STUDIES ON THE CONTROL OF SOFT ROT OF GINGER

BY

V. KURUCHEVE

THESIS

Submitted in partial fulfilment of the Requirements for the degree of MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Pathology
College of Horticulture
VELLANIKKARA :: TRICHUR

1980

DECLARATION

I hereby declare that this thesis entitled "STUDIES ON THE CONTROL OF SOFT ROT OF GINGER" is a bonafide record of work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

College of Horticulture,
Vellanikkara,
7th July, 1980.

Kurucheve, V.

CERTIFICATE

Certified that this thesis is a record of research work done independently by Sri.Kurchheve, V. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellanikkara,
7th July, 1980.

Dr. C.K. Peethambaran,
Assistant Professor,
Department of Plant Pathology.

Approved by:

Chairman: Dr. C.K. Peethambaran

Members:

1. Dr. Abi Cheeran

2. Dr. C.C. Abraham

3. Dr. R.Vikraman Nair

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude and indebtedness to Dr. C.K. Peethambaran, Assistant Professor, Department of Plant Pathology, College of Horticulture, Vellanikkara for suggesting this problem, valuable guidance and encouragement and constant help in the preparation and presentation of this thesis.

I am very grateful to Dr. Abi Cheeran, for all his help and guidance as Head of Department of Plant Pathology and member of Advisory Committee during the investigation. I am also thankful to Dr. C.C. Abraham, Professor of Agricultural Entomology, Dr. R. Vikraman Nair, Associate Professor of Agronomy, College of Horticulture, Vellanikkara for having rendered valuable advice and suggestions as members of the Advisory Committee.

It is my privilege to thank Dr.P.C. Sivaraman Nair, Associate Dean, College of Horticulture, Vellanikkara for providing necessary facilities and encouragement for conducting the research project.

I wish to place on record my deep sense of gratitude and indebtedness to Sri.P.N. Pishorady, Director of Research I/c for approving the project as the University research project and for encouragement.

My special thanks to Sri. V. Sukumara Pillai, Head of Pepper Research Station, Panniyoor; Sri. P.V. Prabhakaran, Associate Professor of Agricultural Statistics, Dr. A.I. Jose, Associate Professor of Soil Science and Agricultural Chemistry, Sri. A. Sukumara Varma, Assistant Professor of Plant Pathology, Sri.S. Ravi and Kumari. Sally K. Mathew, Junior Assistant Professors of Plant Pathology for their constant help throughout the course of this investigation.

In this connection, I wish to express my sincere thanks to my colleague and friends for their cooperation and assistance rendered in the successful completion of this thesis.

The award of the Research Fellowship by the Kerala Agricultural University is gratefully acknowledged.

Vellanikkara,
7th July, 1980.

Kurucheve, V.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

INTRODUCTION

Among the spice crops, for which the Malabar coast is famous all over the world from very ancient times, Ginger occupies a notable position. The produce from the crop, synonymously termed as 'Ginger' is the green or dried rhizome of the herbaceous perennial plant Zingiber officinale Rosc. belonging to the family Zingiberaceae.

India is the foremost country in the production of ginger, its contribution being roughly 50 per cent of the world production (George and Velappan, 1980). The annual production of ginger in this country is estimated to be 70,000 tonnes from about 36,000 hectares, of which, nearly 50 per cent is the contribution of Kerala State (Lakshmanachar, 1980). In terms of export earnings, it stands only next to Pepper and Cardamom, the figure being 130 million rupees worth of foreign exchange during 1978-79.

Due to its ability to adapt under a broad spectrum of agroclimatic conditions, ginger is grown in almost all the States of India to a lesser or greater extent. In all these tracts, diseases attacking the crop is the major problem, hampering production and causing heavy losses to cultivators. A number of pathogens are reported to infect ginger, causing a large number of diseases. Well known among them are the soft rot disease (*Pythium* spp.), bacterial wilt (*Pseudomonas solanacearum*), yellows disease (*Fusarium* spp.) and leafspot (*Phyllosticta zingiberi*). Minor diseases caused by fungal pathogens such as *Helminthosporium*, *Cercospora*, *Piricularia*, *Rhizoctonia*, *Glomerella*, *Coniothyrium*, *Septoria*, etc. and a virus disease too has been reported from different parts of India.

