# EVALUATION OF VARIOUS HERBICIDES ON THE CONTROL OF SHEATH BLIGHT DISEASE (*Rhizoctonia Solani* Kuhn) ON RICE

By

LAKSHMY T. R.

**THESIS**

SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE
**MASTER OF SCIENCE IN AGRICULTURE**
**(PLANT PATHOLOGY)**
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

Department of Plant Pathology
College of Agriculture, Vellayani, Trivandrum.

1984

## DECLARATION

I hereby declare that this thesis entitled "Evaluation of various herbicides on the control of sheath blight disease (*Rhizoctonia solani* Kuhn) on rice" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

(LAKSHMY, T.R.)

College of Agriculture,
Vellayani
25 -6 -1984

## CERTIFICATE

Certified that this thesis entitled "Evaluation of various herbicides on the control of sheath blight disease (*Rhizoctonia solani* Kuhn) on rice" is a record of research work done independently by Smt. T.R. LAKSHMY, 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.

(M. CHANDRASEKHARAN NAIR)
Professor of Plant Pathology
Chairman,
Advisory Committee

College of Agriculture,
Vellayani.
25th June, 1984.

APPROVED BY:

Chairman: Dr. M. CHANDRASEKHARAN NAIR

Members:

1. Shri.K.P. MADHAVAN NAIR

2. Dr. S. BALAKRISHNAN

3. Dr. S. BHAVANI DEVI

## ACKNOWLEDGEMENTS

The author expresses her deep sense of gratitude to

Dr. M. Chandrasekharan Nair, Professor of Plant Pathology for the constant guidance and help during the course of investigation and preparation of the thesis,

Shri. K.P. Madhavan Nair, Associate Professor of Agronomy; Dr. S. Balakrishnan, Associate Professor of Plant Pathology; Dr. (Mrs.) S. Bhavani Devi, Assistant Professor of Plant Pathology, for their sincere help, valuable suggestions and criticism during the course of investigation,

Dr.P. Saraswathy, Associate Professor of Agricultural Statistics for the help during statistical analysis of the data,

Shri. B. Balakrishnan, Assistant Professor of Plant Pathology and Shri.C. Gokulapalan, Ph.D. scholar, Plant Pathology for their valuable helps,

Other members of the staff of Department of Plant Pathology for their whole hearted co-operation and to all her friends who have helped in the completion of this work,

The Department of Agriculture, Kerala for having deputed her to undergo the Post-graduate Degree Course in Plant Pathology.

LAKSHMY, T.R.

CONTENTS

## LIST OF TABLES

# LIST OF TABLES



::::::

## LIST OF ILLUSTRATIONS

## LIST OF PLATES

# INTRODUCTION

# INTRODUCTION

Sheath blight disease of rice caused by Rhizoctonia solani (Kühn) has become prevalent in Kerala with the introduction of high yielding varieties of rice. Now it is the most destructive disease of rice in the State and its occurrence is found endemic in the important rice growing areas of the State, where monoculture is practiced under high fertility conditions, particularly with uniform genetic material in the field.

No rice variety has been found to be completely resistant to this disease and high fertilizer responsive dwarf varieties are more susceptible to this pathogen. The loss due to this disease has been estimated and generally it ranges from 20 to 30 per cent. The high cost of frequent application of fungicides make the rice farmers reluctant to adopt regular spraying which has aggravated the disease problem.

Application of high dose of fertilizers and other inputs without proper protection not only benefit the crop but also its enemies; such as pests, disease causing pathogens and also weeds. Weeds grow very fast in the early stages along with rice and is a serious problem in rice production. It has been estimated that there is about 25.5 per cent reduction in yield in transplanted rice due to weed menace. In addition to removal of nutrients, weeds also harbour pests

and diseases as they serve as their collateral hosts. The sheath blight pathogen can infect and survive on a number of weeds in and around rice fields.

Though effective, due to high cost of labour, farmers are not in a position to resort to hand weeding and are inclined towards the use of herbicides for control of weeds. A number of herbicides are reported to be very useful in controlling weeds in rice crop; and a number of chemicals are at present marketed as herbicides and are recommended for application in rice fields. As with other pesticides, the biological activity of these herbicides are not restricted to target organism, but extends to non target organisms also (Katan and Eshel, 1973). Hence inhibitory and stimulatory effects on harmful or beneficial non target organisms in the environment are possible and a proper understanding of the same is a must before making a large scale application of particular herbicides.

Irrespective of the method of application, the herbicides reach the soil, sooner or later and hence soil pathogens are more affected. The main mode of survival of R. solani; the causal organism of sheath blight disease, is by the soil-borne sclerotia. Some of the herbicides commonly recommended for rice are reported to have inhibitory effect on soil-borne sclerotia of R. solani. On the other hand few other herbicides like 2,4-D enhance the susceptibility of host plants to disease and there are many reports on the

inhibitory effects of herbicides on disease incidence.

However, there is no systematic and detailed study on use of herbicides for disease control, especially to test the indications obtained in the in vitro studies, on how far it can be applicable under field conditions. Hence, the present study has been undertaken to evaluate the side effect of the commonly used herbicides in rice fields, like Fluchloralin, 2,4-D, Bentazon, Benthiocarb, Pendimethalin, Nitrofen, Propanil, and Butachlor, on the control of sheath blight disease of rice; under the following lines of investigation.

A. In vitro studies were undertaken to study the effects of different concentrations of the above herbicides on radial growth, sporulation, number and size of sclerotia formed and its germination and pathogenicity.

B. A pot culture experiment was conducted

1) To study the role of sclerotia in initiating the disease by artificial inoculation.
2) To study the effect of all the above mentioned herbicides on the incidence of sheath blight disease on rice and to study their effect on the viability, germination and pathogenicity of sclerotia under field conditions.
3) The effect of application of field dose of the above herbicides on the natural microflora were investigated and certain microorganisms antagonistic to R. solani were also isolated.

C. A field experiment was conducted in the wet land of the College of Agriculture, Vellayani with selected herbicides to study their effect on the control of sheath blight and control of weeds. The effect of application of the different doses of the above herbicides on soil microflora under wet land conditions were also investigated.

# REVIEW OF LITERATURE

# REVIEW OF LITERATURE

Miyake (1910) first reported a new disease of rice under the name 'Oriental Sheath Blight and leaf spot' from Japan, caused by Sclerotium irregulare. Since then this disease has been reported from many of the rice growing countries of the world. For some time this disease was considered to be mainly confined to the orient, since this has been recorded only from countries like Philippines (Reinking, 1918; Palo, 1926) Sri Lanka (Park and Bertus, 1932) and China (Wei, 1934). However, later on its occurrence has been reported from Brazil, Surinam, Venezuela and Madagascar (Ou, 1972). This disease has been recorded from U.S.A. also (Ryker and Gooch, 1938) and in the recent past it is known to occur throughout the temperate and tropical rice growing areas of the world according to Hashioka and Makino (1969).

Eventhough Butler (1918) mentioned about the occurrence of this disease in India, it was Paracer and Chahal (1963) who first described in detail the sheath blight disease caused by Rhizoctonia solani (Kühn) from Punjab. The occurrence of this disease has been subsequently reported from Punjab by Kohli (1967) and then from Uttar Pradesh by Singh and Pavgi (1969).

This disease was noted in a severe form in Kerala State after the introduction of the high yielding varieties

of rice and was first recorded by Mahendra Prabhath (1971). Since then epidemic outbreak of this disease has been recorded from many other States of India also. In Kerala, sheath blight disease of rice occurs in a severe form in all rice growing regions all through the seasons and is at present the most important constraint in the production of rice in the State.

Symptomatology

Miyake (1910) first described the symptoms of this disease in detail. The initial symptoms appeared as discoloured, ellipsoidal spots on the sheath at or above the water level and also on the leaves. These spots developed into oblong or irregularly elongated lesions present on any part of the leaf sheath which often extends to the leaf blade. Gradually the whole leaf blade get rotten and it can be pulled out easily. Singh and Pavgi (1969) reported that the initial symptoms appeared as oval to irregular straw coloured lesions on the leaf sheath near the leaf base; surrounded by narrow reddish brown band. Lesions increased in size coalesced and covered the whole leaf lamina, which appeared as banded patches. Sclerotia developed in the infected regions. In the case of severe infection the sclerotia were observed on the spikelets and on the partially opened lemma and palea also. Kozaka (1970) observed that the lesions developed on the leaf sheaths were first greenish grey and

ellipsoidal 2 to 3 cm long or more which gradually turned greyish white with a blackish brown narrow margin. Under conditions in Kerala the symptoms are very common on the leaf blades and Ou (1972) has rightly pointed out that in the tropics, leaves of an infected plant are often severely infected and killed by the fungus.

Loss in yield

The actual loss in grain yield often depends on the stage of infection of plants and if infection takes place at an early stage, the damage will be serious. On the other hand the loss will be negligible when the crop is infected at a later stage of growth. According to Mizuta (1956) the reduction in yield due to the disease is 20 per cent if the disease developed upto the flag leaf stage. Tsai (1974) has assessed the yield loss due to rice sheath blight by artificially inoculating the plants at different stages and reported that it varied from 6.05 per cent to 11.73 per cent according to variety and time of infection. After a detailed critical study, Tsai (1975) reported that the loss was maximum when the plants were infected at an early stage of growth.

In Kerala the damage due to the disease was observed to be very serious during the second crop season. Muneera (1973) reported a reduction of 22-28 per cent in grain yield and 22-28 per cent in straw yield due to this disease.

Radhakrishnan (1975) estimated a loss of 29 per cent in grain yield and 23 per cent reduction in straw due to the disease. According to Mathai (1975) the loss in yield due to this disease in Kerala was 25 per cent.

Causal organism

The causal organism was first described as Sclerotium irregulare by Miyake (1910). Sawada (1912) made a detailed study of the disease and reported that the causal organism was identical with Hypochnus sasakii Shirai. The organism was variously named and Matsumoto et al. (1932) and Matsumoto (1934) made a detailed study of the fungus employing a number of isolates. Finally Matsumoto (1934) named the organism as Corticium sasakii (Shirai) Matsumoto and opined that it is the most acceptable name. Ryker and Gooch (1938) studied the morphological characters of the culture of the fungus obtained from China and from Philippines and considered the rice pathogen to be the large sclerotial strain of Rhizoctonia solani. Talbot (1970) after a detailed comparative study concluded that Thanatephorous cucumeris (Frank) Donk is the perfect state of R. solani and Hypochnus solani and Hypochnus filamentosus were considered synonyms of Thanatephorous cucumeris. He considered T. cucumeris as a collective species that includes T. praticola (Kotila) Flentje, Corticium microsclerotia (Weber) and C. sasakii (Shirai) Matsumoto.

Saksena (1979) distinguished two different and distinct strains of R. solani in Indian soils, the root infecting, and the shoot pathogen, which are more responsible for the diseases of crop plants. In India the importance of the aerial strain was realised only after the appearance and spread of sheath blight of rice causing severe blighting of the aerial parts of the plants.

## Anastomosis relationship of Rhizoctonia solani

The grouping of R. solani on the basis of hyphal anastomosis between different strains has gained much importance in the study of this soil borne plant pathogen. R. solani consists of a great number of isolates differing in various characters (Flentje et al., 1979). Capacity for hyphal anastomosis between different isolates provides an indication of relationship within groups of isolates. Parmeter et al. (1969) reported that each anastomosis group has its general tendency in host range and pathogenicity. Richter and Schneider (1953) classified strains of R. solani into six groups. Parmeter et al. (1969) observed that most of the 138 isolates of R. solani, they have isolated and tested, fell into four anastomosis groups.

Lakshmanan et al. (1979 a) reported from Kerala, India, the hyphal anastomosis between strains of R. solani from rice and cowpea. Gokulapalan (1981) found that hyphae of isolates from rice, daincha and groundnut anastomose

freely with each other which establishes the genetic relationship between these isolates; but isolate from sesamum failed to anastomose with any of the other three isolates indicating that it is genetically different from the other isolates.

Morphology of the pathogen

Duggar (1915) observed that the young hyphal branches of R. solani were inclined in the direction of growth and constricted at the point of union with the main hyphae. In mature hyphae, branches arise at right and acute angles near 45° to the main branch (Matz, 1921; Matsumoto, 1921; Palo, 1926). The hyphal measurements of most isolates were between 8-12 µm (Duggar, 1915), 6-12 µm (Flentje, 1956). Sclerotia were superficial, more or less globose in shape, but flattened below, white when young, turn brown at maturity (Matz, 1921; Matsumoto, 1934; Weber, 1963). The size of sclerotia ranged from about 1 mm to several mm (Frederiksen et al., 1938).

The perfect state of rice fungus was first recorded from India by Singh and Pavgi (1969) from Varanasi and described the organism as developing as creamy white crust on the leaf sheath. It was also recorded from Kerala as forming on paddy straw after wetting (Lakshmanan et al., 1979 b).

Survival of the organism

Sclerotia constitute one of the most important links in the life history of the pathogen. Ikata and Hitomi (1930) stated that the sclerotia which fall on the ground before harvest of the crop hibernate in the soil and infect the crop in the following season. Endo (1931) found the fungus over

winter as sclerotia or mycelium and lost their viability in dry soil after 21 months. Park and Bertus (1932) reported that at room temperature in dry or moist soil sclerotia survived for at least 130 days and for 224 days when submerged in water. Nisikado and Hirata (1937) found that sclerotia remained viable evenafter three years at or below 20°0, twenty six months at 25°C, sixteen months at 30°C and six months at 35°C, on steamed rice straw. Sanford (1952) found that availability of susceptible host plants was more important for survival in soil than the dead or living roots of non-susceptible hosts and it dicappeared from heavily infested soil in less than four months in the absence of susceptible crops, but survived under soil planted with susoeptible crops. Mahendra Prabhath et al. (1974) reported that sclerotia lost viability within 60-80 days when they were kept under submerged condition.

Weed hosts of R. solani in rice fields

Tsai (1970) observed the host range of Pellicularia sasakii on weeds comprise eleven families, Cyperaceae and Gramineae being the most important. Mahendra Prabhath (1971) found that sheath blight fungus can infect various hosts of different families, in which include Panicum repens L., Echinoohloa colonum Link and Cyperus rotundus L. Gokulapalan (1981) found wild colocasia (Araceae), Cyperus iria L. (Cyperaceae), Fimbristylis miliaceae Vahl.

(Cyperaceae), Apluda aristida L. (Ponicoideae), Monochoria vaginalis (Burm.F) Presl. are among the rice field weeds which are host plants of sheath blight fungus.

Chemical control

Control of sheath blight by chemicals has been studied by different workers. Hashioka and Saito (1953) found that the growth of Corticium sasakii was inhibited by organo mercuric compounds like Ceresan, Uspulum and Neomercurin. Yoshimura (1954) reported that the degree of damage was reduced by Bordeaux mixture. Kozaka et al. (1957) reported that organo arsenic compound 'Urbazid' was highly effective against sheath blight. Of the various compounds tested, 6-chloro and 6-bromo benzo-xazilone 2 were particularly active against Rhizoctonia (Corticium) solani (Eckstein and Zukowski, 1958) Sinclair (1957) observed that PCNB plus Captan to be promising for the control of Rhizoctonia (Corticium) solani.

Chen and Chien (1961) reported that in Taiwan the disease was best controlled by tuzet plus lime or by 4:8 Bordeaux mixture plus Granosan applied 40-50 days after transplanting. According to Abeygunawardena and De Silva (1964) natural infection by C. sasakii can be reduced by organo arsenic sprays and to a lesser extent by Dodine or Triphenyline hydroxide. Tamura (1965) found that organotin fungicides controlled the fungus in pot culture and field

tests. Takita et al. (1965) reported that sheath blight caused by Pellicularia (Corticium) sasakii was controlled by methyl arsenic compounds and ferric methyl arsenate.

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

Studies by Chien and Hung (1971) revealed that the disease was best controlled by spraying with Benlate W.P. From IRRI, Philippines, Benlate, BAS-3050 F and Hinosan were reported to be effective against sheath blight (Anon., 1973).

Pommer and Zwick (1973) also found that the new systemic fungicide BAS-3050 F to be effective in controlling the disease.

Kozaka (1961) and his co-workers conducted elaborate field trials on the control of sheath blight by fungicides and they also developed techniques for testing the efficacy of fungicides in the lab, by detached leaf techniques.

Antibiotics have also been used for the control of sheath blight of rice (Yamamoto et al., 1965). Fukunaga (1966) found that the antibiotic Polyoxin, was promising and no phytotoxic effect was reported.

Thirumalachar et al. (1969) reported the effectiveness of Aurofungin in inhibiting the growth of Corticium sasakii under field conditions.

In this laboratory many workers have also attempted the chemical control of the disease.

Radhakrishnan (1975) found that application of Aureofungin reduced the intensity of sheath blight infection and recorded an increase in yield of grain as compared to other treatments. Varma and Menon (1977) also reported that Aureofungin sol was effective in reducing the per cent of tiller infection. It was also found that Benlate was superior over Hinosan and Captan in reducing the intensity of disease and thereby increasing the yield (Muneera, 1973). Studies conducted by Jagan Mohan (1977) also revealed that higher levels of potash and application of Benlate and Vitavax controlled the disease.

The effectiveness of Hinosan in controlling sheath blight has been observed by Mahendra Prabhath (1971); Muneera (1973); Mathai (1975); Radhakrishnan (1975) and Kannaiyan and Prasad (1979). Hinosan was found to be superior than Aureofungin in checking the disease (Radhakrishnan, 1975). Though Hinosan was not as effective as Kitazin granules and Aureofungin sol in reducing the disease intensity, it was significantly superior to all other fungicides tested, except Kitazin granules in enhancing the yield (Varma and Menon, 1977). Lakshmanan (1979) also found that Hinosan increased the yield eventhough it was not effective as Vitavax in controlling the disease. Lakshmanan *et al*. (1980) have also

rted that Hinosan was effective in reducing the disease nsity and per cent hill infection. Gokulapalan (1981) observed that Hinosan was effective but ranked third fficacy.

Vitavax which has been generally recommended against diomycetes has been tried under Kerala conditions against th blight. Mahendra Prabhath (1971) observed good elation between lab assay and pot culture evaluation of icides against C. sasakii and reported that Vitavax was rior over all other fungicides in controlling the ase and increasing the yield. Jagan Mohan (1977) found the disease can be controlled by applying higher levels otash followed by spraying Vitavax. This fungicide has found to be effective in checking the disease in the equent trials also under Kerala conditions (Lakshmanan l., 1980; Gokulapalan, 1981; Nair et al., 1983).

Gokulapalan (1981) observed that application of vax and Carbofuran significantly reduced the disease nsity and rice root nematode infestation and increased d considerably.

ct of herbicides

Several studies have indicated the effect of icides on microorganisms, and those groups of microbes h can use the herbicide applied in soil, as food, will rish and increase in population and those to which the

herbicides prove to be toxic will decrease in number (Altman and Campbell, 1977). Most of the herbicides applied to soil at recommended doses will disappear in less than twelve months and so no prolonged effect is expected from herbicides. However, in the case of organisms which develops special survival structures such as sclerotia or chlamydospores the effect may last over twelve months and if it is favourable for its survival, this period of survival may increase for 5 to 10 years, or if it is toxic to potential pathogen their capacity to induce disease may be reduced as pointed out by Altman and Campbell (1977). Rhizoctonia solani being an organism which survives by formation of sclerotia, it is true that some of the herbicides have got beneficial effects on them while others are detrimental to them.

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.

In the in vitro tests with various herbicides by Altman (1969), it was found that twenty five of them were energy sources for R. solani and growth was better in media supplemented with herbicides. Though complete inhibition of growth occurred at 10000 ppm with Tillam and Pyramin, both increased Rhizoctonia damping off in steamed and in

field soil in sugarbeets. The presence of competitive saprophytic microorganisms in the untreated field soil accounted for the reduced damping off and the greater glucose exudate in plants in herbicide treated soil may be the reason for high susceptibility to low levels of Rhizoctonia infection.

Chandler and Santelmann (1968) found that the herbicides Trifluralin and Prometryne were antagonistic to C. solani.

Lai and Semeniuk (1970) found that the herbicide constituent Picloram at 500 ppm increased carbohydrate exudate from maize seedlings and may be the reason for increased root damage due to R. solani in picloram treated soil.

It has been found that 2,4-D, MCPA, Prometryne and Simazine encouraged the development of aerial hyphae of R. solani (Tatsuyama and Jakihara, 1970). The stand of cucumber seedlings was reduced by Rhizoctonia + Dinoseb. Rhizoctonia + Linuron and Rhizoctonia + Pentachlorophenol combinations than Rhizoctonia alone though the herbicide Dinoseb, Linuron and Pentachlorophenol inhibited the mycelial growth of R. solani in vitro. The herbicide might have affected the physiology of the host and increased the susceptibility of the same to the fungal pathogen.

Sezgin (1978) stated that growth of R. solani was significantly altered in the presence of Trifluralin, EPTC and Aretit and virulence on cotton seedlings was increased by herbicides and had no effect on Trichoderma viride.

The increase in pre-emergence and post-emergence damping off caused by R. solani was reported by El-Khadem et al. (1979) by treatment with Trifluralin and Dinitramine at half the recommended dose. Fluometuron at twice the recommended dose was highly phytotoxic and increased post-emergence damping off.

Sumner et al. (1979) found that root rot caused by R. solani, Pythium spp. and Fusarium spp. was increased and root growth and yield of leafy turnip greens decreased in soils receiving herbicide (DCPA) treatments compared with control.

Growth of R. solani at 35°C was stimulated at low rate of Bensulide and NC 8438; and Benifin increased the severity of brown patch and dollar spot by R. solani in turf grass (Karr et al., 1979).

Studies conducted by Lakshmanan and Nair (1980) revealed that 2,4-D did not inhibit the growth of R. solani; but increased the number and size of sclerotia. However, their viability and pathogenicity were unaffected.

Sezgin et al. (1982) reported increased damping off by R. solani, by use of three herbicides and growth of fungi

and sclerotial formation and rhizosphere fungi were affected.

Bain (1961) found that the herbicides Pentachlorophenol; 4-6-dinitrobutylphenol; Isopropyl N-phenyl carbamate and 2-chloro-N, N diallyl acetamide inhibited the growth of Sclerotium rolfsii; Sclerotinia bataticola and Rhizoctonia sp.

Pentachlorophenol used for weed control in rice fields has also been found useful in controlling sheath blight as side effect (Ono and Iwata, 1961; Takatsu and Nishimura, 1962; Inoue and Uchino, 1963; Endo et al., 1965). According to Millikan and Fields (1964) 2,4-D at 100 ppm reduced the growth of Rhizoctonia 86 per cent and Simazine reduced the growth of Rhizoctonia 93 per cent. Ebner (1965) reported that Diuron at 125 µg/ml and Linuron at 60 and 125 µg/ml were sensitive to R. solani. Rodriguez-Kabana et al. (1966) tested the effect of Atrazine, Diuron, EPTC and Paraquat on R. solani and found that the total mycelial dry weight of the fungus was considerably less for each concentration of Atrazine than for check throughout the twenty days incubation period and the degree of inhibition of growth was directly proportional to the increased herbicide concentration from 10 to 70 ppm. Diuron at 0.02 ppm to 2 ppm and EPTC at 0.8 to 40 ppm had little effect on growth of R. solani after an initial inhibition.

Eshel and Katan (1972) recorded the suppression of growth of R. solani with increasing concentration of Benefin

Trifluralin, and Isopropalin.

Grainstein et al. (1976) found that Trifluralin, Nitralin, Butralin and Dinitramine, significantly increased the resistance of egg plant, tomato, and capsicum to R. solani and disease incidence was decreased by 30-90 per cent. Trifluralin increased resistance in cotton in certain cases. Growth of pathogen in vitro was inhibited at concentrations much higher than those used in soil or found in tissues.

R. solani was suppressed by treatment of Prometryne at 40 µg/g of soil and more distinctly by Fluometuron as shown by significantly reduced β-galactosidase and phosphatases activities. Low levels of either herbicides had little effect on this pathogen (Beam et al., 1977).

Inderawati and Heitefuss (1977) tested seven herbicides against Hypochnus (Corticium) sasakii, Pyricularia oryzae Cav. and Xanthomonas oryzae (Dowson) Uyeda and Ishiyama in culture and on disease intensity. Propanil 10 µg/ml commercial formulation reduced 50 per cent growth of all the pathogens in agar medium and was found effective in reducing disease intensity when applied one day before inoculation. The effect of Simetryne and Nitrofen on disease severity was stronger than expected from the small direct action on the pathogen in culture, which may be due to their effect on host plant rather than on the pathogen directly.

Manila and Lapis (1977) from Philippines reported that sheath blight was not affected by the treatments MCPA, 2,4-D and Monocrotophos; while it reduced severity of bacterial blight.

Varma et al. (1978) in Kerala recorded that Avirosan 50 EC, Saturn 50 EC and Machete 50 EC and Rilof H. 50 EC were highly inhibitory to the growth of Corticium sasakii.

Damping off of cowpea by R. solani was decreased by treatment with trifluralin and this effect was attributed to decreased virulence of the pathogen and the direct inhibitory effect of the herbicide on its growth and sclerotial production (Muangsombut and Mercado, 1979).

Dath and Swain (1979) studied the in vitro effect of Butachlor, Nitrofen and Propanil at 25, 50, 100, 250 and 500 ppm concentrations on radial growth of R. solani and found that the growth of fungus was completely suppressed in all the concentrations of Propanil followed by Nitrofen. Butachlor was effective only at higher concentrations of 250 and 500 ppm, and concluded that Propanil and Nitrofen have potentiality in suppressing the growth of sheath blight pathogen.

In a field test in Kerala a foliar application of Saturn at 2 kg ai/ha controlled sheath blight and sheath rot of rice (Corticium sasakii and Sarocladium oryzae respectively) (Vasavan et al., 1980).

Lakshmanan and Nair (1980) reported that Saturn was highly inhibitory to the growth of R. solani (Sheath blight fungi) followed by Sirmate, Tok granules and Machete, and the degree of inhibition was related to the concentration of the herbicide. Sirmate was most effective in preventing the formation of sclerotia which was closely followed by Tok and Saturn. Tok and Saturn at 125, 250 and 1000 ppm increased the size of sclerotia significantly than other treatments. Sclerotia produced in all the treatments were equally viable and pathogenic to rice plants.

A multilocational trial conducted by Kerala Agricultural University at Adoor and Moncompu during 1981-82 on the effect of various herbicides, on the control of sheath blight disease, revealed that Nitrofen 1.25 kg/ha and 1.75 kg/ha, Basagran (Bentazon) 1.75 kg/ha are effective in controlling the incidence and intensity of sheath blight (Anon., 1982 a).

Biological control

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

action on R. solani (Hino, 1935; Josifovic, 1967; Roy, 1977; Henis et al., 1978; Hadar et al., 1979).

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

The inhibitory effect of Bacillus sp. on R. solani has been reported by many workers (Hino, 1935; Cordon and Haenseler, 1939; Michener and Snell, 1949; Dunleavy, 1952; Vasudeva and Chakravarthy, 1954; Olsen, 1965). In an experiment conducted at IRRI, Philippines, the antagonistic action of many bacterial isolates differing in colony characters obtained from the irrigation water of rice fields and sclerotia of R. solani were studied. Many isolates especially those from sclerotia exhibited antagonism to the pathogen (Anon., 1978 ).

