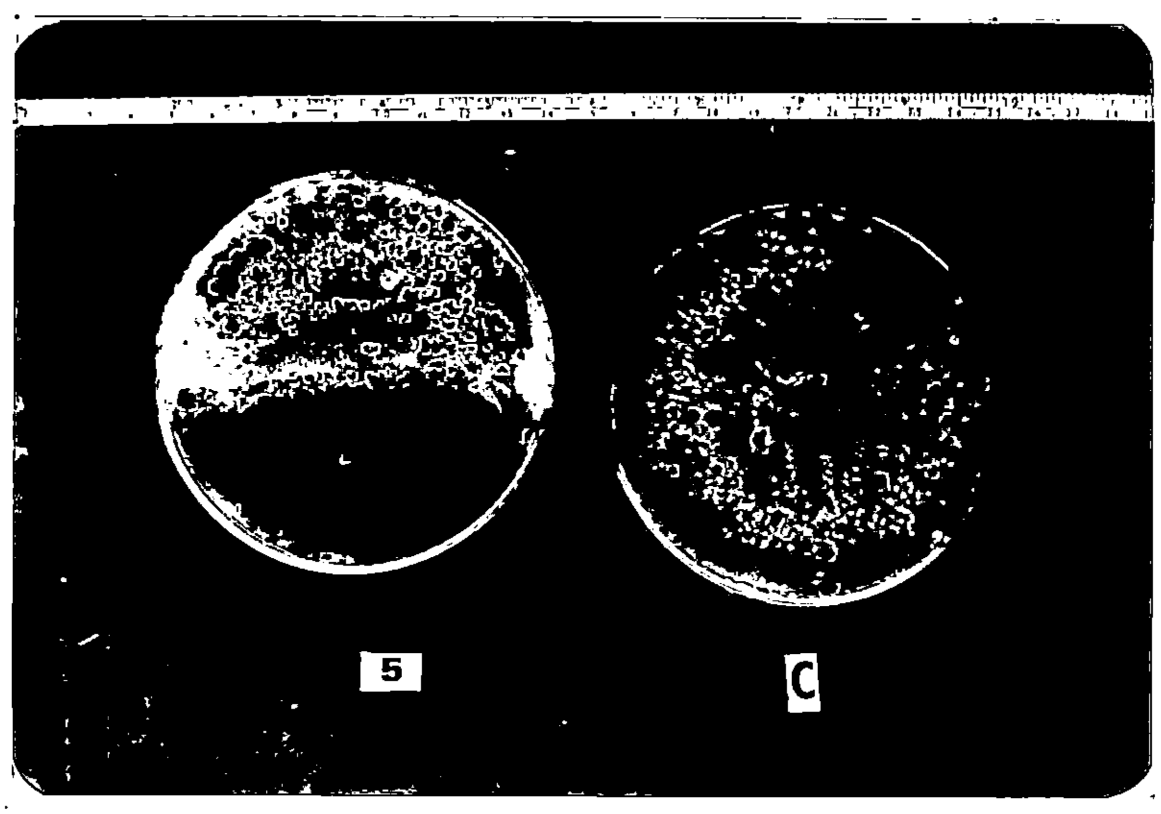
5. *Chaetomium globosum* x *Rhizoctonia solani*

C. *Rhizoctonia solani*

E.

C. *Rhizoctonia solani*

3. *Fusarium semitectum* x *Rhizoctonia solani*


5
C

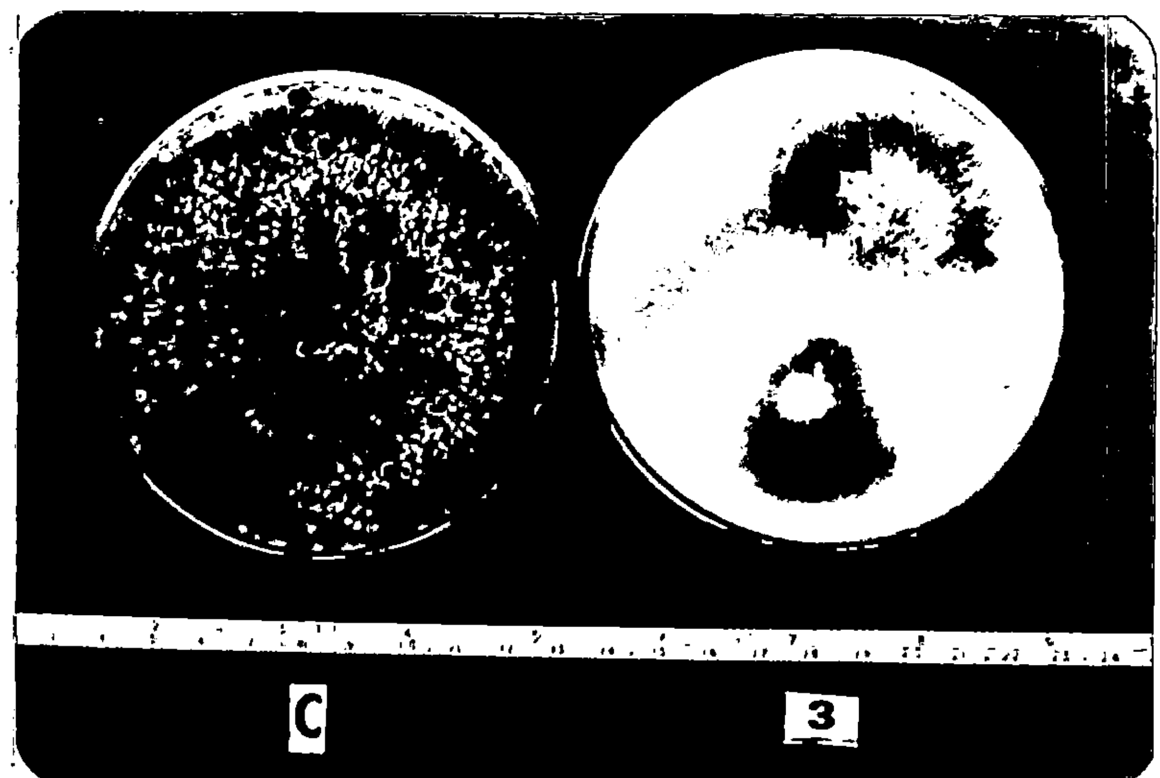

C
3

Plate 1 continued

F.

0. *Penicillium citrinum*

1. *Penicillium citrinum* x *Rhizoctonia solani*

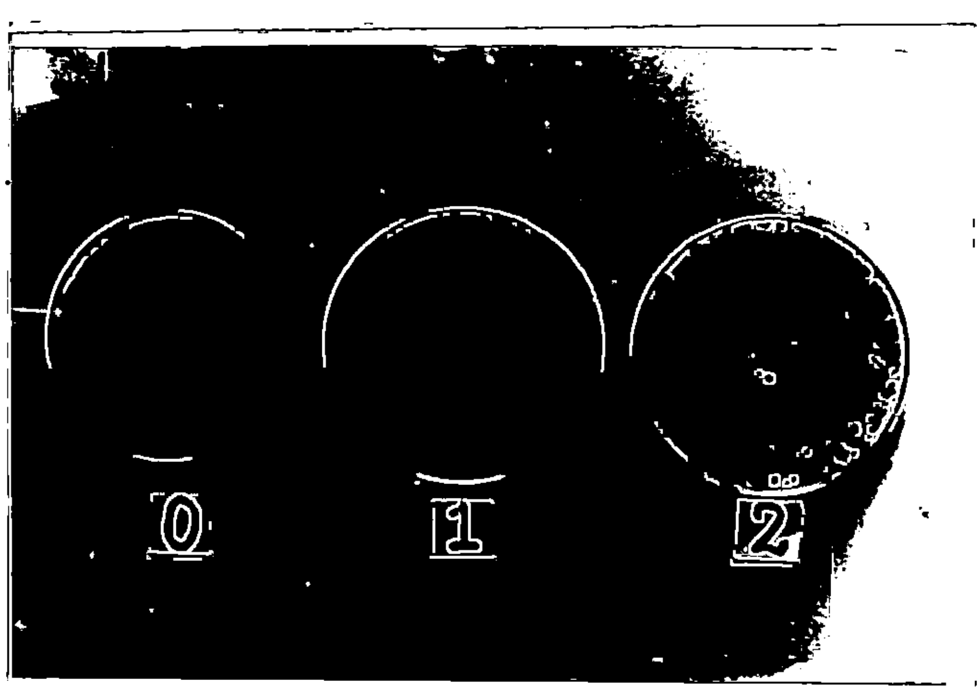
2. *Rhizoctonia solani*

G.

0. *Rhizoctonia solani*

1. *Penicillium oxalicum* x *R. solani*

2. *Penicillium oxalicum*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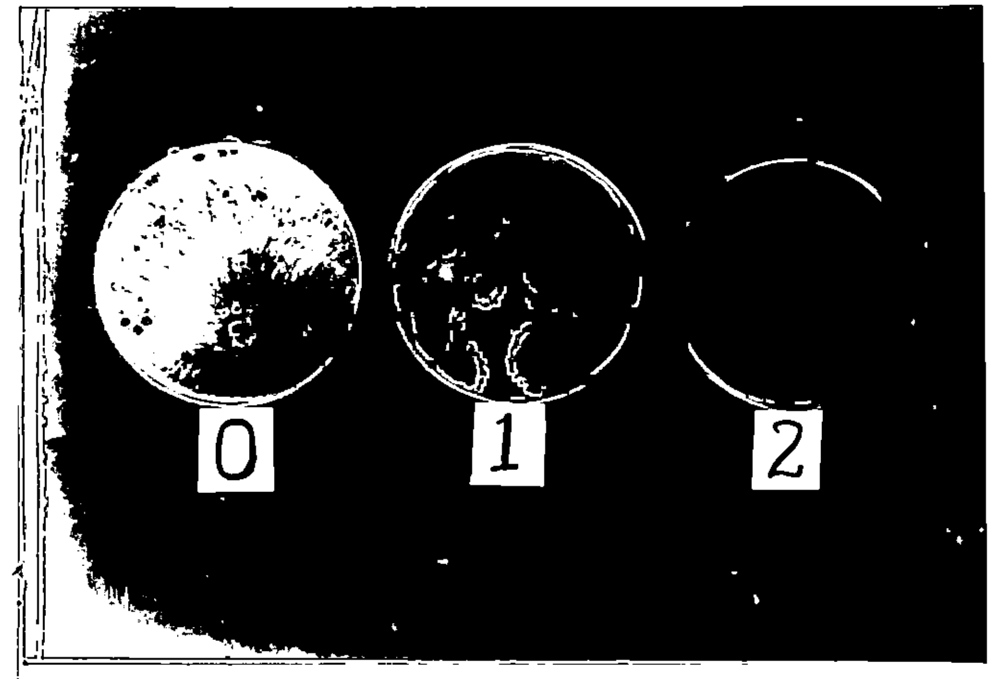

0
1
2

PLATE 1 (Continued)

H.

2. *Penicillium wortmanii* x *Rhizoctonia solani*

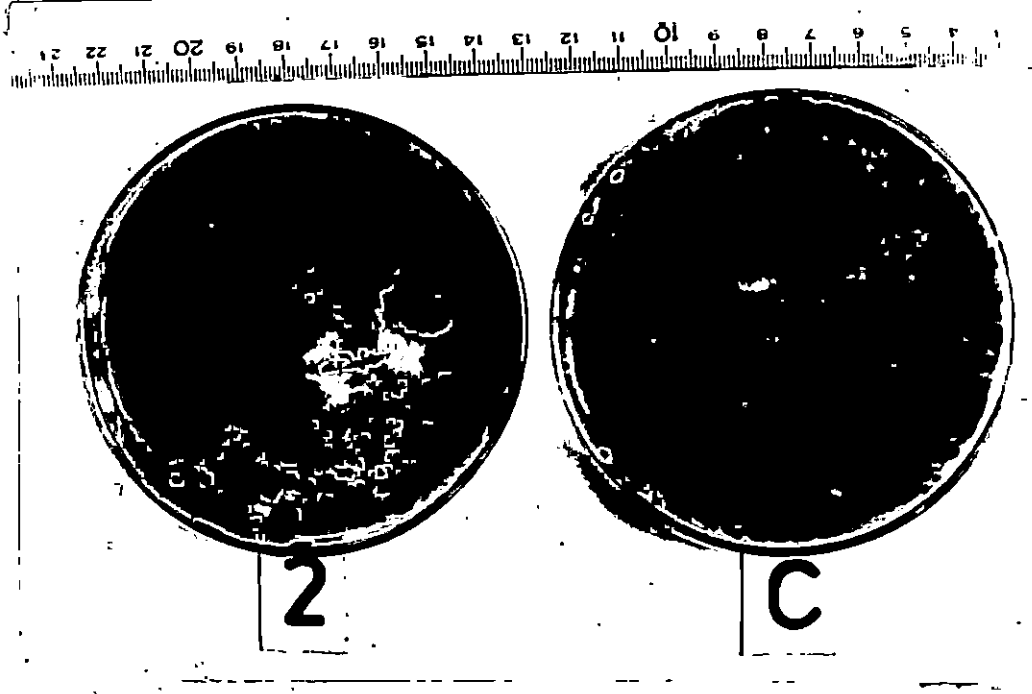
C. *Rhizoctonia solani*

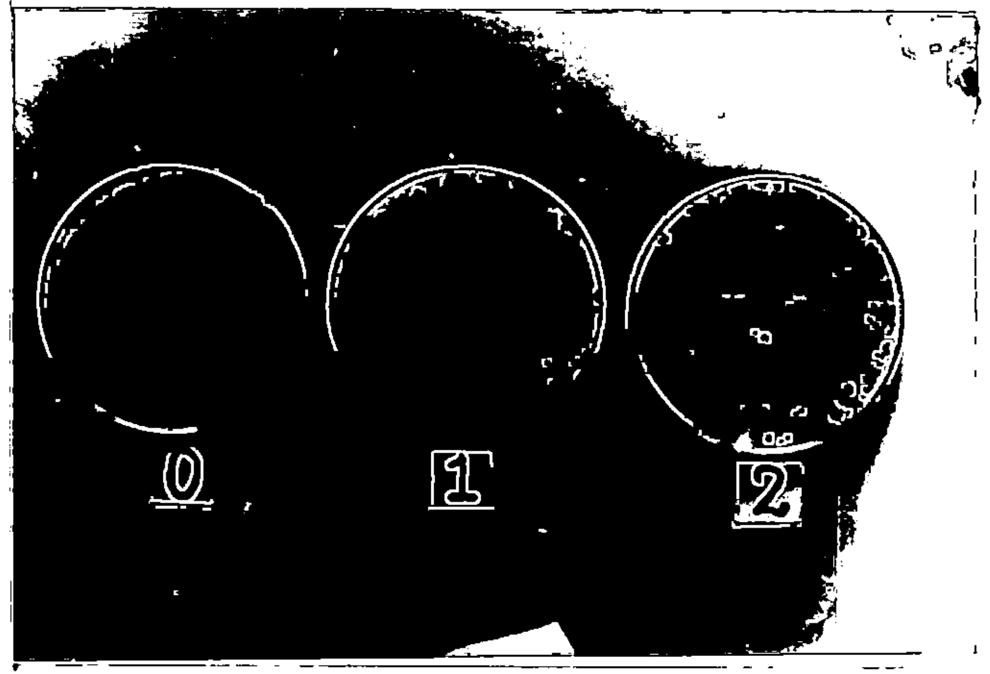
I.

0. *Trichoderma viride*

1. *T. viride* x *R. solani*

2. *Rhizoctonia solani*


2
C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1
2

Table 22. Interactions between fungi antagonistic to *R. solani*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-	+												
2	+	-												
3	+	+												
4	+	+	+											
5	+	+	+	+										
6	+	+	+	-	-									
7	+	+	-	+	+	+								
8	-	+	-	-	-	-	+							
9	-	-	+	+	+	-	-	+						
10	-	-	-	-	+	+	-	+	-					
11	+	+	-	+	+	-	-	+	+	+	+			
12	+	+	+	+	-	-	-	+	+	+				
13	+	+	+	-	-	-	+	-	-	-	-	-		-
14	+	+	+	+	+	-	+	-	-	-	-	-		

\+ Positive interaction

\- No interaction

1 *Aspergillus flavus*
2 *A. niger*
3 *Chaetomium globosum*
4 *Fusarium semetectum*
5 *F. solani*
6 *Gliocladium virens*
7 *Neurospora crassa*
8 *Penicillium citrinum*
9 *P. oxalicum*
10 *P. wortmanii*
11 *Rhizopus oryzae*
12 *R. stolonifer*
13 *Trichoderma harzianum*
14 *T. viride*

Plate 2. Interaction between fungi antagonistic to *R. solani*

A.

1. *Aspergillus flavus* x *Penicillium wortmanii*

2. *Aspergillus flavus*

3. *Penicillium wortmanii*

B.