Among the diseases, the soft rot caused by *Pythium* spp. of fungi is the most serious threat to ginger cultivation due to its widespread and devastating nature. Apart from the crop damage in the field, the stored rhizomes too are affected by these pathogens. Several species of *Pythium* are reported to cause soft rot of ginger resulting in the death of the plant in the field and shrinkage and rot of stored rhizomes. Among them, *Pythium aphanidermatum* (Edson) Fitz. (Mitra and Subramanian, 1928) and *P. myriotylum* Drechsler (Uppal, 1940; Park, 1941; Bertus, 1942) are known to be most common and potent pathogens. Other species of *Pythium* causing soft rot of ginger are *P. butleri* Subram. (Thomas, 1938), *P. complectans* Braun. (Park, 1934), *P. deliense* Meurs. (Haware and Joshi, 1974), *P. gracile* (de Bary) Schrenk. (Butler, 1907), *P. graminicolum* Subram. (Park, 1935) and *P. vexans* de Bary. (Ramakrishnan, 1949). Butler and Bisby (1931) considered *P. butleri* and *P. gracile* to be identical with P. aphanidermatum. Pythium species is an important group of soil-borne fungi, causing several diseases such as rhizome rot, foot rot, pre emergence and post emergence damping off of various cultivated crop plants.

Mainly, two sources of infection are identified viz., infected seed materials and over wintering oospores or hibernating mycelium in the soil. The disease incidence is greater when infected seed materials are used for planting, resulting in pre emergence rotting. So also, severity of the disease is more when there is heavy rainfall resulting in post emergence rotting.

Usually, the disease is not amenable to common fungicides, systemic or contact. It is not therefore surprising that efforts to control the disease has not, so far, met with complete success.

In the present study, an attempt has been made to find out the pathogen responsible for causing soft rot of ginger in the acid lateritic soils of Vellanikkara. Effect of intensity of rainfall on the severity of the disease is also studied. The widely accepted control measure, though not fully effective, is soil drenching with fungicides. In the present investigation, the efficacy of different fungicides in controlling the disease were compared, when applied at different stages of crop growth and in different sequential combinations. Two popular varieties of ginger viz. 'Rio-de-janeiro' and 'Maran' were subjected to the studies.

Review Of Literature

REVIEW OF LITERATURE

The most serious disease of ginger is the soft rot caused by *Pythium* species. Butler (1907) first reported the prevalence of this disease from Surat (Gujarat) in India caused by a species of *Pythium* which was identified as *P. gracile* Sehrenk. Later Butler (1918) stated that the species isolated from ginger differed from *P. gracile* described by Sehrenk and suggested that this might be a new species. Subramaniam (1919) studied the disease from Pusa and he was in full agreement with Butler's (1907, 1918) description about the pathogen and renamed it as *P. butleri* Subram. Later Mitra and Subramanian (1928) from their cross inoculation studies, came to the conclusion that *P. butleri* is a strain of *Pythium aphanidermatum* (Eds). Fits. Butler and Bisby (1931) found *P. gracile* and *P. butleri* to be identical with *P. aphanidermatum*. Sen (1930) reported this pathogen from Assam causing soft rot of ginger.

Park (1941) observed that Surat ginger imported from India and planted in the central and south western divisions of Ceylon developed a soft rot disease and isolated *P. myriotylum* from the affected part which on inoculation in the laboratory showed to be an active parasite on all varieties of ginger, though it was not found on any ginger except that imported from India. He further stated that the local species responsible for the disease in Ceylon was probably P. complectans and that more than one species may be responsible for the disease in India. Uppal (1940) reported that the soft rot of ginger was also caused by P. myriotylum in Bombay State. Bertus (1942) reported from Ceylon that an experimental consignment of Surat ginger from Hong Kong was found to be severely infected with P. myriotylum.