Use of herbicides in the control of weeds in rice fields

Weed spectrum in rice fields in Kerala

In Kerala, Echinochloa colonum (Linn) Link, Fimbristylis miliacea (Linn) Vahl. and Cyperus spp. were the predominating weedflora observed in the wet land rice fields of Moncompu (Pillai and Rao, 1974). According to Nair et al. (1975) the most important weeds found in R.R.S. Pattambi were Echinochloa crus-galli (Linn) P. Beauv., Brachiaria spp.,

Cleome spp, and Fimbristylis miliacea; Echinochloa spp, Cyperus spp, Fimbristylis miliacea, Ammania multiflora (Linn), Ludwigia parviflora (Linn) Roxb. and Monochoria vaginalis (Burm. F) Presl. were the common weeds in rice fields of Vellayani, Kerala (Ravindran, 1976).

Losses in rice production due to weeds

Weed infestation cause considerable reduction in yield in rice. Pillai and Rao (1974) estimated that the yield reduction in rice due to weeds alone was around 15-20 per cent for transplanted rice. The extent of grain yield reduction in transplanted rice due to weeds alone compared to hand weeding amounted to 26 per cent. Many of the rice field weeds are hosts of Sheath blight fungus and they also influence the microclimate (Anon., 1982 c).

Manual weed control

Grist (1953) and Haynes (1955) recommended hand weeding as the best method of controlling weeds in rice fields. Vacchani et al. (1963) from Central Rice Research Institute, Cuttack, reported that hand weeding is as good as herbicidal spray. Ravindran (1976) reported hand weeding on 20th and 40th day after transplanting rice, though increased yields, the net profit was lower due to increased labour charges. Kaushik and Mani (1978) reported that experiments at Indian Agricultural Research Institute, New Delhi, showed that hand

weeding treatments, gave most effective weed control and increased the grain yield.

Chemical weed control

A number of herbicides are reported to be very useful in controlling weeds in cereal crops. Among them Bentazon (Basagran), Pendimethalin (Stomp), Benthiocarb (Saturn), Nitrofen (Tok E.25), Propanil (Stam F. 34), Butachlor (Machete) are the important ones.

Bentazon:-

Experiments at International Rice Research Institute, revealed that Bentazon at 1.5 kg ai/ha gave the highest yield in low land rice (Anon., 1976 b). Weerd and De (1977) found that the herbicide Basagran at 4-5 l/ha gave effective control of Cyperus difformis. Atwell et al. (1978) reported that in a total number of 35 trials carried out, Bentazon at 0.5-1 lb/acre gave good control of broad leaved weeds, sedges and rushes in rice grown under all cultural conditions. Ramazanov (1981) found that Basagran at 2.5 kg/ha post-emergence gave 40-90 per cent control of Scirpus species.

Pendimethalin (Penoxalin)

At International Rice Research Institute, Penoxalin (Pendimethalin) at the rate of 2 kg/ha applied six days after sowing controlled the major weeds; Echinochloa crus-galli, Monochoria vaginalis and Cyperus difformis (Anon., 1974).

Ravindran (1976) found that Penoxalin at 1.5 kg ai/ha applied on the sixth day after transplanting brought down the weed growth and increased the yield. Moursi et al. (1978) found the greatest reduction in fresh and dry weight of Cyperus difformis and fresh weight of Echinochloa crus-galli. Abud (1980) reported the lowest yield from the plots treated with Pendimethalin at 1.25 kg/ha. Penoxalin (g) at the rate of 1.5 kg ai/ha on the sixth day after transplanting is recommended for weed control in rice (Anon., 1982 b).

Benthiocarb

Experiments at Central Rice Research Institute, Cuttack revealed that Benthiocarb gave efficient control of weeds in rice (Anon., 1971). Sridhar et al. (1976) tried several herbicides in rice in which Benthiocarb treated plots recorded better weed control and least phytotoxicity and maximum yield. Gill and Mehra (1981) reported Benthiocarb 1.5-3 kg/ha applied 3-4 days after transplanting rice was highly effective. Benthiocarb has been established as a prominent herbicide for control of weeds in rice both upland and low land conditions. Benthiocarb (EC) at the rate of 2 kg ai/ha on sixth day after transplanting has been recommended (Anon., 1982 b).

Nitrofen

Experiments at CRRI, Cuttack showed that Nitrofen gave efficient weed control in rice (Anon., 1971). Raghavalu

and Moorthy (1976) reported Tok E.25 at 3.5 kg/ha was less effective in rice. Verma et al. (1978) found pre-emergence application of Nitrofen at 2.5 kg/ha gave selective control of grasses, sedges and broad leaved weeds. In dry sown crops pre-emergence spray of Nitrofen at the rate of 1.5 kg ai/ha on the same day of seeding is recommended (Anon., 1982 b); but its efficiency under low land conditions is not yet established.

Propanil

Post-emergence application of Propanil 3 kg ai/ha was recommended by Nair et al. (1974) for control of weeds in direct-seeded rice crop. Stam F.34, 1.6-4 kg/ha in direct-sown rice gave the highest yield (Singh and Singh, 1976) and Mosha et al. (1977) found Propanil to give very good overall weed control. Kaushik and Mani (1980) reported that Propanil at 2 kg/ha was the most efficient herbicide in increasing grain production of rice. Propanil (Stam F.34) 1.75 kg ai/ha in 3 per cent fresh urea solution as spray 12 to 14 days after transplanting is recommended for weed control (Anon., 1982 b).

Butachlor

Baker (1975) found that Butachlor E.C. at 2 kg/ha was effective against grasses under direct-seeded conditions. Butachlor 0.5 kg/ha was found best in direct-sown rice (Zahidul Hoque et al., 1978. Ahmed and Hoque (1981) found

Butachlor at 2 kg ai/ha gave efficient weed control of dry seeded rainfed rice. Butachlor (G) 1 kg ai/ha six days after planting or sowing is recommended for weed control in rice (Anon., 1982 b).

2,4-D

According to Kannaiyan et al. (1981) 2,4-D was superior in controlling weeds in dry seeded wetland rice. It is recommended to apply 2,4-D at 1 kg/ha in 400 l of water, 25 days after transplanting to control broad leaved weeds. Application of 2,4-D Sodium salt @ 1 kg/ha mixed with 10 kg urea/ha 20th day after sowing/transplanting is also recommended in level fields to save spraying charges (Anon., 1982 b).

# MATERIALS AND METHODS

# MATERIALS AND METHODS

## I. Isolation and pure culture of the organism

An isolate of Rhizoctonia solani (Kuhn) causing sheath blight of rice was obtained from naturally infected rice plants of the variety Thriveni collected from the rice fields of the College of Agriculture, Vellayani. For isolation of the pathogen, portions of the infected sheath showing fresh characteristic symptoms, were cut into small bits, surface sterilized with 0.1 per cent mercuric chloride solution for two minutes and washed with three changes of sterile distilled water. The bits were then planted over potato dextrose agar (PDA) in sterile petri dishes and incubated under laboratory conditions (28°C). Twenty four hours later the fungal growth on infected tissues was transferred to PDA slants. The isolate was purified by the hyphal tip method and the organism was maintained on PDA by subculturing periodically.

The isolate was cultured on PDA in 9 cm sterile petridishes under laboratory conditions. The morphological characters, viz., hyphal thickness, branching, formation, number and size of sclerotia etc. were recorded.

The pathogenicity of the isolate was proved by following Koch's postulates. Rice plants of the variety Thriveni were raised in earthen pots of size 32 x 38 cm and were artificially

inoculated by placing two sclerotia of the fungus from fifteen day old culture in between the sheaths of the rice plant and covering with a bit of moist cotton wool and with polythene bags for 48 hours.

The fungus was reisolated from the artificially inoculated rice plants by the method described earlier and compared the hyphal and sclerotial characters with those of the original isolate. The fungus was purified by repeated hyphal tip method and pure culture was maintained on PDA slants for the study.

Mass culturing of R. solani

R. solani was mass cultured on sterilised sand maize medium in 1000 ml Erlenmeyer flasks. Maize meal was thoroughly mixed with washed white sand in the ratio of 1:19 taken in the flask, moistened with water and sterilized by autoclaving under 1.02 $kg/cm^2$ for 15 to 20 minutes. Actively growing three day old culture bits in PDA in petridish were introduced aseptically into the flask with sterilized sand maize medium and were incubated for twenty days for production of sclerotia.

II. In vitro effects of various herbicides on R. solani

a. Radial growth in herbicide amended media

The sensitivity of R. solani to eight herbicides was studied by adopting the modified technique of Borum and Sinclair (1968).

Table 1. Herbicides used for the study on inhibition of *R. solani* in vitro

| Sl. No. | Common name | E.C. Concentration | Chemical name | Producers | Recommended field dose |
|---|---|---|---|---|---|
| 1. | Fluchloralin | Basalin 50 E.C. | N-2(2-chloroethyl)-2,6-dinitro-N-propyl-4-(trifluoromethyl) aniline | BASF India Ltd. | 700 g ai/ha |
| 2. | Bentazon | Basagran 50 E.C. | 3-isopropyl-2-1-3-benzothiadiazin-4-one 2,2-dioxide | -do- | 1.5 kg ai/ha |
| 3. | Benthiocarb (Thiobencarb) | Saturn 50 E.C. | S-(4-Chlorobenzyl)N,N-diethyl-thiol-carbamate | Kumiai Chemical Industry Co. Ltd.Tokyo, Japan (Marketed by Pesticides India, Udaipur) | 1.75 kg ai/ha |
| 4. | Propanil | Stam F.34 E.C. | N-(3,4-dichlorophenyl) propionamide | Mon Santo Chemical Co. | 1.75 kg ai/ha |
| 5. | Butachlor | Machete 50 E.C. | N-(butoxymethyl)-L-Chloro-2,6-diethylacetanilide | Mon Santo India Limited | 2.00 kg ai/ha |
| 6. | Pendimethalin | Stomp 30 E.C. | N-(1-ethylpropyl-2,6-dinitro-3,4-Xylidine | Cynamide India Limited | 1.25 kg ai/ha |
| 7. | Nitrofen | Tok E.25 E.C. | 2,4-dichlorophenyl 4-nitrophenyl ether | Rohm & Mass, USA (Marketed by Indofil Chemicals) | 1.25 kg ai/ha |
| 8. | 2,4-D Sodium salt | Fernoxone (W.P.) 80% | 2,4-dichlorophenoxyacetic acid | Agromore Ltd., India. | 1.00 kg/ha in 400 lit (2500 ppm) |

All the herbicides were first tested in amended media which had 125, 250, 500, 1000 and 2000 ppm active ingredient concentration. The highest concentration tested of each herbicide was below the field dose recommended for the control of weeds. Those herbicides which showed complete inhibition of radial growth of the fungus in culture at the lowest concentration i.e., 125 ppm were again tested at lower concentration of 50 and 25 ppm.

Stock solutions of appropriate concentrations of all the above herbicides were prepared by adding the appropriate quantity of herbicides to the required quantity of sterile distilled water in 250 ml conical flask, serially diluted and immediately used.

The required concentration of these herbicide amended media were prepared by adding appropriate quantity of stock solutions to 50 ml of sterilized PDA prepared in 250 ml conical flask by autoclaving at 1.02 $kg/cm^2$ for 20 to 30 minutes and cooled to 45°C. PDA without herbicide served as control. Fifteen ml of non amended (control) or amended PDA was poured aseptically into a 9 cm sterile petri dish. For each treatment three replications were maintained. After solidification of the media a 5 mm mycelial disc cut out from three day old actively growing culture of this fungus in PDA was placed at the centre of each test plate and incubated under laboratory conditions (28±2°C). The mean diameter of radial growth of mycelium of all the test plates were

recorded from 48 hours after inoculation, periodically at 2 days, 3 days, 7 days and 14 days interval. The test plates were incubated for one month; the growth pattern, colour of mycelium in culture, mycelial texture, hyphal characters etc. of all the treatments were observed and recorded.

b. Effect of herbicides on the formation and viability of sclerotia of Rhizoctonia solani.

(i) Number and size of sclerotia formed

The test plates were incubated for one month and observed under microscope for perfect state formation or sporulation of the mycelium of the various plates amended with the different herbicides. The formation and pattern of formation of sclerotia in the various treatments were recorded fifteen days after inoculation in the amended medium.

The number of sclerotia in those treatments, in which there was sclerotial formation, was counted in each test plates. The size of sclerotia in each treatment was estimated by measuring the diameter of ten sclerotia using a micrometer from each test plate and the average size of sclerotia worked out and compared with that of control.

(ii) Viability of sclerotia

The sclerotia formed in culture plates under those treatments were tested for their ability to germinate. Ten sclerotia each were planted in PDA in petri dishes and

incubated under laboratory conditions (28±2°C). The germination was recorded from the third day of incubation and percentage germination worked out and recorded.

(iii) Pathogenicity of sclerotia and mycelium

The pathogenicity of the sclerotia or the mycelium of the respective treatments was tested by artificial inoculation of the sheaths of susceptible rice plant at the tillering stage with the sclerotia, in case they are formed, or with mycelium from treatments with no sclerotial formation, and surrounded with moist cotton. The lesions developed on each plant was scored for intensity of disease development after ten days.

c. Effect of exposure of sclerotia to various concentrations of herbicides on germination.

Different concentrations of all the herbicides, viz., 1000, 2000, and 3000 ppm active ingredient were prepared by adding appropriate quantity of the stock solution of chemical to 10 ml each of sterile distilled water in sterile test tubes. Sclerotia were cultured in PDA in petri dishes and 10 sclerotia of uniform size from 15 day old culture were transferred to each of the test tube, containing the above herbicidal solutions and treated for different periods i.e., 6, 24 and 48 hours. After treatment for the above periods, from each treatment solutions, the sclerotia were removed, washed in sterile distilled water and planted in PDA in

petri dishes and incubated under laboratory conditions. Germination of sclerotia was recorded from the third day and the percentage of germination worked out and recorded.

III. In vivo effects of herbicides on sheath blight of rice.

A. Pot culture experiment

A pot culture experiment was laid out to study the role of sclerotia in initiating sheath blight disease in rice and to study the effect of the various herbicides in the control of sheath blight. The effect of the herbicides on the viability and pathogenicity of sclerotia in soil and the effect of these herbicides on soil microflora also were assessed.

1. Design: 10 x 4 CRD Variety: Thriveni
2. Replication: 4
3. Treatment: 10

The experiment was laid out in pots of size 22 x 26 cm each filled with 12 kg of soil collected from the wetland area. The soil was puddled well and wetland condition was maintained in the pots as far as possible. NPK @ 70:35:35 was applied as basal dressing. On the next day the pots were planted with 20 day old seedlings of variety Thriveni at the rate of three hills at a spacing of 15 x 15 cm.

Treatments

| Sl. No. | Name of herbicide | Dose per hectare (in kg active ingredient/ha) |
|---|---|---|
| 1. | Fluchloralin | 0.7 |
| 2. | 2,4-D. Sodium salt | 1.0 |
| 3. | Bentazon | 1.5 |
| 4. | Benthiocarb | 1.5 |
| 5. | Pendimethalin | 1.0 |
| 6. | ~~Tok~~.E.25 Nitrofen | 1.25 |
| 7. | Propanil | 1.7 |
| 8. | Butachlor | 1.25 |
| 9. | Control | Water spray (No herbicide) |
| 10. | Control | Uninoculated and untreated |

Inoculation of pots with sclerotia of R. solani

Uniform sized sclerotia produced in sand maize medium were harvested. Ten sclerotia each were loosely packed in muslin cloth packets and two packets each were placed two to three cm deep in the puddled soil in the same day of transplanting in between the transplanted hills; in all the pots except in the control and the positions were marked by pegs. This is to facilitate their subsequent removal for examination. In addition to the above, 1 g of sand maize medium containing approximately ten sclerotia were inoculated in each pot and mixed thoroughly with the soil in the top

5 cm layer. Natural wet land field condition with intermittant drying of soil was maintained throughout the experimental period.

Application of herbicides

Spray solutions of each herbicide in field concentration as per treatment were prepared and sprayed in each pot, using a hand sprayer on the sixth day of transplanting. Water in the pots were drained twelve hours before spraying and again irrigated twenty four hours after treatment with the herbicides and waterlogged condition was maintained. The control pots were sprayed with water and identical condition was maintained.

Study of role of sclerotia in soil in initiating sheath blight disease in rice plants

The soil of the pots in all the treatments except those of the control were artificially inoculated with sclerotia produced in the sand maize media. The development of disease in inoculated and uninoculated pots was observed and recorded.

Assessment of viability of sclerotia

Sample of sclerotia buried in the soil in the experimental pot were recovered two weeks after treatment. Five of them were surface sterilised in 0.1 per cent mercuric chloride, washed in three changes of sterile distilled water, planted in Peptone Dextrose Rose Bengal Streptomycin Agar medium; incubated under laboratory conditions, and germination

was recorded.

Five of the sclerotia recovered from the pots as stated above were used for inoculation on the sheath of susceptible paddy plant at the tillering stage and covered with moist cotton and incubated under field condition. The development of disease was observed and recorded one week after inoculation. The intensity of development of disease was recorded by scoring the lesion developments as described under the field experiment, two weeks after inoculation.

Incidence of sheath blight disease at the tillering stage of the crop

Percentage of infected tillers:- The percentage of infected tillers in each pot was estimated by counting the total tillers and infected tillers in each pot in all the ten treatments.

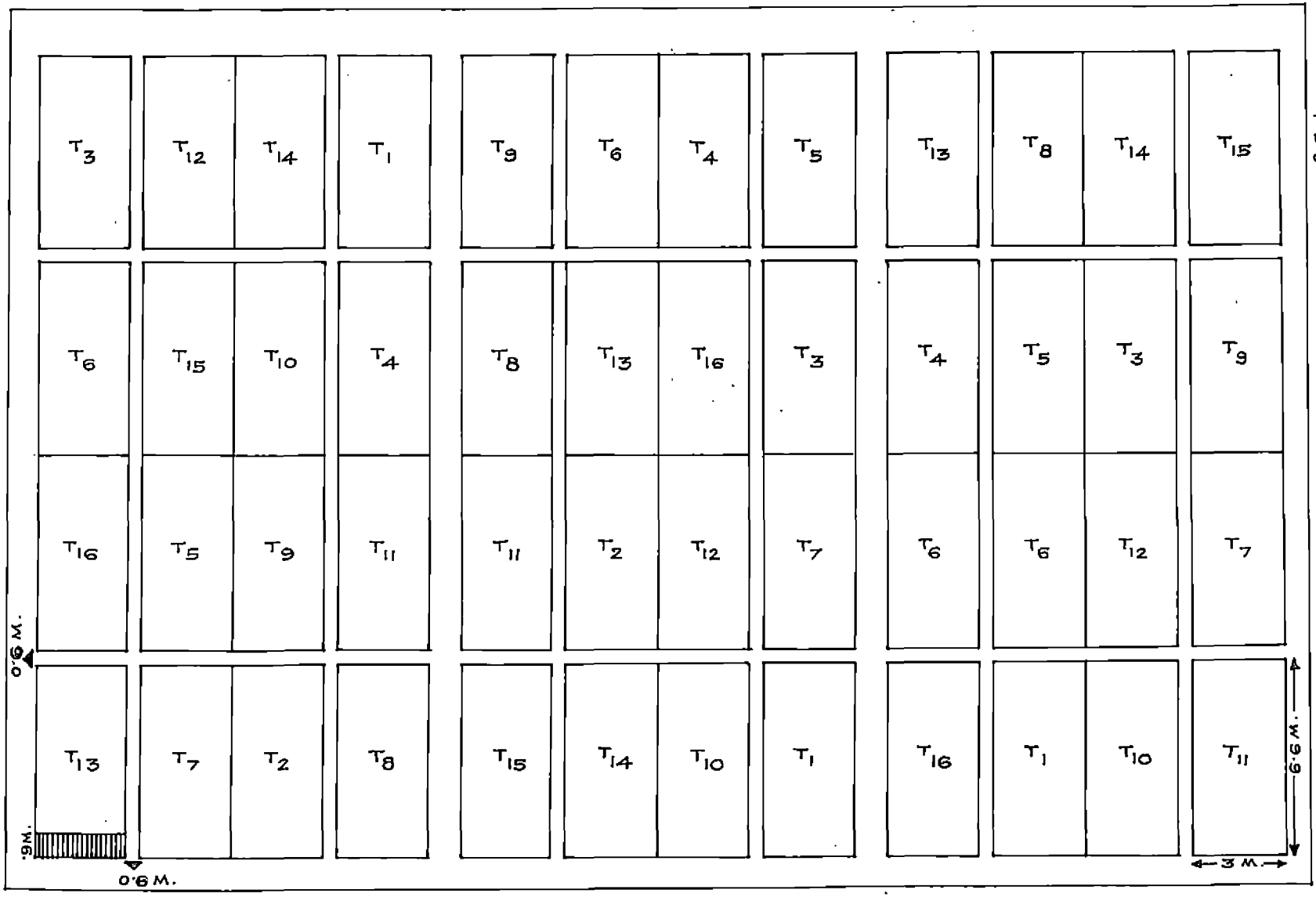
Intensity of sheath blight disease

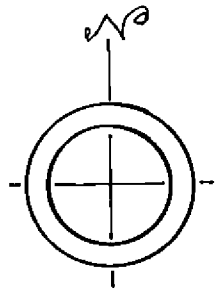
Intensity of incidence of disease was also estimated from each pot by scoring the disease lesions as per the method described under the field experiment and recorded.

B. Field trials

A field trial was conducted to study the effect of different doses of few of the common herbicides on the control of sheath blight and control of weeds. The experiment was laid out in the wet land area of the College of Agriculture, Vellayani during the second crop season of 1982. The

FIG. LAY OUT PLAN - RANDOMISED BLOCK DESIGN.



TREATMENTS - 16
REPLICATION - 3
GROSS PLOT SIZE - 6·6 M. X 3 M.

| TREATMENTS | NAME OF CHEMICAL | a.i kg/ha |
|---|---|---|
| $T_1$ | NITROFEN (TOK-E-25) | 1·25 |
| $T_2$ | " | 1·50 |
| $T_3$ | " | 1·75 |
| $T_4$ | BENTAZON | 1·25 |
| $T_5$ | " | 1·50 |
| $T_6$ | " | 1·75 |
| $T_7$ | BENTHIOCARB | 1·50 |
| $T_8$ | " | 1·75 |
| $T_9$ | " | 2·00 |
| $T_{10}$ | PENDIMETHALIN | 1·00 |
| $T_{11}$ | " | 1·25 |
| $T_{12}$ | " | 1·50 |
| $T_{13}$ | FLUCHLORALIN | 0·700 |
| $T_{14}$ | HINOSAN | 0·600 |
| $T_{15}$ | HAND WEEDING | |
| $T_{16}$ | UNWEEDED CONTROL | |

WEED OBSERVATION AREA.

Details of experiment are as follows:-

| | | | |
|---|---|---|---|
| Lay out: | 16 x 3 RBD | Variety: | Thrivani |
| Replication: | 3 | Date of sowing: | 20-10-1982 |
| Treatments: | 16 | Date of transplanting: | 9-11-1982 |
| Gross plot size: | | 6.6 m x 3 m | |
| Net plot size: | | 5.4 m x 2.6 m | |
| Spacing: | | 15 cm x 10 cm doubles (44 x 30 hills) | |

| Sl. No. | Treatments | Dose (kg/ha) | Quantity of herbicide used for 1 litre of spray liquid/ plot (in ml) |
|---|---|---|---|
| 1. | Nitrofen (Tok E.25) | 1.25 | 10 |
| 2. | " | 1.50 | 12 |
| 3. | " | 1.75 | 14 |
| 4. | Bentazon 50 EC | 1.25 | 5 |
| 5. | " | 1.50 | 6 |
| 6. | " | 1.75 | 7 |
| 7. | Benthiocarb | 1.50 | 6 |
| 8. | " | 1.75 | 7 |
| 9. | " | 2.00 | 8 |
| 10. | Pendimethalin | 1.00 | 6.7 |
| 11. | " | 1.25 | 8.3 |
| 12. | " | 1.50 | 10.0 |

| | | | |
|---|---|---|---|
| 13. | Fluchloralin | 0.7 | 2.9 |
| 14. | Hinosan at tillering and boot leaf stage | 0.600 | 1.2 |
| 15. | Hand weeding | 20th and 40th day of transplanting | |
| 16. | Unweeded control | | |

The seedlings were raised in the nursery following the recommendations of the Package of Practices (Anon., 1981).

Experimental field

Twenty five cents (1000 sq.m) of the experimental area was well prepared by ploughing and digging. Farm yard manure at the rate of 5 t/ha was incorporated uniformly in the field at the time of ploughing. The experiment was laid out in this field in Randomised Block Design with sixteen treatments and three replications as given in the layout plan (Fig. I).

NPK @ 70:35:35 was given in the form of urea, superphosphate and muriate of potash. Half the dose of N and full dose of P and K weighed out separately for each plot and was given as basal dose at the time of final preparation of plots. Twenty day old seedlings were transplanted in 44 rows with 30 hills in each row.

Application of herbicides in the field

The plots were drained completely 24 hours before application of the herbicides. The different herbicides

as per treatments were applied to the respective plots on the sixth day of transplanting at the rate of 1 litre of spray liquid per plot using a knapsack sprayer. Quantity of herbicide used for mixing in 1 litre of water was as given earlier under the treatments.

Water was let in after twenty four hours of spraying of the herbicides.

Estimation of weed growth

Weed growth in each plot was estimated by taking weed counts from 60 x 50 cm area starting from one end of the plot, excluding two border rows on 20th, 40th and 60th day after transplanting and also before harvest. The weeds were pulled out and the number of plants belonging to Graminae, Cyperaceae and broad leaved weeds were counted separately and recorded. The total dry weight of weeds from each plot also recorded. The mean weed growth in each treatment was compared with that of the control plot.

Hand weeding:- Hand weeding was done in one treatment ($T_{15}$) on 20th and 40th day of transplanting after taking the weed count.

Fungicidal treatment:- In one treatment, T.No. 14 the fungicide Hinosan (O-ethyl S,S,diphenyl-dithiophosphate) was sprayed at tillering time and boot leaf stage @ 600 ml/ha in 500 l of water using knapsack sprayer (High volume).

Top dressing:- Half the dose of nitrogen was given as top dressing at the panicle initiation stage (50 days of age) in the form of urea.

An insecticidal prophylactic spray with carbaryl 50 per cent at the rate of 2.5 kg in 500 l of water/ha was given at the panicle initiation stage and at the boot leaf stage.

The date of flowering of the crop was recorded.

Assessment of sheath blight incidence:

Observations on incidence and intensity of sheath blight disease was recorded 16 days before harvest.

Disease incidence was estimated by observing twenty hills from the third hill on the seventh, eleventh, fifteenth and nineteenth row in each plot and percentage of infected hills calculated, recorded and statistically analysed.

The intensity of disease was assessed by scoring all the infected hills from the selected eighty hills, based on the standard evaluation system for rice disease (Anon., 1976 a).

Description

Grade

1. Lesions limited to lower 25 per cent of leaf sheath

3. Lesions present on lower 50 per cent of the leaf sheath

5. Lesions present on more than 50 per cent of leaf sheath

7. Lesions present on more than 75 per cent of leaf sheaths, severe infection on lower leaves and slight infection on upper leaves (Flag and second leaf)

9. Lesions reaching top of tillers, severe infection on all leaves.

Disease index was calculated based on the following formula and statistically analysed.