1. *Aspergillus niger* x *Trichoderma harzianum*

2. *Trichoderma harzianum*

3. *Aspergillus niger*

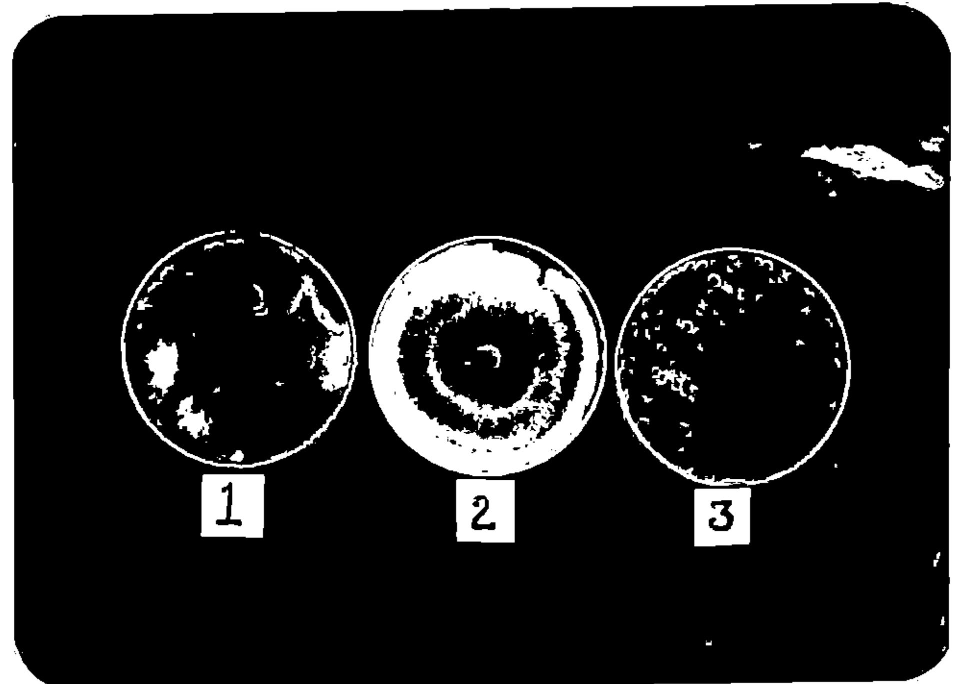
C.

1. *Aspergillus niger* x *Penicillium oxalicum*

2. *Aspergillus niger*

3. *Penicillium oxalicum*

1
2
3


1
2
3

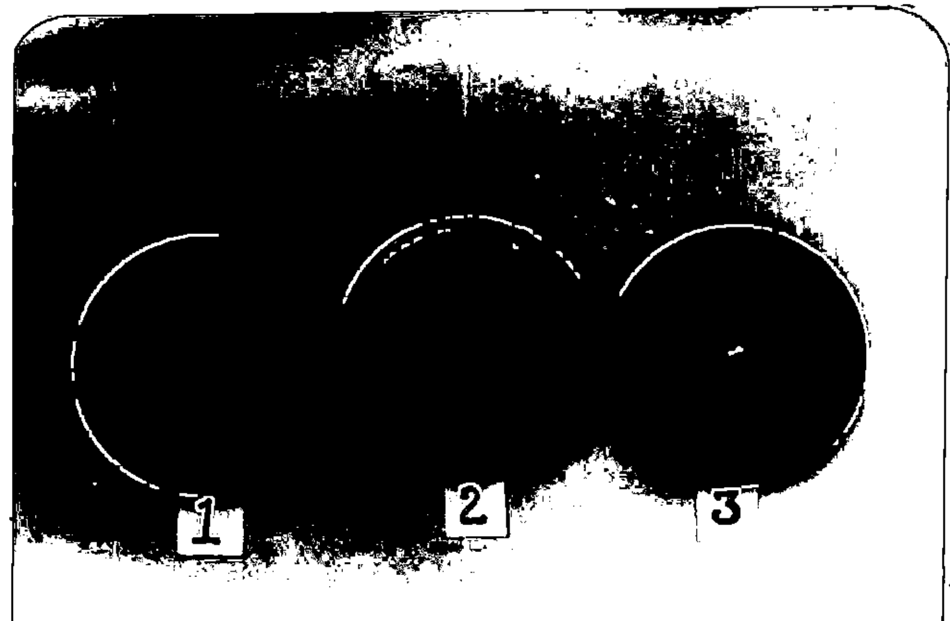

1
2
3

Plate 2 continued

D.

1. *Aspergillus niger* x *Trichoderma viride*

2. *Trichoderma viride*

3. *Aspergillus niger*

E.

1. *Trichoderma viride* x *Penicillium citrinum*

2. *T. viride*

3. *Penicillium citrinum*

F.

1. *Trichoderma viride* x *Penicillium wortmanii*

2. *Trichoderma viride*

3. *Penicillium wortmanii*

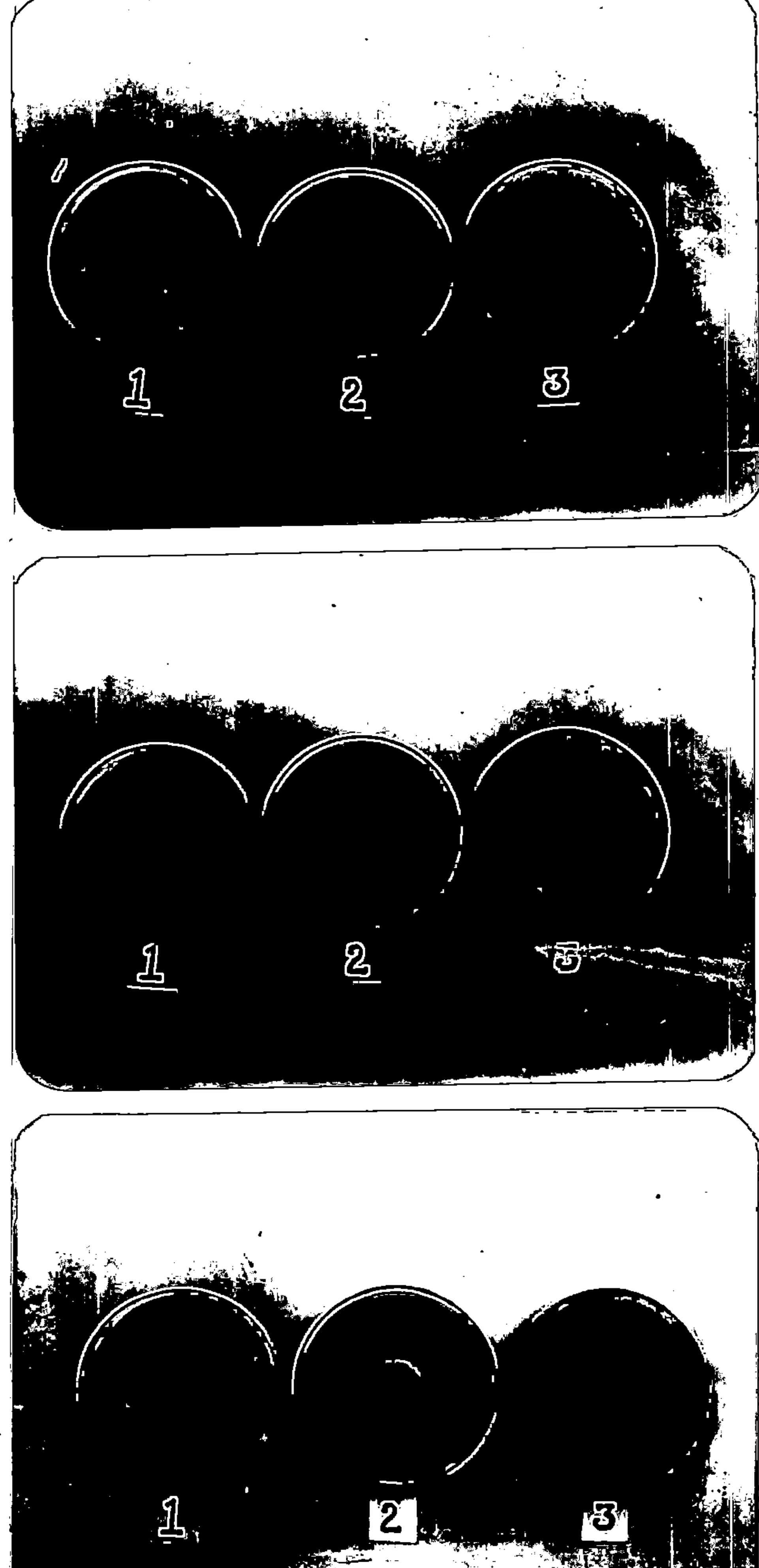

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Plate 2 continued

G.

1. *Trichoderma viride* x *Rhizopus oryzae*

2. *Trichoderma viride*

3. *Rhizopus oryzae*

H.

1. *Trichoderma viride* x *Aspergillus flavus*

2. *Trichoderma viride*

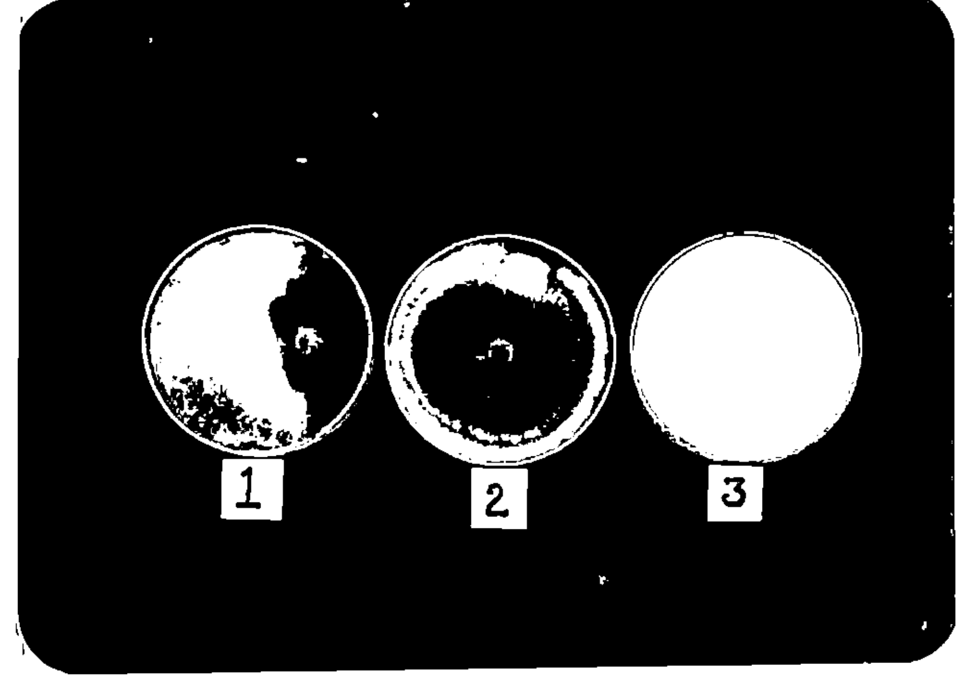
3. *Aspergillus flavus*

I.

1. *Trichoderma viride* x *Trichoderma harzianum*

2. *Trichoderma viride*

3. *Trichoderma harzianum*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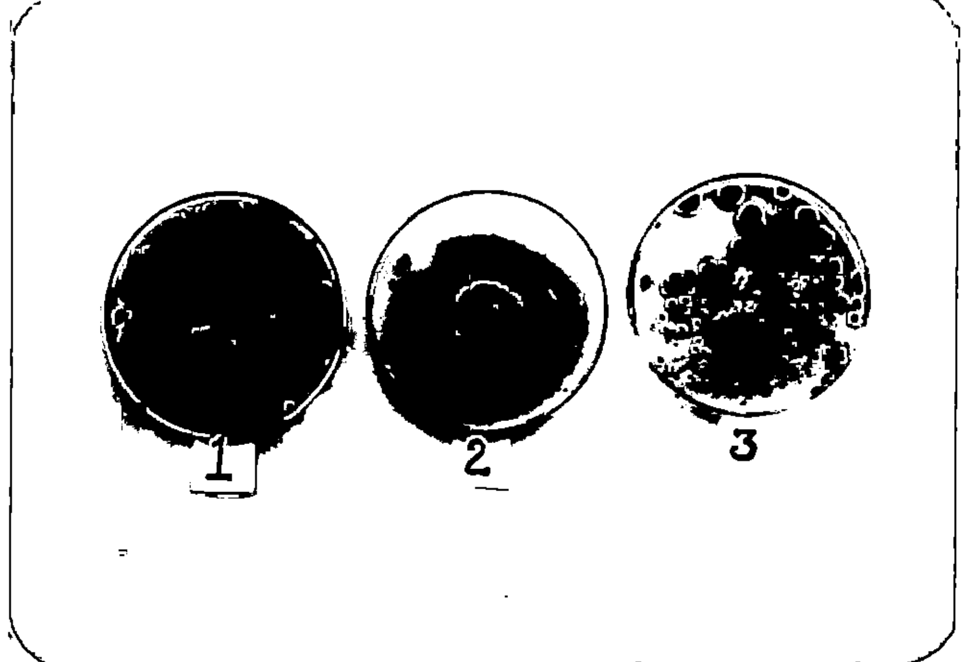
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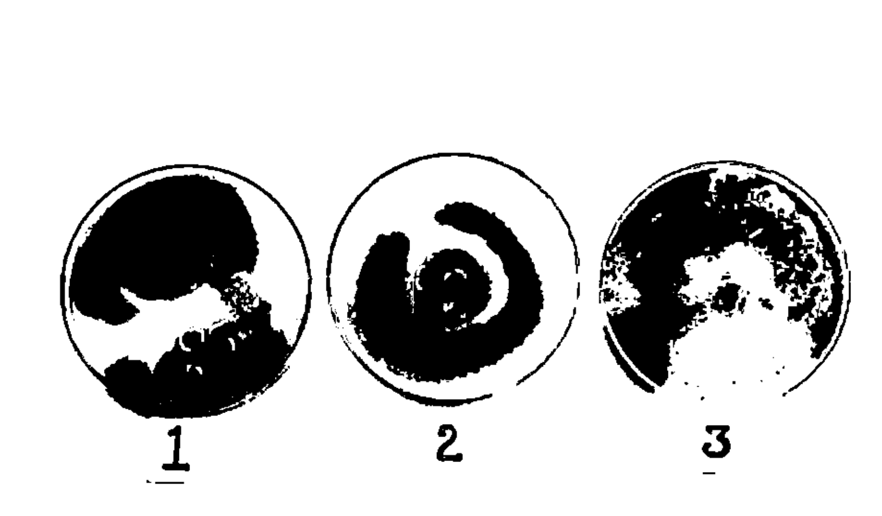
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Table 23. Antagonism of bacteria to *R. solani*

Sl. No.	Bacteria	Reaction
1.	*Acinetobacter* sp.	-
2.	*Alcaligenes* sp.	+
3.	*Bacillus* sp.	+
4.	*Bacillus subtilis*	+
5.	*Chromobacterium* sp.	+
6.	*Corynebacterium* sp.	+
7.	*Propionibacterium* sp.	+
8.	*Pseudomonas*sp.	+
9.	*Rothia* sp.	+
10.	*Xanthomonas* sp.	-

+ Positive antagonism

- No antagonism

PLATE 3. Antagonism of bacteria to *Rhizoctonia solani*

A.

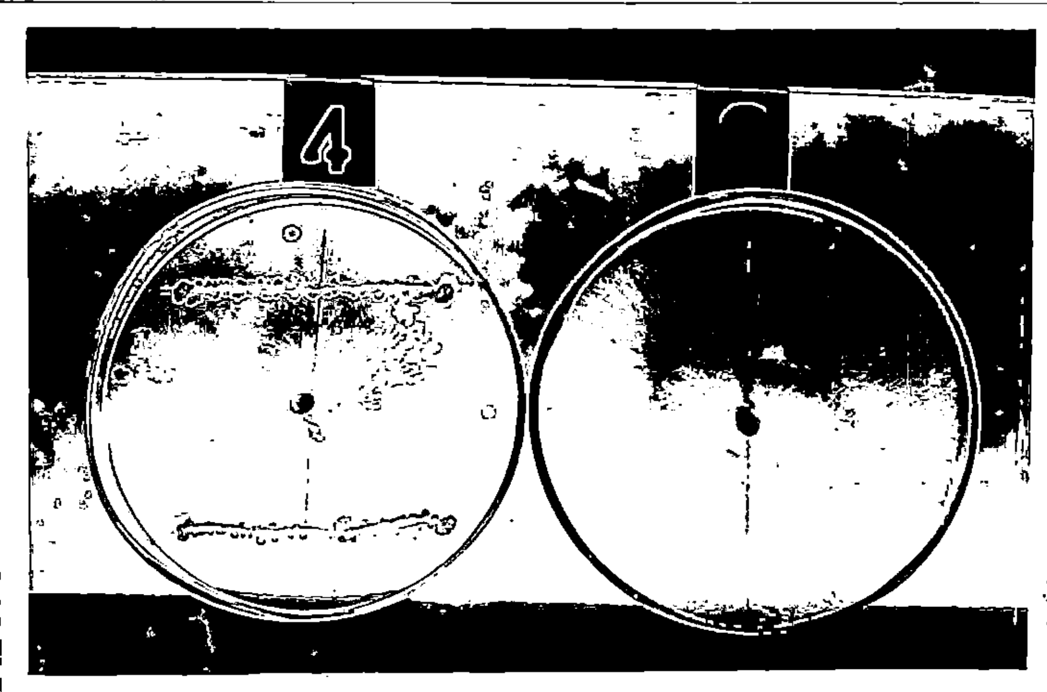
4. *Alcaligenes* sp. x *Rhizoctonia solani*

C. *R. solani*

B.