Ramakrishnan (1949) isolated P. aphanidermatum, P. myriotylum and P. vexans (= P. complectans) from diseased rhizomes in Wynad area. He found that the symptoms produced by P. vexans was akin to those caused by P. aphanidermatum and P. myriotylum on ginger. He further observed that the distribution of P. vexans was restricted to areas of high altitude whereas in the other regions it was P. aphanidermatum or P. myriotylum. Besides the damage in the field, these pathogens caused 50 - 90 per cent damage to stored seed rhizomes. Shahare and Asthana (1962) studied rhizome rot of ginger and stated that, of the four Pythium spp. isolated from diseased material, only P. aphanidermatum and P. myriotylum proved pathogenic.

Haware and Joshi (1974) reported that in addition to *P. aphanidermatum* and *P. vexans*, which cause soft rot of ginger, *P. deliense* could also cause seed rhizome rot and pre emergence damping off of the seedlings. They also reported that when the rhizomes were planted in infested soil, the vigour of the seedling was poor and the plants were succumbed to the disease in adult stage.

There are reports of other organisms involved in rhizome rot of ginger from outside India. Pordesimo and Raymundo (1963) reported the bacterial rot of ginger from Phillippines. osenberg (1963) reported the ginger rhizome rot caused by *Fusarium solani* from Hawaii. He found that other unidentified *Fusarium* spp. were carried over from one planting season to another in the infected seed pieces and soil. Trujillo (1963) studied the *Fusarium* yellows and rhizome rot of ginger in Hawaii. He reported that *Fusarium oxysporum* was consistently associated with the wilted ginger plants in several localities in Hawaii. The inoculated rhizomes developed symptoms in three weeks and were completely rotted in six weeks. The isolate was designated as *Fusarium oxysporum f.* sp. *zingiberi*. *Fusarium* rhizome rot of ginger in Queensland was reported by Teakle (1965).

P. aphanidermatum besides being pathogenic to ginger is pathogenic to an array of other cultivated crops, causing such diseases as damping off, cottony leak, watery root rot, black rot etc. Edson (1915) found the fungus to cause damping off of sugarbeet and raddish seedlings. Subramaniam (1919) observed it on tobacco, papaya and chillies in India. Vaughan (1924) and Gardner (1925) reported a black rot of raddish in Indiana due to *P. aphanidermatum*. Drechsler (1925) described a cottony leak of cucumbers and egg plant in United States by *P. aphanidermatum*. Mitra and Subramanian (1928) found the fungus to cause fruit rot disease on *Luffa actutangula*, *Trichosanthes anguina*, *Cucumis sativus*., *C. melo*, and *Mimordica charantia*. Wright (1930) reported the root rot of *Colocasia antiquorum* to be caused by this fungus. A watery root rot caused by *P. aphanidermatum* on watermelon, muskmelons, honeydew melon and squash in Arizona was reported by Gottieb and Butler (1939). Chiu *et al*. (1945) described the occurrence of the fungus in Kiangsu province of China on *Beminoasa hispida*, watermelon, cucumber, vegetative marrow, squash, *Lagenaria leucantha*, *Luffa actutangula*, *L. cylindrica*, *Mimordica charantia*, cotton, tobacco, egg plant, sweet potato, chinese cabbage, *Pachyrrhizus tuberosus*, *Inomoea reptans*, *Amaranthus tricolar* and *Aleurites fordii*.