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

Observations at the time of harvest

Total number of productive tillers, number of white ears (stem borer infestation) and sheath rot infected tillers were also assessed at the time of harvest from half a square metre area (40 hills).

Yield estimation

An area of 0.9 m x 3 m in each plot on one side was measured separately for observation of weed growth. Except this area the plots were harvested on 30-1-1983 (102 days duration). Two rows on all the other three sides were also left out as border effect, the net area being 5.4 m x 2.6 m; harvested and threshed. Grain and straw yield per hectare were estimated separately and the data statistically analysed. The average grain and straw yield of each treatment was worked out and recorded.

IV. a. (1) Estimation of soil microflora before spraying in the pot culture.

Soil samples were collected randomly from each pot one day after transplanting thoroughly mixed and nine samples each of ten g dry weight equivalent was used for estimation of soil microflora. The total count of fungi, bacteria and actinomycetes were estimated following the procedure of serial dilution plate technique (Johnson and Curl, 1972).

Separate media were used for estimation of fungi, bacteria and actinomycetes. They were, Martins ~~Peptone~~ Dextrose Agar ~~with~~ Rose bengal ~~and~~ streptomycin agar, Soil Extract Agar Medium and Kuster's medium respectively for fungi, bacteria and actinomycetes. From the soil dilutions prepared $10^{-3}$ dilutions were used for Fungi, and $10^{-5}$ dilutions for bacteria and actinomycetes.

One ml of the dilution was transferred to sterile petri dish using a sterile one ml pipette. The plate was rotated gently so as to get a uniform spread of the dilution in the plate. The medium melted and cooled to about 45°C and 15 ml poured into the petri dish and rotated to get an even spread of the inoculum in the medium. The dilutions were plated in triplicate for each soil sample for each group of microorganism and incubated at room temperature. Counts of fungal colonies were taken on the fourth day and for bacteria and actinomycetes after seven days and fourteen days respectively. The number of colonies were counted per ml

of $10^{-3}$ dilution for fungi and $10^{-5}$ dilution for bacteria and actinomycetes. Their population was expressed per one gram dry weight equivalent of soil.

ii Estimation of soil microflora one week after spraying

Soil samples were collected randomly from each pot mixed well and representative samples were drawn from each treatment seven days after spraying and estimation of soil microflora was done from soil samples and expressed as number of colonies per gram of soil on dry weight basis. The total count of fungi, bacteria and actinomycetes were recorded from each treatment and compared with that of control. The method of estimation has been described elsewhere.

b. i) Estimation of soil microflora before spraying of herbicides in the field trial.

Soil samples upto a depth of 7.5 cm were collected randomly from each replication thoroughly mixed and representative samples from composite soils were drawn to estimate the soil microflora at the rate of two samples from each replication. The total count of fungi, bacteria and actinomycetes were estimated following the procedure of serial dilution plate technique (Johnson and Curl, 1972). The number of colonies were counted per ml of $10^{-3}$ dilution for fungi and $10^{-5}$ dilution for bacteria and actinomycetes.

ii) Estimation of soil microflora thirty days after application of herbicides.

Random samples of soil were collected from different parts in each plot upto a depth of 7.5 cm mixed thoroughly and representative samples taken from all the treatments from two replications and estimated the fungal, bacterial and actinomycetes population, data tabulated and statistically analysed.

V. Studies on microorganisms antagonistic to R. solani.

Isolation of microorganisms were made from the sclerotia recovered from soil and from the soil dilution plates used for estimation of soil microflora.

The fungi were tested for their antagonism towards R. solani by the method adopted by Mathur and Sarbhoy (1978). A single sclerotium of R. solani was kept in the centre of each sterile petri dish containing 15 ml of sterilised PDA. Five mm mycelial discs cut from fifteen day old culture of the test fungus were placed at four different places in the petri dish. Four replications were maintained for each treatment. Petri plates inoculated with R. solani alone served as control and incubated under laboratory conditions. Growth of R. solani was recorded five days after inoculation. Percentage inhibition was calculated using the formula

$$\text{Inhibition} = 100 \times \frac{(\text{Growth in control} - \text{Growth in treated plates})}{}$$

The bacterial colonies obtained from the petri plates inoculated with sclerotia recovered from soil were isolated and purified. They were tested to determine their antagonism to R. solani by culturing the bacteria and R. solani in a single petri dish and observing for their antagonistic effect (Anon., 1978).

# RESULTS

# RESULTS

## I. (i). Isolation of the pathogen

The fungus Rhizoctonia solani (Kuhn) for the study was isolated from the sheaths of naturally infected rice plants collected from the rice fields attached to the Instructional Farm of the College of Agriculture, Vellayani and purified. The pathogenicity of the isolate was confirmed following Koch's postulates.

## (ii) Morphology of the pathogen

The morphological characters of the pathogen was studied in detail. The salient features are summarised in Table 2.

Table 2. Morphological features of Rhizoctonia solani isolated from rice.

| Sl. No. | Characters | Range | Average |
|---|---|---|---|
| 1. | Hyphal thickness | 6.69 to 10.83 µm | 8.76 µm |
| 2. | Number of sclerotia formed | 78 to 185 | 131* |
| 3. | Size of Macrosclerotia | | |
| | Length | 856 to 2568 µm | 1844.6 µm |
| | Breadth | 684.8 to 2396 µm | 1514.9 µm |

*Number of sclerotia formed in petri dishes of 90 mm diameter, 16 days after inoculation.

## II. In vitro effects of Herbicides on Rhizoctonia solani

The results of the in vitro studies on the effects of the various herbicides in different concentrations on Rhizoctonia solani are given in Table 3 to 6.

The herbicides used were Fluchloralin, Bentazon, Benthiocarb, Propanil, Butachlor, Pendimethalin, Nitrofen, and 2,4-D Sodium salt as listed out under Materials and Methods (Table No.1).

### (a) Effects on radial growth

The measurements of radial growth of R. solani taken 60 hours and 120 hours after inoculation of media containing different concentrations of the herbicide are given in Table 3.

The results of statistical analysis of data after $\sqrt{x+1}$ transformations for 60 and 120 hours are also presented in Table 4 and 5 respectively.

The different herbicides behaved differently in inhibiting the radial growth at 60 hours (Fig.2) and 120 hours (Fig.3) after inoculation.

There was significant effect in arresting the radial growth of the fungus by the different herbicidal applications. Propanil was found to be the most effective in checking the growth. In the case of Butachlor the radial growth was significantly low in the initial stages, but on prolonged exposure the fungus could make satisfactory growth; especially in lower concentrations. On the overall effect, Propanil was

FIG. EFFECT OF HERBICIDES ON RADIAL GROWTH OF *R. Solani*
60 HOURS AFTER INOCULATION (MEAN VALUE IN mm.)
AT CONCENTRATIONS 25, 50, 125, 250, 500, 1000, 2000 ppm.

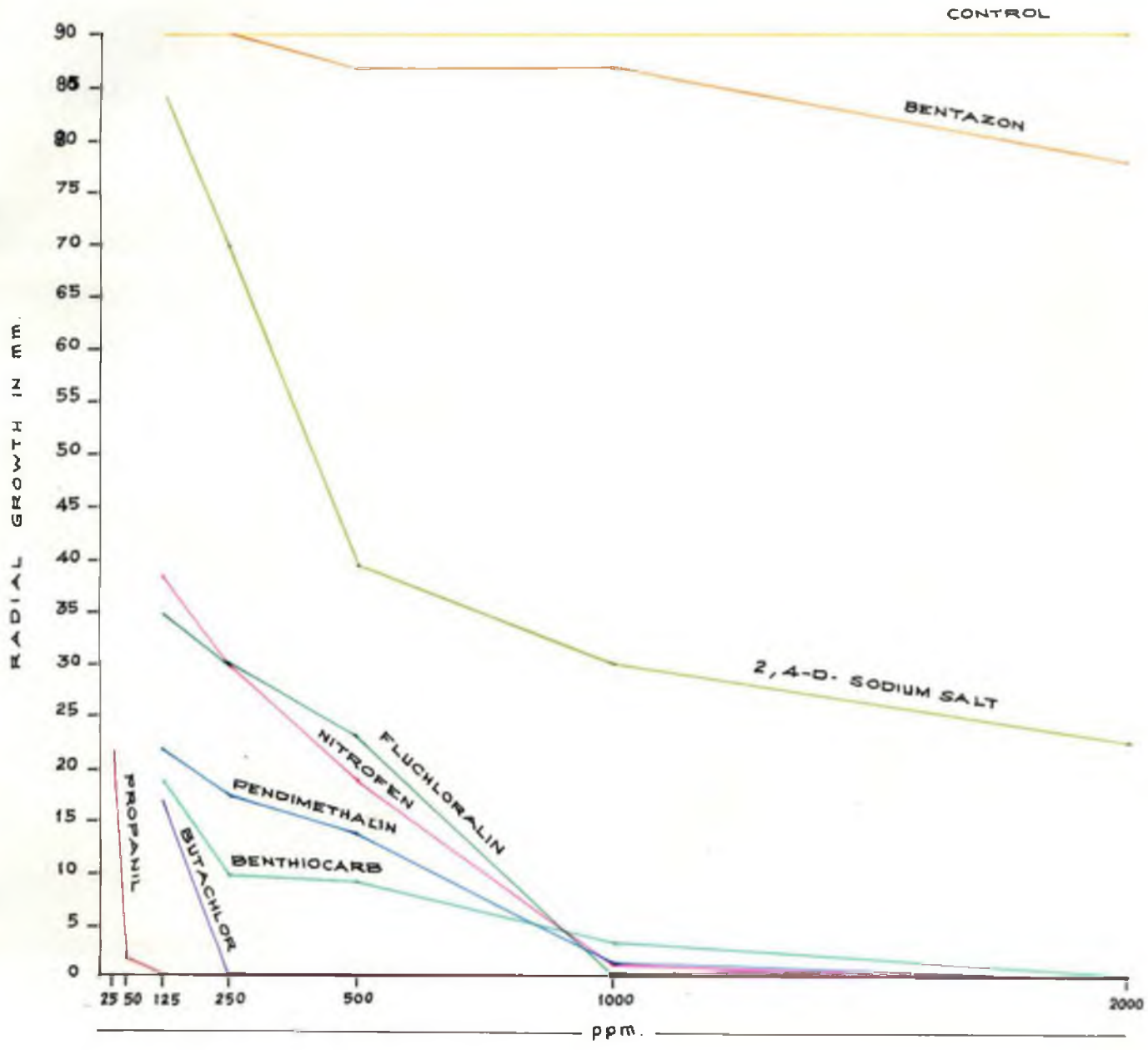


Table 3. Effect of herbicides on radial growth of Rhizoctonia solani 60 and 120 hours after inoculation (Mean value in mm)

| Sl. No. | Herbicides | Concentration in ppm | | | | | | | | | | | | | | Control |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 25 | | 50 | | 125 | | 250 | | 500 | | 1000 | | 2000 | | |
| | | 60 | 120 | 60 | 120 | 60 | 120 | 60 | 120 | 60 | 120 | 60 | 120 | 60 | 120 | 60 |
| 1. | Fluchloralin | | | | | 34.6 | 90.0 | 29.6 | 90.0 | 23.6 | 90.0 | 00.0 | 61.0 | 00.0 | 53.0 | 90 |
| 2. | Bentazon | | | | | 90.0 | 90.0 | 90.0 | 90.0 | 86.6 | 90.0 | 86.6 | 90.0 | 77.7 | 90.0 | 90 |
| 3. | Benthiocarb | | | | | 19.3 | 74.0 | 9.6 | 37.3 | 3.3 | 12.6 | 3.3 | 9.0 | 0.0 | 0.0 | 90 |
| 4. | Propanil | 21.6 | 78.3 | 1.6 | 43.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 90 |
| 5. | Butachlor | | | | | 17.3 | 54.3 | 0.0 | 50.3 | 0.0 | 44.3 | 0.0 | 11.6 | 0.0 | 0.0 | 90 |
| 6. | Pendimethalin | | | | | 22.3 | 90.0 | 18.3 | 90.0 | 14.0 | 76.6 | 0.6 | 16.0 | 0.0 | 0.0 | 90 |
| 7. | Nitrofen | | | | | 38.6 | 90.0 | 29.6 | 64.0 | 19.0 | 40.3 | 0.6 | 2.0 | 0.0 | 0.0 | 90 |
| 8. | 2,4-D Sodium salt | | | | | 84.3 | 90.0 | 69.6 | 90.0 | 39.3 | 90.0 | 30.3 | 90.0 | 23.3 | 90.0 | 90 |

FIG. EFFECT OF HERBICIDES AT DIFFERENT CONCENTRATIONS ON RADIAL GROWTH OF *R. solani* 120 HOURS AFTER INOCULATION (MEAN VALUE IN MM.)

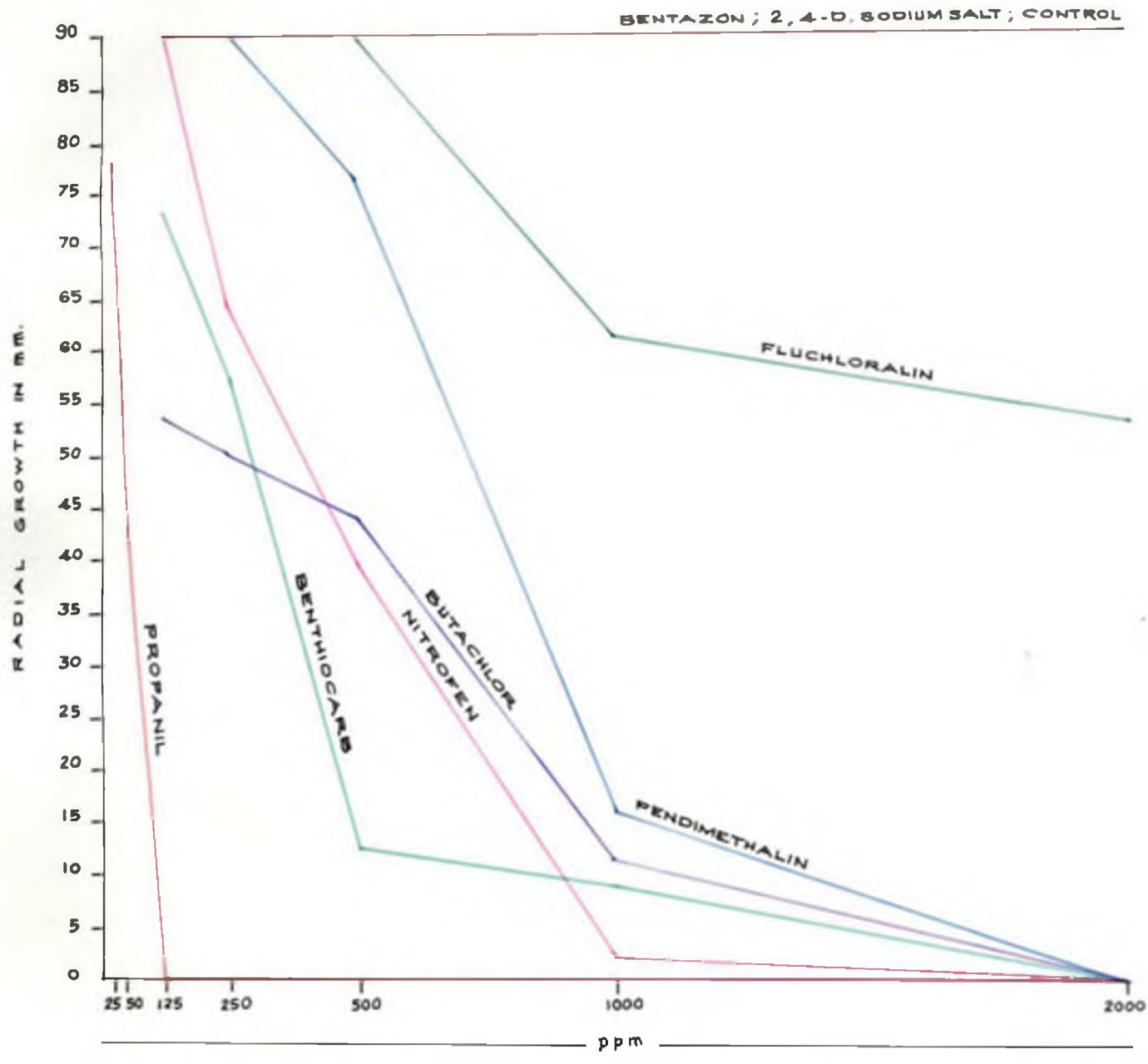


Table 4. Effect of herbicides on radial growth of Rhizoctonia solani (60 hours) after $\sqrt{x+1}$ transformation (Mean value)

| Sl. No. | Herbicides | Concentration in ppm | | | | | | | | Mean for herbicide | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 25 | 50 | 125 | 250 | 500 | 1000 | 2000 | Control | | |
| 1. | Fluchloralin | - | - | 5.960 | 5.537 | 4.966 | 1.000 | 1.000 | 9.539 | 4.668 | 5 |
| 2. | Bentazon | - | - | 9.539 | 9.539 | 9.362 | 9.326 | 8.865 | - | 9.361 | 8 |
| 3. | Benthiocarb | - | - | 4.503 | 3.260 | 3.210 | 2.060 | 1.000 | - | 3.928 | 3 |
| 4. | Propanil | 4.752 | 1.626 | 1.000 | 1.000 | 1.000 | - | - | - | 3.152 | 2 |
| 5. | Butachlor | - | - | 4.280 | 1.000 | 1.000 | 1.000 | 1.000 | - | 2.962 | 1 |
| 6. | Pendimethalin | - | - | 4.823 | 4.390 | 3.854 | 1.276 | 1.000 | - | 4.147 | 4 |
| 7. | Nitrofen | - | - | 6.297 | 5.537 | 4.468 | 1.275 | 1.000 | - | 4.686 | 6 |
| 8. | 2,4-D Sodium salt | - | - | 9.236 | 8.405 | 6.338 | 5.570 | 4.932 | - | 7.338 | 7 |

C.D. for comparison between herbicides = 0.13

" " levels within herbicide = 0.33

Table 5. Radial growth of Rhizoctonia solani (120 hours) after $\sqrt{x+1}$ transformation (Mean value)

| Sl. No. | Herbicides | 25 | 50 | 125 | 250 | 500 | 1000 | 2000 | Mean for herbicides | Rank | Control |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Fluchloralin | - | - | 9.53 | 9.53 | 9.53 | 7.79 | 7.34 | 8.87 | 6 | 9.53 |
| 2. | Bentazon | - | - | 9.53 | 9.53 | 9.53 | 9.53 | 9.53 | 9.53 | 7 | 9.53 |
| 3. | Benthiocarb | - | - | 8.63 | 7.62 | 3.65 | 3.08 | 1.00 | 5.58 | 2 | 9.53 |
| 4. | Propanil | 8.42 | 6.32 | 1.00 | 1.00 | 1.00 | - | - | 4.67 | 1 | 9.53 |
| 5. | Butachlor | - | - | 7.43 | 7.16 | 6.73 | 3.54 | 1.00 | 5.89 | 3 | 9.53 |
| 6. | Pendimethalin | - | - | 9.53 | 9.53 | 8.79 | 3.51 | 1.00 | 7.08 | 5 | 9.53 |
| 7. | Nitrofen | - | - | 9.53 | 8.05 | 6.42 | 1.73 | 1.00 | 6.04 | 4 | 9.53 |
| 8. | 2,4-D Sodium salt | - | - | 9.53 | 9.53 | 9.53 | 9.53 | 9.53 | 9.53 | 8 | 9.53 |

C.D. for comparison between herbicides = 0.81

" " levels within herbicide = 1.90

Plate No.1.

Effect of different concentrations of Fluchloralin on radial growth of R. solani 60 hours after inoculation.

Concentrations in ppm

1. 250

2. 500

3. 1000

4. 2000

C. Control

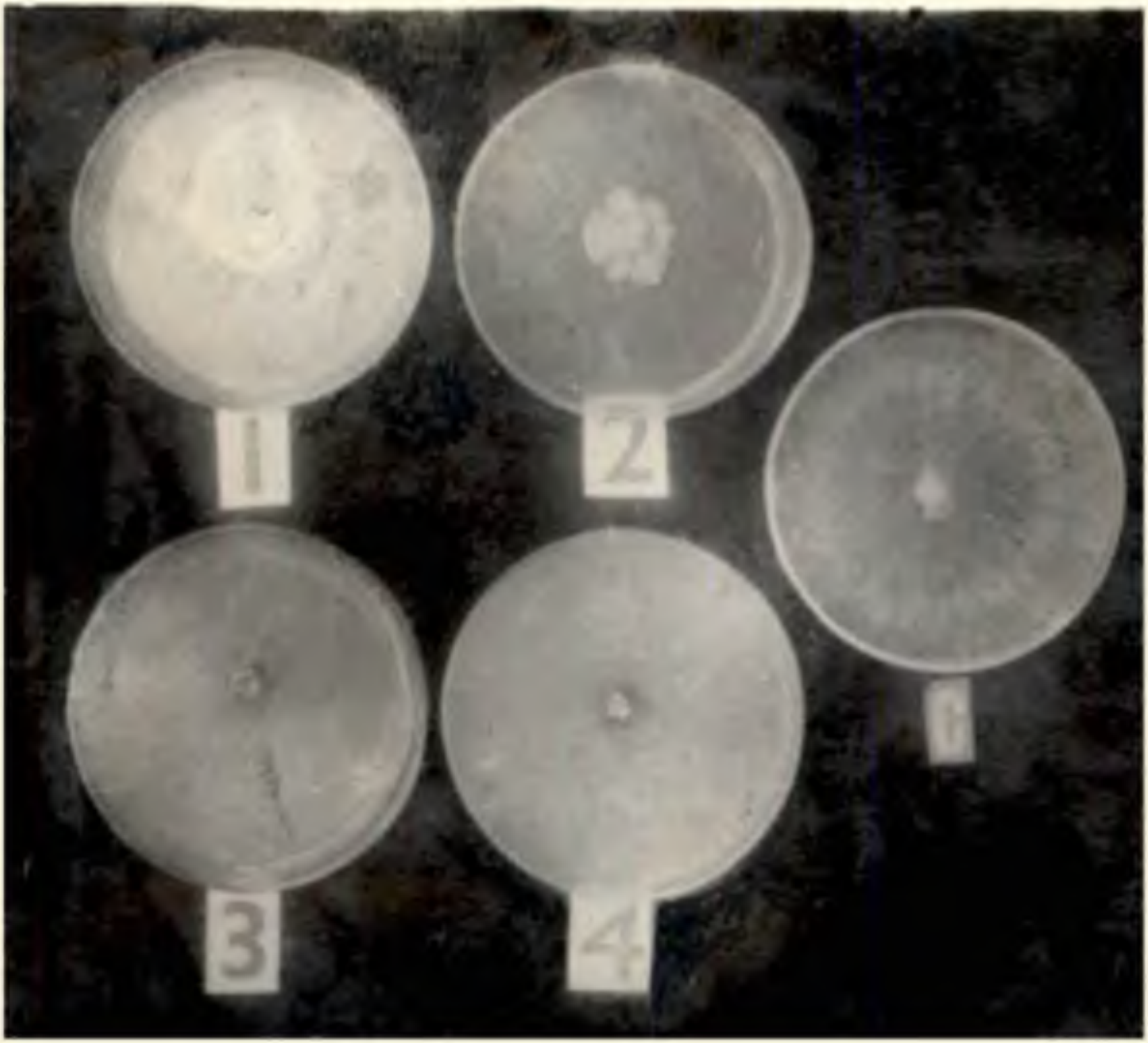

1
2
3
4

Plate No.2.

Effect of different concentrations of Bentazon on radial growth of R. solani after 60 hours of inoculation.

Concentrations in ppm

1. 250
2. 500
3. 1000
4. 2000

C. Control


1
2
3
4

followed by Benthiocarb; Butachlor and Nitrofen on prolonged exposure in inhibiting the radial growth. Bentazon and 2,4-D Sodium salt were ineffective in inhibiting the radial growth of the test fungus. The growth characters of the fungus was significantly different in the various herbicides tested which are briefly summarised as follows:-

1. Fluchloralin

Initially there was complete inhibition of growth at 1000 ppm and 2000 ppm. There was significant reduction of radial growth at lower concentrations compared to control. But the organism could overcome the inhibitory effect of the herbicides and grow when incubated for longer periods, in all the concentrations tested. After 120 hours of incubation except at 1000 ppm and 2000 ppm concentrations, the mycelial growth completely covered the 90 mm petri dish. There was aerial growth of brown discoloured mycelium reaching the lids with clear concentric zonations at the lower concentrations of this herbicide used viz., 125 and 250 ppm. At higher concentrations also increased radial growth was noticed, but the brown discoloured mycelium was thin and growing on the surface of the medium only.

2. Bentazon

No significant reduction of radial growth was noticed in any of the concentrations tested. In the higher concentrations initially there was some retardation in growth. The

Plate No. 3.

Effect of different concentrations of Benthiocarb on radial growth of R. solani 60 hours after inoculation.

Concentrations in ppm

1. 125
2. 250
3. 500
4. 1000
5. 2000

C. Control

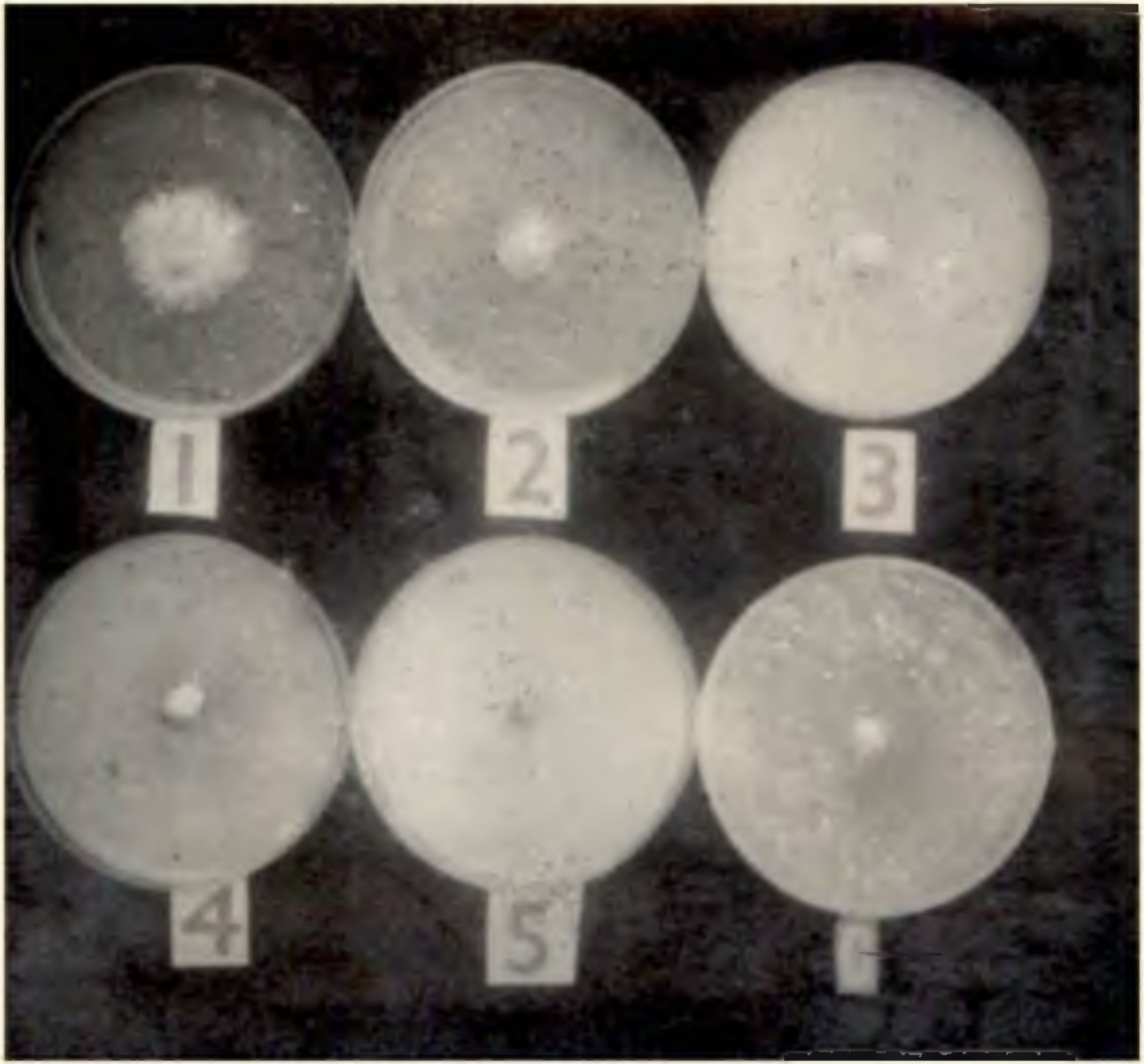

1
2
3
4
5

Plate No.4.