1. *Bacillus* sp. x *Rhizoctonia solani*

C. *Rhizoctonia solani*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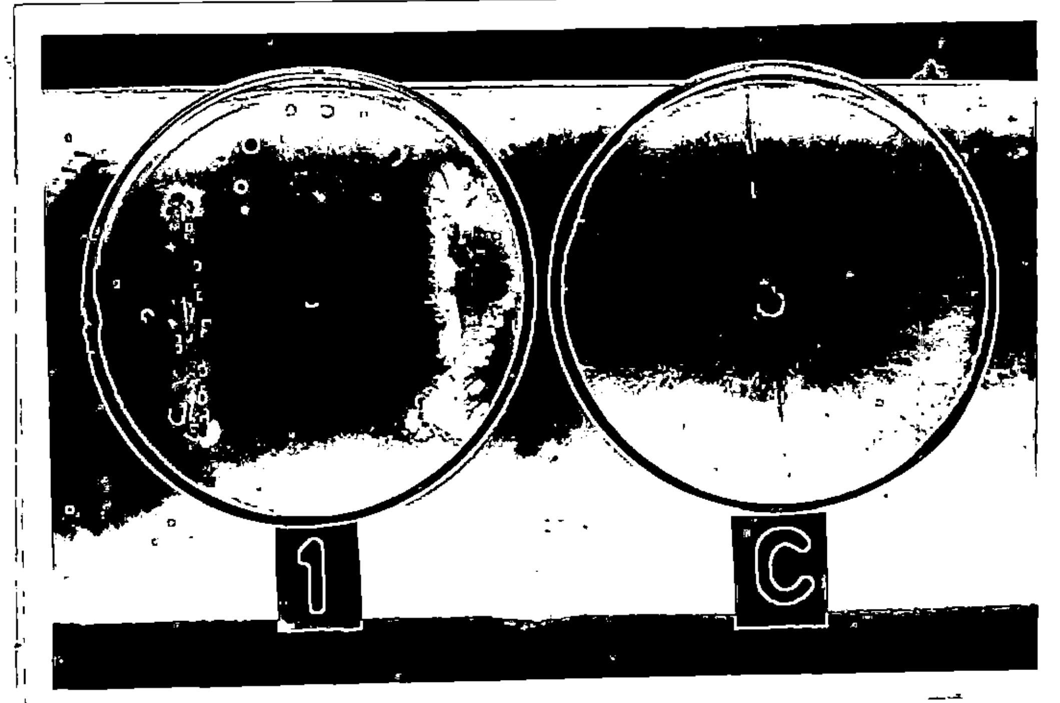

1
C

Plate 3 continued

C.

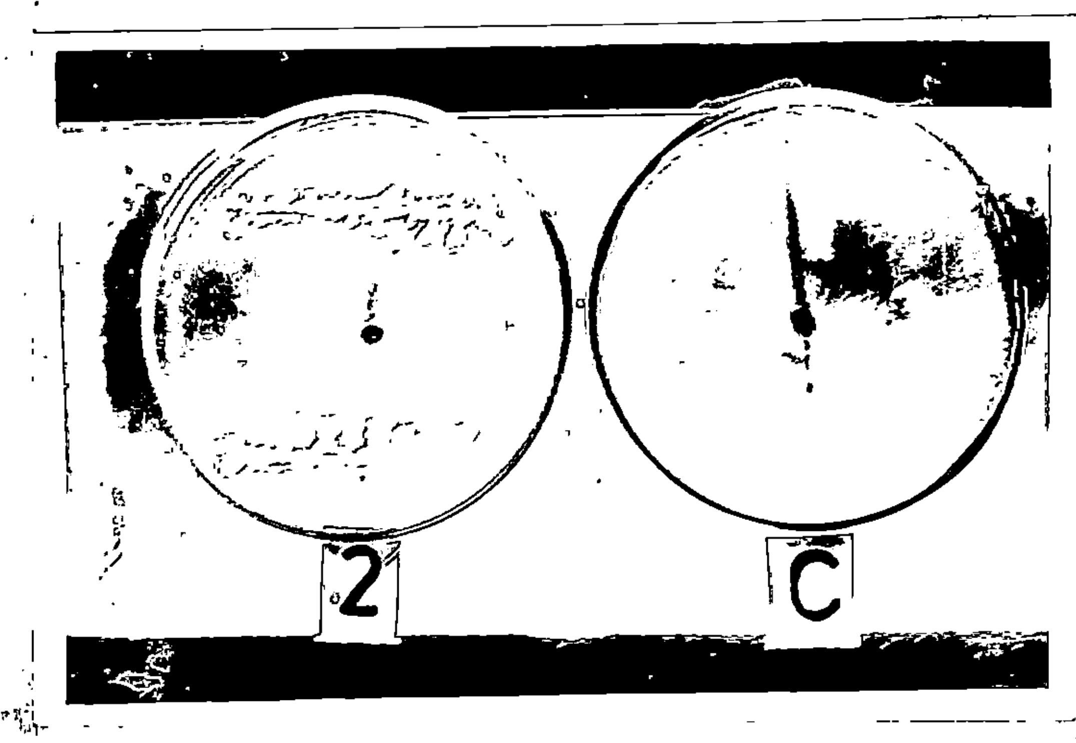
2. *Bacillus subtilis* x *Rhizoctonia solani*

C. *Rhizoctonia solani*

D.

3. *Propionibacterium* sp. x *Rhizoctonia solani*

C. *Rhizoctonia solani*



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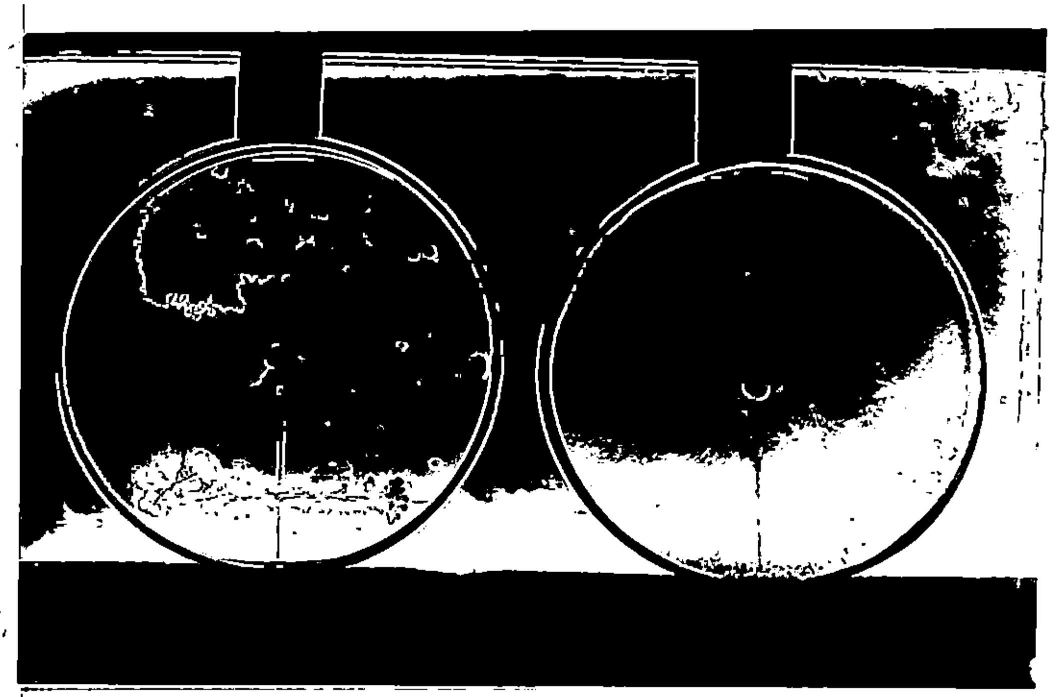


D

Table 24. Interactions between bacteria antagonistic to *R. solani*

	Alcaligenes sp.	*Bacillus* sp.	*B. subtilis*	*Chromobacterium* sp.	*Corynebacterium* sp.	*Propionibacterium* sp.	*Pseudomonas* sp.	*Rothia* sp.
Alcaligenes sp.	−							
Bacillus sp.	+							
B. subtilis	−	+						
Chromobacterium sp.	+	+	+					
Corynebacterium sp.	−	−	−	−				
Propionibacterium sp.	+	−	−	+	−			
Pseudomonas sp.	+	−	−	−	−	+		
Rothia sp.	+	+	+	−	−	−	−	

+ Positive interaction

− No interaction

Plate 4. Interaction between bacteria antagonistic to *R. solani*

A.

1. *Bacillus* sp. x *Bacillus subtilis*

2. *Bacillus subtilis*

3. *Bacillus* sp.

B.

1. *Bacillus subtilis* x *Propionibacterium* sp.

2. *Bacillus subtilis*

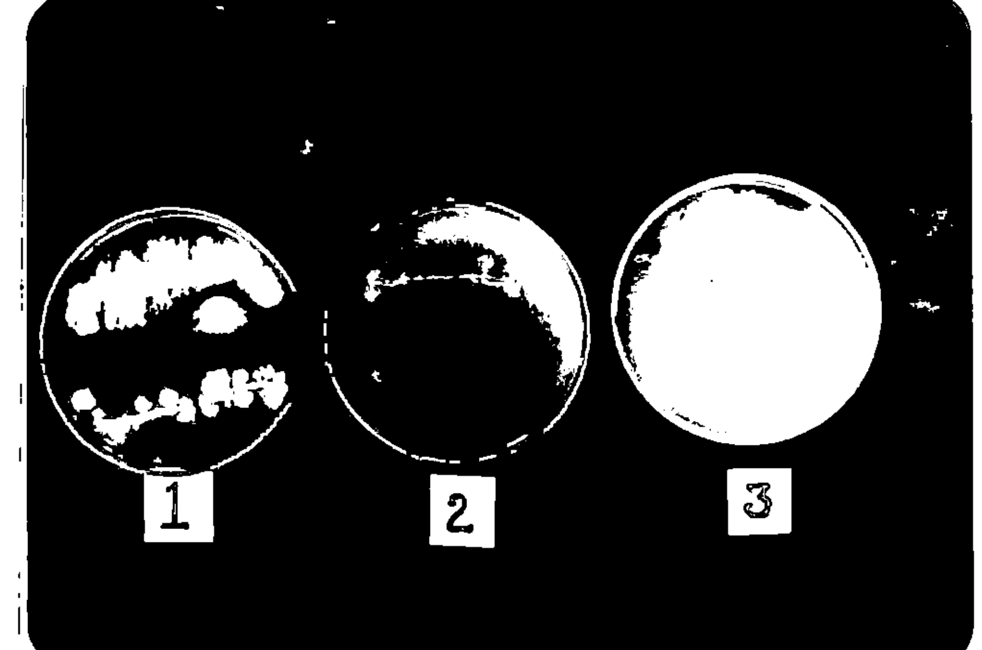
3. *Propionibacterium* sp.

C.

1. *Bacillus subtilis* x *Rothia* sp.

2. *Bacillus subtilis*

3. *Rothia* sp.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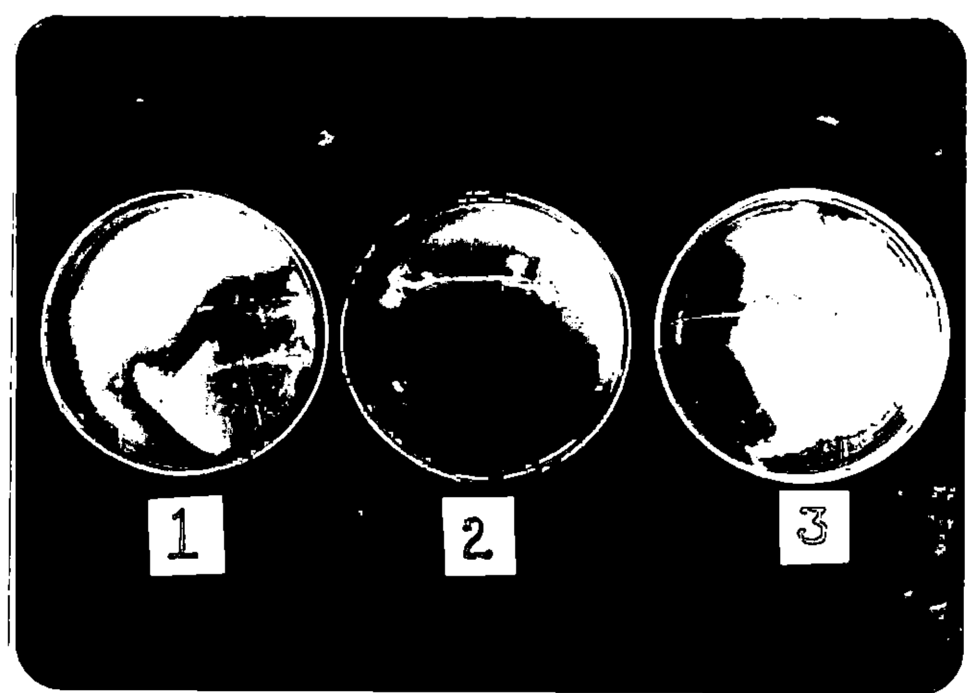
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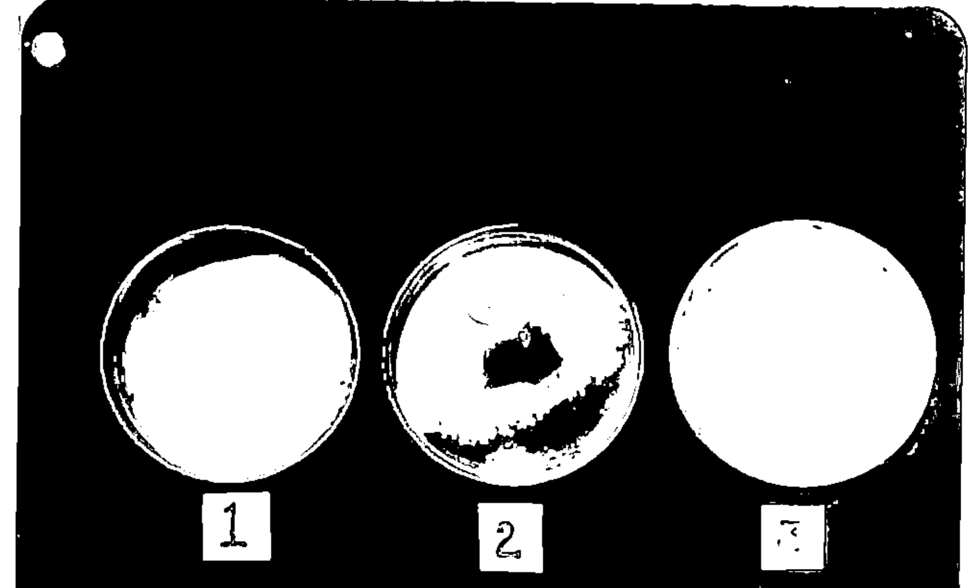
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Among the antagonistic bacteria *Corynebacterium* sp. did not show any antagonistic reaction against the other bacterial isolates. The maximum antagonistic reaction against other bacterial antagonists was observed in *Alcaligenes* sp. *Bacillus subtilis* was not antagonistic against *Alcaligenes* sp., *Corynebacterium* sp. *Propionibacterium* sp. and *Pseudomonas* sp.

4.8.6. Interactions between fungi and bacteria antagonistic to *R. solani*

The isolates of *Bacillus* were found to be antagonistic to all the isolates of antagonistic fungi (table 25, plate 5 A-D). *Propionibacterium* sp. was not antagonistic to any of the fungal isolates and *Chromobacterium* sp. and *Rothia* sp. were antagonistic only to *Penicillium wortmanii* and *Rhizopus stolonifer* respectively.

4.8.7. Antagonism of actinomycetes to *R. solani*

None of the five isolates of actinomycetes showed antagonism and *R. solani* was found to overgrow the actinomycetes and completely cover the plates.

4.8.8. Effect of antagonistic bacteria on the survival of *R. solani*

Inhibition of germination of sclerotia of *R. solani* by antagonistic bacteria was recorded after keeping the

Table 25. Interactions between fungi and bacteria antagonistic to *R. solani*

	Alcaligenes sp.	*Bacillus* sp.	*Bacillus subtilis*	*Chromobacterium* sp.	*Corynebacterium* sp.	*Propionibacterium* sp.	*Pseudomonas* sp.	*Rothia* sp.
Aspergillus niger	-	+	+	-	+	-	-	-
A. flavus	-	+	+	-	-	-	-	-
Chaetomium globosum	-	+	+	-	-	-	+	-
Fusarium semitectum	+	+	+	-	-	-	-	-
F. solani	-	+	+	-	-	-	-	-
Gliocladium virens	-	+	+	-	-	-	-	-
Neurospora crassa	-	+	+	-	-	-	-	-
Penicillium citrinum	-	+	+	-	-	-	-	-
P. oxalicum	-	+	+	-	-	-	-	-
P. wortmanii	-	+	+	+	+	-	-	-
Rhizopus oryzae	-	+	+	-	-	-	-	-
R. stolonifer	-	+	+	-	-	-	-	-
Trichoderma harzianum	+	+	+	-	-	-	-	-
T. viride	+	+	+	-	-	-	-	-

+ Positive interaction

- No interaction

Plate 5. Interaction between fungi and bacteria antagonistic to *R. solani*

A.

1. *Bacillus subtilis* x *Chaetomium globosum*

2. *Chaetomium globosum*

3. *Bacillus subtilis*

B.