Pythium spp. have been found to survive in soil for periods of 2 - 12 years (Hoppe, 1966) but the survival structures in different species have not been adequately demonstrated. Lockwood (1960) showed that mycelium of P. aphanidermatum was completely destroyed when four day old cultures on agar media were covered with field soil for one or two weeks. The role of zoospores in survival is not clear. Luna and Hine (1964) demonstrated that zoospores of P. aphanidermatum encyst rapidly on being introduced into soil not containing a natural population of the fungus. The organism was recovered seven days after seeding with zoospores. This indicates that zoospores can survive as resistant structures for a short span of time (Trujillo and Hine, 1965). Some workers have reported that in sphaerosporangiate group of Pythium, sporangia can act as a survival structure in soil. Stanghellini and Nigh (1972) reported that the oospores of Pythium spp. survive for a long period of time and germinate when stimulated. They were able to record the oospore of P. aphanidermatum after 16 months from infested oat roots, burried at 5 cm and 20 cm depth in fallow field soil. Microscopic examination revealed that colonies of the fungus originated from oospores within the infested root tissues. No lobulate sporangia or mycelia was observed in the roots. Thomas (1938) reported that oospores of the fungus were found on the scales of preserved rhizomes of ginger which under certain conditions damaged the stored rhizomes.

Trujillo and Marclay (1966) observed that oospores of P. aphanidermatum were able to withstand extreme conditions and survive in dry soil at freezing temperature for several months. Peethambaran (1975) reported that vegetative hyphae of P. aphanidermatum and P. graminicolum survived for less than 10 days in air dry or wet soil at 25°C or at room temperature. Sporangia of P. aphanidermatum survived for 6 weeks in air dry soil and for 4 weeks in wet soil at 25°C and room temperature while sporangia of P. graminicolum survived for 4 and 2 weeks, respectively, under similar conditions of incubation. Oospores of these 2 species survived for more than 48 weeks under different conditions of incubation. But a fixed temperature of 25°C was more favourable than fluctuating temperature for prolonging viability of oospores in soil and the dry soil was more favourable than wet soil for retaining viability of oospores.

Indrasenan and Paily (1974) reported that among the 21 varieties tested, Maran was the most resistant variety against P. aphanidermatum infection while Balagopal et al. (1975) found Nadiya and Narasapattam were moderately resistant to this disease out of 22 varieties tested by them.

Using Poison food technique Fawcett *et al*. (1957) assessed the activity of a wide range of fungicides on *P. ultimum*. Soumini Rajagopalan (1961) found that, out of 6 fungicides tried only ceresan wet at 1000 and 2000 ppm was found fungicidal to *P. aphanidermatum*. Grover and Dutt (1972) reported that ceresan wet at low concentrations *in vitro* was the most inhibitory to mycelial growth and the formation of sporangium and oospore. Indra Malhan *et al*. (1975) observed that *P. aphanidermatum* and *P. butleri* were least sensitive to benomyl. Seema Wahab and Sharma (1976) found that ceresan 700 ppm was sufficient to inhibit the growth of *P. aphanidermatum* completely. They also reported that thiram ranked first out of five fungicides tried. Sivan *et al*. (1978) reported that 2000 ppm of captan, 500 ppm of aretan, 1000 ppm of thiram and dexon each gave 100 per cent inhibition of *P. debaryanum*. Sharma and Joshi (1979) reported that out of five fungicides tested against *P. myriotylum*, *in vitro*, only four fungicides namely bavistin, dithane M-45, ceresan and kitazin gave good control. Benlate was not effective.

Several studies aimed at the control of soft rot in the field were conducted by different workers. McRae (1911) suggested collection and burning of diseased plants, crop rotation, use of disease free seed and preventing water logging as possible control measures. Similar recommendations were also given by Subramaniam (1919).