Effect of different concentrations of Propanil on radial growth of *R. solani* 60 hours after inoculation.

Concentrations in ppm

1. 125
2. 250
3. 500
4. 1000
5. 2000

C. Control


1
2
3
4
5
6

fluffy aerial mycelial growth reached the lids and covered the dish completely irrespective of the concentrations.

3. Benthiocarb

This herbicide had significant inhibitory effect on the radial growth of the fungus even at the lowest concentration of 125 ppm. The increase in radial growth after prolonged period of incubation i.e., 120 hours was also less as compared to other treatments particularly in the higher concentrations. The petri dishes were subjected to prolonged observations and no growth was noticed at 2000 ppm even after one month. The mycelial growth observed also was scanty and white in colour.

4. Propanil

There was complete inhibition of mycelial growth in all the concentrations tested upto the lowest viz., 125 ppm. Hence, still lower concentrations also were tested. There was only very slight mycelial growth at 50 ppm and there was reduction of radial growth at 25 ppm, compared to control after 60 hours of incubation. At 120 hours of incubation at the lower concentration used, there was radial growth, but the mycelial development was very scanty.

5. Butachlor

Reduction in radial growth in all the concentrations tested was noticed. Very scanty mycelial development was observed at 120 hours of incubation, though the radial growth was increased.

Plate No.5.

Effect of different concentrations of Butachlor on radial growth of R. solani - 60 hours after inoculation

Concentrations in ppm

1. 125
2. 250
3. 500
4. 1000
5. 2000

C. Control

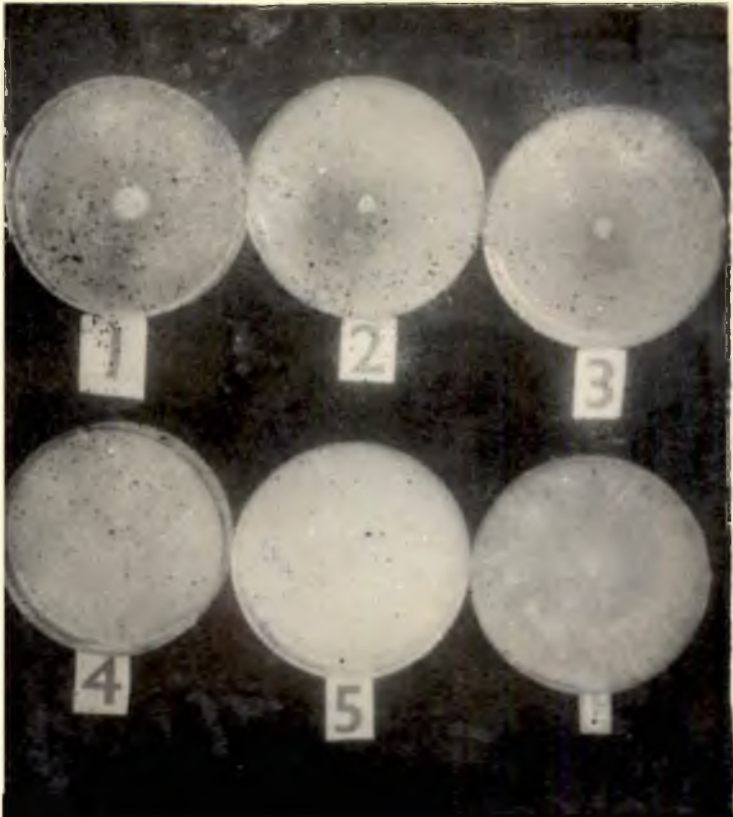

1
2
3
4
5

Plate No.6.

Effect of different concentrations of Pendimethalin on radial growth of R. solani - 60 hours after inoculation.

Concentrations in ppm

1. 125
2. 250
3. 500
4. 1000
5. 2000

C. Control

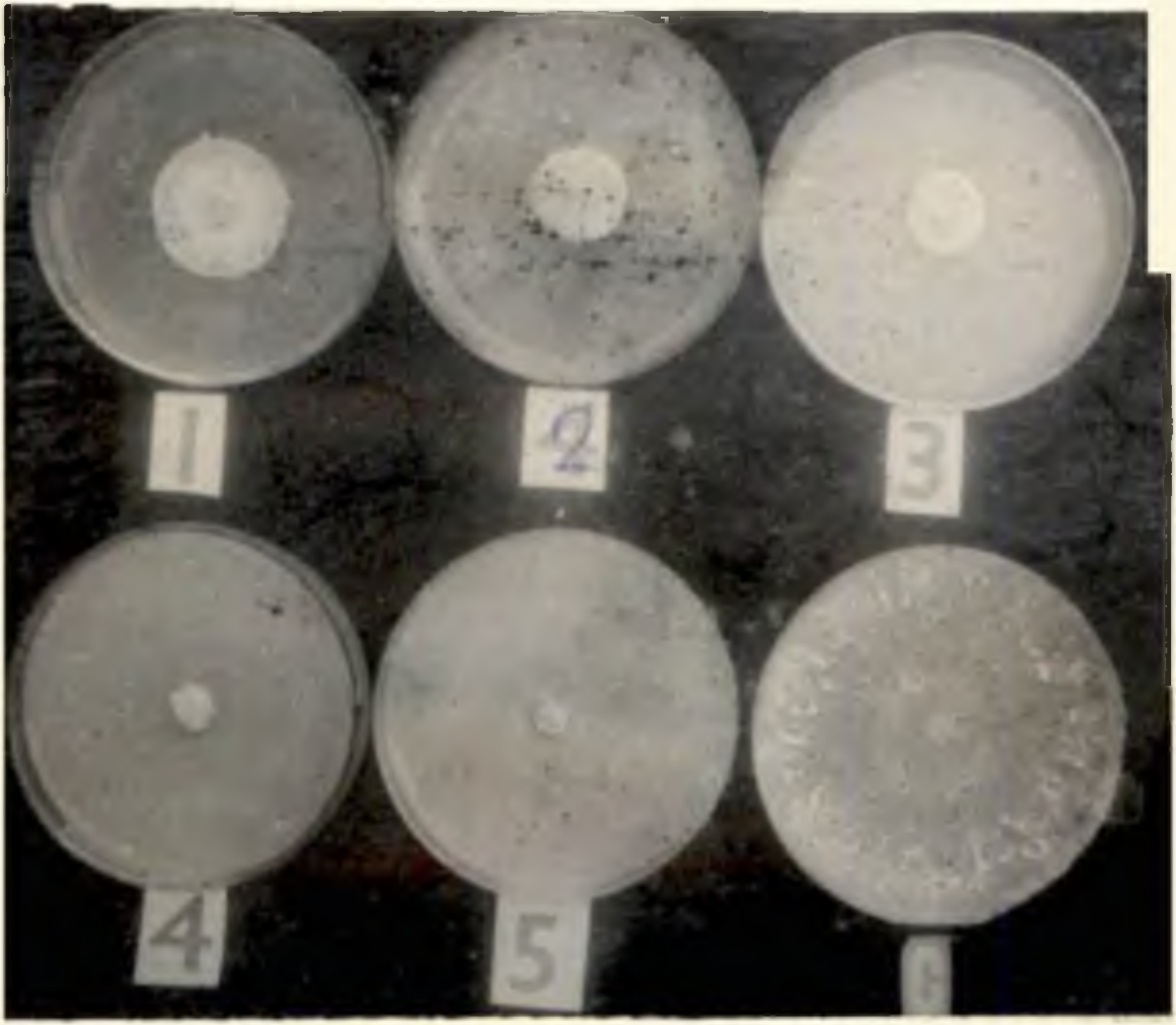
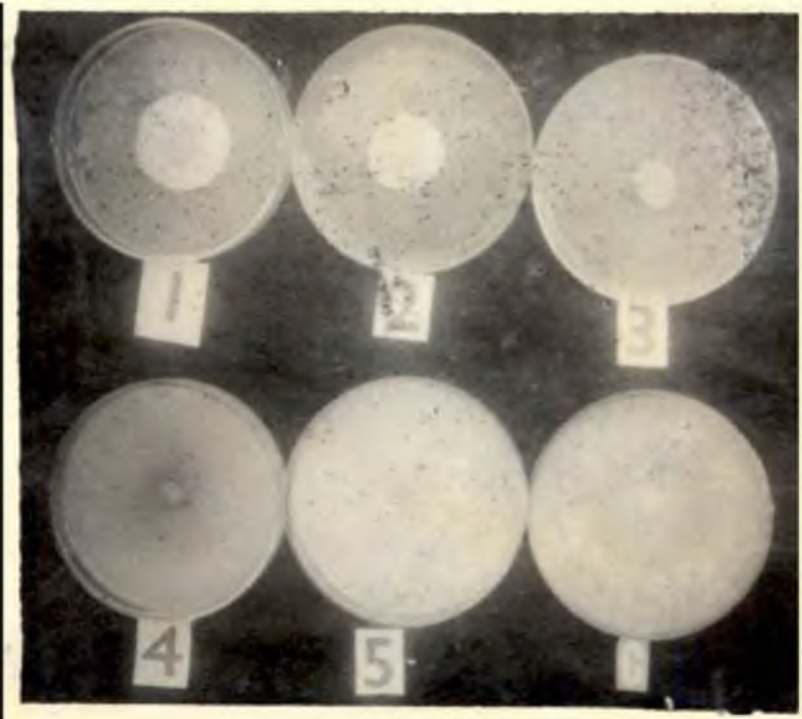

1
2
3
4
5

Plate No.7.

Effect of different concentrations of Nitrofen on radial growth of R. solani - 60 hours after inoculation.

Concentrations in ppm

1. 125
2. 250
3. 500
4. 1000
5. 2000
C. Control


1
2
3
4
5
6

6. Pendimethalin

As compared to control, there was significant inhibition of radial growth in all the concentrations tested. However, after 120 hours of incubation there was good radial growth at the lower concentrations tested, viz., 125 and 250 ppm. There was no growth at 2000 ppm even after 120 hours of incubation.

7. Nitrofen

This herbicide also showed significant inhibition of radial growth of Rhizoctonia solani in all the concentrations tested. After 120 hours of incubation, there was increase in radial growth except at 2000 ppm, where there was complete lysis of the mycelium.

8. 2,4-D sodium salt

An initial lag growth phase was noticed in all the concentrations tested, with decrease in radial growth with increasing concentrations; as compared to control. But there was a sudden increase in growth more vigorous than control with the formation of large number of white sclerotial primordia in all the concentrations tested; after three days of incubation.

(b) (i) Effect of herbicides on formation and viability of sclerotia by Rhizoctonia solani

(a) Effect of herbicides on number of sclerotia

The effect of the various herbicides in different

concentrations in culture media on the formation of sclerotia was estimated by counting the number of sclerotia formed in each treatment and presented in Table 6.

It can be seen from the table that, Benthiocarb, Butachlor and Nitrofen were equally effective in inhibiting the formation of sclerotia even at a very low concentration of 125 ppm. In the case of Propanil which was tested at 25 and 50 ppm there was poor development of sclerotia at these concentrations also. Bentazon and 2,4-D Sodium salt were ineffective in inhibiting the formation of sclerotia. On the other hand, Bentazon exerted stimulatory effect and enhanced the number of sclerotia formed.

Even in case of herbicides which have not completely inhibited the cformation of sclerotia, the various concentrations exerted varying influences.

1. Fluchloralin

After fifteen days of growth, in the lower concentrations of 125 ppm and 250 ppm few microsclerotia were formed on the aerial mycelial growth. At the higher concentration of 500 ppm, a ring of sclerotial mass in the form of black encrustations was noted, and no sclerotial formation was observed in the still higher concentrations.

2. Bentazon

After three days of incubation, large number of white

Table 6. Effect of herbicides on formation of sclerotia by Rhizoctonia solani (Mean number of sclerotia per 90 mm petri dish) ( $\sqrt{x+1}$ transformed values in paranthesis)

| Sl. No. | Herbicide | Concentration in ppm | | | | | | | Mean for herbicide | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 25 | 50 | 125 | 250 | 500 | 1000 | 2000 | | |
| 1. | Fluchloralin | - | - | 24.6 (5.05) | 22.0 (4.79) | 9.0 (3.11) | 0.0 (1.00) | 0.0 (1.00) | 11.1 (2.993) | 4 |
| 2. | Bentazon | - | - | 52.3 (7.29) | 85.3 (9.20) | 96.3 (9.85) | 123.3 (11.14) | 129.0 (11.39) | 97.24 (9.778) | 7 |
| 3. | Benthiocarb | - | - | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 1 |
| 4. | Propanil | 14.0 (3.78) | 5.0 (2.42) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | - | - | 3.8 (1.814) | 3 |
| 5. | Butachlor | - | - | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 1 |
| 6. | Pendimethalin | - | - | 2.3 (2.02) | 0.3 (1.40) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.52 (1.00) | 2 |
| 7. | Nitrofen | - | - | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 1 |
| 8. | 2,4-D Sodium salt | - | - | 74.0 (8.68) | 76.3 (8.78) | 102.3 (10.12) | 110.0 (10.52) | 79.6 (8.97) | 88.4 (9.411) | 5 |
| 9. | Control | - | - | - | 91.0 (9.56) | - | - | - | 91.0 (9.56) | |

C.D. for comparison between herbicides = 0.71

" " levels within herbicide = 1.60

## Plate No.8.

Effect of different concentrations of 2,4-D Sodium salt on radial growth of *R. solani* - 60 hours after inoculation.

Concentrations in ppm

1. 250
2. 500
3. 1000
4. 2000
C. Control

## Plate No.9.

Effect of 2,4-D on *R. solani* - 15 days after inoculation.

Concentration in ppm

1. 250
2. 500
3. 1000
4. 2000
C. Control


1
2
3
4


1
2
3
4

sclerotial primordia and brown sclerotia were formed. The number of sclerotia formed after fifteen days of incubation are presented in Table 6.

3. Pendimethalin

Only four sclerotia were formed per dish in the lowest concentrations after twenty days of incubation.

4. 2,4-D sodium salt

Three days after inoculation, large number of white sclerotial primordia were noticed, which soon developed into fully formed sclerotia. Even after fifteen days, there were increased growth and continuous formation of white sclerotial primordia.

(i) (b) Effect of herbicides on size of sclerotia

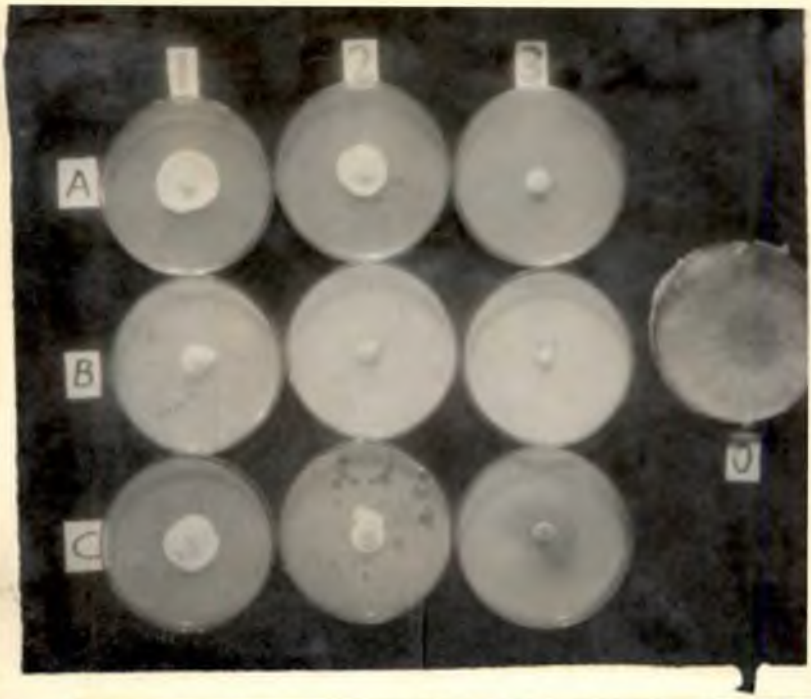
The herbicides exerted influences not only on the number of sclerotial formation, but on the size of the same also. The average size of sclerotia formed in the different treatments are furnished in Table 7.

The differences in size of the sclerotia found in different treatments were significant. Sclerotia were smallest in treatment with Fluchloralin which was significantly lower than those in the control. 2,4-D sodium salt increased the size of sclerotia significantly than all the other herbicides tested. The different concentrations also exerted significant effect on the size of the sclerotia.

Inhibition of radial growth of R. solani by different herbicides

| Plate No.10. | Concentration in ppm | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| A. Fluchloralin | 500 | 750 | 1000 |
| B. Benthiocarb | " | " | " |
| C. Pendimethalin | " | " | " |
| O Control | | | |

| Plate No.11. | Concentration in ppm | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| A. Nitrofen | 500 | 750 | 1000 |
| B. Butachlor | 125 | 250 | 500 |
| D. Propanil | 25 | 50 | 125 |
| C. Control | | | |


A
B
C
D

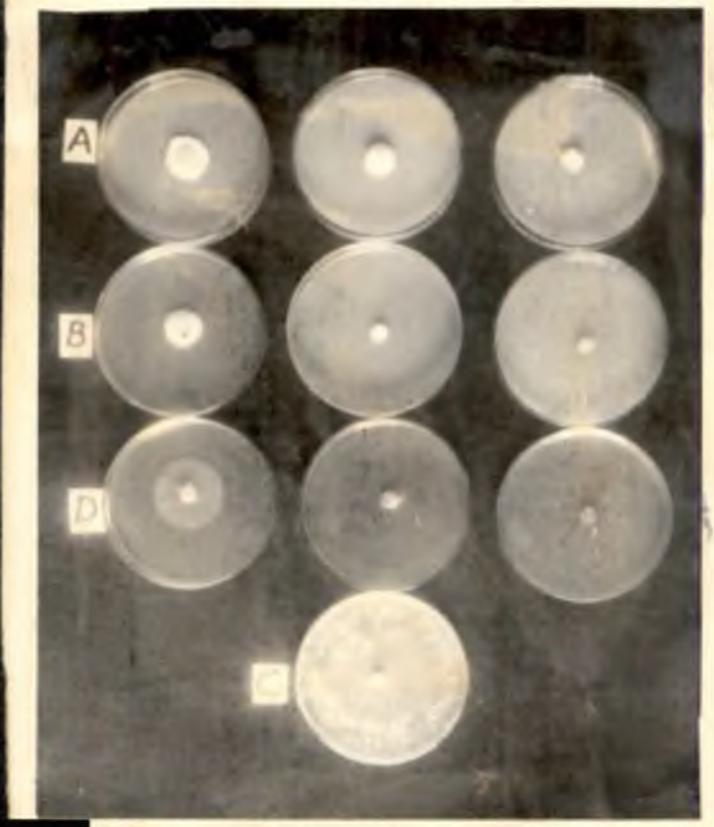

A
B
D
C

Table 7. Effect of herbicides on size of sclerotia (Mean diameter in mm ( $\sqrt{x+1}$ transformation value in paranthesis)

| Sl. No. | Name of herbicides | (Concentration in ppm) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 125 | 250 | 500 | 1000 | 2000 | Mean for herbicides | Rank |
| 1. | Fluchloralin | 1.033 (1.413) | 0.923 (1.385) | 2.680 (1.919) | 0.0 (1.00) | 0.0 (1.00) | 0.921 (1.3437) | 1 |
| 2. | Bentazon | 1.607 (1.614) | 1.640 (1.658) | 1.760 (1.660) | 1.933 (1.712) | 1.692 (1.640) | 1.726 (1.6504) | 3 |
| 3. | 2,4-D Sodium salt | 1.722 (1.649) | 1.837 (1.684) | 1.870 (1.693) | 1.942 (1.714) | 2.295 (1.815) | 1.933 (1.711) | 4 |
| 4. | Control | | 1.623 (1.619) | | | 1.623 (1.619) | | 2 |

C.D. for comparison between herbicides = 0.040

C.D. for comparison between levels within herbicides = 0.090

(ii) Viability of sclerotia produced in the herbicide amended media

The viability of sclerotia formed in all the treatments was tested by observing their capacity to germinate; as detailed under Materials and Methods. The results as percentage germination of sclerotia are presented in Table 8.

Table 8. Germination of sclerotia (percentage)

| Sl. No. | Herbicides | Concentration in ppm | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 25 | 50 | 125 | 250 | 500 | 1000 | 2000 |
| 1. | Fluchloralin | - | - | 100 | 100 | 100 | - | - |
| 2. | Bentazon | - | - | 100 | 100 | 100 | 100 | 100 |
| 3. | Benthiocarb | - | - | - | - | - | - | - |
| 4. | Propanil | 100 | 100 | - | - | - | - | - |
| 5. | Butachlor | - | - | - | - | - | - | - |
| 6. | Pendimethalin | - | - | 100 | - | - | - | - |
| 7. | Nitrofen | - | - | - | - | - | - | - |
| 8. | 2,4-D sodium salt | - | - | 100 | 100 | 100 | 100 | 100 |
| 9. | Control | - | 100 | 100 | 100 | 100 | 100 | 100 |

Results presented in Table 8 clearly show that wherever, there is sclerotial formation they are viable.

(iii) Pathogenicity of sclerotia or mycelium from the herbicide amended culture media

The reaction of sheath inoculation of susceptible

paddy plants with sclerotia (wherever they are formed) or mycelium in culture amended with 1000 ppm of the herbicides (where no sclerotia formed) are presented in Table 9. In the case of propanil the test was carried out with mycelial growth taken from dishes containing 50 ppm test material.

Table 9. Pathogenicity of sclerotia or mycelium from herbicide amended media

| Sl. No. | Name of herbicide | Concentration of herbicides (ppm) | Reaction |
|---|---|---|---|
| 1. | Fluchloralin | 1000 | +ve |
| 2. | Bentazon | 1000 | ,, |
| 3. | Benthiocarb | 1000 | ,, |
| 4. | Propanil | 50 | ,, |
| 5. | Butachlor | 1000 | ,, |
| 6. | Pendimethalin | 1000 | ,, |
| 7. | Nitrofen | 1000 | ,, |
| 8. | 2,4-D sodium salt | 1000 | ,, |
| 9. | Control | | |

In all cases the results were positive, since the test plants have taken up infection.

Though the test plates were incubated for long periods and observed the mycelium under the microscope, no perfect state of the fungus could be observed in the test plates.

(c) *In vitro* effects of varying periods of exposure of sclerotia to herbicides, on germination

The germination of ten sclerotia treated with 1000 ppm, 2000 ppm, 3000 ppm for different periods of 6 hours, 24 hours and 48 hours with each of the herbicides was tested by planting in PDA plates and the results are furnished in Table 10.

It has been observed that the germination of the sclerotia exposed to 2000 and 3000 ppm of propanil, even for a short period of 6 hours, could be inhibited completely. The lower concentration of 1000 ppm were also effective when exposed for prolonged periods. Benthiocarb 2000 ppm and 3000 ppm when treated for 48 hours could also inhibit germination of sclerotia of *Rhizoctonia solani*.

It has been particularly observed that the sclerotia, when treated with Bentazon 3000 ppm for 48 hours, found to germinate within the treatment medium itself. In other treatments of Bentazon, the sclerotia germinated well on the next day itself, after planting in PDA plates and thus Bentazon is found to enhance the germination of sclerotia.

## III. *In vivo* effects of herbicides on sheath blight of rice

### A. Pot culture experiment

A pot culture experiment was conducted to study the *in vivo* effects of the herbicides on the control of sheath blight disease of rice, on the germination and pathogenicity of sclerotia, and to study their effects on soil microflora

Table 10. *In vitro* effects of herbicidal treatment on sclerotial germination

| Sl. No. | Name and concentration of herbicides (conc. in ppm) | | Percentage of sclerotia germinated from treatments of varying duration | | |
|---|---|---|---|---|---|
| | | | 6 hr | 24 hr | 48 hr |
| 1. | Fluchloralin | 1000 | 80 | 30 | 20 |
| | | 2000 | 70 | 20 | 10 |
| | | 3000 | 80 | 20 | 10 |
| 2. | Bentazon | 1000 | 100 | 100 | 100 |
| | | 2000 | 80 | 90 | 80 |
| | | 3000 | 100 | 100 | 100 |
| 3. | Benthiocarb | 1000 | 90 | 80 | 100 |
| | | 2000 | 80 | 50 | 10 |
| | | 3000 | 100 | 20 | 0 |
| 4. | Propanil | 1000 | 40 | 0 | 0 |
| | | 2000 | 0 | 0 | 0 |
| | | 3000 | 0 | 0 | 0 |
| 5. | Butachlor | 1000 | 90 | 80 | 50 |
| | | 2000 | 80 | 60 | 60 |
| | | 3000 | 70 | 80 | 80 |
| 6. | Pendimethalin | 1000 | 100 | 80 | 100 |
| | | 2000 | 80 | 70 | 80 |
| | | 3000 | 80 | 80 | 70 |
| 7. | Nitrofen | 1000 | 100 | 80 | 50 |
| | | 2000 | 80 | 80 | 10 |
| | | 3000 | 50 | 80 | 10 |
| 8. | 2,4-D | 1000 | 70 | 90 | 80 |
| | | 2000 | 70 | 100 | 80 |
| | | 3000 | 60 | 70 | 80 |
| 9. | Control (Untreated) | | 100 | 90 | 100 |

Plate No.12.

Infection of Rice Plant by *R. solani*

A. Rice Plant from soil inoculated pot

B. Rice Plant from uninoculated pot

under wet land conditions.

(i) Infection of rice plants by R. solani

Infection of the rice plants was noticed from the fifth day of transplanting i.e., from the fifth day of inoculation of the fungus sclerotia in the soil in pots. Infection was first noticed on the lower leaves which touched the water surface and the soil and later on the lower sheaths which covered the stem. Plants in uninoculated pots showed no infection.