1. *Bacillus subtilis* x *Penicillium wortmanii*

2. *Penicillium wortmanii*

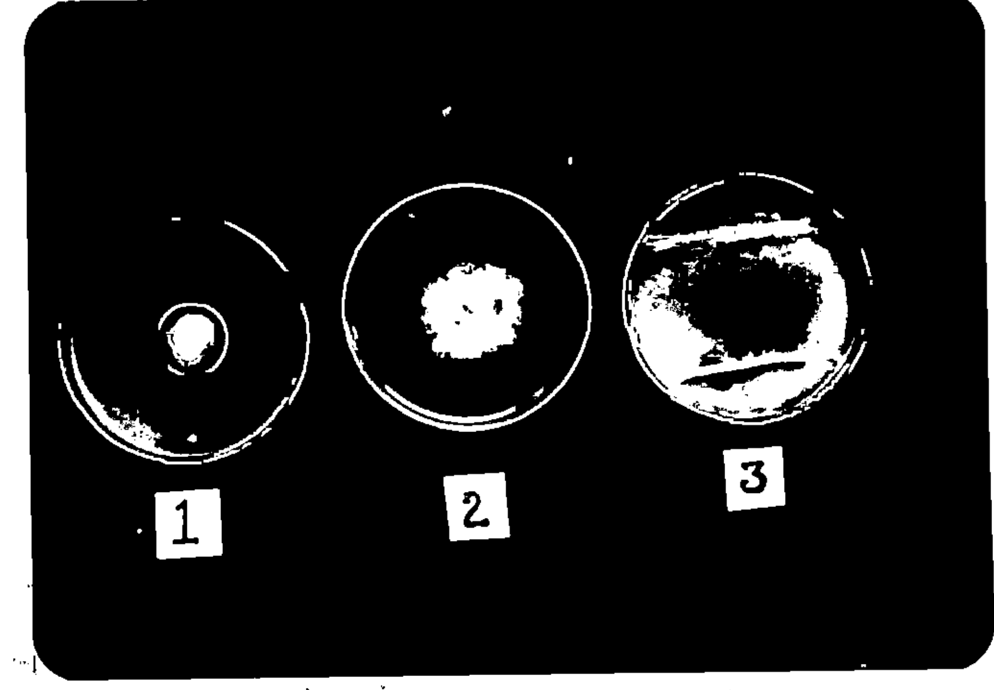
3. *Bacillus subtilis*

C.

1. *Bacillus subtilis* x *Trichoderma harzianum*

2. *Trichoderma harzianum*

3. *Bacillus subtilis*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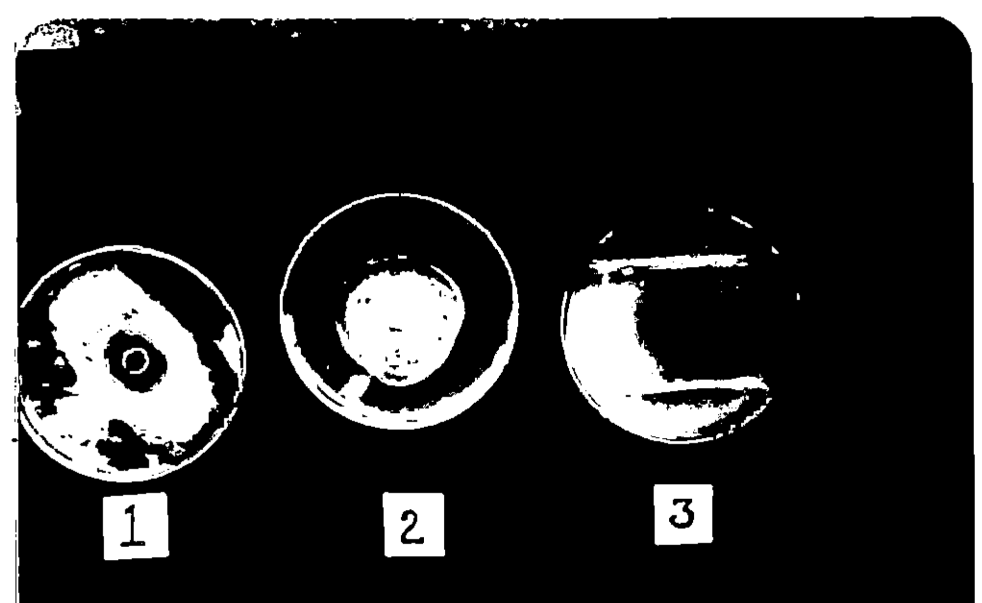
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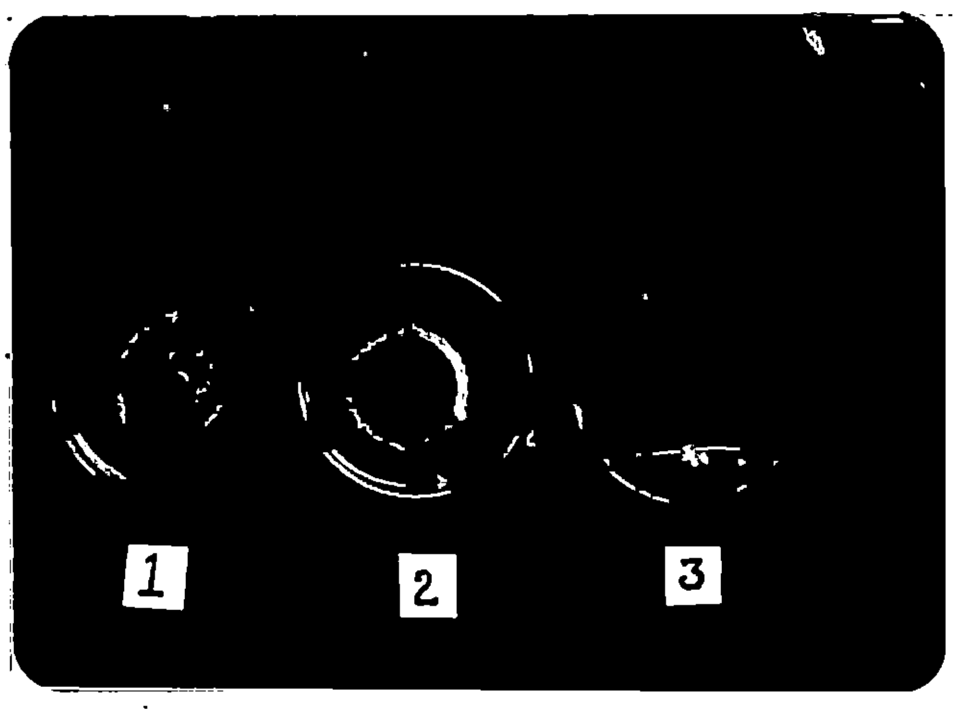
Plate 5 continued

D.

1. *Bacillus subtilis* x *Trichoderma viride*

2. *Trichoderma viride*

3. *Bacillus subtilis*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3

sclerotia in bacterial suspension for ten minutes, one week, two weeks, four weeks and six weeks.

Among the different treatments, T_2 (Bacillus subtilis) was found to have the maximum inhibition on the sclerotia of R. solani even by keeping them only for ten minutes in the bacterial suspension (table 26). T_5 (Propionibacterium sp.) showed the least antagonistic action after ten minutes of treatment. In general, T_4 (Chromobacterium sp.), T_5 (Propionibacterium sp.) and T_6 (Pseudomonas sp.) were less inhibitory compared to other treatments.

After two weeks T_2 caused complete inhibition and after six weeks all bacterial isolates tested caused more than 95 per cent inhibition. In pooled analysis also T_2 was the best treatment having highest antagonism.

4.8.9. Effect of antagonistic bacteria on sheath blight of rice caused by R. solani

4.8.9.1. Disease incidence

All the antagonistic bacteria were found to be effective in reducing the incidence of sheath blight. Among the different treatments, the incidence of sheath blight in T_1 (Bacillus sp.) and T_2 (Bacillus subtilis) was found to be on par and was lesser than that in the other treatments. The respective percentages of hill infection in T_1 and T_2 were

Table 26. Effect of antagonistic bacteria on the survival of *R. solani*

Treatment	Period in bacterial suspension					
	10 minutes	1 week	2 week	4 week	6 week	Pooled mean
T_1	60.01(50.76)	74.64(59.74)	95.77(78.11)	97.81(81.45)	98.72(83.48)	89.10(70.71)
T_2	61.63(51.82)	88.01(69.72)	99.99(90.00)	99.99(90.00)	99.99(90.00)	95.92(78.30)
T_3	52.42(46.37)	82.28(65.08)	97.81(81.56)	98.38(82.65)	99.93(94.33)	90.40(71.97)
T_4	47.60(43.61)	71.93(57.98)	94.46(76.37)	96.25(78.80)	97.67(81.19)	85.50(67.59)
T_5	38.71(38.46)	67.81(55.41)	89.56(71.13)	94.67(76.63)	96.27(78.84)	80.90(64.09)
T_6	44.74(41.96)	58.65(50.08)	87.91(69.62)	89.84(71.39)	95.11(77.19)	78.02(62.05)
T_7	59.64(50.54)	76.11(60.71)	97.97(79.94)	98.26(82.39)	99.99(90.00)	91.20(72.72)
T_8	56.60(43.77)	78.77(62.54)	93.66(75.29)	97.93(81.71)	99.99(90.00)	90.12(71.68)
T_9	0.00	0.00	0.00	0.00	0.00	0.00
CD (0.05)	1.26	0.09	0.50	2.14	0.98	6.67

Figures in parentheses indicate transformed values

29.90 and 31.20. T_8 (Corynebacterium sp.) with 60.00 per cent hill infection was found to be least effective in reducing the incidence of the disease (table 27).

4.8.9.2. Disease intensity

All the antagonists were found to be effective in reducing disease intensity (table 27). T_1, T_2 and T_3 were on par and were more effective than the other treatments.

4.9. *In vitro* effect of plant protection chemicals on antagonistic fungi and *R. solani*

4.9.1. Fungicides

Among the six fungicides tested at three concentrations each, ziram was found to have less inhibitory action on majority of the antagonistic fungi (table 28). This was least inhibitory to *R. solani* also. Next to ziram it was carbendazim which showed less inhibitory action on antagonistic fungi and at the same time it could effectively inhibit the growth of *R. solani*. Carboxin also did not show inhibitory action on many antagonistic fungi and caused considerable inhibition of the growth of *R. solani* at different concentrations tested.

Edifenphos was inhibitory to many antagonistic fungi in comparison with other fungicides tested. But this fungicide was found to be effective in inhibiting the growth of *R. solani* also.

Table 27. Effect of antagonistic bacteria on sheath blight of rice

Treatments	Disease incidence	Disease intensity
T_1 (*Bacillus* sp.)	29.90(33.17)	1.86(1.36)
T_2 (*Bacillus subtilis*)	31.20(33.92)	2.01(1.41)
T_3 (*Rothia* sp.)	41.10(39.88)	2.06(1.44)
T_4 (*Chromobacterium* sp.)	50.50(45.30)	4.20(2.05)
T_5 (*Propionibacterium* sp.)	41.20(39.92)	4.80(2.19)
T_6 (*Pseudomonas* sp.)	44.00(41.54)	5.27(2.29)
T_7 (*Alcaligenes* sp.)	39.10(38.68)	2.99(1.73)
T_8 (*Corynebacterium* sp.)	60.00(50.77)	5.62(2.37)
T_9 Control	98.70(83.44)	6.50(2.55)
CD (0.05)	4.66	0.09

Figures in parentheses indicate transformed values

Table . 28. *In vitro* effect of fungicides on *R. solani* and Antagonistic organisms
(Per cent inhibition over control)

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
T_1	81.90 (64.50)	83.80 (65.74)	59.30 (50.34)	83.80 (66.26)	81.56 (66.14)	60.29 (50.92)	38.80 (38.55)	76.50 (61.00)	75.39 (60.24)	76.30 (60.87)	74.80 (59.86)	24.39 (29.58)	28.15 (32.03)	58.10 (49.69)	53.20 (45.81)
T_2	77.20 (61.52)	81.10 (67.29)	60.80 (51.21)	86.00 (68.03)	83.67 (67.79)	73.18 (58.79)	38.80 (38.55)	84.80 (67.08)	80.03 (63.43)	88.30 (66.63)	84.20 (66.54)	28.20 (32.06)	36.74 (37.29)	71.10 (57.50)	56.70 (48.86)
T_3	78.00 (62.02)	87.40 (69.23)	79.00 (62.72)	87.20 (69.03)	85.74 (67.78)	80.63 (63.87)	67.80 (55.44)	88.00 (69.67)	83.34 (65.88)	88.00 (69.73)	88.00 (69.73)	34.41 (35.90)	49.02 (44.42)	81.10 (64.26)	81.50 (64.54)
T_4	67.00 (54.90)	56.70 (48.88)	68.10 (55.78)	54.60 (47.66)	52.41 (52.76)	83.75 (66.20)	57.40 (49.27)	64.60 (53.52)	61.26 (51.49)	38.60 (38.43)	66.70 (54.74)	17.18 (24.77)	17.64 (24.82)	81.60 (64.56)	67.00 (55.08)
T_5	75.30 (60.22)	67.80 (55.42)	76.90 (61.25)	65.60 (54.07)	63.41 (59.24)	85.94 (67.95)	72.40 (58.27)	70.00 (56.81)	69.32 (56.34)	67.00 (54.94)	73.00 (58.71)	21.81 (27.83)	25.89 (80.58)	84.10 (66.30)	73.30 (57.84)
T_6	87.60 (69.39)	81.20 (64.31)	88.30 (69.96)	76.10 (60.76)	73.87 (55.39)	88.37 (70.03)	80.40 (63.74)	86.60 (68.50)	82.51 (65.25)	71.90 (57.96)	88.00 (69.73)	75.18 (60.10)	37.38 (37.68)	88.40 (70.06)	88.50 (70.16)
T_7	21.10 (27.38)	75.60 (60.39)	64.90 (53.68)	70.20 (56.91)	67.78 (60.22)	46.28 (42.85)	68.50 (55.89)	71.10 (57.49)	68.96 (56.12)	68.90 (56.10)	83.30 (65.91)	23.12 (25.73)	25.50 (30.32)	44.50 (41.80)	27.70 (31.73)
T_8	37.00 (37.47)	81.90 (64.80)	72.70 (58.49)	77.60 (61.75)	75.37 (64.82)	57.78 (49.46)	82.20 (65.08)	83.30 (65.91)	79.47 (63.03)	77.00 (61.37)	87.60 (68.65)	33.83 (35.55)	38.56 (38.37)	55.60 (48.19)	42.50 (40.66)
T_9	82.70 (65.45)	88.10 (69.86)	88.30 (70.00)	84.20 (66.57)	61.91 (51.90)	68.55 (55.87)	83.30 (69.96)	88.30 (69.96)	83.71 (66.17)	83.30 (65.91)	88.30 (69.73)	87.17 (68.99)	42.98 (40.95)	67.50 (55.21)	75.20 (60.14)
T_{10}	29.60 (32.96)	70.70 (57.25)	60.00 (50.78)	28.80 (32.43)	77.94 (66.34)	60.38 (50.97)	41.70 (40.20	66.10 (54.40)	67.34 (55.12)	66.10 (54.40)	87.80 (69.54)	18.76 (25.66)	20.80 (27.13)	58.20 (49.69)	58.90 (50.12)
T_{11}	47.00 (43.30)	76.50 (60.99)	72.30 (58.27)	35.20 (36.37)	36.15 (37.23)	72.97 (58.65)	50.00 (45.00)	79.80 (63.29)	78.39 (62.27)	71.10 (57.49)	88.50 (70.19)	32.81 (34.93)	32.44 (34.70)	71.10 (57.49)	75.90 (60.62)
T_{12}	60.00 (50.78)	85.60 (67.69)	80.50 (63.74)	37.00 (37.45)	24.64 (29.60)	83.57 (65.91)	62.80 (52.42)	88.30 (60.99)	86.26 (68.22)	82.20 (65.03)	88.70 (70.33)	46.61 (43.04)	49.20 (44.53)	81.10 (64.26)	88.30 (70.00)
T_{13}	51.50 (45.85)	70.70 (57.26)	73.10 (58.72)	22.20 (28.11)	29.42 (39.07)	65.70 (54.13)	77.40 (61.62)	65.40 (53.98)	65.19 (53.82)	68.60 (56.56)	78.30 (62.24)	19.97 (26.54)	21.32 (27.49)	66.30 (54.51)	73.40 (58.92)
T_{14}	71.80 (57.61)	82.20 (65.00)	80.40 (63.74)	37.50 (37.75)	39.76 (42.64)	75.49 (60.30)	38.00 (69.71)	75.50 (60.32)	74.89 (59.90)	80.40 (63.73)	84.80 (67.06)	69.77 (56.62)	67.23 (56.06)	72.50 (58.36)	78.20 (62.19)
T_{15}	82.60 (65.35)	88.30 (70.03)	88.40 (70.06)	43.70 (41.38)	45.02 (42.34)	88.84 (70.46)	88.30 (69.96)	88.30 (70.03)	83.15 (65.74)	87.60 (69.35)	88.50 (70.22)	87.47 (69.24)	83.02 (65.69)	88.50 (70.16)	88.30 (70.03)
T_{16}	62.20 (52.08)	81.90 (64.86)	45.20 (42.24)	22.20 (28.11)	37.55 (37.52)	24.92 (29.94)	31.30 (34.00)	58.90 (50.12)	59.82 (50.64)	58.70 (50.02)	31.70 (34.27)	69.15 (56.24)	69.08 (56.19)	22.10 (28.01)	19.10 (25.89)
T_{17}	75.20 (60.15)	83.90 (66.33)	65.20 (53.87)	37.50 (37.75)	37.12 (42.21)	57.41 (49.29)	56.70 (48.80)	72.30 (58.20)	71.12 (57.47)	71.50 (57.73)	54.10 (47.34)	87.56 (69.32)	82.96 (55.60)	54.50 (47.55)	56.30 (48.62)
T_{18}	88.50 (70.16)	87.90 (69.64)	71.40 (57.63)	44.90 (42.04)	45.17 (42.23)	77.18 (61.44)	70.00 (56.78)	75.60 (60.42)	73.90 (59.25)	44.90 (42.04)	60.50 (51.07)	88.63 (70.66)	88.71 (70.33)	78.00 (61.99)	61.50 (51.65)
CD (0.05)	4.91	2.32	3.48	4.81	4.93	3.14	3.43	2.29	2.65	1.66	1.45	3.31	3.81	3.48	4.24

Figures in parenthesis indicate transformed values

a - *Aspergillus niger*　　b - *Aspergillus flavus*　　c - *Chaetomium globosm*
d - *Fusarium semitectum*　　e - *Fusarium solani*　　f - *Gliocladium virens*
g - *Neurospora crassa*　　h - *Penicillium citrinum*　　i - *Penicillium oxalicum*
j - *Penicillium wortmanii*　　k - *Rhizoctonia solani*　　l - *Rhizopus oryzae*
m - *Rhizopus stolonifer*　　n - *Trichoderma harzianum*　　o - *Trichoderma viride*

4.9.2. Insecticides

In general, methyl parathion was found to be least inhibitory to many antagonistic fungi (table 29). This insecticide was not having much inhibitory action against *R. solani* also. Phorate was inhibitory to most of the antagonistic fungi as well as to *R. solani*. Carbaryl and Carbofuran were inhibitory to some antagonistic fungi and to *R. solani*. The other insecticides were inhibitory to some antagonistic fungi and at the same time not much effective against *R. solani*.