Park (1935) observed that immersing seed ginger in 0.1 per cent mercuric chloride for two hours either just after harvesting or just before sowing yielded many more plants than untreated seed. Thomas (1941) reported that seed treatment just before planting with wettable ceresan (0.25 per cent, 30 minutes) was an effective method of checking rhizome rot caused by Pythium spp. in the field while the best method for preserving seed ginger in pits was by 90 minutes immersion in 0.1 per cent mercuric chloride. According to Mundkur (1949) external application of fungicides alone might not be quite effective as the mycelium and fruiting bodies are located inside the rhizome. Anonymous (1953) reported that effective control of rhizome rot of ginger due to Pythium spp. in the storage pits on the west coast of Madras by treating ginger rhizomes with 0.1 per cent mercuric chloride or 0.25 per cent ceresan; while field wilt was best controlled by soil application of cheshunt compound and colloidal copper. It was also found that bordeaux mixture and mercuric chloride depressed both germination and yield of ginger.

Bhagwat (1960) reported that soft rot of ginger caused by P. myriotylum could be satisfactorily controlled by dipping the rhizomes in 2 : 2 : 50 bordeaux mixture and by application of the fungicide to the soil eight days before sowing. He also reported good control of the disease by soil drenching with cheshunt compound at the rate of 1 ounce/2 gallon of water. Shahare and Asthana (1962) reported that seed treatment of ginger by different chemicals was not effective, but soil treatment with boardeaux mixture (4 : 4 : 50); 0.35 per cent perenox and (rather less successfully) 0.15 per cent of dithane Z-78 suppressed the disease.

Kothari (1966) observed that treatment with mercuric chloride gave the highest germination of ginger. No germination took place in the plots even after 2 months which were drenched with bordeaux mixture. Plots treated with thiram 0.2 per cent (soil drench) showed poor development of ginger rhizomes. Sharma and Dohroo (1980) reported that seed dip in 0.2 per cent solution of dithane M-45 or daconil was highly effective in controlling the soft rot disease as well as in increasing yield in the field. They also reported that seed dip before storing in 0.1 per cent emisan-6, 0.3 per cent blitox 50, 0.1 per cent mercuric chloride, 0.2 per cent dithane M-45 or daconil again were highly effective in controlling the disease in pits.

Control of soft rot in other crops were also reported by various workers. Gattani and Kaul (1951) reported that dusting tomato seeds with cuprous oxide, copper sulphate, both at 1½ oz/lb seed or ceresan 0.2 oz/lb seed or soaking in 1.0 per cent copper sulphate solution reduced the incidence of damping off by 10, 11, 13 and 29 per cent respectively. Boswell et al. (1952) reported that pepper seedling damping off caused by *Rhizoctonia solani* and *Pythium* spp. was reduced by seed treatment with arasan, thiram 50 and phygon. Ramakrishnan and Soumini (1954) reported that rhizome and root rot of turmeric have not occurred in inoculated soil drenched with cheshunt compound or 0.1 per cent ceresan solution at one gal. per sq. yard; while 70 per cent of the plants in untreated plots were affected. Shumilenko (1964) found that soil fungi such as *Pythium* and *Rhizoctonia* could be effectively controlled by 50 per cent thiram at 50 g/m^2 and 0.4 per cent thiram suspensions at 4 l/m^2.

Grover and Dutt (1972) reported that tomato seeds germinated best when the soil was treated with ceresan wet or copper oxychloride. Post emergence damping off was significantly reduced when untreated seeds were sown in infested soil drenched with copper oxychloride, carboxin, captan, agrosan GN, oxycarboxin, dithane M-45 or brassicol. All except the last three greatly reduced seed germination. Ramakrishnan *et al.* (1973) reported that drenching the soil with 0.025 per cent dexon reduced pre and post emergence damping off in tomato and egg plant, whereas similar treatment with 0.1 per cent thiram reduced only pre emergence damping off. Richardson (1973) found that mixtures of chloroneb and thiram (1 : 1 ratio 2.5 g mixture/kg seed) applied to pea seeds gave more effective control of seed rot and damping off (*P. ultimum*) than by applying them separately. Venkata Rao and Kannaiyan (1974) reported that seed treatment with captan, thiram, ceresan (2 gms/kg of seed) controlled the *Pythium* root rot of rice. Harper (1968) and Crosier *et al.* (1970) reported that seed dressings of both benomyl and thiabendazole fungicides were ineffective against the phycomycete fungi causing pre emergence losses in peas. Jharia *et al.* (1977) reported that out of nine fungicides tested, seed treatment with thiram plus captan (1 : 1) 0.3 per cent by weight was highly effective in checking the pre and post emergence losses and mortality at adult stage in chillies. The treatment also resulted in higher yields.