(ii) Effect of soil application of herbicides on viability of sclerotia in the soil

Ten sclerotia were recovered from soil from each treatment fourteen days after spraying of the herbicide in the pots and germination of five of them were tested by planting in Peptone, Dextrose Rose Bengal Streptomycin Agar medium after surface sterilisation in 0.1 per cent mercuric chloride solution for one minute and incubation under laboratory condition. Germination of sclerotia was observed after 24 hours for four days and data were statistically analysed after angular transformation. The results are presented in Table 11.

Table 11. Viability of sclerotia recovered from pots treated with different herbicides

| Sl. No. | Name of herbicide | Mean germination percentage - 15 days after spraying |
|---|---|---|
| 1. | Fluchloralin | 60.64 |
| 2. | 2,4-D Sodium salt | 63.80 |
| 3. | Bentazon | 70.44 |
| 4. | Benthiocarb | 60.64 |
| 5. | Pendimethalin | 65.47 |
| 6. | Nitrofen | 52.33 |
| 7. | Propanil | 52.49 |
| 8. | Butachlor | 54.00 |
| 9. | Control | 80.78 |

C.D. for comparison of treatment means = 12.61

Nitrofen, Propanil, Butachlor, Fluchloralin, Benthiocarb

2,4-D, Pendimethalin, Bentazon, Control

There is significant difference in the percentage germination of sclerotia recovered from soil from different treatments. Among the different treatments maximum percentage of germination was in the control plots followed by Bentazon and Pendimethalin.

Germination of sclerotia was least in Nitrofen followed by Propanil, Butachlor, Benthiocarb and 2,4-D which are on par.

(iii) Pathogenicity of sclerotia recovered from soil 14 days after spraying

The sclerotia recovered from soil were inoculated on the sheath of susceptible paddy plants and the pathogenicity recorded after one week based on development of lesions and the results are given in the Table 12.

Table 12. Efficiency of sclerotia recovered from treated pots in initiating sheath blight

| Sl. No. | Herbicide | Pathogenicity | | | | Intensity of lesion according to 0-9 scale | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RI | RII | RIII | RIV | RI | RII | RIII | RIV | Mean |
| 1. | Fluchloralin | +ve | +ve | +ve | -ve | 3 | 3 | 5 | 0 | 2.75 |
| 2. | 2,4-D Sodium salt | +ve | +ve | +ve | +ve | 3 | 3 | 5 | 3 | 3.50 |
| 3. | Bentazon | +ve | +ve | +ve | +ve | 3 | 1 | 7 | 3 | 3.50 |
| 4. | Benthiocarb | +ve | +ve | +ve | +ve | 3 | 3 | 3 | 3 | 3.00 |
| 5. | Pendimethalin | +ve | +ve | +ve | +ve | 3 | 5 | 3 | 3 | 4.66 |
| 6. | Nitrofen | +ve | +ve | -ve | -ve | 1 | 1 | 0 | 0 | 0.50 |
| 7. | Propanil | -ve | +ve | -ve | -ve | 0 | 1 | 0 | 1 | 0.50 |
| 8. | Butachlor | +ve | +ve | -ve | +ve | 1 | 3 | 0 | 1 | 1.25 |
| 9. | Control | +ve | +ve | +ve | +ve | 3 | 3 | 5 | 3 | 3.50 |

The sclerotia recovered from soil which received the various treatments, on artificial inoculation of rice plants showed that they all retained the pathogenicity. However, there were differences noted in the intensity of attack as evidenced by the differences in the disease score of each

treatment. Sclerotia recovered from plots which received Nitrofen (Tok E.25), Propanil and Butachlor, even though found to be infective, resulted only in mild symptoms on leaf sheath.

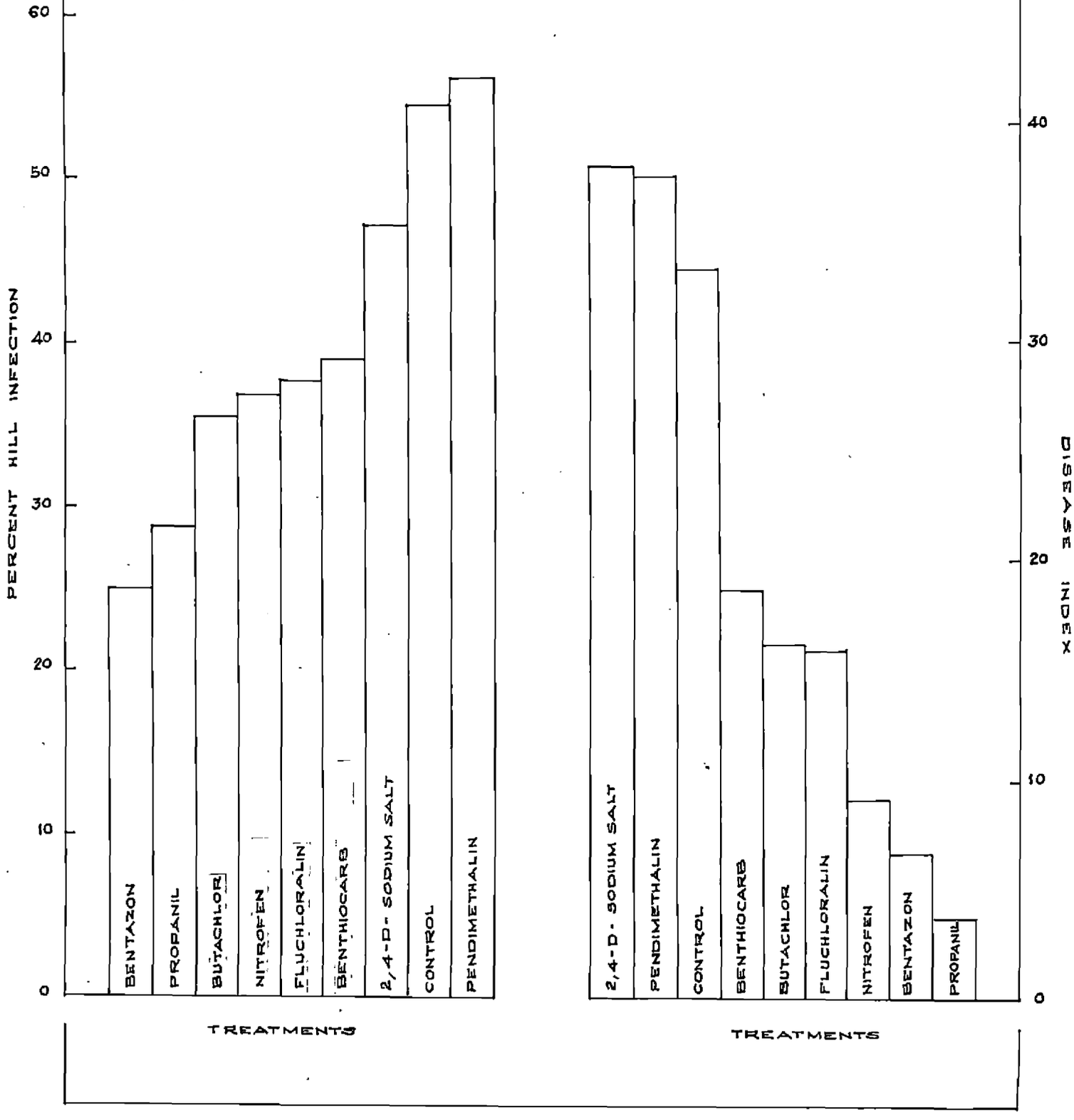
(iv). Percentage of infection

The per cent tiller infection was estimated by counting total number of tillers and the infected tillers, at the late tillering stage, i.e. at 60 days of age of the plants. The data were analysed after angular transformation. All the tillers in the treatment pots were examined for sheath blight incidence and the percentage of incidence and intensity were scored, recorded and presented in Table 13.

Table 13. Effect of various herbicides on the sheath blight incidence and intensity under pot culture experiment

| Sl. No. | Name of herbicide | Per cent Tiller infection | Rank | Mean Intensity | Rank |
|---|---|---|---|---|---|
| 1. | Fluchloralin | 37.74 | 5 | 17.12 | 4 |
| 2. | 2,4-D Sodium salt | 47.42 | 7 | 38.10 | 9 |
| 3. | Bentazon | 25.23 | 1 | 6.80 | 2 |
| 4. | Benthiocarb | 39.35 | 6 | 17.90 | 6 |
| 5. | Pendimethalin | 56.75 | 9 | 37.70 | 8 |
| 6. | Nitrofen | 37.13 | 4 | 9.10 | 3 |
| 7. | Propanil | 28.86 | 2 | 6.20 | 1 |
| 8. | Butachlor | 35.67 | 3 | 17.40 | 5 |
| 9. | Control | 54.92 | 8 | 33.10 | 7 |

FIG. EFFECT OF HERBICIDES ON INCIDENCE AND INTENSITY OF SHEATH BLIGHT.



C.D. for comparison for treatment means (for incidence) 12.30

C.D. for comparison for treatment means (for intensity) 9.18

a) Per cent tiller infection Fig. 4 a

Plants in Bentazon treated pots showed the least per cent tiller infection followed by Propanil, Butachlor and Nitrofen which are on par. In 2,4-D Sodium salt and Pendimethalin treated pots there are increase in per cent hill infection.

b) Disease intensity Fig. 4 b

Propanil is found most effective in reducing the intensity of sheath blight, followed by Bentazon and Nitrofen which are found equally effective. Pendimethalin and 2,4-D Sodium salt are found to increase the intensity of sheath blight. However, statistically they are on par with control.

B. Effect of herbicides on control of sheath blight disease - Field trial

The per cent hill infection and the average disease intensity calculated for the different treatments are tabulated and presented in Table 14.

The different herbicides had varying effects on sheath blight of rice. Maximum control was obtained by Hinosan spraying at tillering and boot leaf stage and it is significantly superior to all other treatments. This is followed by Nitrofen 1.75 kg ai/ha and 1.5 kg ai/ha and the treatments

Table 14. Effect of various herbicides on the control of sheath blight of rice

| Treatment No. | Treatments | (kg ai/ha) | Mean per cent hill infection after angular transformation | Rank | Mean disease intensity Index | Rank |
|---|---|---|---|---|---|---|
| 1. | Tok E.25 (Nitrofen) | 1.25 | 41.24 | 9 | 14.25 | 7 |
| 2. | ,, | 1.50 | 32.95 | 3 | 4.57 | 1 |
| 3. | ,, | 1.75 | 30.20 | 2 | 5.53 | 2 |
| 4. | Bentazon | 1.25 | 34.88 | 5 | 9.16 | 4 |
| 5. | ,, | 1.50 | 46.08 | 14 | 17.38 | 10 |
| 6. | ,, | 1.75 | 45.74 | 13 | 11.75 | 6 |
| 7. | Benthiocarb | 1.50 | 34.68 | 4 | 9.85 | 5 |
| 8. | ,, | 1.75 | 37.16 | 8 | 15.50 | 9 |
| 9. | ,, | 2.00 | 42.58 | 10 | 18.79 | 11 |
| 10. | Pendimethalin | 1.00 | 54.40 | 15 | 21.24 | 14 |
| 11. | ,, | 1.25 | 36.67 | 7 | 21.90 | 15 |
| 12. | ,, | 1.50 | 44.24 | 12 | 19.20 | 12 |
| 13. | Fluchloralin | 0.700 | 36.25 | 6 | 14.53 | 8 |
| 14. | Hinosan | 600 ml/ha | 21.44 | 1 | 7.03 | 3 |
| 15. | Hand weeding | | 43.56 | 11 | 19.90 | 13 |
| 16. | Control | | 60.12 | 16 | 43.20 | 16 |

C.D. for comparison of treatment means for per cent hill infection 8.86

Ranking $\overline{14}$, 3, $\overline{2,7,4,13,11,8}$; $\overline{1,9,15,12,6,5}$ $\overline{10,16}$

C.D. for comparison of treatment mean for disease index = 6.302

Ranking $\overline{2,3,14,4,7}$; $\overline{6,1,13,8,5,9,12,15}$; $\overline{10,11,16}$

Benthiocarb 1.5 kg ai/ha, Bentazon 1.25 kg ai/ha, Fluchloralin, Pendimethalin 1.25 kg ai/ha and Benthiocarb 1.75 kg ai/ha are found equally effective. Pendimethalin (Stomp) 1.00 kg ai/ha, was on par with control in respect of hill infection.

With regard to the intensity of attack Nitrofen (Tok E.25) 1.5 kg ai/ha is found to be the most effective in reducing the intensity of attack followed by Nitrofen (Tok E.25) at the rate of 1.75 kg ai/ha; Hinosan, Bentazon 1.25 kg ai/ha and Benthiocarb 1.5 kg ai/ha which were on par with Nitrofen (Tok E.25) at 1.5 kg ai/ha. Pendimethalin 1.00 kg ai/ha and 1.25 kg ai/ha were on par with control.

Effect of various herbicides on grain and straw yield

The mean grain and straw yield are tabulated and presented in Table 15. Statistical analysis of data on grain yield revealed that the effects due to treatments are significant at 1% level. The maximum average grain yield was recorded by hand weeding followed by Hinosan, Fluchloralin, Pendimethalin and Benthiocarb 1.5 kg ai/ha which were on par. Grain yield was least in Nitrofen (Tok E.25) 1.75 kg ai/ha and was found significantly inferior to all other treatments except Benthiocarb 1.5 kg ai/ha, Nitrofen (Tok E.25) 1.5 kg ai/ha, Control and Bentazon 1.5 kg ai/ha which were on par.

There was no significant effect of treatments on straw yield. However, maximum straw yield was recorded by Fluchloralin followed by Benthiocarb 1.5 kg ai/ha and

Table 15. Effect of various herbicides on the grain and straw yield of rice

| Sl. No. | Treatments (kg ai/ha) | | Average grain yield in kg/plot | Rank | Grain yield in kg/ha | Average straw yield in kg/plot | Straw yield in kg/ha |
|---|---|---|---|---|---|---|---|
| 1. | Nitrofen (Tok E.25) | 1.25 | 4.48 | 7 | 3197.93 | 8.97 | 6395.8 |
| 2. | ,, | 1.50 | 3.97 | 13 | 2828.65 | 9.33 | 6646.9 |
| 3. | ,, | 1.75 | 3.24 | 16 | 2311.66 | 6.90 | 4918.7 |
| 4. | Bentazon | 1.25 | 4.52 | 6 | 3220.08 | 10.16 | 7236.4 |
| 5. | ,, | 1.50 | 3.76 | 15 | 2680.94 | 9.43 | 6720.8 |
| 6. | ,, | 1.75 | 4.20 | 11 | 2991.45 | 10.01 | 7134.4 |
| 7. | Benthiocarb | 1.50 | 4.62 | 5 | 3290.59 | 11.77 | 8389.9 |
| 8. | ,, | 1.75 | 3.97 | 12 | 2828.65 | 9.08 | 6469.7 |
| 9. | ,, | 2.00 | 4.35 | 10 | 3101.94 | 9.64 | 6868.5 |
| 10. | Pendimethalin | 1.00 | 4.72 | 4 | 3367.79 | 8.61 | 6132.4 |
| 11. | ,, | 1.25 | 4.38 | 9 | 3124.07 | 10.16 | 7237.8 |
| 12. | ,, | 1.50 | 4.48 | 8 | 3197.93 | 10.50 | 7481.5 |
| 13. | Fluchloralin | 700 g | 4.78 | 3 | 3404.72 | 12.99 | 9254.0 |
| 14. | Hinosan | 600 ml/ha | 5.11 | 2 | 3641.06 | 9.43 | 6720.8 |
| 15. | Hand weeding | | 5.39 | 1 | 3839.03 | 9.05 | 6447.5 |
| 16. | Control | | 3.94 | 14 | 2806.49 | 10.19 | 7259.9 |

C.D. for comparison of grain yield = 0.76

Grain yield T. 15, 14, 13, 10, 7, 4, 1, 12, 11, 9, 6, 8, 2, 16, 5, 3

Pendimethalin 1.5 kg ai/ha. The straw yield was least in Nitrofen (Tok E.25) 1.75 kg ai/ha and Pendimethalin 1.00 kg ai/ha.

Effect on weed growth

The different species of weeds collected from the experimental plots were identified and grouped into grasses, sedges and broad leaved weeds. Among the weeds the grass Brachiaria ramosa (Griseb) Stapt. was the predominating weed followed by Monochoria vaginalis (broad leaved weed). The other weed species recorded were Echinochloa colonum, Echinochloa crus-galli and Panicum sp. among the grasses. Cyperus iria, Cyperus rotundus and Fimbristylis miliacea among the sedges and Ludwigia parviflora among broad leaved weeds.

(i) Weed counts

The data on total weed counts for four intervals at 20th, 40th and 60th day after spraying and before harvest were statistically analysed after $\sqrt{x+1}$ transformation and the analysis of variance table are presented in Appendix

Mean weed counts on 20th day after transplanting

Weed counts were least in treatments Bentazon 1.50 kg ai/ha and Pendimethalin 1.25 kg ai/ha followed by Bentazon 1.75 kg ai/ha and Pendimethalin 1.00 kg ai/ha which were on par with all other herbicidal treatments. Hand weeding

Table 16. Mean values of total weed population at different intervals from $0.5m^2$ after $\sqrt{x+1}$ transformation

| Sl. No. | Treatment (kg ai/ha) | | 20th | 40th | 60th | At harvest time |
|---|---|---|---|---|---|---|
| 1. | Nitrofen (Tok E.25) | 1.25 | 1.47 | 6.68 | 8.79 | 8.25 |
| 2. | ,, | 1.50 | 1.86 | 5.57 | 6.34 | 6.62 |
| 3. | ,, | 1.75 | 1.47 | 5.75 | 6.36 | 5.48 |
| 4. | Bentazon | 1.25 | 2.05 | 6.22 | 6.12 | 4.66 |
| 5. | ,, | 1.50 | 1.13 | 4.05 | 5.31 | 5.99 |
| 6. | ,, | 1.75 | 1.24 | 6.17 | 4.82 | 4.99 |
| 7. | Benthiocarb | 1.50 | 1.80 | 5.75 | 4.51 | 4.52 |
| 8. | ,, | 1.75 | 1.51 | 4.92 | 5.28 | 4.34 |
| 9. | ,, | 2.00 | 1.33 | 5.43 | 4.58 | 3.84 |
| 10. | Pendimethalin | 1.00 | 1.24 | 5.69 | 5.30 | 4.47 |
| 11. | ,, | 1.25 | 1.13 | 4.63 | 4.53 | 3.59 |
| 12. | ,, | 1.50 | 1.48 | 4.42 | 4.72 | 5.32 |
| 13. | Fluchloralin | 700 | 1.47 | 5.49 | 5.01 | 5.95 |
| 14. | Hinosan | 600 ml | 4.48 | 6.42 | 7.11 | 6.99 |
| 15. | Hand weeding | | 7.79 | 6.25 | 4.64 | 7.53 |
| 16. | Control (Unweeded) | | 4.68 | 7.25 | 8.93 | 10.31 |
| | C.D. 0.05 | | 1.53 | 1.54 | 2.31 | 2.14 |

(before weeding) recorded the maximum intensity of weed growth which was on par with Hinosan and control plots.

Mean weed counts 40 days after spraying

The estimation of weed population, 40 days after spraying revealed that Bentazon 1.5 kg ai/ha was the most effective herbicide in reducing the total weed population and the total weed counts in treatments Pendimethalin 1.5 kg ai/ha, Pendimethalin 1.25 kg ai/ha; Benthiocarb 1.75 kg ai/ha, Benthiocarb 2.00 kg ai/ha, Fluchloralin, Nitrofen (Tok E.25) 1.50 kg ai/ha are on par with Bentazon 1.5 kg ai/ha. Control plots had the maximum intensity of weed population and the next higher weed population was in Nitrofen (Tok E.25), 1.25 kg ai/ha; Hinosan and Hand weeding treatments.

Mean weed counts 60 days after spraying

Weed intensity was least in Benthiocarb 1.5 kg ai/ha followed by Pendimethalin 1.25 kg ai/ha and these were on par with all other herbicidal treatments other than Nitrofen (Tok E.25) 1.25 kg ai/ha.

Mean weed counts before harvest

Treating Pendimethalin 1.25 kg ai/ha had the least weed intensity followed by Benthiocarb 2.00 kg ai/ha and Benthiocarb 1.75 kg ai/ha T.16 (Control) had the maximum weed growth followed by Nitrofen (Tok E.25) 1.25 kg ai/ha.

Dry weight of weeds.

The mean dry weight of weeds recorded on the 20th,

40th, 60th and at harvest time are tabulated in Table 17.

Table 17. Total mean dry weight of weeds from 0.5 $m^2$ area at 20 days interval after spraying

| Sl. No. | Treatment (kg ai/ha) | | 20th day | 40th day | 60th day | At harvest time |
|---|---|---|---|---|---|---|
| 1. | Nitrofen (Tok E.25) | 1.25 | 0.043 | 1.50 | 5.00 | 6.40 |
| 2. | ,, | 1.50 | 0.033 | 1.36 | 5.00 | 4.30 |
| 3. | ,, | 1.75 | 0.003 | 1.25 | 3.90 | 3.10 |
| 4. | Bentazon | 1.25 | 0.220 | 1.33 | 5.70 | 1.70 |
| 5. | ,, | 1.50 | 0.033 | 0.64 | 3.93 | 4.16 |
| 6. | ,, | 1.75 | 0.066 | 1.30 | 2.26 | 2.50 |
| 7. | Benthiocarb | 1.50 | 0.110 | 1.50 | 4.93 | 2.60 |
| 8. | ,, | 1.75 | 0.010 | 0.86 | 3.39 | 1.86 |
| 9. | ,, | 2.00 | 0.013 | 1.41 | 2.80 | 1.50 |
| 10. | Pendimethalin | 1.00 | 0.005 | 1.40 | 5.63 | 1.93 |
| 11. | ,, | 1.25 | 0.033 | 0.30 | 2.60 | 1.70 |
| 12. | ,, | 1.50 | 0.230 | 1.66 | 2.90 | 3.13 |
| 13. | Fluchloralin | 700 | 0.091 | 1.18 | 4.03 | 5.30 |
| 14. | Hinosan | 600 ml/ha | 0.670 | 2.16 | 7.23 | 5.20 |
| 15. | Hand weeding | | 0.433 | 1.30 | 4.53 | 3.90 |
| 16. | Unweeded control | | 0.617 | 2.56 | 8.86 | 6.53 |
| | C.D. 0.05 | | 0.024 | 1.051 | 2.167 | 2.14 |

All doses of all the herbicides tested were found effective in reducing the dry weight of weeds. Dry weight was least in Tok E.25, 1.75 kg ai/ha followed by Pendimethalin,

1.00 kg ai/ha, Benthiocarb 1.75 kg ai/ha, and Benthiocarb 2.00 kg ai/ha.

When the dry weight of grasses at forty days after spraying were compared, it was found that Pendimethalin 1.25 kg ai/ha recorded the least dry weight of weeds followed by Bentazon 1.50 kg ai/ha and Benthiocarb 1.75 kg ai/ha. The treatment No.16 viz., control recorded the highest dry weight of grasses and the next higher was the treatment with Hinosan.

Data on the 60th day after spraying showed that Bentazon 1.75 kg ai/ha recorded the least dry weight of grasses followed by T.11 (Pendimethalin 1.25 kg ai/ha) and T.9 (Benthiocarb 2.00 kg ai/ha). Treatment No.16 (Control) recorded the maximum dry weight and the next higher one was Treatment with Hinosan. In hand weeded plot, the dry weight was on par with treatment Benthiocarb 1.50 kg ai/ha; Nitrofen (Tok E.25), 1.5 kg ai/ha, 1.25 kg ai/ha, Pendimethalin 1.00 kg ai/ha.

The data on the total dry weight of grasses recorded at the harvest time showed that Benthiocarb was most effective in reducing the dry weight of weeds. This was followed by Pendimethalin 1.25 kg ai/ha; Bentazon 1.25 kg ai/ha; Benthiocarb 1.75 kg ai/ha and Pendimethalin 1.00 kg ai/ha. All other treatments were found less effective in the control of weeds which last upto harvest stage.

Weed control efficiency of herbicides

Weed control efficiency of different treatments over control was calculated on the basis of total mean dry weight of weeds at harvest time and presented in Table 18.

Table 18. Weed control efficiency of different herbicides in rice field (from 0.5 $m^2$) (Calculated based on data at harvest time)

| Tr. No. | Treatments (kg ai/ha) | | Mean weed population | Weed control efficiency | Mean dry weight of weeds | Weed control efficiency |
|---|---|---|---|---|---|---|
| 1. | Nitrofen (Tok E.25) | 1.25 | 69.30 | 34.90 | 6.90 | -5.60 |
| 2. | ,, | 1.50 | 48.00 | 54.84 | 4.30 | 34.15 |
| 3. | ,, | 1.75 | 33.00 | 68.95 | 3.10 | 52.52 |
| 4. | Bentazon | 1.25 | 21.30 | 79.96 | 1.70 | 73.96 |
| 5. | ,, | 1.50 | 39.30 | 63.02 | 4.16 | 36.29 |
| 6. | ,, | 1.75 | 24.60 | 76.85 | 2.50 | 61.71 |
| 7. | Benthiocarb | 1.50 | 20.30 | 80.90 | 2.60 | 60.18 |
| 8. | ,, | 1.75 | 20.60 | 80.62 | 1.86 | 71.51 |
| 9. | ,, | 2.00 | 14.60 | 86.26 | 1.50 | 77.02 |
| 10. | Pendimethalin | 1.00 | 20.30 | 80.90 | 1.93 | 70.44 |
| 11. | ,, | 1.25 | 13.60 | 87.20 | 1.70 | 73.96 |
| 12. | ,, | 1.50 | 27.60 | 74.03 | 3.13 | 52.06 |
| 13. | Fluchloralin | 700 | 35.00 | 67.07 | 5.30 | 18.83 |
| 14. | Hinosan | 600 ml/ha | 50.00 | 52.96 | 5.20 | 20.36 |
| 15. | Hand weeding | | 57.00 | 46.37 | 3.90 | 40.27 |
| 16. | Unweeded control | | 106.30 | - | 6.53 | - |

Maximum weed control efficiency was recorded by T.11 (Pendimethalin 1.25 kg ai/ha) followed by T.9 (Benthiocarb 2.00 kg ai/ha) based on population of weeds and by T. Benthiocarb 2.00 kg ai/ha followed by Pendimethalin 1.25 kg ai/ha based on dry weight of weeds.

Auxiliary characters (Productive tillers, white ear heads (Stem borer) and sheath rot)

Total productive tillers, stem borer attack (Scirpophaga incertulas Walker) and sheath rot by Sarocladium oryzae Saw. were also estimated from 0.5 sq. metre area in two random samples from each of the treatments. The data were statistically analysed and results are furnished in Table 19.

The data on productive tillers in the different treatments were found statistically significant at 5% level.

Maximum productive tillers were in Fluchloralin treated plots followed by Bentazon 1.25 kg ai/ha, handweeding, Pendimethaline 1.00 kg ai/ha, Benthiocarb 1.75 kg ai/ha, Benthiocarb 1.50 kg, Control, Pendimethalin 1.75 kg ai/ha, and 1.50 kg ai/ha. Number of productive tillers were least in treatments Nitrofen 1.75 kg ai/ha then Bentazon 1.50 kg ai/ha, Bentazon 1.75 kg ai/ha, Nitrofen 1.50 kg ai/ha.