4.9.3. Herbicides

2,4-D was found to be less inhibitory to majority of the antagonistic fungi compared to the other herbicides tested (table 30). Propanil was very much inhibitory to most of the antagonistic fungi and *R. solani*. Bentazone and thiobencarb were found to be inhibitory to lesser number of antagonistic fungi when compared with propanil. But they were inhibitory to *R. solani*.

4.10. Effect of antagonistic fungi and plant protection chemicals on survival of *R. solani* and intensity of sheath blight of rice

4.10.1. Survival of *R. solani*

The results showed that among the antagonistic fungi

Table .29 *In vitro* Effect of Insecticides on *R. solani* and Antagonistic Organisms

(Per cent inhibition over control)

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
T_1	59.30 (50.34)	65.90 (54.29)	71.90 (57.96)	50.00 (45.00)	52.59 (46.47)	74.10 (59.42)	44.40 (41.79)	66.70 (54.74)	64.09 (53.16)	70.80 (58.26)	82.60 (65.35)	21.93 (27.92)	22.20 (28.12)	70.70 (57.26)	70.70 (56.33)
T_2	65.20 (53.85)	72.60 (58.43)	75.20 (60.13)	75.00 (60.00)	74.13 (59.40)	81.50 (64.51)	64.80 (53.63)	82.20 (65.07)	80.37 (63.68)	77.80 (61.89)	86.90 (68.76)	27.69 (37.74)	26.70 (31.09)	77.80 (61.89)	76.30 (60.87)
T_3	73.00 (58.67)	86.70 (68.63)	86.80 (68.73)	85.20 (67.37)	83.61 (65.33)	83.30 (69.96)	76.00 (60.65)	88.30 (70.00)	84.12 (66.49)	88.30 (69.99)	88.10 (69.86)	33.66 (35.45)	33.60 (35.45)	88.60 (70.26)	80.80 (63.98)
T_4	64.80 (53.63)	71.70 (57.86)	50.00 (45.00)	73.80 (59.15)	72.97 (58.65)	46.30 (42.86)	69.30 (56.33)	73.30 (58.91)	71.50 (57.71)	72.20 (58.19)	77.10 (61.37)	21.25 (27.44)	19.60 (26.26)	71.70 (57.84)	60.70 (51.20)
T_5	73.00 (58.67)	79.20 (62.86)	57.10 (49.05)	82.60 (65.35)	85.57 (67.65)	78.50 (62.39)	76.00 (60.63)	81.90 (64.79)	81.11 (64.21)	79.70 (63.22)	86.30 (68.24)	21.65 (27.71)	21.80 (27.85)	79.50 (63.09)	86.50 (68.43)
T_6	83.30 (65.91)	88.10 (69.80)	70.40 (57.04)	88.40 (70.06)	88.41 (70.07)	88.60 (70.23)	81.90 (64.79)	88.30 (70.03)	87.04 (68.87)	88.40 (70.10)	87.40 (69.22)	75.05 (60.01)	78.50 (63.39)	87.60 (69.42)	88.60 (70.23)
T_7	58.20 (49.69)	55.50 (48.19)	65.60 (64.06)	67.10 (54.99)	67.30 (55.10)	50.00 (45.00)	71.60 (57.74)	69.30 (56.33)	69.26 (56.31)	44.40 (41.81)	79.60 (63.18)	23.29 (28.84)	24.80 (29.85)	44.50 (41.81)	72.20 (58.19)
T_8	70.70 (57.25)	72.60 (58.43)	72.20 (58.19)	73.00 (58.67)	71.85 (57.94)	83.00 (65.62)	80.50 (63.81)	77.10 (61.37)	74.46 (59.62)	67.00 (54.97)	83.30 (65.90)	35.16 (36.35)	35.20 (36.37)	67.00 (54.96)	82.20 (65.08)
T_9	83.40 (65.93)	85.60 (67.67)	78.20 (62.17)	81.70 (64.66)	79.63 (63.15)	88.20 (69.96)	88.40 (70.09)	85.60 (67.67)	84.08 (66.46)	74.10 (59.42)	87.70 (69.45)	87.05 (68.88)	88.20 (69.87)	74.10 (59.42)	86.50 (68.43)
T_{10}	73.00 (58.67)	28.90 (32.50)	51.10 (45.64)	64.50 (53.40)	63.73 (52.95)	57.80 (49.60)	73.30 (58.91)	64.80 (53.62)	65.19 (53.82)	25.20 (30.10)	70.00 (56.80)	20.37 (26.82)	20.30 (26.78)	51.80 (46.06)	65.20 (53.84)
T_{11}	78.50 (62.39)	64.10 (53.21)	60.00 (50.78)	65.90 (54.29)	67.78 (55.39)	71.10 (57.50)	79.30 (62.91)	72.60 (58.43)	71.85 (57.92)	65.90 (54.29)	82.60 (65.35)	32.24 (35.80)	35.20 (36.38)	65.80 (54.18)	73.70 (59.16)
T_{12}	88.30 (69.96)	76.90 (61.24)	77.50 (61.71)	75.60 (60.37)	74.08 (59.37)	88.40 (70.09)	88.30 (70.03)	86.00 (68.00)	82.78 (65.46)	75.90 (60.63)	87.60 (69.42)	46.44 (42.94)	47.60 (43.30)	77.50 (61.65)	85.60 (67.69)
T_{13}	40.70 (39.66)	69.80 (56.68)	51.90 (46.06)	61.90 (51.86)	62.97 (52.49)	63.00 (52.53)	77.40 (61.62)	53.00 (46.70)	52.50 (46.41)	70.00 (56.79)	59.60 (50.55)	21.29 (27.47)	19.60 (26.26)	70.00 (56.80)	43.70 (41.38)
T_{14}	48.90 (44.36)	73.00 (58.71)	63.00 (52.54)	69.60 (56.56)	69.26 (56.31)	70.70 (57.26)	84.60 (66.89)	68.20 (55.65)	62.23 (52.06)	73.10 (58.72)	75.90 (60.63)	71.15 (57.49)	72.30 (58.21)	78.00 (58.72)	53.00 (46.70)
T_{15}	61.10 (51.42)	81.60 (64.56)	75.60 (60.39)	83.30 (65.91)	87.50 (69.50)	87.20 (69.03)	86.50 (68.43)	78.50 (62.39)	76.12 (60.72)	88.50 (70.23)	83.30 (65.91)	86.86 (68.72)	88.30 (70.03)	81.30 (64.34)	76.70 (61.11)
T_{16}	73.40 (58.95)	69.70 (56.59)	67.00 (54.96)	76.40 (60.92)	75.90 (60.61)	70.70 (57.26)	82.20 (65.07)	70.40 (57.03)	71.52 (57.72)	76.00 (60.65)	77.40 (61.63)	68.55 (55.86)	68.00 (55.57)	70.00 (56.80)	71.90 (57.96)
T_{17}	77.80 (61.39)	81.60 (64.56)	73.00 (58.68)	82.20 (65.07)	82.23 (65.04)	71.90 (57.98)	87.00 (68.90)	85.20 (67.38)	81.31 (64.36)	77.00 (61.37)	86.30 (68.28)	87.17 (68.98)	88.20 (69.96)	85.40 (67.54)	77.10 (61.37)
T_{18}	83.30 (65.91)	88.50 (70.13)	78.90 (62.65)	88.30 (69.96)	87.23 (69.03)	87.60 (69.42)	88.30 (69.96)	88.20 (69.93)	86.14 (68.15)	87.80 (69.52)	88.50 (70.23)	88.85 (70.47)	88.60 (70.29)	88.50 (70.16)	83.30 (65.91)
CD (0.05)	2.06	2.43	2.60	1.46	1.84	2.68	2.75	1.47	1.73	2.37	1.52	3.32	3.55	2.43	1.49

Figures in parenthesis indicate transformed values

a - *Aspergillus niger*
b - *Aspergillus flavus*
c - *Chaetomium globosum*
d - *Fusarium semitectum*
e - *Fusarium solani*
f - *Gliocladium virens*
g - *Neurospora crassa*
h - *Penicillium citrinum*
i - *Penicillium oxalicum*
j - *Penicillium wortmanii*
k - *Rhizoctonia solani*
l - *Rhizopus oryzae*
m - *Rhizopus stolonifer*
n - *Trichoderma harzianum*
o - *Trichoderma viride*

Table. 30 *In vitro* Effect of Herbicides on *R. solani* and Antagonistic organisms
(Per cent inhibition over control)

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
T_1	54.10 (47.34)	54.45 (47.53)	78.10 (62.13)	56.30 (48.62)	58.33 (49.78)	70.74 (57.23)	53.70 (47.13)	68.50 (55.89)	70.01 (56.77)	58.90 (50.12)	71.90 (57.96)	56.30 (48.60)	56.70 (48.83)	71.90 (57.96)	71.90 (57.96)
T_2	64.10 (53.18)	62.62 (52.29)	79.20 (62.91)	76.70 (61.12)	75.93 (60.59)	78.85 (62.39)	68.50 (55.87)	84.40 (66.72)	86.98 (68.82)	69.60 (56.56)	81.60 (64.56)	73.76 (59.16)	75.20 (60.14)	78.50 (62.39)	80.40 (63.74)
T_3	71.70 (57.84)	72.15 (58.77)	88.30 (70.03)	86.90 (68.75)	86.32 (68.26)	84.55 (66.83)	79.50 (63.09)	88.20 (69.93)	88.52 (70.17)	78.50 (62.39)	87.50 (69.28)	82.99 (65.61)	81.90 (64.30)	84.50 (66.79)	85.70 (67.82)
T_4	74.10 (59.40)	73.33 (58.89)	63.30 (52.71)	66.30 (54.52)	65.19 (53.82)	47.96 (43.01)	65.60 (54.06)	61.90 (51.88)	64.46 (53.38)	64.50 (53.45)	65.50 (54.06)	65.56 (54.04)	65.90 (54.29)	40.40 (39.46)	47.00 (43.30)
T_5	80.00 (63.46)	79.13 (62.79)	70.40 (57.02)	76.30 (60.87)	74.45 (59.61)	62.41 (52.17)	71.10 (57.47)	70.40 (57.02)	68.63 (55.81)	71.50 (57.75)	70.00 (56.79)	69.26 (56.11)	71.50 (57.73)	53.40 (46.92)	59.30 (50.34)
T_6	87.10 (68.98)	87.41 (69.19)	86.30 (68.27)	86.50 (68.43)	84.26 (66.60)	88.33 (70.00)	85.60 (67.69)	88.30 (69.99)	87.41 (69.19)	84.10 (66.49)	88.80 (70.43)	87.85 (64.76)	81.10 (64.26)	86.30 (68.24)	86.60 (68.58)
T_7	53.70 (47.13)	54.04 (47.30)	34.10 (35.71)	25.90 (30.60)	27.75 (31.78)	30.44 (33.48)	54.50 (47.55)	51.90 (48.06)	58.35 (49.79)	46.70 (43.09)	35.20 (36.37)	27.82 (31.82)	25.90 (30.58)	38.90 (38.58)	29.60 (32.96)
T_8	64.50 (53.40)	64.23 (53.24)	78.10 (62.13)	66.70 (54.74)	67.05 (54.95)	78.64 (62.45)	63.40 (52.75)	74.10 (59.40)	72.42 (58.30)	57.30 (49.48)	77.00 (61.37)	70.19 (56.88)	70.00 (56.80)	66.70 (54.74)	79.70 (63.22)
T_9	85.40 (67.53)	83.91 (66.32)	83.70 (66.19)	85.90 (67.97)	84.71 (66.95	85.38 (67.49)	86.70 (68.59)	37.00 (68.90)	86.12 (68.10)	73.90 (59.30)	88.40 (70.19)	75.07 (60.12)	76.00 (60.65)	82.20 (65.07)	87.00 (68.90)
T_{10}	42.90 (40.95)	44.78 (41.99)	72.60 (58.43)	25.90 (30.58)	28.83 (32.15)	75.74 (60.47)	75.90 (60.62)	44.40 (41.80)	48.14 (43.92)	40.70 (39.66)	71.90 (57.98)	26.36 (30.88)	25.90 (30.58)	71.80 (57.96)	76.30 (60.87)
T_{11}	60.80 (51.21)	62.60 (52.27)	78.10 (62.13)	71.10 (57.49)	71.12 (57.47)	83.71 (66.17)	81.50 (64.51)	76.00 (60.65)	74.64 (59.87)	65.20 (53.84)	77.80 (61.87)	74.10 (59.38)	76.00 (60.65)	81.60 (65.56)	84.70 (66.93)
T_{12}	73.00 (58.68)	72.20 (58.80)	83.00 (65.66)	81.20 (64.28)	79.81 (63.28)	87.65 (69.40)	88.60 (70.23)	81.60 (64.56)	75.30 (60.85)	76.70 (61.12)	83.70 (66.19)	81.30 (64.35)	81.90 (64.80)	86.10 (68.14)	88.50 (70.13)
T_{13}	71.50 (57.75)	72.59 (58.41)	74.10 (59.42)	60.80 (51.21)	62.05 (51.95)	81.85 (64.76)	75.20 (60.12)	44.50 (41.80)	46.29 (42.86)	71.50 (57.72)	68.50 (55.87)	64.45 (53.38)	64.80 (53.62)	83.00 (65.62)	84.20 (66.61)
T_{14}	83.00 (65.62)	82.60 (65.32)	78.10 (62.13)	71.80 (57.26)	69.26 (56.31)	88.30 (69.97)	83.40 (65.94)	71.90 (57.96)	70.38 (57.00)	82.20 (65.08)	78.50 (62.39)	76.30 (60.87)	75.60 (60.39)	87.40 (69.22)	88.50 (70.16)
T_{15}	88.00 (69.96)	88.26 (69.93)	88.50 (70.16)	79.30 (62.94)	79.44 (63.01)	87.80 (69.50)	88.40 (70.13)	85.60 (67.67)	84.63 (66.89)	88.40 (70.09)	88.50 (70.19)	87.87 (64.77)	82.80 (65.48)	88.10 (69.86)	88.60 (70.13)
T_{16}	41.10 (39.88)	41.96 (40.31)	45.50 (42.44)	22.60 (28.36)	23.13 (28.86)	54.23 (47.41)	53.10 (47.12)	83.00 (65.62)	82.32 (65.11)	40.60 (39.57)	43.70 (41.38)	24.42 (29.60)	23.00 (28.66)	51.80 (46.04)	53.70 (47.13)
T_{17}	65.90 (54.29)	64.45 (53.37)	76.70 (61.12)	69.70 (28.67)	70.56 (57.11)	69.56 (56.49)	54.80 (53.62)	86.90 (68.74)	86.31 (68.20)	51.10 (45.64)	73.30 (58.90)	50.74 (45.41)	50.00 (45.00)	63.00 (52.53)	64.80 (53.63)
T_{18}	75.80 (60.52)	75.54 (60.47)	86.30 (68.28)	78.90 (62.67)	78.35 (62.24)	82.05 (64.90)	86.10 (68.12)	88.10 (69.86)	88.29 (69.97)	60.70 (51.20)	88.10 (69.80)	73.72 (59.14)	75.60 (60.38)	60.70 (51.17)	82.40 (65.20)
CD (0.05)	1.81	1.69	1.64	2.20	1.06	2.05	1.98	2.81	2.49	3.52	1.61	2.57	2.47	2.68	2.39

Figures in parenthesis indicate transformed values

a – *Aspergillus niger*　b – *Aspergillus flavus*　c – *Chaetomium globosm*
d – *Fusarium semitectum*　e – *Fusarium solani*　f – *Gliocladium virens*
g – *Neurospora crassa*　h – *Penicillium citrinum*　i – *Penicillium oxalicum*
j – *Penicillium wortmanii*　k – *Rhizoctonia solani*　l – *Rhizopus oryzae*
m – *Rhizopus stolonifer*　n – *Trichoderma harzianum*　o – *Trichoderma viride*

tried, Trichoderma viride caused maximum reduction in the survival of R. solani (40.28 per cent) which was on par with T. harzianum. Fusarium semitectum recorded least inhibition. Among the three chemicals tested bentazone and carboxin were on par in reducing the survival of R. solani. Carbofuran was least effective.