Fungicides which are applied in soil, to control soil microorganisms are in turn degraded and made non toxic by several microorganisms. Further, several fungi become resistant to the fungicides applied, and thus the fungicide becomes ineffective. The degradation and loss of fungicides occurs in soil due to several physical and chemical factors such as leaching of water soluble fungicides, decomposition of the chemicals used as fungicides, etc.

Munnecke (1961) found that persistence of water soluble compounds, such as nabam and MMDD were greatly affected by leaching. The less soluble materials such as thiram, captan, ferbam and PCNB were less easily leached, but their movement was affected to a greater degree than is explainable solely on the basis of water solubility. Munnecke and Mickail (1967) reported that the control of pea damping off due to P. ultimum was directly related to the concentration of thiram in the soil which in turn depended on the initial concentration. The rate of decomposition increased with an increase in concentration and was carried out by soil organisms including P. ultimum as well as by chemical and physical means. Control of damping off by thiram was neither eradicative nor caused by stimulation of antagonistic organism. An increase in the use of soil fungicide is likely to lead to increased development of organism resistant to these compounds.

Nesheim and Linn (1968) reported that thiram was released more readily from the soil with the lowest clay content. Woodcock (1971) reported that the degradation of two unidentified divalent sulphur degradation products of thiram also occurred more rapidly in nonsterile soil than the sterile soil. Raghu *et al.* (1974) reported that thiram degradation occurred more rapidly in nonsterile than in sterile soil.

Booer (1944) demonstrated that all mercury compounds when applied to the soil, were decomposed into metallic mercury. When the chloride ion was involved, the governing factor was the rate of decomposition of mercurous chloride. With other inorganic compounds of mercury direct reduction to the metal took place. The decomposition of ethyl mercury or phenyl mercury group was accompanied by the loss of half the mercury, whereas no mercury appeared to have been lost when methoxy ethyl mercury group decomposed. Takechi and Ide (1958) assayed four organic mercury compounds against *Ophiobolus* (*Cochliobolus*) *sativus* as soil fungicide mixtures and the soil and filtrate were assayed after washing. They suggested that methyl mercury iodide combined with soil without losing fungicidal activity. Ethyl mercury phosphate was fairly fungicidal initially but lost its activity after washing. Methoxy ethyl mercury chloride and phenyl mercury acetate were both poorly fungicidal throughout, though the filtrate of the former retained some activity.

Sharma and Jain (1966) reported that those copper fungicides forming a suspension remained on the soil surface when applied as a drench and copper ions were adsorbed by soil colloids, thus making the fungicides ineffective. Soluble organomercurials were effective against _Pythium_ sp. 2-3 inch below the soil surface. Bordeaux mixture was effective if used dry at 4000 ppm coppersulphate but this dose was uneconomic and phytotoxic. Peethambaran (1977) tried 12 fungicides in soil to find out the longivity of fungicides. Significant reduction in the _P. aphanidermatum_ population was noticed in captan, duter, dithane M-45, copper sulphate and vitavax treated soils for 20 days.

Richardson (1954) reported a means for determining the thiram content of treated soil, by applying the paper disk bio assay technique with _Glomerella cingulata_ as the test organism. Thiram persisted in sandy soil for over two months but disappeared from compost soil within one week. Thiram treatment changed the microbial balance in the soil, the number of bacteria being increased and the fungi decreased for sometime. Thiram was shown to be selective in its action against fungi. Penicillium and Trichoderma being resistant, their population was increased after treatment. Thiram treatment rendered the soil more difficult to infest artificially with P. ultimum and also prevented a natural increase in the populations of damping-off organisms resulting from repeated cropping. This protection of seedlings persisted much longer by the combined action of the selective toxicity of the fungicide on the damping-off organism and increase in population of the beneficial organism.