Stem borer counts were least in Hinosan treated plots, and maximum in Fluchloralin treated plots followed by Nitrofen (Tok E.25) 1.50 kg ai/ha and then in Handweeding, Unweeded control and Nitrofen 1.25 kg ai/ha. Sheath rot infection was least in Hinosan treated plots and Benthiocarb, treatment at

Table 19. Effect of different herbicidal application on productive tillers, white earheads (Stem borer infection) and sheath rot infection (Average observation per 0.5 sq.m area)

| Tr. No. | Treatments (kg ai/ha) | | Average productive tillers | Average white ears | Average of sheath rot infection |
|---|---|---|---|---|---|
| 1. | Nitrofen (Tok E.25) | 1.25 | 154 | 4.00 | 4.30 |
| 2. | ,, | 1.50 | 151 | 5.00 | 6.00 |
| 3. | ,, | 1.75 | 128 | 3.00 | 4.00 |
| 4. | Bentazon | 1.25 | 194 | 1.60 | 5.30 |
| 5. | ,, | 1.50 | 130 | 3.30 | 6.30 |
| 6. | ,, | 1.75 | 147 | 2.30 | 5.60 |
| 7. | Benthiocarb | 1.25 | 167 | 3.00 | 3.30 |
| 8. | ,, | 1.50 | 175 | 1.60 | 3.30 |
| 9. | ,, | 1.75 | 153 | 1.30 | 1.60 |
| 10. | Pendimethalin | 1.00 | 180 | 1.00 | 5.30 |
| 11. | ,, | 1.25 | 162 | 3.60 | 6.00 |
| 12. | ,, | 1.50 | 163 | 1.30 | 4.00 |
| 13. | Fluchloralin | 700 | 203 | 6.30 | 6.60 |
| 14. | Hinosan | 600 ml/ha | 155 | 0.33 | 1.60 |
| 15. | Handweeding | | 192 | 4.30 | 4.60 |
| 16. | Unweeded control | | 166 | 4.39 | 4.30 |

C.D. for comparison of treatment for productive tillers = 42.86

13, 4, 15, 10, 8, 7, 16, 12, 11 | 14, 1, 9, 2, 6, 5, 3

2.00 kg ai/ha. Sheath rot infection was maximum in Fluchloralin and Bentazon 1.50 kg ai/ha and then in Pendimethalin 1.25 kg ai/ha.

IV. (a) Effect of herbicide treatments on soil microflora

Nine composite soil samples collected at random from the pots were used for estimation of fungi, bacteria and actinomycetes before treatment with the herbicides. The population of the same in the soil before being used for this experiment are given in Table 20.

Table 20. Average number of microorganisms present in experimental soil before treatment

| Sl. No. | | Average No. in plates | Estimated population/g dry soil |
|---|---|---|---|
| 1. | Fungi | 10.000 | 10000 |
| 2. | Bacteria | 6.625 | 662000 |
| 3. | Actinomycetes | 12.160 | 1216000 |

Composite ssil samples collected from each treatment were used for estimation of soil microflora, maintaining three replications in each treatment. The total counts of fungi, bacteria and actinomycetes were estimated. The data were statistically analysed and the mean counts for each treatment are given in Table 21.

Table 21. Effect of herbicidal treatment on population of soil microflora (Average number /90 mm plate)

| Tr. No. | Herbicide | Mean counts of fungi | Mean counts of bacteria | Mean counts of actinomycetes |
|---|---|---|---|---|
| 1. | Fluchloralin | 60 | 1.33 | 1.13 |
| 2. | 2,4-D Sodium salt | 58 | 26.30 | 13.30 |
| 3. | Bentazon | 89 | 69.00 | 25.66 |
| 4. | Benthiocarb | 58 | 16.60 | 5.33 |
| 5. | Pendimethalin | 37 | 9.00 | 166.00 |
| 6. | Tok E.25 (Nitrofen) | 51 | 3.00 | 3.66 |
| 7. | Propanil | 65 | 14.00 | 2.66 |
| 8. | Butachlor | 79 | 7.00 | 3.00 |
| 9. | Control | 61 | 3.33 | 8.33 |

C.D. for fungal population = 20.87
C.D. for bacteria = 5.92
C.D. for actinomycetes = 13.057

The fungal population significantly varied in the various treatments. It was maximum in Bentazon treated plots which is significantly higher than that in all other treatments. This is followed by Butachlor, Propanil, Control, Fluchloralin and 2,4-D Sodium salt and Benthiocarb, which are found on par. Fungal population was least in Pendimethalin treated plots followed by Tok E.25 (Nitrofen) which are on par.

Treatment effects on bacterial population were also significant. Bacterial counts were least in soil treated with Fluchloralin, Tok E.25 followed by Control and Butachlor which are on par. Bacterial counts were maximum in Bentazon treated soil followed by 2, 4-D Sodium salt and Benthiocarb, which are significantly different from each other.

There is significant effect in total counts of actinomycetes also, due to the treatments. Actinomycetes population were least in Fluchloralin, followed by Propanil and Butachlor and were maximum in Pendimethalin treated soil followed by Bentazon and 2,4-D Sodium salt.

(b) Effect of herbicides on soil microflora in the wet land (Field experiment)

The average number of fungi, bacteria and actinomycetes of the experimental area estimated before spraying and presented in Table 22.

Table 22. Average number of microorganisms present in experimental field before treatment.

| Sl. No. | | Average No. in plate | Estimated population/ g dry soil |
|---|---|---|---|
| 1. | Fungi | 20 | 20000 |
| 2. | Bacteria | 7.5 | 750000 |
| 3. | Actinomycetes | 5.2 | 520000 |

Population of fungi, bacteria and actinomycetes

were estimated thirty days after spraying, the data statistically analysed and presented in Table 23.

Table 23. Effect of herbicidal treatments on soil microflora in the wet land (Average number 90 mm plate)

| Sl. No. | Treatments | (kg ai/ha) | Mean counts of fungi | Mean counts of bacteria | Mean counts of actinomycetes |
|---|---|---|---|---|---|
| 1. | Nitrofen (Tok E.25) | 1.25 | 19 | 8.5 | 5.0 |
| 2. | ,, | 1.50 | 16 | 11.0 | 5.0 |
| 3. | ,, | 1.75 | 14 | 9.0 | 5.0 |
| 4. | Bentazon | 1.25 | 22 | 7.0 | 3.0 |
| 5. | ,, | 1.50 | 31 | 12.0 | 5.0 |
| 6. | ,, | 1.75 | 29 | 7.0 | 6.0 |
| 7. | Benthiocarb | 1.50 | 26 | 14.0 | 3.0 |
| 8. | ,, | 1.75 | 21 | 9.0 | 7.0 |
| 9. | ,, | 2.00 | 28 | 8.5 | 5.0 |
| 10. | Pendimethalin | 1.00 | 20 | 13.5 | 3.0 |
| 11. | ,, | 1.25 | 16 | 8.5 | 6.0 |
| 12. | ,, | 1.50 | 25 | 12.0 | 5.0 |
| 13. | Fluchloralin | 700 g ai/ha | 31 | 14.5 | 6.0 |
| 14. | Hinosan | 600 ml/ha | 24 | 10.5 | 5.0 |
| 15. | Hand weeding | | 29 | 9.0 | 3.0 |
| 16. | Control (Unweeded) | | 12 | 12.0 | 6.0 |

C.D. for comparison of treatment means for fungi = 7.21

T $\overline{5, 13, 6, 15, 9, 7, 12, 14}$ $\overline{4, 8, 10, 1, 2, 11}$ $\overline{3, 16}$

Fungi

The effects due to treatments are statistically significant in the case of fungal population estimated thirty days after spraying. The maximum fungal colonies were in Bentazon 1.50 kg ai/ha (T.5) i.e. 31000 numbers and least was in T.16 (Control) being 12000.

Bacteria

Effect due to treatments are not statistically significant. However, the maximum average counts were in Fluchloralin (T.13) being 1350000/ha and the minimum in Bentazon 1.75 kg (T.6) being 700000 Nos.

Actinomycetes

Effect due to treatments were not statistically significant. Average maximum counts were in soil samples from Benthiocarb 1.75 kg ai/ha treated plots (T.8) being 700000.

V. Studies on microorganisms antagonistic to Rhizoctonia solani

Fungi and bacteria isolated from the sclerotia of Rhizoctonia solani and also from soil were tested for their antagonistic activity on the test organism and found that three isolates of fungus and three of the bacterial isolates were antagonistic to the pathogen.

Plate No.13.

Antagonism of microorganisms against R. solani

1. Trichoderma viride
2. Aspergillus niger
3. Aspergillus flavus

A. }
B. } Antagonistic bacteria
C. }

0 Control. R. solani


A
B
C
O
1
2
3

*Trichoderma viride* Pers. ex Fr.

*Aspergillus niger* Van Tiegh

*Aspergillus flavus* Link

were the fungal species which were found antagonistic and parasitising on *R. solani* (Plate No. 13 ). The mycelial growth of *R. solani* were found very thin and scanty and there was no sclerotial formation.

Three types of bacterial cultures (Plate No.13) were found inhibiting the growth of *R. solani*.

The percentage inhibition of radial growth of *R. solani* by the different antagonistic microorganisms are recorded in Table 24.

Table 24. Growth inhibition of *Rhizoctonia solani* by different antagonistic microorganisms

| Name of test organism | Source | Radial growth of *R. solani* in mm | Percentage of inhibition |
|---|---|---|---|
| *Fungi* | | | |
| 1. *Trichoderma viride* | Soil dilution plate | 9 | 90.0 |
| 2. *Aspergillus niger* | ,, | 5 | 94.0 |
| 3. *Aspergillus flavus* | Sclerotia | 17 | 81.0 |
| *Bacterial isolates* | | | |
| A. Isolate A | Sclerotia | 37 | 58.8 |
| B. Isolate B | ,, | 12 | 86.6 |
| C. Isolate C | Petri plate of *R. solani* culture | 48 | 46.6 |

# DISCUSSION

# DISCUSSION

Sheath blight of rice has become the most destructive of diseases of this crop in Kerala and its occurrence is endemic in the important rice tracts of the State. Control of weeds is another important problem faced by the rice farmers. In the recent past, due to the high cost of labour, use of herbicides has become a common practice for control of weeds in rice fields. Most of the herbicides are known to have inhibitory or stimulating effects on the non-target soil organisms also (Katan and Eshel, 1973). Some of the commonly used herbicides are reported to have inhibitory effect on soil borne sclerotia of Rhizoctonia solani (Kühn). On the other hand some other herbicides like 2,4-D are reported to enhance the susceptibility of host plants to diseases.

Benthiocarb, Penoxalin (Pendimethalin), Propanil, Machete (Butachlor), 2,4-D, Tok E.25 etc. are recommended for the control of weeds in the rice fields in Kerala (Anon., 1982 b). Hence the present investigations were undertaken to make a critical study of the side effects of the application of the above herbicides in checking the sheath blight disease. Studies were also undertaken to assess the in vitro effects of these herbicides on the growth of the fungus mycelium; sclerotial formation and its

viability and pathogenicity. The *in vivo* effects of these on the incidence of sheath blight, on the survival of sclerotia in soil etc., were also carried out, in addition to the study on their effects on the control of weeds. Studies were also undertaken how these herbicides affect the microflora in soil and also about the antagonism of some microorganisms on *R. solani*, the causal organism of sheath blight of rice.

A highly virulent isolate of this pathogen was used for the study. The morphological characters of the same were studied in detail. *Rhizoctonia solani* is known as a versatile fungus and in the study, with four isolates of *R. solani* in Kerala, Lakshmanan (1979) showed that they differed in some of the morphological characters and also in pathogenicity. An isolate from cowpea produced typical sheath blight symptoms on rice, but a local isolate from jack fruit produced only mild symptoms on inoculated rice plants. The characters of the present isolate was almost identical with those of rice isolate reported by Lakshmanan (1979).

Out of the eight herbicides tested *in vitro* on their inhibitory effect on the growth of *R. solani*, the fungus behaved differently in its growth and sclerotial formation, in media amended with different herbicides.

Fluchloralin has been found to reduce mycelial growth significantly at higher concentrations of 1000 ppm and above only. No sclerotia formation was also noticed at higher

concentrations. At lower concentrations also eventhough there was mycelial growth and sclerotia formation, the growth was very scanty and only few sclerotia which were of smaller size were formed. It has been pointed out by Verma *et al.* (1979) that this chemical has no effect on *Rhizoctonia bataticola* Taub & Butler, but reduced the radial growth of mycelium of *Fusarium oxysporum* f.*ciceri* (Padwick) Subran. and *Sclerotium rolfsii* Sacc. This chemical also considerably reduced the number of sclerotia formed in *Sclerotium rolfsii*, and clustering of sclerotia was also noted in the treatments.

According to Kataria and Singh (1981), Fluchloralin inhibited the growth of *Pythium butleri* Subran. in potato dextrose broth and Kotwal *et al.* (1982) found that mycelial dry weight of *S. rolfsii*, *Helminthosporium sativum* Pam. King and Bakke and *F. oxysporum* f.sp. *ciceri* was reduced at 500 µg/ml and 1000 µg/ml of the herbicide incorporated PDS (broth); and *Sclerotium rolfsii* did not form sclerotia in media amended with the herbicide.

The result of the present study are thus more or less as those reported for *Sclerotium rolfsii*.

It is very much interesting to note the behaviour of Bentazon on *R. solani*. It resulted only in slight retardation in growth at higher concentrations and on longer incubation also stimulated growth. Mycelial growth was more fluffy and it stimulated formation and germination of sclerotia also.

Basagran (Bentazon) was found to stimulate the growth of Fusarium solani f. sp. phaseoli (Burk.) Snyder and Hansen, in culture (Mussa and Russell, 1977) and according to Verma et al. (1979), Bentazon has no effect on R. bataticola, but highly toxic to S. rolfsii. Kotwal et al. (1982) also got the same result with this herbicide on S. rolfsii.

It is evident from the results that Benthiocarb is highly toxic to the test fungus, and the radial growth decreased with increasing concentration of the chemical, and had no growth at the highest concentration of the chemical. Even after prolonged incubation the chemical completely prevented formation of sclerotia in all the concentrations tested. The herbicide did not inhibit germination of sclerotia, except for the highest concentration for prolonged period, in which case a little inhibition was noticed. Varma et al. (1978) and Lakshmanan and Nair (1980) also reported that Saturn 50 E.C. (Benthiocarb) was highly inhibitory to R. solani in vitro and the amended media supported only few sclerotia. However, in the present study complete inhibition of sclerotial formation was noticed irrespective of the various concentrations of the chemical tested. Benthiocarb was found to be highly inhibitory to a few other fungi like Rhizoctonia bataticola, Fusarium oxysporum f.sp.ciceri and Sclerotium rolfsii (Verma et al., 1979); Helminthosporium sativum, F. oxysporium ciceri and S. rolfsii (Kotwal et al.,

1982). In both these studies it was also found that Benthiocarb completely inhibited sclerotial formation in S. rolfsii. Hence Benthiocarb can be considered as a herbicide which is highly inhibitory to many of the soil borne plant pathogenic fungi and hence has the potential of reducing the inoculum of soil borne fungal pathogen including Rhizoctonia solani thereby reducing disease intensity.

Of all the eight herbicides tested Propanil (Stam F.34) was found to be the most effective one in inhibiting mycelial growth of R. solani. Complete lysis of the test fungus was noticed even at a low concentration of 125 ppm of the chemical in the media. At still lower concentrations of 50 and 25 ppm, slight inhibition of radial growth was noticed. The viability and pathogenicity of sclerotia formed in amended media were found to be not affected by the herbicide. However, sclerotia treated with higher concentration of the herbicide for short period and lower concentration for prolonged period inhibited germination of the same. Inderawati and Heitefuss (1977) reported 50 per cent reduction of radial growth of Corticium sasakii with 10 µg/ml commercial formulation of Propanil. Dath and Swain (1979) found complete inhibition of radial growth of C. sasakii, in the presence of 25 to 500 ppm of this chemical. According to them this herbicide was the most effective one to inhibit the growth of Corticium sasakii among the ten herbicides they have tested. The results of

the present study also are in conformity with these findings and Propanil can be considered as a herbicide with high potentiality in suppressing the growth of sheath blight organism. This herbicide was also found to be effective *in vitro* in suppressing the growth of *Pyricularia oryzae* cav. and *Xanthomonas oryzae* (Dowson) Uyeda and Ishiyama (Inderawati and Heitefuss, 1977).

In the lower concentrations tested, Butachlor was found to inhibit the radial growth of *R. solani*. However, there was revival of growth even at higher concentrations. Significant retardation was noticed only at a concentration of 2000 ppm. Butachlor as Machete 50 E.C. was found to inhibit radial growth and sclerotial formation in *R. solani* (Varma *et al.*, 1978). Dath and Swain (1979) and Lakshmanan and Nair (1980) reported more or less the same effect. But in the present study Butachlor in all the concentrations tested completely inhibited formation of sclerotia and mycelial development was also thin. Linear growth of other fungi like *Rhizoctonia bataticola*; *Fusarium oxysporum* and *Sclerotium rolfsii* were also inhibited by this herbicide (Verma *et al.*, 1979).

Only higher concentrations of Pendimethalin (Stomp) were found effective in the inhibition of *Rhizoctonia solani*. However, formation of sclerotia was inhibited completely even with a concentration of 250 ppm and the other higher

concentrations which indicate that the herbicide will not favour the survival of the fungus. But the pathogenicity and viability of the fungus were not affected by this herbicide. The fungitoxicity of this herbicide was reported by Verma et al. (1979) in the case of other soil borne plant pathogens and by Abdulla and Manchi (1979) in the case of Pythium spp.

Kotwal et al. (1982) also found that the chemical considerably reduced the mycelial dry weight of S. rolfsii and sclerotia formation was inhibited. The fungitoxicity of this chemical has also been reported by Vyas and Khare (1983) on R. bataticola and F. oxysporum.

In the present study it was found that even on prolonged incubation, Nitrofen (Tok E.25) checked the radial growth of the test fungus, and formation of sclerotia was completely inhibited in all the concentrations tested. But the pathogenicity and germination of sclerotia were not inhibited considerably. Fungitoxicity of the chemical was reported by Inderawati and Heitefuss (1977) on Corticium sasakii, Pyricularia oryzae and Xanthomonas oryzae. On R. solani, also the fungitoxic effect of this chemical has been reported by Dath and Swain (1979) and Lakshmanan and Nair (1980). According to Verma et al. (1979) the toxicity of this herbicide is more on S. rolfsii, than on R. bataticola, and F. oxysporum. Sclerotia formation was also inhibited

and clustering of sclerotia noted in S. rolfsii. Vyas and Khare (1983) also reported the high toxicity of the chemical on S. rolfsii than on R. bataticola and F. oxysporum. Fungicidal effect of the herbicide 2,4-D Sodium salt was entirely different from all other herbicides tested. The test organism showed a lag growth phase at the early stage followed by an accelerated growth phase with the production of large number of white sclerotial primordia than that in the control. The herbicide also enhanced the sclerotial production, though the number of fully formed sclerotia was less, they were bigger in size and secondary sclerotial primordia were formed continuously which shows the enhancement of growth and survival of the fungus. The sclerotia were also viable and pathogenic. Kurodani et al. (1959) found that the linear growth rate of Hypochnus sasakii was stimulated by the presence of 2,4-D in the medium. The same effect has been reported by others like Tatsuyama and Jakihara (1970) and Lakshmanan and Nair (1980). However, according to Millikan and Fields (1964) there was only 86 per cent inhibition of growth in 100 ppm of the chemical in a nutrient solution.

The above results clearly shows that Propanil was the most effective in inhibiting the radial growth of the test organism. This is being followed by Benthiocarb, Nitrofen and Butachlor.

It is also evident that Bentazon and 2,4-D Sodium salt can enhance the growth, survival and germination of Rhizoctonia solani and can enhance the population of this fungus in soil. Altman (1969) found that twenty five of the conventional herbicides recommended in the crop production stimulated Rhizoctonia solani in vitro and the fungus grew better in media supplemented with these herbicides, than in unsupplemented media and stated that some fungi use herbicides as an energy source. Crafts and Robbins (1962) suggested that the stimulated growth of the fungus due to 2,4-D may be due to the increase in RNA synthesis resulting in auxin-kinetin imbalance and induced growth due to abnormal cell division.

The effect of herbicides on plant disease has been recently reviewed by Katan and Eshel (1973) and also by Altman and Campbell (1977). But there is very little information on the effect of herbicides on soil-borne plant pathogens in unsterilised field soil. Most studies have been either with sterile soil or with culture media. In the present study in the pot culture experiment sudden development of symptoms, typically on leaf blade which touched the water surface were noticed. ~~This ... where soil borne sclerotia constitute the plants in the pot, where soil borne sclerotia constitute a major source of inoculum.~~

In pot culture experiment, when rice plants raised in

pots were artificially inoculated with sclerotia of the organism and the various herbicides were applied it was found that infection was least in Bentazon treated pots and in minimising intensity of sheath blight Bentazon is second to Propanil. But in vitro studies with Bentazon showed that it stimulated the growth of the rice sheath blight pathogen. From the results of the present study it is evident that stimulation of growth and reproduction within culture media may have little significance as those occurring in natural soil, since the quantity of herbicide added to soil at the usual recommended dose amounts to less than 0.1 per cent of the organic matter constituent of soil (Katan and Eshel, 1973). Richardson (1959) has shown that Prophan (I.P.C.) and TCA reduced Fusarium wilt of tomato, but were not toxic to the fungus in culture and he has suggested that the change in metabolism of the host might have affected disease development.

Propanil ranks second in reducing tiller infection, however, it recorded maximum reduction in sheath blight intensity. It may be due to the high toxicity on the pathogen, even in the lower concentrations as evidenced in the in vitro studies. Chakrabarti and Sen (1978) reported that application of propanil can exclude Helminthosporium oryzae Breda de Haan from rice plants. Butachlor and Nitrofen (Tok E.25) were found equally effective in reducing tiller infection, and Nitrofen (Tok E.25) in reducing disease intensity.

Tok E.25 was reported to reduce disease intensity in rice against Corticium sasakii, Pyricularia oryzae and Xanthomonas oryzae and was found superior to Stam F.34 (Inderawati and Heitefuss, 1977). In reducing tiller infection, Fluchloralin and Benthiocarb were also found superior than Pendimethalin and 2,4-D Sodium salt and control. Pendimethalin and 2,4-D Sodium salt were found to increase per cent tiller infection and disease intensity, but were not statistically significant. According to Kataria and Singh (1981) Fluchloralin applied to soil, reduced seedling damping off by Pythium butleri at 20-25°C and enhanced damping off at 30°C. Abdulla and Manchi (1979) reported that the herbicide Stomp (Pendimethalin) reduced virulence of Pythium spp. and delayed emergence of tomato seedlings; when the soil was treated with the herbicide.

Kurodani et al. (1959) reported that sheath blight disease of rice was increased by spraying with 2,4-D and according to Manila and Lapis (1977) the disease was not affected by 2,4-D.

Leontera and Voitovich (1959) reported control of blister smut of maize in the field by spraying 2,4-D and Chakrabarti and Sen (1978) reported that Helminthosporium oryzae was chemically excluded by 2,4-D treatment. Hodges (1980) found that soil drenching with 2,4-D enhanced disease on leaves of all ages above that of control while 2,4-D applied as spray had little influence on pathogenesis on

*Poa pratensis* infected by *Dreshslera sorokiniana*.

Results of soil application of herbicides on viability of sclerotia revealed that the sclerotia recovered from soil treated with all the herbicides were viable and pathogenic on the host. At field application dose, these herbicides would not be toxic to the fungus; even with those which inhibited germination *in vitro*. However, there were variation in the degree of viability and pathogenicity. This may be due to the effect of different herbicides on the survival structures of the pathogen or may be due to the enhancement of growth of other antagonistic microorganisms in the soil. Only mild symptoms of sheath blight were noticed when rice plants were inoculated with sclerotia recovered from soil treated with Nitrofen (Tok E.25), Propanil and Butachlor compared with control.

In the field trial with selected herbicides conducted in the typical wet land paddy fields the fungicide Hinosan applied at tillering and boot leaf stage ranked first in reducing tiller infection (21.44 per cent). But in reducing intensity of sheath blight incidence Nitrofen (Tok E.25) applied at the rate of 1.5 kg ai/ha and 1.75 kg ai/ha; Bentazon 1.25 kg ai/ha and Benthiocarb 1.5 kg ai/ha were found equally effective and were on par with the application of the fungicide Hinosan. Except in the case of application of Pendimethalin 1.00 kg ai/ha and 1.25 kg ai/ha all other

herbicidal treatments reduced per cent tiller infection and reduced disease intensity.

In the pot culture trial Bentazon 1.5 kg ai was found most effective in reducing tiller infection and in the field trial Bentazon 1.25 kg ai was found as effective as Nitrofen (Tok E.25), but less effective than treatment with Hinosan. In both the trials Nitrofen (Tok E.25), 1.5 kg ai/ha was found effective in reducing disease intensity.

In the case of grain yield hand weeded plots recorded maximum yield of 3839 kg/ha which was closely followed by Hinosan treatment, Fluchloralin and Pendimethalin 1 kg ai/ha. However, it may be mentioned here that Pendimethalin was not effective in reducing disease intensity. Grain yield was less in treatments with Nitrofen (Tok E.25) 1.75 kg ai/ha, Bentazon 1.5 kg ai/ha than that of the control.

Considering the weed population at the different intervals, it can be seen that at the early stages Bentazon 1.50 kg; Pendimethalin 1.5 kg and 1.75 kg and at later stage Benthiocarb 1.5 kg, Pendimethalin 1.25 kg and Benthiocarb 2 kg were found most effective in controlling the weed population.

There are many reports in literature on the efficacy of the above herbicides in reducing weed growth in rice fields which are in conformity with the present results. In a total number of thirty five trials Bentazon 0.5-1 lb/acre gave good control of sedges, rushes and broad leaved weeds

(Atwell et al., 1978). At I.R.R.I. Penoxalin (Pendimethalin) 2 kg ai/ha applied six days after spraying controlled major weeds like Monochoria vaginalis, Echinochloa crus-galli and Cyperus sp. (Anon., 1974) and 1.5 kg ai of the chemical on the sixth day of planting was found effective by Ravindran (1976). Penoxalin G 1.5 kg ai/ha on the sixth day is recommended for weed control in rice in Kerala (Anon., 1982 b). Benthiocarb has been established as a prominent herbicide for control of weeds in rice fields and the present result is in conformity with the effectiveness of the recommended dose of 2 kg ai/ha on sixth day of planting (Anon., 1982 b). Pre emergence application of Nitrofen at 2.5 kg ai/ha gave selective control of grasses, sedges and broad leaved weeds, (Verma et al., 1978) and in the present study the herbicide reduced dry weight of weeds at the early stage only. The major weed population in the field in the present study were Bracharia ramosa and Monochoria vaginalis.

While comparing productive tillers and yield, it is clear that more grain and straw yield were recorded in treatments where the productive tillers were more. Though productive tillers were not high in Hinosan treated plots, the stem borer infestation, sheath blight incidence and sheath rot infection were least in Hinosan treated plots. However, maximum grain yield was recorded in hand weeded treatments where the number of productive tillers were also more. This is in accordance with the findings of Vacchani

et al. (1963), Ravindran (1976), Kaushik and Mani (1978). When the number of tillers were high, the chances of disease intensity of sheath blight increases, but were not as high as to cause a reduction in yield.