Carboxin + Fusarium solani recorded the least survival of 26.91 per cent, which was on par with Carboxin + F. semitectum, Carboxin + T. viride, and Carboxin + T. harzianum (table 31). All the other Carboxin - fungi combinations were on par with the control, where Carboxin alone was applied.

In combination with carbofuran, T. viride as well as F. solani recorded the minimum survival of 38.65 per cent which was on par with the effect of carbofuran + T. harzianum and carbofuran + P. wortmanii. All other carbofuran-fungi combinations were not better than carbofuran alone.

Regarding the effect of herbicide with antagonistic organisms, it was observed that minimum survival was recorded by bentazone + F. semitectum which was on par with bentazone + T. viride, and bentazone + T. harzianum. All the other bentazone-fungi treatments did not show any significant difference with bentazone alone.

Table 31. Effect of antagonistic fungi and plant protection chemicals on the survival of R. solani (Percentage)

Antagonistic organisms	Carboxin	Carbofuran	Bentazone	Control
Aspergillus niger	52.67(46.51)	53.35(46.90)	41.33(39.99)	61.35(51.30)
Aspergillus flavus	41.32(39.99)	47.67(43.64)	43.30(41.13)	52.34(46.32)
Fusarium semitectum	33.93(35.62)	46.99(43.25)	29.92(33.15)	65.07(53.75)
Fusarium solani	26.91(31.24)	38.65(38.42)	57.49(49.29)	56.04(48.45)
Penicillium wortmanii	40.98(39.79)	40.99(39.79)	44.00(41.54)	50.35(45.18)
Penicillium citrinum	50.00(44.98)	51.33(45.75)	49.65(44.78)	56.01(48.43)
Rhizopus stolonifer	47.66(43.64)	49.00(44.40)	47.30(43.45)	55.70(48.25)
Trichoderma viride	33.66(35.45)	38.65(38.42)	35.43(36.51)	40.28(39.37)
Trichoderma harzianum	35.66(36.65)	40.65(39.60)	37.47(37.73)	42.29(40.55)
Control	51.35(45.75)	54.72(47.69)	51.01(45.56)	56.70(48.83)

CD (0.05) Chemicals - 1.943

" " Fungi x chemicals - 6.145

" " Fungi - 3.072

Figures in parentheses indicate transformed values

F. semitectum was effective in combination with carboxin and bentazone, while its combination with carbofuran was also better than F. semitectum alone. F. solani was very effective when used in combination with carboxin which was followed by F. solani + Carbofuran, while F. solani + bentazone was on par with F. solani alone.

T. viride as well as T. harzianum were effective in reducing the survival of R. solani. However, the effect of their combinations with the plant protection chemicals were not better than their individual effects.

When all the treatments and their combinations were compared with absolute control (56.70) it was found that only T. viride and T. harzianum were effective in reducing the survival of R. solani and the individual effects of all the other antagonistic fungi and Carbofuran were not better than that of control.

4.10.2. Intensity of sheath blight

Among the different antagonistic fungi, T. viride was the most effective in reducing the intensity of sheath blight, with a disease score of 2.68 (table 32). A. niger was the least effective (5.68) which was on par with control (5.91). All the plant protection chemicals were on par in reducing the intensity of sheath blight and were significantly better than control.

Table 32. Effect of antagonistic organisms and plant protection chemicals on intensity of sheath blight of rice

Antagonistic organisms	Carboxin	Carbofuran	Bentazone	Control
Aspergillus niger	2.34(1.53)	3.38(1.83)	7.33(2.70)	5.68(2.38)
Aspergillus flavus	3.97(1.99)	4.31(2.07)	3.93(1.98)	4.72(2.17)
Fusarium semitectum	3.14(1.77)	4.09(2.02)	3.21(1.79)	3.97(1.99)
Fusarium solani	2.99(1.73)	3.70(1.92)	3.07(1.75)	3.84(1.96)
Penicillium wortmanii	3.97(1.99)	3.83(1.95)	4.23(2.05)	4.20(2.06)
Penicillium citrinum	3.72(1.93)	4.28(2.07)	4.02(2.00)	4.60(2.14)
Rhizopus stolonifer	4.22(2.05)	4.23(2.05)	4.45(2.09)	4.48(2.11)
Trichoderma viride	2.59(1.61)	2.79(1.67)	2.59(1.61)	2.68(1.63)
Trichoderma harzianum	2.99(1.73)	3.23(1.79)	2.96(1.72)	3.40(1.84)
Control	4.04(2.01)	4.46(2.11)	4.11(2.02)	5.91(2.43)

CD (0.05) for fungi - 0.182

" " for chemicals - 0.115

" " for fungi x chemicals - 0.365

Figures in parentheses indicate transformed values

Among the carboxin + fungi as well as carbofuran + fungi combinations both the species of *Trichoderma* and *Fusarium* and *A. niger* had significantly reduced the intensity of sheath blight and their effects were on par.

Bentazone + *A. niger* with a disease score of 7.33 was the least effective among bentazone + fungi combinations. Both the species of *Trichoderma* and *Fusarium* and *A. flavus* were effective in combination with bentazone in reducing the intensity of sheath blight and their effects were on par. *A. niger* was effective in combination with Carboxin and Carbofuran while its combination with bentazone (7.33) was on par with the effect of *A. niger* alone (5.68).

Both the species of *Trichoderma* and *Fusarium* were effective in reducing the intensity of sheath blight. The individual effects of these fungi were on par with the effects of their combinations with the three plant protection chemicals used.

Except *A. niger* + bentazone (7.33), *A. flavus* + Carbofuran (4.31), *P. citrinum* + Carbofuran (4.28) and *R. stolonifer* + bentazone (4.45) all the other treatment combinations were significantly better than the absolute control (5.91) in reducing the intensity of sheath blight.

4.11. Field evaluation of plant protection chemicals and antagonistic microorganisms on population of soil microflora and sheath blight of rice

4.11.1. Effect on population of soil microorganisms

Pretreatment data on the population of microorganisms did not show significant differences in different plots.

4.11.1.1. Fungi

Population of fungi was, in general, more during the virippu season both in boot leaf stage as well as ten days before harvest (table 33). As the crop matured, there was a decrease in the fungal population. In Mundakan the treatment T_9 (edifenphos + bentazone + carbofuran + _T. viride_) supported the maximum population, viz., 37.35 and 35.12, respectively, in boot leaf and ten days before harvest. A similar trend was observed in virippu season also. The treatments T_1, T_6, T_7 and T_{11} were on par with T_9 in both the stages of observation and in both the seasons of the experiment.

Among the treatments, barring the absolute control (T_{17}), the least population of fungi in Mundakan was recorded in T_{16} both at boot leaf stage (19.74) and ten days before harvest (15.81). At boot leaf stage T_{15} was on par with T_{16}. In Virippu T_4 recorded the least population of fungi

both at boot leaf stage (19.71) and ten days before harvest (17.82) and it was on par with T_{16}.

4.11.1.2. Bacteria

Population of bacteria was also, in general, more during the Virippu season both in boot leaf stage as well as ten days before harvest (table 33). Bacterial population also showed a decreasing trend as the crop matured. Excepting the boot leaf stage at Mundakan season, T_{12} (edifenphos + bentazone + phorate + *Bacillus subtilis*) supported the maximum population of bacteria. In Mundakan at boot leaf the maximum population was in T_6. Effects of T_1, T_2, T_3 and T_7 were on par in both the stages of observation in both the seasons of the experiment.

Among the treatments, barring absolute control (T_{17}), the least population of bacteria in both Mundakan and Virippu was in T_{16} (edifenphos + thiobencarb + phorate + *B. subtilis*) which was on par with T_{15}.

4.11.1.3. Actinomycetes

Population of actinomycetes in Virippu did not show significant differences among the treatments in both stages of crop growth (table 33). During Mundakan at boot leaf stage, T_{11} (edifenphos + bentazone + phorate + *T. viride*) supported the maximum population (3.12). This was on par

Table.33 Effect of plant protection chemicals and antagonists on population of soil microorganisms

Treatments	Mundakan						Virippu					
	Boot leaf stage			10 days before harvest			Boot leaf stage			10 days before harvest		
	Fungi	Bacteria	Actinomycetes	Fungi	Bacteria	Actinomycetes	Fungi	Bacteria	Actinomycetes	Fungi	Bacteria	Actinomycetes
T_1	37.19 (6.09)	18.48 (4.29)	1.68 (1.64)	32.62 (5.71)	14.41 (3.79)	1.12 (1.46)	38.98 (6.24)	17.29 (4.15)	1.95 (1.71)	36.79 (6.06)	15.78 (3.97)	0.93 (1.39)
T_2	32.94 (5.74)	16.96 (4.11)	1.23 (1.49)	28.31 (5.32)	12.93 (3.69)	0.21 (1.10)	34.48 (5.87)	17.07 (4.13)	2.19 (1.78)	32.17 (5.67)	15.00 (3.87)	0.45 (1.21)
T_3	32.37 (5.69)	18.52 (4.30)	1.47 (1.57)	28.34 (5.33)	14.40 (3.79)	1.23 (1.49)	29.63 (5.42)	18.42 (4.29)	2.19 (1.79)	30.17 (5.49)	16.46 (4.05)	0.45 (1.21)
T_4	18.07 (4.25)	13.57 (3.68)	1.12 (1.45)	13.87 (3.72)	9.35 (3.05)	0.39 (1.18)	19.71 (4.44)	13.47 (3.67)	2.16 (1.78)	17.82 (4.22)	11.43 (3.38)	0.39 (1.18)
T_5	36.60 (6.06)	14.64 (3.82)	1.47 (1.57)	32.66 (5.72)	10.31 (3.21)	0.45 (1.20)	36.15 (6.01)	14.37 (3.79)	1.95 (1.72)	36.64 (6.05)	12.46 (3.52)	0.22 (1.10)
T_6	34.17 (5.85)	18.55 (4.30)	1.68 (1.64)	32.24 (5.67)	14.60 (3.82)	0.65 (1.28)	38.59 (6.21)	18.68 (4.31)	2.71 (1.93)	36.54 (6.04)	16.45 (4.05)	0.65 (1.29)
T_7	33.84 (5.82)	17.40 (4.17)	0.93 (1.39)	34.30 (5.86)	13.04 (3.61)	0.45 (1.20)	41.25 (6.42)	17.57 (4.19)	2.11 (1.76)	39.34 (6.27)	15.11 (3.88)	0.65 (1.29)
T_8	33.53 (5.79)	15.15 (3.89)	1.95 (1.71)	29.19 (5.40)	11.18 (3.39)	0.46 (1.21)	35.52 (5.96)	15.45 (3.93)	2.91 (1.97)	33.66 (5.80)	13.16 (3.62)	0.56 (1.25)
T_9	37.35 (6.11)	13.89 (3.71)	1.43 (1.56)	35.12 (5.92)	9.60 (3.09)	0.39 (1.18)	41.37 (6.43)	13.25 (3.64)	2.35 (1.83)	39.43 (6.27)	11.85 (3.44)	0.56 (1.25)
T_{10}	32.69 (5.71)	15.69 (3.94)	1.62 (1.61)	28.73 (5.36)	14.45 (3.80)	0.45 (1.21)	34.99 (5.91)	18.63 (4.31)	2.24 (1.79)	32.82 (5.72)	16.62 (4.07)	0.22 (1.10)
T_{11}	36.42 (6.03)	14.02 (3.79)	3.12 (2.03)	32.61 (5.71)	12.05 (3.47)	0.56 (1.25)	37.49 (6.12)	16.36 (4.04)	2.97 (1.99)	35.68 (5.97)	14.28 (3.77)	0.95 (1.40)
T_{12}	32.09 (5.66)	13.87 (3.72)	1.68 (1.64)	28.05 (5.29)	14.92 (3.86)	2.06 (1.75)	34.07 (5.83)	18.89 (4.34)	2.63 (1.90)	32.79 (5.67)	16.70 (4.08)	0.91 (1.37)
T_{13}	34.47 (5.87)	9.90 (3.15)	1.68 (1.64)	30.55 (5.52)	12.04 (3.47)	1.23 (1.49)	36.48 (6.04)	16.10 (4.01)	2.48 (1.86)	34.53 (5.87)	12.48 (3.53)	0.65 (1.29)
T_{14}	25.66 (5.06)	8.26 (2.87)	2.19 (1.78)	21.76 (4.66)	10.22 (3.19)	0.65 (1.28)	27.78 (5.27)	14.49 (3.80)	2.70 (1.92)	25.77 (5.07)	12.41 (3.53)	0.45 (1.26)
T_{15}	22.85 (4.78)	8.99 (2.88)	1.96 (1.72)	18.80 (4.33)	10.39 (3.22)	1.16 (1.46)	24.54 (4.95)	14.79 (3.84)	2.91 (1.97)	22.62 (4.75)	10.55 (3.24)	0.83 (1.35)
T_{16}	19.74 (4.44)	7.48 (2.73)	1.95 (1.71)	15.81 (3.97)	8.44 (2.92)	0.93 (1.39)	21.78 (4.66)	12.56 (3.54)	2.97 (1.99)	19.62 (4.42)	9.03 (3.01)	0.93 (1.39)
17	14.21 (3.77)	6.05 (2.46)	1.25 (1.50)	10.17 (3.19)	7.39 (2.72)	1.92 (1.71)	12.39 (3.52)	11.63 (3.41)	3.45 (2.11)	9.85 (3.14)	9.55 (3.09)	1.63 (1.65)
CD (0.05)	0.33	0.26	0.35	0.33	0.34	0.46	0.35	0.31	0.38	0.31	0.33	N.S.

(Figures in parenthesis indicate transformed values)

with T_8, T_{14}, T_{15} and T_{16}. At ten days before harvest the maximum actinomycete population was in T_{12} (edifenphos + bentazone + phorate + B. subtilis) which was on par with T_1, T_3, T_{15} and T_{16} (table 33).

4.11.2.1. Disease incidence

Incidence of sheath blight was the lowest in T_1 (carboxin + bentazone + carbofuran + T. viride) in most of the observations during both the seasons (table 34). In boot leaf stage of Mundakan season, incidence of sheath blight in T_1 was on par with the majority of other treatments also. T_5 (carboxin + thiobencarb + carbofuran + T. viride) was on par with T_1 in both the observations of Mundakan season. T_5 was on par with T_1 at ten days before harvest during Virippu also.

Barring the absolute control (T_{17}) the highest incidence of sheath blight did not occur consistently in any of the treatments. T_{10} (edifenphos + bentazone + carbofuran + B. subtilis) and T_{11} (edifenphos + bentazone + phorate + T. viride) showed highest incidence of sheath blight at boot leaf stage and ten days before harvest, respectively during Mundakan season. T_{10} and T_{11} were on par at both the observations of the season. T_6 (carboxin + thiobencarb + carbofuran + B. subtilis) recorded highest incidence of the disease in both the observations of Virippu.

Table 34. Effect of plant protection chemicals and antagonists on incidence of sheath blight (percentage)

Treatments	Mundakan		Virippu	
	Boot leaf	10 days before harvest	Boot leaf	10 days before harvest
T_1	50.49 (45.26)	33.20 (35.17)	34.10 (35.71)	33.45 (35.32)
T_2	59.65 (50.54)	43.47 (41.23)	49.18 (44.51)	43.40 (41.19)
T_3	52.21 (46.25)	47.69 (43.65)	40.32 (39.40)	49.37 (44.63)
T_4	58.89 (50.10)	49.29 (44.58)	46.79 (43.14)	44.33 (41.73)
T_5	50.76 (45.41)	33.14 (35.14)	46.53 (42.99)	41.08 (39.85)
T_6	61.81 (51.80)	44.25 (41.68)	59.10 (50.22)	50.85 (45.45)
T_7	52.33 (46.31)	48.99 (44.40)	45.63 (42.47)	40.90 (39.74)
T_8	54.54 (47.58)	52.62 (46.48)	47.01 (43.21)	42.09 (40.44)
T_9	60.64 (51.13)	42.55 (40.70)	50.54 (45.29)	45.54 (42.42)
T_{10}	69.44 (56.42)	46.98 (43.25)	45.81 (42.58)	43.14 (41.04)
T_{11}	65.85 (54.22)	54.44 (47.53)	52.06 (46.16)	47.08 (43.31)
T_{12}	65.11 (53.77)	49.50 (44.69)	50.06 (45.01)	45.05 (42.14)
T_{13}	55.69 (48.25)	45.28 (42.27)	48.39 (44.35)	44.17 (41.63)
T_{14}	60.67 (51.14)	52.72 (46.54)	51.95 (46.10)	46.82 (43.16)
T_{15}	59.92 (50.71)	10.78 (39.67)	48.96 (44.39)	46.51 (42.98)
T_{16}	69.19 (56.26)	46.81 (43.15)	47.89 (43.77)	42.97 (40.94)
T_{17}	82.00 (64.93)	71.40 (57.64)	66.74 (54.78)	73.97 (59.32)
CD (0.05)	8.16	5.52	5.84	5.94

(Figures in parenthesis indicate transformed values)

4.11.2.2. Disease intensity

Intensity of sheath blight was the least in T_1 (carboxin + bentazone + carbofuran + T. viride) in the experiments conducted during both the seasons and in both the stages of crop in which the observations were recorded (table 35). This was on par with T_{10} (edifenphos + bentazone + carbofuran + B. subtilis). Barring absolute control (T_{17}) highest disease intensity was recorded in T_{16} (edifenphos + thiobencarb + phorate + B. subtilis) in all the four observations. This was on par with T_{15} (edifenphos + thiobencarb + phorate + T. viride) and T_{13} (edifenphos + thiobencarb + carbofuran + T. viride).