The possibility of soil fungi to develop resistance to fungicides is high, since in soil, fungi are so intimately associated with fungicides. This, combined with the established facts that fungi may be trained to adopt to fungicides in vitro (Parry and Wood 1958, 1959; Brook and Chesters, 1957; Grover and Moore 1961; Elsaid and Sinclair, 1964) made the probability almost a certainity. Domsch (1959, 1960 a, b) did not find any great differences in the susceptibility of bacteria, streptomyces or soil fungi to six fungicides namely nabam, vapam, captan, TMTD, allylalchohol and an arsenical compound.

Munnecke (1967) stated that natural soil contains a multitude of organisms in continuously changing equlibria, that will function as a biological buffer system. This biological buffer system reduces the plant pathogenic microbial population. When this buffer system is modified by fungicidal application, the buffer capacity is greatly reduced and fungicide treatment may completely fail by subsequent reintroduction of the pathogen.

Materials and Methods

MATERIALS AND METHODS

The experiment was conducted from May, 1978 to January 1979 at the Instructional Farm, attached to the College of Horticulture, Vellanikkara.

Site, Climate and Soil

The farm is situated at 32.1°N latitude and 16.76°E longitude at an altitude of 22.25 m. The area has a typical humid tropical climate. The soil of the experimental area was deep, well drained, lateritic and moderately acid (pH 5). The soil contained 1.544 per cent organic carbon, 0.198 per cent total nitrogen, 0.0025 per cent available phosphorus and 0.0325 per cent available potassium. It contained 24 per cent coarse sand, 21.2 per cent fine sand, 22.65 per cent silt and 30.15 per cent clay.

Isolation and identification of the pathogen

The organism causing the soft rot disease was isolated from the infected rhizomes and collar region of diseased ginger plants by using standard isolation methods (Riker and Riker, 1936). The culture of the fungus was maintained in oatmeal agar medium. For studying the morphological characters, actively growing culture discs of the fungus were kept in sterilised distilled water for 24 hours and it was observed under the microscope.

The microscopic drawings and measurements of the pathogen were carried out by using Olympus research microscope with maximum possible magnification. The morphological characters like colour and thickness of mycelium, size and shape of sporangia, sporangial germination, size and shape of oogonium and antheridium and their attachment were studied.

Pathogenicity test

The pathogenicity tests were carried out both in *in vitro* and *in vivo*. For artificial inoculation, the detached ginger rhizomes were clearly washed in running water to remove the soil particles and it was then surface sterilised with absolute alcohol. Small holes were made on surface of rhizomes with sterilized corkborer and inoculum was placed in it, under aseptic condition. The inoculated rhizomes were kept in aseptic moist chambers and incubated at room temperature (24 to 30°C) till complete rotting of the rhizomes took place.

One month old potted plants were used for proving pathogenicity test. The mycelial mat of *P. aphanidermatum* grown on oatmeal agar was mixed with top five cm. soil and wet cotton wool was placed over the inoculated soil surface for 48 hours. The development of symptoms from the initial stage onwards were observed regularly.

Bio assay of fungicides

A bio assay study with different fungicides were carried out using poison food technique (Zentmayer, 1955) to find out the most effective fungicide against P. aphanidermatum. The name, active ingredient and concentrations (in ppm) of the different fungicides tried are given below.