Soil borne pathogens exist in the soil in active or in passive form and are much influenced by the dense population of the microflora and microfauna which exist in natural soil. The quantity, quality and activity of microorganisms in the soil are important in determining the inoculum density of the pathogen and consequently the disease incidence and also the survival of the pathogen in the soil in the absence of proper host (Alexander, 1961; Garret, 1970).

Soil organisms which are antagonistic to the pathogen are very common in natural soil. A herbicide reaching the soil might be toxic to certain pathogen and yet be beneficial to it in the soil environment by suppressing antagonists to a greater extent. The disturbance in biological equilibrium may be by decrease in number, reduction in capacity to produce antibiotic, reduction in ability to compete with the pathogen for nutrient (Katan and Eshel, 1973).

The results of in vivo studies in pot culture and the effects of herbicides on soil microflora, shows that there was a general increase in number of fungal colonies estimated two weeks after transplanting, as shown by the population in the untreated control in Table No.21. This may be due to the availability of more nutrients in soil and

may be due to the stimulation by the root exudates. But it is clear that the fungal population significantly varied in different treatments. The bacterial and actinomycetes colonies were less in the untreated control. But there were significant variation in the different treatments in both the cases.

In the soil treated with Bentazon, the fungal and bacterial colonies are found to be the maximum and also there was a high population of actinomycetes. This shows that Bentazon has a stimulatory effect on soil microorganisms. Similar results of increase in fungal, bacterial and actinomycetes population in soil by Trifluralin had been reported by Tang et al. (1970).

The present finding of an enhancement in population in the case of other microorganisms due to Bentazon treatment can cause a growth inhibition of R. solani in soil, due to competition for nutrients and due to the increase in antagonistic organisms. This can be a reason for decrease in disease though the herbicide stimulated growth of R. solani in vitro.

Butachlor, Propanil, Fluchloralin, 2,4-D Sodium salt, and Benthiocarb, did not influence the fungal population. But there was an increase in bacterial population due to these herbicide except in Fluchloralin and there was not much variation in actinomycetes population due to the effects of the above herbicides.

In Fluchloralin treated plots soil population of bacteria and actinomycetes were least.

(Nitrofen( Tok E.25) inhibited all the three groups of microorganisms while Pendimethalin inhibited soil fungi, but actinomycetes population was found to be on the increase.

In the field experiment, there was not much variation between the soil microflora before application of the various treatments and one month after spraying of herbicides. However, least fungal population was in control plots and maximum in Bentazon 1.5 kg ai/ha treated soil. It has been suggested that normal rates of application of most herbicides have no pronounced adverse effect on the soil microflora at least as far as total populations are concerned (Bollen, 1961; Audus, 1964).

The results of study on the effect of antagonistic microorganisms on R. solani revealed that the fungal and bacterial antagonists were found to restrict the radial growth of R. solani in culture media to a considerable extent. Among the fungi, Aspergillus niger and Trichoderma viride exhibited higher degree of antagonism than A. flavus as indicated in table 24.

The antagonistic activity of T. viride towards R. solani has been well established, by many workers (Ogura and Akai, 1965; Naim and El Esawy, 1965; Naiki and Ui, 1972; Roy, 1977). From this laboratory itself Gokulapalan (1981) recorded the

antagonistic activity of A. flavus and A. niger on R. solani.

Olsen (1965) observed the antagonistic activity of Bacillus subtilis Cohn. em.prazn on R. solani. In the trials conducted at I.R.R.I., Philippines several bacterial isolates from sclerotia of R. solani were found to have strong antagonistic activity towards R. solani (Anon., 1978).

# SUMMARY

## SUMMARY

Investigations on the effects of the herbicides; Fluchloralin, Bentazon, Benthiocarb, Pendimethalin (Stomp), Propanil (Stam F.34), Butachlor, Nitrofen (Tok E.25) and 2,4-D Sodium salt, in inhibiting the growth and survival of the causal organism of sheath blight disease of rice, Rhizoctonia solani Kühn have been carried out. In vivo studies on the effect of these chemicals in reducing sheath blight incidence also has been done in pot culture experiments and in trials under field conditions.

Of all the eight herbicides tested, Propanil was the most toxic one, which completely inhibited radial growth of the test organism even at a lower concentration of 125 ppm a.i. Inhibition of radial growth was less and formation of a few sclerotia were noted at lower concentration of 25 and 50 ppm of this chemical. This herbicide prevented sclerotial germination at higher concentrations of 2000 and 3000 ppm and also at lower concentration when treated for prolonged periods.

Benthiocarb, Nitrofen and Butachlor were also found highly toxic to the test fungus which decreased the radial mycelial growth with increasing concentrations of the chemical. At the highest concentration of 2000 ppm used, growth was completely inhibited. The three chemicals

completely prevented formation of sclerotia in all the concentrations. Benthiocarb slightly reduced the germination of sclerotia, when treated with higher concentration for prolonged period, while germination was not affected by the other chemicals tested. Only higher concentrations of Pendimethalin and Fluchloralin inhibited radial growth and sclerotia formation. Size of sclerotia was much reduced in Fluchloralin treatments and at higher concentration sclerotia were not formed in both the herbicide treatments. Germination of sclerotia was also not much affected.

Bentazon in all the concentrations tested showed to stimulate mycelial growth and also formation and germination of sclerotia though slight inhibition of radial growth at the higher concentrations were noted initially. In the case of 2,4-D Sodium salt, the test organism though showed an initial lag growth phase, was followed by an accelerated growth phase with the production of large number of sclerotial primordia. Size of sclerotia formed was also bigger and thus enhanced the growth and survival of R. solani in culture.

In the pot culture trial, when soil was inoculated with sclerotia sudden development of symptoms of sheath blight was noted indicating that soil borne sclerotia constitute the major source of inoculam. Sheath blight incidence was least in Bentazon treated pots and in the case of minimising intensity Bentazon was second to Propanil. Propanil recorded

maximum reduction in sheath blight intensity. Butachlor and Nitrofen were equally effective in reducing tiller infection, and Nitrofen reduced disease intensity. Pendimethalin and 2,4-D Sodium salt increased per cent tiller infection and disease intensity.

Sclerotia recovered from soil treated with all the herbicides were found to be viable and pathogenic on the host. However, there were variation in the degree of viability and pathogenicity.

In the field trial conducted with selected herbicides, along with the fungicide Hinosan, it was observed that Hinosan treatment (at tillering and boot leaf stages) was the most effective treatment in reducing tiller infection, but Nitrofen (Tok E.25) applied at the rate of 1.5 kg ai/ha reduced intensity of sheath blight, and this was on par with Nitrofen (Tok E.25) at 1.75 kg ai/ha, Bentazon 1.25 kg ai/ha and Benthiocarb 1.5 kg ai/ha in reducing intensity of sheath blight.

In the case of grain yield, hand weeded plots recorded maximum yield of 3839 kg/ha.

At the early stages of the crop Bentazon 1.50 kg, Pendimethalin 1.5 kg and 1.75 kg, and at later stages Benthiocarb 1.5 kg, Pendimethalin 1.25 kg and Benthiocarb 2 kg were found most effective in controlling weed population in rice fields. The major weed sp. in the field were Bracharia ramosa and Monochoria vaginalis.

Maximum productive tillers were in Fluchloralin treated plots followed by Bentazon 1.25 kg ai/ha and in hand weeded treatments and least in treatment with Nitrofen (Tok E.25) 1.75 kg ai/ha.

Stem borer infestation was least in Hinosan treated plots and maximum in Fluchloralin treated plots.

Sheath rot infection was least in Hinosan treated plots and also in treatments with Benthiocarb 2 kg ai/ha.

From the results of *in vitro* and *in vivo* studies it can be concluded that Propanil (Stam F.34), Benthiocarb, Nitrofen and Butachlor are highly toxic to *R. solani* in culture, and Bentazon and 2,4-D Sodium salt stimulated growth and survival of the test fungus in culture. Propanil, and Nitrofen were also found to be effective in reducing the sheath blight disease in pot culture experiments also. 2,4-D Sodium salt stimulated the pathogen in culture and also increased sheath blight in pot culture experiments.

There was a general increase in soil microflora two weeks after transplanting of rice plants. Bentazon stimulated total population of fungi, bacteria and actinomycetes in soil. Butachlor, Propanil and 2,4-D Sodium salt increased the bacterial population. Fluchloralin and Nitrofen inhibited fungi, bacteria and actinomycetes in soil. Pendimethalin stimulated actinomycetes population. Wet land paddy soil of the field did not show much variation in soil

microflora one month after application of the herbicides. However maximum fungal population was in treatment with Bentazon 1.5 kg ai/ha.

Aspergillus niger and Trichoderma viride exhibited higher degree of antagonism to R. solani in culture than Aspergillus flavus.

# REFERENCES

## REFERENCES


Abdulla, M.H. and Manchi, S.F. (1979). Interaction between a Pythium and the herbicide 'Stomp'. Trans. Br. mycol. Soc. 72: 213-218.

Abeygunawardena, D.V.W. and De Silva, E.M.P. (1964). Chemotherapeutic investigations on sheath blight of rice. Trop. Agriculturist 120: 149-158.

*Abud, J.K. (1980). Comparison of herbicides. Institute Rio Grandense de Arroz. 155-157.

Ahmed, N.U. and Zahidul Hoque, M. (1981). Weed control in dry seeded rainfed bunded rice and its residual effect on weed growth of subsequent transplanted rice. Rice Res. Newsl. 6(2): 13-14.

Alexander, M. (1961). Introduction to Soil Microbiology. New York, Wiley pp. 467.

Altman, J. (1969). Predisposition of sugarbeets to Rhizoctonia damping off with herbicides. Phytopathology 59: 1015.

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

Anonymous (1971). Annual Report, CRRI: 96-102.

Anonymous (1973). Plant Pathology. The International Rice Research Institute, Annual Report for 1972, IRRI, Philippines, 123-126.

Anonymous (1974). Weed control in transplanted rice. Annual Report IRRI, 223-234.

Anonymous (1976 a). Standard evaluation system for rice. International Rice Research Institute, Laguna, Philippines. pp. 64.

Anonymous (1976 b). Zero tillage in rice. Annual Report. IRRI:230-231.

Anonymous (1978). Plant Pathology. The International Rice Research Institute, Annual Report for 1977, IRRI, Philippines, 178-180.

Anonymous (1981). Package of Practices Recommendations. Kerala Agricultural University, Vellanikkara, pp.171.

Anonymous (1982 a). Evaluation of herbicides for the control of sheath blight of rice. Annual Report. Kerala Agricultural University, pp. 98.

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

Anonymous (1982 c). Weed problems in Rice - Conference on epidemiology and control of Rice Diseases. 1982. College of Agriculture, Vellayani, Kerala.

Atwell, S., Cole, C. and Zarecor, D. (1978). Bentazon for control of broad leaf weeds and sedges in rice. Proc. 31st Annual meeting of Southern Weed Sci. Society: 125-126.

Audus, L.J. (1964). Herbicides behaviour in soil. II. Interaction with soil microorganisms. In. L.J.Audus (Ed.). The Physiology and biochemistry of herbicides, New York, Academic Press, pp. 196.

Bain, D.C. (1961). Effect of various herbicides on some soil fungi in culture. Pl. Dis. Reptr. 45: 814-817.

Baker, J.B. (1975). Drill seeded herbicide comparison test. 66th Annual Progress Report. Rice Experiment Station, Crowley, Louisiana: 96-106.

*Beam, H.W., Curl, E.A. and Rodriguez-Kabana, R. (1977). Effect of the herbicides Fluometuron and Prometryne on Rhizoctonia solani in soil cultures. Can. J. Microbiol. 23: 617-623.

Bollen, W.B. (1961). Interaction between pesticides and Soil Microorganisms. Ann. Rev. Microbiol. 15: 69-92.

Borum, D.E. and Sinclair, J.B. (1968). Evidence for systemic protection against Rhizoctonia solani with vitavax in cotton seedlings. Phytopathology 58: 976-980.

Butler, E.J. (1918). Fungi and diseases in plants. Thacker, Spink and Co., Calcutta, pp. 547.

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

Chandler, J.M. and Santelmann, P.W. (1968). Interaction of four herbicides with Rhizoctonia solani on seedling cotton. Weed Sci. 16: 453-456.

*Chen, C.C. and Chien, C.C. (1961). Studies on the fungicidal control of the banded sclerotial disease of rice. Spl. Publ. Coll. Agric. Taiwan Uni. 10: 179-196.

Chien, C.C. and Hung, Y.C. (1971). Studies on the control of sheath blight of rice by systemic fungicides. J. Taiwan Agric. Res. 20: 37-46.

Cordon, T.C. and Haenseler, C.M. (1939). A bacterium antagonistic to Rhizoctonia solani. Soil Sci. 47: 207-214.

Craft, A.S. and Robbins, W.W. (1962). Weed Control. Mc Graw Hill Book Company, New York and London, pp. 660.

Dath, A.P. and Swain, A. (1979). In vitro effects of certain nematicides and weedicides on Cortioium sasakii. Indian J. Mycol. Pl. Pathol. 9: 95-96.

*Duggar, B.M. (1915). Rhizoctonia crocorum (Pers.) DC. and R. solani Kuhn (Corticium vagum B & C.) with notes on other species. Ann. Missouri Botan. Garden 2: 403-458.

Dunleavy, J.M. (1952). Control of damping-off of sugarbeet by Bacillus subtilis. Phytopathology 42: 465.

*Ebner, L. (1965). Uber die Nebnwirkung verschiedener Harnstoff-Herbizide anf einige Pilzarten Z. Pflkrankh. Pflanzenpathol Pflanzenschutz Band 72: 344-350.

*Eckstein, Z. and Zukowski, E. (1958). The fungicidal properties of some benzo-xazolane derivatives. Przem Chem. 37: 418-420.

El Khadem, M., Zahran, M. and EL. Kazzuz, M.K. (1979). Effect of the herbicides Trifluralin, Dinitramine and Fluometuron on Rhizoctonia disease in cotton. Plant and Soil 51: 463-470.

*Endo, S. (1931). Studies on the sclerotium disease of the rice plant. V. Ability of overwintering of certain important fungi causing Sclerotium diseases of the rice plant and their resistance to dry conditions. Forsch. Geb. Pflanzenkrankh (Tokyo) 1: 149-167.

*Endo, S. (1935). Studies on the antagonism of micro-organisms. V. Pathogenicity of Hypochnus sasakii Shirai, Hypochnus centrifugus Tul. and Sclerotium orizae sativae as influenced by the antagonistic action of certain fungus antagonists. Bull. Miyazaki Coll. Agric. For. 8: 61-73.

*Endo, S., Shinohara, S. and Hara, S. (1965). Effect of PCP-Na herbicide on sheath blight of rice plant.I. The inhibitive mechanism of the PCP-Na herbicide to the occurrence of the disease.II.Residual effectiveness of PCP-Na herbicide on Pellicularia sasakii (Shirai). S.Ito in irrigation. Bull. Coll. Agric. Vet. med. Nihon Univ. 20: 1-9, 11-17.

Eshel, Y. and Katan, J. (1972). Effect of dinitroanilines of solanaceous vegetables and soil fungi. Weed Sci. 20: 243-246.

Flentje, N.T. (1956). Studies on Pellicularia filamentosa (Pat) Rogers. I. Formation of the perfect stage. Trans. Br. Mycol. Soc. 39: 343-356.

Flentje, N.T., Stretton, H.M. and McKenzie, A.R. (1970). Mechanism of variation in Rhizoctonia solani. In. J.R. Parmeter, Jr. (ed). Rhizoctonia solani, Biology and Pathology. University of California Press, Berkeley, pp. 52-65.

*Frederiksen, T., Jorgensen, C.A. and Neilsen, O. (1938). Undersogelser Over Kartoflens of Rodfiltsvamp Og dens Bekaempelse. Tidsskr. Plantecvl. 42: 1-64.

Fukunaga, K. (1966). Antibiotics and new fungicides for control of rice diseases. 11th Pacific Sci. Congr. Plant diseases in the Pacific. Tokyo, 170-180.

Garrett, S.D. (1970). Pathogenic Root Infecting Fungi. London & New York: Cambridge. Univ. Press. pp. 294.

Gill, H.S. and Mehra, S.P. (1981). Tolerance of rice cultivars to butachlor and benthiocarb. Oryza. 18: 24-28.

Gokulapalan, C. (1981). Role of the rice root nematode in the incidence of sheath blight disease of rice in Kerala. M.Sc.(Ag.) Thesis. Kerala Agricultural University. pp. 89.

Grainstein, A., Katan, J. and Eshel, Y. (1976). Effect of dinitroaniline herbicides on plant resistance to soil borne pathogens. Phytopathology 66: 517-522.

Grist, D.H. (1953). Rice. Longman Green & Co., London, New York, Toronto, 142-147.

Hadar, Y., Chet, I., and Henis, Y. (1979). Biological control of Rhizoctonia solani damping off wheat bran culture of Trichoderma harzianum. Phytopathology 69: 64-68.

Hashioka, Y. and Makino, M. (1969). Rhizoctonia group causing the rice sheath spot in the temperate and tropical regions with special reference to Pellicularia sasakii and Rhizoctonia oryzae. Res. Bull. Fac. Agric. Gifu. Univ. 28: 51-63.

Hashioka, Y. and Saito, T. (1953). Phytopharmacology of the Rice diseases. I. In vitro tests on application of the dust fungicides to the important pathogenic fungi. Res. Bull. Coll. Agric., Gifu. 2: 12-18.

Haynes, W.D. (1955). Rice Mechanisation in Malaya. Int. Rice Comm. Newsl. 16(1): 6-7.

Henis, Y., Ghaffar, A. and Baker, R. (1978). Integrated control of Rhizoctonia solani damping off of radish: Effect of successive plantings, PCNB and Trichoderma harzianum on pathogen and disease. Phytopathology 68: 900-907.

*Hino, I. (1935). Antagonistic action of soil microbes with special reference to plant hygiene. Trans. third int. Congr. Soil Sci. 1: 173-174.

Hodges, C.F. (1980). Interaction of sequential leaf senescence of Poa pratensis and pathogenesis by Drechslera sorokiniana as influenced by post emergent herbicides. Phytopathology 70: 628-630.

*Ikata, S. and Hitomi, T. (1930). On the mode of primary infection through sclerotia and field observations on the basidiospore formation in the earliest stage of monko-disease (Hypochnus sasakii (Shirai) of the rice plants. J. Pl. Prot. Tokyo 17: 17-28.

Inderawati, E. and Heitefuss, R. (1977). Effects of herbicides on disease of rice (Oryza sativa). Weed Sci. 25: 441-447.

Inoue, Y. and Uchino, K. (1963). Studies on sheath blight of rice plant caused by Pellicularia sasakii (Shirai) S. Ito. I. Ecology of damage and chemical control. Minist. Agric. For Fish. Res. Council, Japan, appointed Expt. No.4 at Yamaguchi Agric. Exp. Stn. pp.136.

*Jaarsveld, A. (1942). The influence of various soil fungi on the virulence of Rhizoctonia solani Kuhn. Phytopath. Z. 14: 1-75.

Jagan Mohan, K.P. (1977). Studies on the control of sheath blight of rice caused by Corticium sasakii (Shirai) Matsumoto. M.Sc.(Ag.) Thesis, Kerala Agricultural University pp. 53.

Johnson, L.F. and Curl, E.A. (1972). Isolation of groups of microorganisms from soil. Methods for Research on the Ecology of Soil-Borne plant pathogens. Burgees Publishing Company.pp. 6-33.

*Josifovic, M. (1967). Hyperparasitism on fungi and the biological control of plant diseases. Studii Cerc. Biol., Ser. bot. 19: 173-180.

*Kannaiyan, S. and Prasad, N.N. (1979). Effect of foliar spray of certain fungicides in the control of sheath blight disease of rice. Res. Bull., Macco Agric. Digest 4: 3-6.

Kannaiyan, S., Govindarajan, K. and Levin, H.D. (1981). Studies on the chemical control of weeds in dry seeded wet land rice. Int. Rice Res. Newsl. 6(2): 14.

Karr, G.W., Jr., Gudauskar, R.T. and Dickens, R. (1979). Effect of three herbicides on selected pathogens and disease of turf grass. Phytopathology 69: 279-282.

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

*Kataria, H.R. and Dharam Singh, D. (1981). Pathogenesis of Pythium butleri on cowpea as influenced by two herbicides. Zeitschriftfur Pflanzenkrankheiten und Pflanzenschatz. 88: 734-743.

Kaushik, S.K. and Mani, V.S. (1978). Weed control in direct seeded and transplanted rice. Indian J. Weed Sci., 10: 73-78.

Kaushik, S.K. and Mani, V.S. (1980). Effect of chemical weed control on the nutrition and seed yield of direct sown rice. Indian J. Agric. Sci., 50: 41-44.

Kohli, C.K. (1967). Pathogenicity and host range studies on the paddy sheath blight pathogen. R. solani Kuhn. J. Res. Ludhiana 3: 37-40.

Kotwal, I., Vyas, S.C., Verma, R.K. and Jain, A.C. (1982). Laboratory screening of some herbicides against three pathogens. Pesticides 16: 13-14.

Kozaka, T. (1961). Ecological studies on sheath blight of rice plant caused by Pellicularia sasakii (Shirai) S. Ito and its chemical control. Chuyoku agric. Res. 20: 1-133.

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

*Kozaka, T., Sonku, Y. and Yunoki, T. (1957). Studies on the effectiveness of "Tuzet" for controlling sheath blight of rice plants. Chugoku Agrl. Res. 6: 1-42.

*Kurodani, K., Yokogi, K. and Yamamoto, M. (1959). On the effect of 2-4-dichlorophenoxy acetic acid to Mycelial growth of Hypochnus sasakii Shirai. Forsch. Geb. Pflahzenkrankh Kyoto 6: 132-135.

Lai, M.T. and Semeniuk, G. (1970). Picloram - induced increase of carbohydrate exudation from corn seedlings. Phytopathology 60: 563-564.

Lakshmanan, P. (1979). Studies on sheath blight of rice with special reference to the survival of the causal organism and control of the disease. M.Sc.(Ag.) Thesis. Kerala Agricultural University, pp.98.

Lakshmanan, P. and Nair, M.C. (1980). In vitro effects of certain herbicides on Rhizoctonia solani Kuhn. Pesticides, 14(11): 30-31.

Lakshmanan, P., Nair, M.C. and Menon, M.R. (1979 a). Collar rot and web blight of cowpea caused by Rhizoctonia solani in Kerala, India. Plant Dis. Reptr. 63: 292-330.

Lakshmanan, P., Bhavani Devi, S. and Nair, M.C. (1979 b). Occurrence of Thanatephorus cucumeris as a weed fungus on mushroom beds. Curr. Sci. 48: 543-544.

Lakshmanan, P., Nair, M.C. and Menon, M.R. (1980). Comparative efficiency of certain fungicides on the control of sheath blight of rice. Pesticides, 25(2): 31-32.

*Leontera, (Mme.N.) and Voitovich, (K). (1959). A new method for control of blister smut of Maize. Agrik. Viterit. Moldav. 3: 71-72.

Mahendra Prabhath, C.A. (1971). Studies on sheath blight of rice caused by Corticium sasakii (Shirai). Matsumoto M.Sc.(Ag.) Thesis, University of Kerala, pp. 80.

Mahendra Prabhath, C.A., Menon, M.R., Devi, L.R. and Ramakrishnan, C.K. (1974). Studies on the viability of sclerotia of Corticium sasakii (Shirai) Matsumoto. Agric. Res. J. Kerala 12: 96-98.

*Manila, C.E. and Lapis, D.B. (1977). Severity of rice blast, bacterial blight and sheath blight in rice after application with herbicides and insecticides. Philippine Agriculturist 61: 1-11.

Mathai, G. (1975). Studies on the effect of fungicides and silica in the control of sheath blight of rice caused by Corticium sasakii (Shirai) Matsumoto. M.Sc.(Ag.) Thesis, Kerala Agricultural University, pp. 58.

Mathur, S.B., and Sarbhoy, A.K. (1978). Biological control of Sclerotium root rot of sugarbeet. Indian Phytopath. 31: 365-367.

Matsumoto, T. (1921). Studies on the physiology of the fungi. XII. Physiological specialization in Rhizoctonia solani Kuhn. Ann. Missouri. Botan. Garden 8: 1-62.

Matsumoto, T. (1934). Some remarks on the taxonomy of the fungus Hypochnus sasakii Shirai. Trans. Sapporo Nat. Hist. Soc. 13: 115-120.

*Matsumoto, T., Yamamoto, W. and Hirane, S. (1932). Physiology and parasitism of the fungi generally referred to as Hypochnus sasakii (Shirai). Differentiation of the strains by means of hyphal fusion and culture in differential media. J. Soc. Trop. Agric. (Formosa) 4: 370-386.

*Matz, J. (1921). The Rhizoctonias of Porto Rico. Porto Rico Dept. Agr. J. 5(1): 31.

Michener, H.D. and Snell, N. (1949). Two antifungal substances from Bacillus subtilis cultures. Arch. Biochem. New York, 22: 208-214.

Millikan, D.F. and Fields, M.L. (1964). Influence of some representative herbicidal chemicals upon the growth of some soil-fungi. Phytopathology 54: 901.

*Miyake, I. (1910). Studien uber diepilze der. Reispflanze in Japan J. Coll. Agric. Tokyo 2: 237-276.

Mizuta, H. (1956). On the relation between yield and inoculation times of sheath blight Corticium sasakii in the earlier planted paddy rice. Ass. Pl. Prot. Kyashu. 2: 100-102.

Mosha, C.J., Mollel, S.L. and Sambai, L.M. (1977). Evaluation of three herbicides for dry planted rice. Miscellaneous Report. Tropical Pesticides Research Institute. 946: 7.

*Moursi, M.A., Rizk, T.Y., Fayed, M.T. and Harsennien, E.E. (1978). Effect of some recently developed herbicides applied with different methods on the common weeds in rice. Res. Bull. Fac. Agrl. Ain. Shams. Univ. 813: 15.

*Muangsombut, E.B. and Mercado, B.L. (1979). Decreased incidence of Rhizoctonia solani damping off in cowpea by trifluralin treatment. Philippine Agriculturist. 62: 226-231.

Mukherjee, N. (1978). Sheath blight of rice (Thanetophorus cucumeris) and its control possibilities. Pesticides, 12(2): 39-40.

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

Mussa, A.E.A., and Russell, P.E. (1977). The influence of pesticides and herbicides on the growth and virulence of F. solani f.sp. phaseoli. J. Agri. Sci. 88: 705-709.

*Naiki, T. and Ui, T. (1972). The microorganisms associated with the sclerotia of Rhizoctonia solani Kuhn in soil and their effects on the viability of the pathogen. Mem. Fac. Agric. Hokkaido Univ. 8: 252-256.

*Naim, M.S. and El-Esawy, A.A. (1965). Variations in the cultural characteristics of Rhizoctonia solani and its antagonists, Aspergillus terreus and Aspergillus flavus occurring in the rhizosphere of cotton. Mycopath. Mycol. appl. 27: 161-168.

Nair, M.C., Balakrishnan, B., Rajendran Pillai, M.V., Gokulapalan, C. and Aiyer, R.S. (1983). New strategy for the control of sheath blight of rice. Indian Phytopath. 36: 187.

Nair, H.R., Pillai, G.R., Pisharody, P.N. and Gopalakrishnan, R. (1975). Investigations on the competing ability of rice with weeds in the rainfed uplands. Agric. Res. J. Kerala 13: 146-151.