4.11.2.3. Grain and straw yields

During both the seasons T_1 has consistently recorded the highest grain yield as well as straw yield (table 36). Barring the absolute control (T_{17}) the lowest yields were recorded in T_{16}, except the grain yield during Virippu. Straw yield in T_{10} was on par with T_{16} as well as in T_{17}, during Mundakan season. In grain yield also T_{10} was only better than T_{16}. The grain yield in Virippu was lowest in T_4 which was on par with T_{16} and T_{10}.

Table.35. Effect of plant protection chemicals and antagonists on intensity of sheath blight

Treatments	Mundakan		Virippu	
	Boot leaf stage	10 days before harvest	Boot leaf stage	10 days before harvest
T_1	2.90	3.00	2.52	2.71
T_2	3.20	3.99	2.87	3.22
T_3	3.34	3.65	3.10	3.41
T_4	3.76	3.94	3.49	3.70
T_5	3.44	3.71	3.15	3.46
T_6	3.29	3.58	2.97	3.31
T_7	3.43	3.71	3.14	3.45
T_8	4.00	4.22	3.72	3.99
T_9	3.20	3.37	3.02	3.15
T_{10}	2.91	3.28	2.55	2.92
T_{11}	3.80	4.09	3.57	3.85
T_{12}	4.02	4.12	3.75	3.89
T_{13}	4.08	4.28	3.85	4.08
T_{14}	3.82	4.11	3.56	3.89
T_{15}	4.14	4.32	3.91	4.10
T_{16}	4.24	4.45	3.99	4.21
T_{17}	5.57	5.58	5.20	5.40
CD (0.05)	0.22	0.21	0.22	0.23

Table 36. Effect of plant protection chemicals and antagonists on grain and straw yields of rice (kg/plot)

Treatments	Mundakan		Virippu	
	Grain	Straw	Grain	Straw
T_1	4.31	7.64	5.95	10.98
T_2	2.16	4.53	4.60	8.84
T_3	3.00	5.76	4.76	9.13
T_4	2.76	5.02	3.79	7.65
T_5	3.00	6.01	5.82	10.86
T_6	2.83	5.26	5.35	10.04
T_7	3.29	6.64	5.45	10.29
T_8	2.43	4.49	4.59	8.60
T_9	2.85	5.53	5.23	10.15
T_{10}	1.93	3.39	4.49	8.08
T_{11}	2.72	5.73	5.20	9.94
T_{12}	2.54	5.13	4.49	8.72
T_{13}	2.53	4.90	4.95	8.85
T_{14}	3.95	7.47	4.28	7.19
T_{15}	2.55	4.94	4.19	8.39
T_{16}	0.98	1.86	3.89	7.47
T_{17}	0.84	1.72	2.54	5.04
CD (0.05)	0.86	1.74	0.74	1.36

DISCUSSION

DISCUSSION

The saprophytic survival of plant pathogens will greatly depend upon their competitive saprophytic ability. In the present studies it was found that the percentage of colonization of Rhizoctonia solani as well as the percentage of infectivity of colonized straw bits decreased along with a decrease in the inoculum content in the soil. The same trend was observed when the inoculum used was culture bits or sclerotia of R. solani. The decrease in the saprophytic colonization and infectivity was more under submerged condition than under dry condition. Only a few kinds of organisms are capable of growth and reproduction under low water potential (Cook and Papendick, 1970). Thus the possibility of antagonism may be lower in dry conditions which explains the longer survival in dry conditions. This was observed both in dry land as well as wet land soils. The competitive saprophytic ability of a fungus in soil would depend not only on the growth rate, production of antibiotics or toxins, and antibiotics produced by other microorganisms, but also on other microdeterminants of soil ecosystem including number and variety of antagonists exploiting a substrate (Garrett, 1956). The situations in the dry land soil and wet land soil under submerged conditions were found to be very much unfavourable for the saprophytic colonization and infectivity of R. solani.

In sterilized soil, the percentage of colonization was very high when compared with the unsterilized soil. The presence of antagonistic microorganisms (Rosales and Mew, 1982) and their activities in the unsterilized soil may be responsible for this reduction in the percentage of colonization in the unsterilized soil.

There was a general decline in the survival of R. solani with the increase in the incubation period in the soil. In general the saprophytic colonization of R. solani was more in soil kept in dry condition than in submerged condition. The decrease in the saprophytic survival of R. solani with the duration of incubation (Papavizas and Davey, 1961) and higher saprophytic colonization in soils maintained at dry conditions regardless of the soil origins (Rosales and Mew, 1982) have been noted elsewhere also. The reduction of colonization under submerged conditions may be due to a decline in soil aeration (Blair, 1943), lysis of fungal mycelium as a result of increased bacterial activity (Kovoor, 1954) and other unfavourable ecological factors associated with the anaerobic conditions.

All the amendments tested were found to cause stimulation of fungal population. The population of fungi showed an increasing trend from the second week to two weeks before

harvest. The pooled analysis showed that among the different treatments T_8 (groundnut cake) supported the maximum population of fungi and T_{12} (groundnut shell) the minimum. Mitchell and Alexander (1962) reported a decrease in the fungal population in soil amended with chitinous materials. In the present study even though T_{10} (fish waste) contained chitinous materials like prawn waste, there was no decrease in the fungal population. But it is noticed that the increase in the fungal population in this treatment was less when compared with most of the other treatments. This may be due to the fact that fish waste contained many other non chitinous materials (eg. sodium chloride) also, which may have different types of effect on the fungal flora. An increase in the fungal population after soil amendment with saw dust, crop residues and oil cakes was observed by many workers (Barton, 1961; Smith and Ashworth, 1965; Latham and Watson, 1967; Huber and Watson, 1970; Babu George, 1981). A similar trend was observed in the present study also. Wajidkhan _et al._ (1974) observed that application of oil cakes of neem, groundnut and castor increased the total population of fungi in the rhizosphere of egg plant but adversely affected the frequency of parasitic fungi such as _Colletotrichum_ sp., _Rhizoctonia solani_ and _Fusarium_ sp.

In the present experiment also oil cakes were found to cause pronounced increase in the soil fungal population.

During two weeks after planting and tillering stage highest fungal population was in T_9 (punna cake), and at maximum tillering stage it was in T_7 (neem cake). At the boot leaf stage T_8 (groundnut cake) showed the highest fungal population.

All the amendments tested were found to cause stimulation of bacterial population also. In all the treatments the bacterial population was highest at the maximum tillering stage. The increased rhizosphere effect at the time of the vigorous growth of the plants may have contributed to this situation. But in the case of fungi and actinomycetes the trend was by and large, a general increase in the population. The general trend of decrease in the bacterial population after the maximum tillering stage may be due to the decline in vigour of plants as well as probably due to the antagonistic action of the increased fungal and actinomycetes population.

General increase in the population of bacteria in soil due to the soil amendments has been recorded by various workers (Venkatesan, 1962; Smith and Ashworth, 1965; Reddi and Rao, 1965; Henis et al., 1967). But Rouatt and Lochhead (1955) by using crop residues, Maloy and Burkholder (1959) by using manures and saw dust, Mitchell and Alexander (1962) by using chitin as soil amendments could not find much changes

in the bacterial population. Khanna (1970) observed a decrease in the bacterial population during early stages of decomposition of oil cakes in the rhizosphere of pea and pigeon pea. In the present investigation it was observed that the oil cakes amended soil recorded an increasing trend of bacterial population during the early stages, but after the maximum tillering stage, there was a general reduction in the population in T_8 (groundnut oil cake) and T_9 (punna oil cake) amended soils, possibly due to the antibacterial action of the decomposition products of these oil cakes.

All the amendments tested were found to cause stimulation of actinomycetes population. The pooled analysis showed that among the different treatments T_{11} (paddy husk) supported the maximum population of actinomycetes.

Increased population of actinomycetes in soil amended with organic materials has been recorded by many workers from different places (Lochhead and Landerkin, 1949; Rajan and Alexander, 1987). The crop remains like straw and husk from different crops have been reported to be good soil amendments capable of increasing the population of actinomycetes. Oat straw, soybean straw and rice husk are among such crop remains (Papavizas, 1963; Smith and Ashworth, 1965; Babu George, 1981). In the present investigation, it was found that there is considerable difference in the population

of actinomycetes in soil amended with various amendments during the later stages of crop growth.

Survival of soil-borne plant pathogens is greatly influenced by various organic amendments.

In general the trend of survival of the pathogen from tillering stage to two weeks before harvest was a decrease in the amended soils except in T_4 (eupatorium leaves) and T_9 (punna cake) and in T_1 (control) there was a general increase in the survival. A reduced activity of sclerotial fungi due to amendments has been reported (Papavizas and Davey, 1960, 61; Akhtar, 1969; Hakeem and Ghaffar, 1977; Kannayian and Prasad, 1981a; Babu George, 1981). Charchar and Bolkan (1980) observed a decrease in the population of R. solani in the rhizosphere of beans by incorporating paddy husk. In the present study also paddy husk was found to be the most effective amendment in reducing the survival of R. solani. All the other treatments also reduced the saprophytic survival of R. solani. Organic amendments act in a variety of ways to control soil-borne plant pathogens such as stimulation of general microbial activity in soil with increased competition for the pathogen, changes in pH of the soil with resultant effect on the microbial population, toxicity of chemicals produced in the soils during decomposition of residues and inhibition or depression

of sporulation by the pathogen. Thus it is indicative that the addition of organic amendments either directly or indirectly through microbial antagonism reduced the survival of the pathogen (R. solani) in the soil. The survival of R. solani in the soil during different stages of growth of rice was found to be influenced in a varying manner by the organic amendments. Eventhough this information is of academic interest, its practical utility in the control of sheath blight caused by R. solani is doubtful since it is not possible to manipulate the incorporation of organic materials of the desired stages of decomposition during the different stages of growth of the crop. Hence the effect of organic amendments as assessed by the survival of the pathogen at the time of harvest of the crop can alone be taken as a criterion for selecting an organic amendment suitable for controlling the disease caused by a soil borne pathogen.

Incidence of sheath blight was in general low when organic amendments were incorporated in the soil. T_{11} (paddy husk) and T_{12} (groundnut shell) were superior to all other treatments. T_7 (neem cake) and T_{10} (fish waste) also recorded less disease incidence, when compared with other treatments.

The intensity of sheath blight was found to increase slightly from maximum tillering stage to two weeks before

harvest, in majority of the cases. But in green leaf and oil cake amended pots there was a decreasing trend in the intensity of the disease.

Khare and Jharia (1987) discussed in detail the role of organic amendments in biocontrol of plant diseases. They suggested that organic matter added to soil modifies, physical, chemical and biotic environment of soil, initiate succession of events which help in the biocontrol of plant diseases, by providing better growth conditions to the host, less favourable conditions to pathogens, increase antagonistic microflora, stimulate germination of spore forms followed by lysis, inactivate pathogens by direct action of chemicals from amendment materials leading to lysis of germination of hyphae, immobilize nitrogen and nutrients favouring competition and serve as food base for the production of stimulatory and inhibitory volatile substances.

The decreasing trend in the intensity of sheath blight may be due to one or more of the above factors. Alexander and Rajan (1987) found that the intensity as well as incidence of sheath blight of rice can be reduced by neem cake. In the present study also T_7 (neem cake) was found to be effective in reducing sheath blight incidence. Rajan (1980) tried oil cakes of neem, marotti, rubber seed and punna, coconut pith, saw dust and rice husk against sheath blight and sheath

rot of rice. He observed that intensity of both diseases have been reduced in amended plots. He suggested that this may be due to the stimulation of saprophytes leading to a reduction in the pathogen population or better plant tolerance because of increased nutrition offered by the amendments.

Maximum yield was recorded in T_{11} (paddy husk). The effect of T_{10} (fish waste) and T_{12} (groundnut shell) were on par with that of T_{11} (paddy husk). It was observed that all the amendments recorded higher yield than T_1 (control) except T_4 (eupatorium leaves). Babu George (1981) also observed increase in yield of rice due to paddy husk application. Increase in yield due to different organic amendments was reported by many workers from different places (Singh, 1968; Loshakov and Gusev, 1976; Rajan and Alexander, 1987). They suggested that the increase in yield may be due to the increase in the microbial population, which has resulted in low disease incidence and intensity. In the present study, there was a reduction in the yield by the application of saw dust compared to other treatments, except T_4 (eupatorium leaves), T_3 (clerodendron leaves) and T_1 (control). Saw dust is a material of high carbon/nitrogen ratio, and is therefore known to immobilise the available nitrogen in soil (Gupta, 1970).

The viability of sclerotia is greatly influenced by incorporation of organic amendments. In the present study the minimum survival of sclerotia was noted in fish waste amended soil. Premletha Dath (1982) found that daincha, sunhemp and mung leaves drastically reduced the viability of sclerotia of R. solani under laboratory conditions, and suggested that in daincha amended soil, number of antagonistic organisms were more than in the other treatments, and hence the reduction in survival may be due to the effect of antagonistic organisms. Sunar and Chohan (1971) found that soil amended with groundnut cake showed increasing number of rhizosphere microflora. The results of the present study also showed a similar trend. In T_{11} (fish waste) the survival percentage was very low and total microbial population and antagonistic organisms were more compared to other treatments. Papavizas (1970) reported that the effectiveness of some organic amendments in controlling R. solani diseases or in suppressing saprophytic activities may be associated with the modifications of the soil ecosystem resulting in a severe nitrogen deficiency. Papavizas and Davey (1960) observed that amendments with a number of green manure crops substantially increased the total number of soil and rhizosphere fungi, actinomycetes as well as total number of soil bacteria, with the suppression of the incidence of R. solani disease of bean. In the present study also in T_2 (glyricidia leaves) the total microbial population and

antagonistic organisms were considerably more than most of the treatments. Hence the inhibition of survival of R. solani may be due to the saprophytic microflora including the antagonistic microorganisms.

The population of R. solani was increased by the application of N. It was also observed that of the treatments K_1 and P_1K_1 reduced the population of R. solani and the control pots recorded maximum population of R. solani in soil.

Application of inorganic fertilizers are known to reduce the survival of certain soil borne plant pathogens (Sadasivan, 1970 and Garrett, 1971). Kannaiyan and Prasad (1973) found that potassium alone and in combination with phosphorus reduced the survival of R. solani in soil. They suggested that application of potassium in soil was found to be unfavourable for the multiplication of the pathogen, in contrast to P and N. Wensley and McKeen (1964) noticed a reduction in the population of musk melon wilt fungus Fusarium oxysporum f. sp. melonis in calcium and potassium amended soil. Kannaiyan and Prasad (1973) found that soils amended with potassium chloride suppressed the survival of musk melon wilt fungus, F. oxysporum f. sp. melonis. The findings of the present study is in confirmity with these reports. Kannaiyan (1977) found that actinomycete and

bacterial population increased with simultaneous decrease in the *R. solani* population due to potassium application and reported that the depressing effect of potassium might be due to an increase in the antagonistic microorganisms. Potassium application was inhibitory to the multiplication of musk melon wilt fungus in the host plant has been reported by Ramasamy and Prasad (1975). The results of the present studies also clearly indicated that K reduced the survival of *R. solani* and also the existence of the saprophytic pathogens in soil. Dahlsson (1976) and Mariappan and Viswanathan (1986) found that infection by *R. solani* is favoured by the application of higher levels of N. A similar trend is observed in the present study also. The application of inorganic fertilizers alters the soil microflora which in turn may influence the survival of the pathogens (Emmimath and Rangaswamy, 1971). The possible role of soil microflora in the survival of soil-borne plant pathogens has been reported by several workers (Garrett, 1959; Bhaskaran and Prasad, 1971; and Kannaiyan and Prasad, 1975).

The maximum survival of *R. solani* was at 15 per cent moisture level. There was a reduction in the survival of *R. solani* corresponding to an increase in moisture level from 15 to 45 per cent. Blair (1943) and Papavizas and Davey (1961) reported that saprophytism was significantly higher when the soil moisture was maintained at 20 to 60

per cent of the moisture holding capacity than when it was maintained at moisture contents higher than 60 per cent. They also reported that at 90 per cent moisture level, saprophytic colonization was almost eliminated. The reduction in survival at high soil moisture was due to a decline in soil aeration with an increase in moisture content (Blair, 1943) and stimulation of bacterial activity which resulted in the lysis of fungal mycelium (Kovoor, 1954). Satischandra et al. (1980) found that the growth of R. bataticola was adversely affected at high soil moisture of 60 to 80 per cent WHC (water holding capacity) and saprophytic activity was maximum at 20 per cent WHC. Similar type of behaviour of R. solani has been reported by many earlier workers also (Blair, 1943 and Sneh et al., 1972). The results of the present study agree with the above findings. This indicates that the fungus is sensitive to high moisture content of soil and it cannot survive for a long period under anaerobic conditions. It seems that the low survival of R. solani under high soil moisture may be also due to the effect of antagonistic organisms.

The most favourable temperature for the survival of R. solani was found to be between 20 and 30°C. Papavizas and Davey (1961) observed that saprophytic survival of R. solani in green house loamy sand occurred at 20°C and they found that the survival decreased markedly at 30°C.