Nair, R.R., Vidyadharan, K.K., Pisharody, P.N. and Gopalakrishnan, R. (1974). Comparative efficiency of new herbicides for weed control in direct seeded rice fields. Agric. Res. J. Kerala 12: 24-27.

*Nisikado, Y. and Hirata, K. (1937). Studies on the longevity of sclerotia of certain fungi under controlled environmental factors. Bericht. Ohara Inst. Landwirts. Forsch. Kurashiki 7: 535-547.

*Ogura, H. and Akai, S. (1965). Studies on Rhizoctonia solani Kuhn (Pellicularia filamentosa (Pat) Rogers). IV. The activity of antagonists to R. solani Kuhn, Ann. Phytopath. Soc. Japan 30: 219-224.

*Olsen, C.M. (1965). Antagonistic effects of microorganisms on Rhizoctonia in soil. Diss. Abstr. 25: 3783-3784.

*Ono, K. and Iwata, K. (1961). Control of sheath blight disease of rice plant by PCP. Nogyo Oyobi Engei. 36: 71-74.

Ou, S.H. (1972). Rice diseases. Commonwealth Mycological Institute, Kew Surrey, England pp. 368.

*Palo, M.A. (1926). Rhizoctonia disease of rice. I. a. Study of the disease and the influence of certain conditions upon the viability of the sclerotial bodies of the causal fungus. Philipp. Agric. 15: 361-375.

Paracer, C.S. and Chahal, D.S. (1963). Sheath blight of rice caused by Rhizoctonia solani Kuhn, a new record in India. Curr. Sci. 32: 328-329.

*Park, M. and Bertus, L.S. (1932). Sclerotial diseases of rice in Ceylon. I. Rhizoctonia solani Kuhn. Ceylon J. Sci. Seet. 11: 319-331.

Parmeter, J.R., Sherwood, R.T. and Platt, W.D. (1969). Anastomosis grouping among isolates of Thanatephorus cucumeris. Phytopathology 59: 1270-1278.

Pillai, G.K. and Rao, M.V. (1974). Current studies of Herbicide research on rice in India. Paper presented at the Annual International Rice Research Conference held at I.R.R.I. Manila, Philippines from 22nd to 25th April, 1974.

Pommer, E.H. and Zwick, W. (1973). Efficacy of systemic fungicides against basidiomycetes. Indian Phytopath. 27: 53-58.

Radhakrishnan, T.C. (1975). Studies on the control of sheath blight of Rice caused by Corticium sasakii (Shirai) Matsumoto. M.Sc.(Ag.) Thesis, Kerala Agricultural University, pp.

Raghavelu, P. and Moorthy, V.S. (1976). Weed control in direct sown upland rice. Andhra Agric. J. 20: 20-22.

*Ramazanov, Kh.D. (1981). "Basagran" - An effective herbicide against clubrush in rice crops. Vestnik Sel'skokhozy aistvennoi Nauki Kazakh Stana 24: 37-39.

Ravindran, C.S. (1976). Chemical control of weeds in transplanted rice during third crop season. M.Sc.(Ag.) Thesis, Kerala Agricultural University. pp. 75.

Reinking, O.A. (1918). Philippine Economic Plant Diseases. Philipp. J. Sci. 13: 165-274.

*Richardson, L.T. (1959). Effect of insecticides and herbicides applied to soil on the development of plant Disease II. Early blight and Fusarium wilt of tomato. Can. J. Plant Sci. 39: 30.

*Richter, H. and Schneider, R. (1953). Studies on the morphological and biological differentiation of R. solani. Phytopath. Z. 20: 167-226.

Rodriguez-Kabana, R., Curl, E.A. and Funderburk, H.H. Jr. (1966). Effect of herbicides on growth of Rhizoctonia solani. Phytopathology 56: 1332-1333.

*Roy, A.K. (1977). Parasitic activity of Trichoderma viride on the sheath blight fungus of rice (Corticium sasakii). Z. Pflkrankh. Pflanzenschutz 84: 675-683.

Ryker, T.C. and Gooch, F.S. (1938). Rhizoctonia sheath spot of rice. Phytopathology 28: 233-246.

Saksena, H.K. (1979). Epidemiology of diseases caused by Rhizoctonia species. In Proceedings of the consultants group discussion on Resistance to soil borne diseases of legumes. Y.L. Nene (Ed.) ICRISAT. Andhra Pradesh, pp. 59-64.

Sanford, G.B. (1952). Persistence of Rhizoctonia solani (Kuhn) in soil. Can. J. Bot. 30: 652-664.

*Sawada, K. (1912). "Shirakinibuyo" of Camphor. Spec. Bull. Formosa Agric. Exp. Stn. 4: 805.

*Sezgin, E. (1978). Investigation on the effects of some herbicides on the growth and virulence of Rhizoctonia solani and Trichoderma viride. J. Turkish. Phytopathol. 7: 105-112.

*Sezgin, E., Karcililioglu, A. and Yemiscioglu, V. (1982). Investigations on the effects of some cultural applications and antagonistic fungi on Rhizoctonia solani Kuhn and Verticillium dahliae Klebb in Algean region. II. Effects of herbicides on antagonistic fungi. J. Turkish. Phytopathol. 11: 79-91.

*Shukla, A.N. and Dwivedi, R.S. (1979). Survival of Rhizoctonia solani Kuhn under the influence of staling growth products of some aspergilli and its growth response to some phenolic substances. Proc. Ind. Nat. Sci. Acad. 45(B): 269-272.

Sinclair, J.B. (1957). Laboratory and green house screening of certain fungicides for control of Rhizoctonia damping-off of cotton seedlings. Pl. Dis. Reptr. 41: 1045-1050.

Singh, R.A. and Pavgi, M.S. (1969). Oriental sheath and leaf spot of rice. Pl. Dis. Reptr. 53: 444-445.

Singh, R.P. and Singh, M. (1976). Effect of herbicides on weed control and yield of direct seeded rice under puddled condition. J. Scientific Res. Banaras Hindu University, 27(1-2): 51-54.

Sridhar, T.S., Yogeswar Rao, Y. and Sankar Reddy, G.H. (1976). Effect of granular herbicides on the control of weeds in rice directly seeded in puddled soil. Madras Agric. J., 61: 431-433.

Sumner, D.R., Glaze, N.C., Dowler, C.C. and Johnson, A.W. (1979). Herbicide treatments and root disease of turnip in intensive cropping system. Pl. Dis. Rept. 63: 801-805.

*Takatsu, S. and Nishimura, J. (1962). Studies on the control of sheath blight of rice plant.IV. Effect of sodium salt of pentachlorophenol. Bull. Hyogo Pref. agric. Exp. Stn. 10: 27-30.

*Takita, K., Tanaka, T., Nose, K. and Fukunaga, K. (1965). Organo arsenic fungicide. Relationship between anti-microbial activity and chemical constitution of organo arsenic compounds. Bull. natn. Inst. agric. Sci., Tokyo, Ser. C. 19: 1-46.

Talbot, P.H.B. (1970). Taxonomy and nomenclature of the perfect state. In J.R. Parmeter, Jr. (Ed). Rhizoctonia solani, Biology and Pathology, University of California Press, Berkeley, pp. 20-21.

*Tamura, H. (1965). Effect of organo-tin fungicides for control of rice blast and rice sheath blight. Bull. natn. Inst. agric. Sci. Tokyo Ser. G. 18: 135-204.

Tang, A., Curl, E.A. and Rodriguez-Kabana (1970). Effect of trifluralin on inoculum density and spore germination of Fusarium oxysporum f. sp. vasinfectum in soil. Phytopathology 60: 1082.

*Tatsuyama, K.S. and Jakihara, K. (1970). Influence of herbicide treatments on the occurrence of soil-borne plant disease. Ann. Phytopath. Soc. Japan 36:290-294.

Tsai, W.H. (1970). Studies on relations between weeds and Rice diseases. I. Observations on the host range of Rice sheath blight fungus (Pellicularia sasakii) on weeds. J. Taiwan Agric. Res. 19: 48-51.

Tsai, W.H. (1974). Assessment of yield losses due to rice sheath blight at different inoculation stages. J. Taiwan Agric. Res. 23: 188-194.

Tsai, W.H. (1975). Studies on the relationships of disease severity to yield and yield loss in rice sheath blight disease. Plant Bull. Taiwan 17: 410-417.

Thirumalachar, M.J., Pavgi, M.S. and Singh, R.A. (1969). In vitro activity of three antifungal antibiotics against Protomyces macrosporus, Taphrina maculans and Corticium sasakii. Hindustan Antibiotic Bull. 11: 189-190.

*Umeda, V. (1973). Hinosan, a fungicide for control of rice blast. Japan Pesticide Information 17: 25-28.

Vacchani, M.V., Choudhari, M.S. and Mitra, M.N.N. (1963). Control of weeds in rice by selective herbicides. Paper presented at Rice Research Workers Conference, Cuttack.

Varma, A.S. and Menon, M.R. (1977). Fungicidal trial on the control of sheath blight of rice. Madras Agric. J. 64: 416-417.

Varma, A.S., Peethambaran, C.K., Balakrishnan, S. and Menon, M.R. (1978). *In vitro* effects of certain herbicidal formulations on *Corticium sasakii* (Shirai) Matsumoto. *Agri. Res. J. Kerala* **16**: 114-116.

Vasavan, M.G., Rajan, K.M., and Thomas, M.J. (1980). Herbicides in plant disease control. *IRRN*. **5**: 18.

*Vasudeva, R.S. and Chakravarthy, B.P. (1954). The antibiotic action of *Bacillus subtilis* in relation to certain parasitic fungi, with special reference to *Alternaria solani* (Ell & Mart) Jones & Grout. *Ann. Appl. Biol.* **41**: 612-618.

Verma, O.P.S., Tyagi, R.C. and Katyal, S.K. (1978). Efficacy of new herbicides on the control of weeds in transplanted rice in Haryana State. *Pesticides* **12**: 21-22.

Verma, R.K., Vyas, S.C., Shastry, P.I. and Jain, A.C. (1979). Laboratory screening of some herbicides against three soil borne fungi. *Indian Phytopath.* **32**: 394-396.

Vyas, S.C. and Khare, M.N. (1983). Seminar on pesticides and Environment. Aug. 4-5, 1983. Abstract of papers. Dept. of Entomology. Tamil Nadu Agrl. Univ. Coimbatore.

Weber, G.F. (1963). *Pellicularia* spp. Pathogenic on sorghum and pearl millet in Florida. *Pl. Dis. Reptr.* **47**: 654-656.

Weerd, J.C.V. and De (1977). *Cyperus difformis* - world wide rice economy. *Agricultural News from BASF*. **2**: 7-10.

*Wei, C.T. (1934). Rhizoctonia sheath blight of rice. *Bull. Univ. Nanking Coll. Agric. For.* **15**: 21.

Weindling, R. (1932). Trichoderma lignorum as a parasite of other soil fungi. Phytopathology 22: 837-845.

Weindling, R. (1934). Various fungi recently found to be parasitic on Rhizoctonia solani. Phytopathology 24: 1141.

*Yamamoto, H., Iwata, T., Shibata, M., Mizuno, K. and Miyake, A. (1965). Streptomyces multispiralis knob.sp. and a new antibiotic, neobumidin, which controls sheath blight. Pellicularia filamentosa sasakii on rice. Agric. Biol. Chem. 29: 360-368.

*Yoshimura, S. (1954). On the scale for estimating degree of severity of sheath blight by Hypochnus sasakii (Shirai) in rice plant. Ann. Phytopath. Soc. Japan 19: 58-60.

Zahidul Hoque, M., Hobbs, P.R. and Ahmed, A. (1978). Weed management studies on direct seeded and transplanted rice in 1976. in Bangladesh. IRRN. 3: 19-20.

*Originals not seen

# APPENDICES

APPENDIX I

LIST OF HERBICIDES AND THEIR CHEMICAL NAMES REFERRED IN THIS THESIS



| Sl.No. | Common name | Chemical name |
|---|---|---|
| *1. | Aretit | 4-6-dinitro-2-Sec-butylphenyl acetate |
| 2. | Atrazine | 2-Chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine |
| 3. | Benifin | N-butyl-N-ethyl-2,6-dinitro-4-trifluoromethylaniline |
| 4. | Bensulide | N-(2-(O,O-di-isopropyldithiophosphorul.)ethyl)benzene sulphonamide |
| 5. | Bentazon | 3-isopropyl-2,1,3,-benzothiadiazin-4-one-2,2-dioxide |
| 6. | Benthiocarb | S-(4-Chlorobenzyl)-N,N-diethylthiolcarbamate |
| 7. | Butachlor | N-(butoxymethyl)-α-chloro-2,6-diethylacetanilide |
| 8. | Butralin | N-S-butyl-4-t-butyl-2,6-dinitroaniline |
| 9. | 2,4-D | 2,4-Dichlorophenoxy acetic acid |
| 10. | Dinitramine | N',N'-diethyl-2,6-dinitro-4-trifluoromethyl-m-phenylenediamine |
| 11. | Dinoseb | 2-(1-methylpropyl)-4,6-dinitrophenol |
| 12. | Diuron | N'-(3,4-dichlorophenyl)-N,N-dimethyl urea |
| 13. | E.P.T.C. | S-ethyl N, N-dipropyl (thiocarbamate) |
| 14. | Fluchloralin | N-(2-chloroethyl)-2,6-dinitro-N-propyl-4-(trifluoromethyl)aniline |
| 15. | Fluometuron | N'-(3-trifluoromethylphenyl)-N,N-dimethyl urea |
| 16. | Linuron | N'-(3,4-dichlorophenyl)-N-methoxy-N-methylurea |
| 17. | Machete | 2-Chloro-2,6-dimethyl-N-(butoximethyl) acetanilide |
| 18. | M.C.P.A. | 4,Chloro-2-methylphenoxy acetic acid |
| 19. | Nitralin | 4-(methylsulphonyl)-2-6-dinitro-N,N-dipropylaniline |

continued

| Sl.No. | Common name | Chemical name |
|---|---|---|
| 20. | Nitrofen | 2,4-dichlorophenyl 4-nitrophenyl ether |
| 21. | Paraquat | 1,4'-dimethyl-4,4'-bipyridylium |
| 22. | P.C.P. | Pentachlorophenol |
| 23. | Pendimethalin | N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine |
| 24. | Picloram | 4-amino-3,5,6-trichloropicolinic acid |
| 25. | Prometryne | 4,6-bisisopropylamino-2-methylthio-1,3,5-triazine |
| 26. | Propanil | N-(3,4-dichlorophenyl) propionamide |
| *27. | Pyramin | 1-phenyl-4-amino-5-chloro-pyridazone-6. |
| 28. | Simazine | 2-chloro-4,6-bisethylamino-1,3,5-triazine |
| 29. | Simetryne | 4,6-bisethylamino-2-methylthio-1,3,5,-triazine |
| 30. | Sirmate | 3,4,Dichlorobenzyl Methyl carbamate |
| *31. | Tillam | n-propyl N-ethyl-N(n-butyl)thiolcarbamate (PEBN) |
| 32. | Trifluralin | 2,6-dinitro-N,N-dipropyl-4-trifluoro-methylaniline |

Ref: List of common names and chemical names of Herbicides
Weed abstracts - May 1983 Vol. 32. No.5.

*Weeds of the world - Biology and Control - Lawrence J.King, 1974
Wiley Eastern Private Ltd., New Delhi.

## APPENDIX II

### POTATO DEXTROSE AGAR

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

## APPENDIX III

### SAND MAIZE MEDIUM

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

## APPENDIX IV

### MARTINS' ROSE BENGAL STREPTOMYCIN AGAR

| | | |
|---|---|---|
| Dextrose | - | 10.0 g |
| Peptone | - | 5.0 g |
| Potassium dihydrogen phosphate | - | 1.0 g |
| Rose bengal | - | 1 part in 30000 parts in the medium |
| Agar | - | 20.0 g |
| Streptomycin | - | 30.0 g |
| Distilled water | - | 1000 ml |

## APPENDIX V

### SOIL EXTRACT AGAR

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

## APPENDIX VI

### KUSTERS MEDIUM

| | | |
|---|---|---|
| Agar | - | 20.0 g |
| Glycerol | - | 10.0 g |
| Casin | - | 0.3 g |
| $MgSO_4$ | - | 0.5 g |
| $FeSO_4$ | - | 0.1 g |
| $KNO_3$ | - | 2.0 g |
| NaCl | - | 2.0 g |
| $K_2HPO_4$ | - | 0.5 g |
| $CaCO_3$ | - | 0.2 g |

APPENDIX VII

Analysis of variance table

Effect of herbicides on radial growth of R. solani 60 hours and 120 hours after $x+1$ transformation

| Source | Df | 60 hours | | 120 hours | |
|---|---|---|---|---|---|
| | | M.S.S. | F Calculated | M.S.S. | F Calculated |
| Total | 143 | | | | |
| Between Herbicides | 7 | 87.69 | 2072.48** | 46.15 | 30.99** |
| Between levels within herbicides | | | | | |
| H1 | 5 | 31.89 | 753.84** | 3.13 | 2.10 |
| H2 | 5 | 0.20 | 4.84** | 0.00 | 0.00 |
| H3 | 5 | 26.90 | 635.73** | 36.00 | 24.16** |
| H4 | 5 | 35.74 | 844.73** | 51.47 | 34.55** |
| H5 | 5 | 36.23 | 856.32** | 28.43 | 19.08** |
| H6 | 5 | 28.69 | 678.07** | 40.02 | 26.86** |
| H7 | 5 | 31.28 | 739.20** | 43.53 | 29.22** |
| H8 | 5 | 11.68 | 276.17** | 0.00 | 0.00 |
| Error | 96 | 0.42 | | 1.48 | |

| | | |
|---|---|---|
| 60 hours | 1. C.D. for comparison between herbicides | = 0.13 |
| | 2. C.D. for comparison between levels within herbicides | = 0.33 |
| 120 hours | 1. C.D. for comparison between herbicides | = 0.81 |
| | 2. C.D. for comparison between levels within herbicides | = 1.90 |

**Significant at 1% level

## APPENDIX VIII

### Analysis of variance table

Effect of herbicides on number of sclerotia after x+1 transformation

| Source | Df | M.S.S. | F Calculated |
|---|---|---|---|
| Total | 122 | | |
| Treatment | 40 | | |
| Herbicide | 7 | 216.94 | 225.47** |
| Between levels within herbicide | 32 | 3.40 | 3.54** |
| Treatment Vs Control | 1 | 106.47 | 110.65** |
| Error | 82 | 0.96 | |

C.D. for comparison between herbicides = 0.71

C.D. for comparison between levels within herbicides = 1.60

**Significant at 1% level

## APPENDIX IX

### Analysis of variance table

Effect of herbicides on size of sclerotia after transformation x+1

| Source | Df | M.S.S. | F calculated |
|---|---|---|---|
| Total | 47 | | |
| Treatment | 15 | | |
| Between herbicide | 2 | 0.582 | 198.39** |
| Treatment Vs Control | 1 | 0.007 | 2.41 |
| Between levels | 12 | 0.142 | 48.61** |
| Error | 32 | 0.002 | |

C.D. for comparison between levels = 0.09

C.D. for comparison within herbicide = 0.04

**Significant at 1% level

APPENDIX X

Analysis of variance table

Viability of sclerotia recovered from pots treated with different herbicides

| Source | Df | M.S.S. | F Calculated |
|---|---|---|---|
| Total | 35 | | |
| Treatment | 9 | 345.000 | 4.56* |
| Error | 27 | 75.647 | |

C.D. for comparison between treatments = 12.619

## APPENDIX XI

### Analysis of variance table

Effect of various herbicides on sheath blight incidence and intensity (Pot culture)

| Source | Df | Incidence (Tiller infection) | | Intensity (Disease index) | |
|---|---|---|---|---|---|
| | | M.S.S. | F Calculated | S.S. | F Calculated |
| Total | 35 | | | | |
| Treatment | 8 | 465.96 | 6.4** | 654.88 | 16.34** |
| Error | 27 | 71.96 | | 40.06 | |

C.D. for comparison between treatments for incidence = 12.30

C.D. for comparison between treatment for intensity = 9.18

APPENDIX XII

Analysis of variance table

Effect of various herbicides on the control of Sheath Blight (Field Experiment)

| Source | Df | Per cent hill infection | | Disease Index | |
|---|---|---|---|---|---|
| | | M.S.S. | F Calculated | M.S.S. | F Calculated |
| Total | 47 | | | | |
| Treatment | 15 | 259.72 | 9.19** | 133.26 | 9.32** |
| Error | 30 | 28.25 | | 14.29 | |

| | |
|---|---|
| C.D. for comparison between treatments for per cent hill infection | 8.86 |
| C.D. for comparison between treatments for disease index | 6.30 |

**Significant at 1% level

APPENDIX XIII

Analysis of variance table

Effect of various herbicides on grain and straw yield

| Source | Df | Grain yield | | Straw yield | |
|---|---|---|---|---|---|
| | | M.S.S. | F Calculated | M.S.S. | F Calculated |
| Total | 47 | | | | |
| Treatment | 15 | 0.758 | 3.575* | 4.99 | 1.32 |
| Error | 30 | 0.212 | | 3.77 | |

C.D. for comparison of treatment means for grain yield $\bar{x}$ = 0.767

*Significant at 5% level

APPENDIX XIV

Analysis of variance table

Effect of various herbicides on the control of weeds (Total weed population) at different intervals

| Source | Df | 20th | | 40th | | 60th | | At harvest | |
|---|---|---|---|---|---|---|---|---|---|
| | | M.S.S. | F Calculated | M.S.S. | F Calculated | M.S.S. | F Calculated | M.S.S. | F Calculated |
| Total | 47 | | | | | | | | |
| Treatment | 15 | 10.07 | 11.88** | 2.178 | 2.52* | 6.16 | 3.19** | 9.78 | 5.92** |
| Error | 30 | 0.847 | | 0.861 | | 1.93 | | 1.65 | |

C.D. for comparison between treatments (20 days) = 1.53

" " (40 days) = 1.54

" " (60 days) = 2.31

" " (At harvest) = 2.14

* Significant at 5% level

** Significant at 1% level

APPENDIX XV

Analysis of variance table

Effect of various herbicides on control of weeds (Total dry weight of weeds) at different intervals

| Source | Df | 20th | | 40th | | 60th | | At harvest | |
|---|---|---|---|---|---|---|---|---|---|
| | | M.S.S. | F Calculated | M.S.S. | F Calculated | M.S.S. | F Calculated | M.S.S. | F Calculated |
| Total | 47 | | | | | | | | |
| Treatment | 15 | 0.144 | 5.97** | 1.439 | 3.615** | 9.80 | 5.7** | 9.78 | 5.92** |
| Error | 30 | 0.241 | | 0.398 | | 1.69 | | 1.65 | |

C.D. for comparison between treatments (20 days) = 0.259

" " " (40 days) = 1.051

" " " (60 days) = 2.167

" " " (At harvest) = 2.140

**Significant at 1% level

APPENDIX XVI

Analysis of variance table

Effect of different herbicidal application on formation of productive tillers

| Source | Df | M.S.S. | F Calculated |
|---|---|---|---|
| Total | 47 | | |
| Treatment | 15 | 1360.00 | 2.05* |
| Error | 30 | 660.95 | |

C.D. for comparison of treatment means = 42.86

*Significant at 5% level

APPENDIX XVII

Analysis of variance table

Effect of herbicidal treatment on population of soil microflora (Pot culture) 7 days after spraying

| Source | Df | Fungi M.S.S. | Fungi F Calculated | Bacteria M.S.S. | Bacteria F Calculated | Actinomycetes M.S.S. | Actinomycetes F Calculated |
|---|---|---|---|---|---|---|---|
| Total | 26 | | | | | | |
| Treatment | 8 | 675.25 | 4.55** | 1346.70 | 112.97** | 8504.20 | 146.77** |
| | | | 3.71 | | | | |
| Error | 18 | 148.11 | | 11.92 | | 57.94 | |

C.D. for comparison of treatment mean for fungi = 20.87

" " " bacteria = 5.92

" " " actinomycetes = 13.05

**Significant at 1% level

APPENDIX XVIII

Analysis of variance table

Effect of herbicidal treatment on population of soil microflora in wet land (Field experiment) 30 days after spraying

| Source | Df | Fungi | | Bacteria | | Actinomycetes | |
|---|---|---|---|---|---|---|---|
| | | M.S.S. | F Calculated | M.S.S. | F Calculated | M.S.S. | F Calculated |
| Total | 31 | | | | | | |
| Treatment | 15 | 72.85 | 5.54** | 174.5 | 1 | 2.498 | 1 |
| Error | 15 | 13.13 | | 434.6 | | 3.000 | |

C.D. for comparison of treatment means = 7.721

**Significant at 1% level

# EVALUATION OF VARIOUS HERBICIDES ON THE CONTROL OF SHEATH BLIGHT DISEASE *(Rhizoctonia Solani* Kuhn) ON RICE

By

**LAKSHMY T. R.**

**ABSTRACT OF A THESIS**

SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENT FOR THE DEGREE

**MASTER OF SCIENCE IN AGRICULTURE**

**(PLANT PATHOLOGY)**

FACULTY OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

Department of Plant Pathology

College of Agriculture, Vellayani, Trivandrum.

1984

ABSTRACT

Both *in vitro* and *in vivo* studies on the effect of few common herbicides on *Rhizoctonia solani* and on sheath blight of rice, were carried out.

The *in vitro* studies revealed that Propanil (Stam F.34) was the most toxic herbicide to *Rhizoctonia solani* Kühn, the rice sheath blight pathogen, which completely inhibited mycelial growth at a very low concentration of 125 ppm. Benthiocarb, Nitrofen (Tok E.25) and Butachlor also have high potentiality in decreasing radial growth and also in inhibiting the formation of sclerotia.

Soil borne sclerotia was found the major source of inoculam in initiating sheath blight diseases. Among the various herbicides tested, Nitrofen, Propanil and Butachlor reduced the degree of pathogenicity of soil borne sclerotia of R. solani; Propanil effected maximum reduction of sheath blight in pot culture experiments followed by Nitrofen. Butachlor and Nitrofen were equally effective in reducing sheath blight under pot culture experiment. Nitrofen (Tok E.25) applied at 1.5 kg ai, 1.75 kg ai were equally effective as Hinosan in reducing sheath blight in field trial also.

Fluchloralin and Pendimethalin were unfavourable for growth and survival of *R. solani* in culture, but Pendimethalin resulted in an increase in sheath blight disease under pot culture experiment and also in the field

trial.

Bentazon stimulated growth, formation and germination of sclerotia in culture, but ranked first in reducing sheath blight incidence under pot culture experiment. In the field trial Bentazon 1.25 kg ai/ha was as effective as Hinosan treatment in reducing sheath blight.

2,4-D Sodium salt stimulated growth and formation of sclerotia after an initial lag growth phase in culture, and also increased the incidence and intensity of sheath blight under pot culture experiment.

At the early stage Bentazon 1.5 kg ai/ha, and Benthiocarb 1.5 kg ai/ha reduced weed population in the field trial.

Bentazon stimulated growth of fungi, bacteria and actinomycetes in soil, but Nitrofen (Tok E.25) and Fluchloralin inhibited all these three major soil microorganisms. Butachlor, Propanil and 2,4-D Sodium salt stimulated bacterial population and Pendimethalin stimulated actinomycetes in soil. There was not much variation in soil microflora after one month.

Aspergillus niger and Trichoderma viride were found to be highly antagonistic to Rhizoctonia solani in culture.