Bateman and Dimock (1959) reported that R. solani was most active saprophytically at 26 to 30°C and significantly less active above and below this range of temperature. The results of the present study also are in confirmity with the above findings. The low survival of R. solani at this temperature may be due to the effect of saprophytes which are known to be antagonistic to R. solani (Weindling, 1934; Niam and El-Esawy, 1965; Upadhyay and Rai, 1978; Gokulapalan and Nair, 1984; Lulu Das, 1986).

Saprophytic survival of R. solani was found to vary with variation in soil pH. Survival was found to be maximum at pH 7 and 9. At low pH the survival was also found to decrease. Blair (1943) reported that R. solani favoured a soil reaction range of pH 5.8 and 8.1. But Papavizas and Davey (1961) found that a neutral reaction was optimum for the growth of R. solani. In the present study it was found that R. solani colonizes well in neutral to alkaline conditions (pH 7 to 9).

There are various reports on the presence of soil microorganisms which are antagonistic to sheath blight pathogen, under natural soil conditions. Among the various fungi tested for antagonism, fourteen species were found to be antagonistic to R. solani. It was also observed that the various organisms differ greatly in their antagonistic

effect. Certain microorganisms exhibited a higher degree of antagonism against R. solani, compared to others. Among the antagonistic fungi 12 species including Trichoderma viride and T. harzianum were found to possess good antagonistic ability. The antagonistic activity of T. viride against R. solani has already been well established (Orgura and Akai, 1965; Naim and El-Esawy, 1965; Naiki and Ui, 1972; Ferrera-Cerrato, 1976; Lulu Das, 1986). The effectiveness of T. harzianum against R. solani was also recorded by many workers (Hadar et al., 1979; Elad et al., 1981; Rosales and Mew, 1982; Lulu Das, 1986). Among the other antagonistic fungi against R. solani, Aspergillus flavus (Gokulapalan and Nair, 1984 and Lulu Das, 1986), Neurospora crassa (Endo et al., 1973) and Penicillium oxalicum and Chaetomium globosum (Lulu Das, 1986) were reported to possess significant antagonistic properties.

In the present studies, among the different antagonistic organisms A. flavus, A. niger, Fusarium semitectum, F. solani, Gliocladium virens, Neurospora crassa, Penicillium citrinum, P. oxalicum, Rhizopus stolonifer, R. oryzae, Trichoderma viride and T. harzianum showed the B type of interaction i.e. overgrowing of test organism on R. solani, which is regarded as the most effective antagonistic reaction. A perusal of literature showed that Penicillium wortmanii and Rhizopus oryzae are first reports as antagonistic organisms on R. solani.

The importance of antagonistic fungi in the soil environment for the control of soil-borne plant pathogens cannot be over emphasised. The presence of a number of antagonistic fungi has been reported against different soil-borne plant pathogens including R. solani by different workers from many countries. Although many attempts have been made to control soil-borne plant pathogens by means of antagonistic microorganisms, only very few have been found successful under field conditions, probably due to the effect of unfavourable soil ecological factors including the activities of other soil microorganisms. A successful antagonist, apart from having the capacity to grow and multiply in the environment in which it is introduced and ability to attack the target organisms, should not possess harmful effects against other potential antagonists and should not succumb to their activities. In the present studies Aspergillus niger was found to have very good antagonistic activity against R. solani, but at the same time it was highly antagonistic to many other soil microorganisms antagonistic to R. solani. Therefore A. niger cannot be a desirable candidate for the biological control of sheath blight of rice caused by R. solani. In general, in the present study Trichoderma spp. were without much harmful effects to other antagonists and at the same time highly antagonistic to R. solani.

Among the different species of bacteria isolated and tested all except *Xanthomonas* sp. and *Acinetobacter* sp. were antagonistic to *R. solani*. Eventhough *Corynebacterium* sp. and *Alcaligenes* sp. did not show antagonism against other species of bacteria antagonistic to *R. solani* they were not used for field trials since they were not commonly observed in the paddy soils of different tracts of Kerala. At the same time, *Bacillus subtilis* was a comparatively more common species of bacterium observed in the different soil types and it showed satisfactory antagonism against *R. solani*. Moreover, among the different antagonistic species of bacteria tested, *B. subtilis* was found to have maximum inhibition on the sclerotia of *R. solani*. This inhibitory effect was observed even after keeping the sclerotia in bacterial suspension for only ten minutes. *B. subtilis* is antagonistic to many fungi antagonistic to *R. solani*, but it was not possible to select an antagonistic bacterium which is adapted to the paddy soils of Kerala and at the same time not antagonistic to other fungi which are antagonistic to *R. solani*.

In pot culture experiment, the antagonistic bacteria were found to be effective in reducing the incidence and intensity of sheath blight of rice. Among them *B. subtilis* and *Bacillus* sp. were superior to almost all other antagonistic species of bacteria tested. Considering all these points *B. subtilis* was selected for the field trial for the

control of sheath blight of rice. *B. subtilis* has been reported to be antagonistic to *R. solani* from different places (Lily *et al*., 1952; Olsen, 1965). The use of *B. subtilis* in the control of plant diseases has been reported by Utkhede and Rahe (1979) and Jharia and Khare (1986).

None of the isolates of actinomycetes in the present investigation showed antagonism against *R. solani* indicating the commonly occurring actinomycetes in the Kerala soils may not have the potentiality to suppress the population of *R. solani*.

During recent years the use of fungicides, insecticides and herbicides in paddy fields is on the increase. Many of these plant protection chemicals have inhibitory effects on non target organisms also which include many antagonistic microorganisms which may play a very important role in suppressing the activities of the pathogenic microorganisms in less disturbed ecosystems. In the *in vitro* studies to find out the effect of plant protection chemicals on antagonistic fungi and *R. solani* it was found that eventhough Ziram was less inhibitory to the majority of the antagonistic fungi, it was least inhibitory to *R. solani* as well. Among other fungicides tested carbendazim, carboxin and edifenphos were very effective in suppressing the growth of *R. solani*. Considering their effectiveness against *R. solani* and other

useful side effects, carboxin and edifenphos were tried in the field along with other pesticides and antagonists for the control of sheath blight. Many workers have reported the effectiveness of carbendazim, carboxin and edifenphos in the control of *R. solani*, *in vitro* as well as *in vivo* (Edgington and Barron, 1967; Datta and Sharma, 1976; Kataria and Grover, 1977; Gokulapalan, 1981; Roy, 1981; Dash and Panda, 1984).

Among the insecticides tested, phorate, carbaryl and carbofuran were inhibitory to *R. solani* and to some antagonistic fungi. The inhibitory effect of phorate and other insecticides against *R. solani* was reported by several workers (Hacskayle and Stewart, 1962; Lakshmanan and Nair, 1980; Lulu Das, 1986). The antifungal properties of herbicides have been well documented. Eventhough in the present study 2,4-D was found less inhibitory to majority of the antagonistic fungi it has already been reported (Kurodani *et al*, 1959) that sheath blight of rice got increased by the application of 2,4-D. Bentazone and thiobencarb were found to be inhibitory to *R. solani* and at the same time they were less inhibitory to many antagonistic fungi. The inhibitory effects of these herbicides have already been reported by Lulu Das (1986).

When the effects of antagonistic fungi and plant protection chemicals on the survival of *R. solani* were compared

it was found that among antagonistic fungi, only _T. viride_ and _T. harzianum_ were effective in reducing the survival and among the chemicals carboxin and bentazone were effective.

Among the combination of antagonistic fungi and plant protection chemicals, _Trichoderma_ spp. and _Fusarium_ spp. were in general effective with all the three plant protection chemicals tested.

An almost similar trend was observed in reducing the intensity of sheath blight, when these fungi were used in combination with carboxin and bentazone. But carbofuran was also effective in reducing the intensity of sheath blight, when used in combination with these antagonistic fungi unlike its effect on the survival of _R. solani_. The results of the present studies not only confirm the inhibitory effects of carboxin, carbofuran and bentazone reported by earlier workers (Datta and Sharma, 1976; Gokulapalan, 1981; Lulu Das, 1986) but also throw light to the possibility of using these antagonists in combination with plant protection chemicals.

The carboxin + bentazone + carbofuran + _T. viride_ combination was the best in reducing the incidence as well as intensity of sheath blight. The individual effects of all these have been well established (Lulu Das, 1986).

The results of the present studies indicate that these plant protection chemicals and antagonists can be effectively

applied for better control of sheath blight disease. Under pot culture studies there were indications to show that carbofuran is not much effective in reducing the survival of *R. solani*. But the results of the field experiments conducted during two seasons show that the use of carbofuran in combination with plant protection chemicals and antagonist enhances the efficacy of the treatment in controlling sheath blight. The role of carbofuran in reducing the incidence and intensity of sheath blight of rice was investigated by Gokulapalan (1981) and he found that soil application of carbofuran reduces the population of rice root nematode (*Hirschmanniella oryzae*) the infestation of which facilitates the infection process of *R. solani*.

The treatment T_1 (carboxin + bentazone + carbofuran + *T. viride*) was consistently superior to other treatments during both the seasons in reducing the incidence of disease as well as in increasing grain and straw yield. On the other hand T_{16} (edifenphos + thiobencarb + phorate + *B. subtilis*) was the least effective among the various treatments. These results were in line with the earlier findings on the individual effects of the constituent chemicals and antagonists on the sheath blight pathogen (Mathre, 1968; Naiki and Ui, 1972; Mukherjee, 1978; Lulu Das, 1986).

Eventhough there were variations in the population of soil microflora in different treatments in the two seasons of the experiment, these were very much inconsistent so that it is difficult to correlate between the changes in the microflora and incidence and intensity of sheath blight. In the present studies estimations have been made only on the changes in the total microflora ~~have been made~~. In order to arrive at definite conclusions on the changes in the incidence and/or intensity of sheath blight *vis a vis*, the variations in the specific soil microorganisms brought about by the application of different plant protection chemicals and antagonists, detailed investigations on the qualitative changes in the soil microorganisms are required.

SUMMARY

SUMMARY

Sheath blight caused by *Rhizoctonia solani* Kühn is one of the important diseases of rice.

The present investigation was undertaken to make a critical assessment of the nature of survival and various factors affecting the survival of *R. solani* in soil. The Cambridge method was employed to determine the competitive ability and survival of *R. solani*. The results showed that submerged condition affected the competitive saprophytic ability of *R. solani* as indicated by low percentage of colonization and low infectivity on Triveni seedlings. The studies also revealed that regardless of soil origin, colonization was considerably higher in soil maintained at dry condition than at submerged condition.

Various agronomical and ecological factors affected the survival of *R. solani*. Among the organic amendments, paddy husk reduced the survival of *R. solani*, and increased the yield of rice. Application of nitrogen favoured while potash reduced the survival of *R. solani*. Maximum survival of *R. solani* was observed when the soil moisture level was at 15 per cent, temperature between 20°C and 30°C and pH 7.

Among the microorganisms isolated from the soils of Kerala, 14 species of fungi, viz., *Aspergillus flavus*,

A. niger, *Chaetomium globosum*, *Fusarium semitectum*, *F. solani*, *Gliocladium virens*, *Neurospora crassa*, *Penicillium citrinum*, *P. oxalicum*, *P. wortmanii*, *Rhizopus oryzae*, *R. stolonifer*, *Trichoderma harzianum*, *T. viride*, and eight species of bacteria, viz., *Alcaligenes* sp., *Bacillus* sp., *B. subtilis*, *Chromobacterium* sp., *Corynebacterium* sp., *Propionibacterium* sp., *Pseudomonas* sp., and *Rothia* sp. were found to be antagonistic to *R. solani*.

The interactions between the 14 species of fungi antagonistic to *R. solani* were tested and it was observed that *A. niger* was inhibitory to 11 other fungi tested, while *T. harzianum* and *T. viride* were without much interaction with other antagonistic fungi.

The results of the interactions between the eight bacterial isolates antagonistic to *R. solani* showed that the maximum antagonistic reaction against other bacterial isolates was by *Alcaligenes* sp.

Studies on the interactions between fungi and bacteria antagonistic to *R. solani* indicated that the isolates of *Bacillus* were antagonistic to all the isolates of antagonistic fungi.

The *in vitro* evaluation of fungicides on *R. solani* and on antagonistic organisms revealed that ziram was less

inhibitory to majority of the antagonistic fungi. But it was least inhibitory to R. solani. Carbendazim, edifenphos and carboxin were very effective in suppressing the growth of R. solani, but showed less inhibitory action on antagonistic fungi.

Among the insecticides tested methyl parathion was found to be least inhibitory to many antagonistic fungi and also to R. solani. Carbaryl, carbofuran and phorate were inhibitory to most of the antagonistic fungi as well as to R. solani. Studies on the effect of herbicides on the in vitro growth of various fungi showed that 2,4-D was less inhibitory to many of the antagonistic fungi. Bentazone and thiobencarb were inhibitory to a few antagonistic fungi, and to R. solani.

Pot culture experiment to study the effect of application of antagonistic organisms, fungicide, insecticide, and herbicide on the intensity of sheath blight and survival of R. solani showed Trichoderma viride and T. harzianum were effective in reducing the intensity of sheath blight and survival of R. solani. Among the three chemicals tested bentazone and carboxin were effective in reducing the survival of R. solani while carbofuran was least effective. Trichoderma harzianum, T. viride, Fusarium semitectum, F. solani, Aspergillus niger in combination with carboxin and carbofuran reduced intensity of sheath blight.

Results of the field experiment showed that the treatment T_1 where carboxin + bentazone + carbofuran + *T. viride* were applied, recorded the least incidence and intensity of sheath blight of rice during mundakan as well as virippu seasons. The highest grain and straw yield was also observed in this treatment combination.

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* Originals not seen

APPENDIX

Appendix-I

Composition of media used

Peptone dextrose agar with rose bengal (Martin, 1950)

Peptone	5.0 g
Dextrose	10.0 g
KH_2PO_4	1.0 g
$MgSO_4.7H_2O$	0.5 g
Agar	20.0 g
Distilled water	1000 ml
Rose bengal	1 part in 30,000 parts of the medium
Streptomycin	30.0 mg
pH	6.8

Soil extract agar (Allen, 1957)

Glucose	1.0 g
K_2HPO_4	0.5 g
Soil extract	100.0 ml
Distilled water	900.0 ml
Agar	20.0 g
pH	6.8 - 7

Kuster and Williams' medium (Kuster and Williams, 1964)

Starch	10 g
Casein	0.3 g
KNO_3	2.0 g
Nacl	2.0 g
K_2HPO_4	2.0 g
$MgSO_4$	0.5 g
$CaCO_3.7\ H_2O$	0.2 g
$FeSO_4.\ 7H_2O$	0.01 g
Agar	20.0 g
Distilled water	1000 ml
pH	7.1 - 7.2

Selective medium for <u>Rhizoctonia solani</u> (Ko and Hora, 1971)

K_2HPO_4	1.0 g
$MgSO_4\ 7H_2O$	0.5 g
Kcl	0.5 g
$FeSO_4\ 7H_2O$	10.0 mg
$NaNO_2$	0.2 g
Gallic acid	0.4 g
Dexon	90.0 mg
Chloramphenicol	50.0 mg
Streptomycin	50.0 mg
Agar agar	20.0 g
Distilled water	1000 ml
pH	7.00

SURVIVAL OF *RHIZOCTONIA SOLANI* KÜHN WITH SPECIAL REFERENCE TO ANTAGONISTIC SOIL MICROFLORA

BY

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ABSTRACT

Studies were undertaken to make a critical assessment of the nature of survival and various factors affecting the survival of *R. solani* in soil. It was found that submerged condition reduced the competitive saprophytic ability of *R. solani*.

Various agronomical and ecological factors influenced the survival of *R. solani*. Among the organic amendments paddy husk reduced the survival of *R. solani* and increased yield of rice. The survival of *R. solani* was maximum when the moisture level was 15 per cent, temperature between 20°C and 30°C, and at pH 7.

Among the microorganisms isolated from the soils of Kerala, 14 species of fungi, and eight species of bacteria were antagonistic to *R. solani*. *A. niger* was inhibitory to 11 other fungi tested, while *T. harzianum* and *T. viride* were without much interaction with other antagonistic fungi. *Alcaligenes* sp. and *Bacillus* spp. were the bacteria antagonistic to other bacterial isolates and to all isolates of antagonistic fungi as well as to *R. solani*.

The *in vitro* evaluation of fungicides on *R. solani* and on antagonistic organisms revealed that ziram was less inhibitory to majority of antagonistic fungi, but was also

least inhibitory to _R. solani_. Carbendazim, edifenphos and carboxin were very effective in suppressing the growth of _R. solani_, while they showed less inhibitory action on antagonistic fungi.

Among the insecticides tested methyl parathion was found to be least inhibitory to many antagonistic fungi and also to _R. solani_. Herbicides, bentazone and thiobencarb were inhibitory to few antagonistic fungi and to _R. solani_. Results of the pot experiment showed that among the antagonists _Trichoderma viride_ and _T. harzianum_ and among the chemicals carboxin and bentazone were effective in reducing the survival of _R. solani_. _Trichoderma harzianum_, _T. viride_, _Fusarium semitectum_, _F. solani_ and _Aspergillus niger_ in combination with carboxin and carbofuran reduced the intensity of sheath blight.

From the field experiments, it was observed that combination of carboxin + bentazone + carbofuran + _T. viride_ was the best in reducing the disease as well as in increasing the grain and straw yield.