1.	Dithane Z-78	75 per cent ethylene bis dithiocarbamate	100, 250, 500
2.	Dithane M-45	75 per cent coordination product of zinc ion and manganous ethylene bis-dithio carbamate	-do-
3.	Ziride	80 per cent zinc dimethyl dithiocarbamate	-do-
4.	Bayer 5072	P-Dimethyl amino-benzene diazo sodium sulfonate	-do-
5.	Difolatan	N-1, 1, 2, 2 - Tetrachloro ethyl thiocis - 4 - cyclohexene - 1, 2 - dicarboximide	-do-
6.	Antracol	Zinc-propylene-bis-dithocarbamate	-do-
7.	Brassicol	75 per cent pentachloro nitrobenzene	-do-
8.	Benlate	Methyl-1-butyl carbamoyl	-do-
9.	Bavistin	2 - (Methoxy - carbamoyl) - benzimidazole	-do-

10.	Cheshunt compound	2 parts copper sulphate plus 11 parts ammonium carbonate	100, 250, 500
11.	Agallol 3	3 per cent mercury as methoxy ethyl mercury chloride	-do-
12.	Thiride 75 WP	75 per cent tetramethyl thiuram disulphide	-do-

A separate study was conducted with cheshunt compound, agallol and thiride in different concentrations to fix minimum effective dose required for 100 per cent inhibition of the fungus. In order to find out the synergistic effect of cheshunt compound, agallol and thiride, these fungicides were mixed together in all possible combinations in different concentrations (10, 50, 100, 250 and 500 ppm) and was tested against P. aphanidermatum, using poison food technique.

In all the bio assay studies radial growth and cultural characters of the fungus grown on poisoned oatmeal agar were observed for a period of one week. The per cent inhibition of the growth of P. aphanidermatum in treatments was calculated by the equation,

$$I = \frac{100\,(C - T)}{C} \qquad \text{(Vincent, 1927)}$$

Where

I = inhibition of fungal growth

C = growth in check

T = growth in treatment

Field studies

The experiment was laid out in randomised block design. The land was ploughed well and raised beds of 3 x 1 metre with 25 cm height were formed with 30 cm wide channels around each plot. Forty-eight seed rhizomes with uniform size having one or two sprouted buds were sown in each plot. Two varieties of ginger namely 'Rio-de-janeiro' and 'Maran' obtained from Horticultural Research Station, Ambalavayal were used in this experiment. These rhizomes were preserved earlier by soaking them in 0.25 per cent agallol 3 solution for 30 minutes. Cultural operations were carried out as per the Package of practice recommendations (Anonymous, 1978).

Cheshunt compound, agallol and thiride at 2000 ppm, 500 ppm and 2000 ppm concentrations respectively were used for drenching the soil in the field experiment. Every square metre of the plot received 2.5 litres of the fungicidal solution. In the control plot, water was drenched at the same rate. The number and sequences of application of the different fungicides are given below.

Sequence of application of different fungicides against the soft rot disease of ginger.

Treatment Numbers	Before planting (May)	1 month after planting (June)	3 months after planting (August)	4 months after planting (September)
1	Ch	x	x	x
2	x	Ch	x	x
3	x	x	Ch	x
4	x	x	x	Ch
5	Ch	Ch	x	x
6	Ch	Ch	Ch	x
7	Ch	Ch	Ch	Ch
8	Ag	x	x	x
9	x	Ag	x	x
10	x	x	Ag	x
11	x	x	x	Ag
12	Ag	Ag	x	x
13	Ag	Ag	Ag	x
14	Ag	Ag	Ag	Ag
15	Th	x	x	x
16	x	Th	x	x
17	x	x	Th	x
18	x	x	x	Th
19	Th	Th	x	x
20	Th	Th	Th	x
21	Th	Th	Th	Th
22	Ch	Ag	x	x
23	Ch	Th	x	x
24	Ag	Th	x	x
25	Ag	Ch	x	x
26	Th	Ch	x	x

27	Th	Ag	x	x
28	Ch	Ag	Th	x
29	Ch	Th	Ag	x
30	Ag	Th	Ch	x
31	Ag	Ch	Th	x
32	Th	Ch	Ag	x
33	Th	Ag	Th	x
34	Ch	Ag	Th	Ch
35	Ch	Th	Ag	Ch
36	Ag	Th	Ch	Ag
37	Ag	Ch	Th	Ag
38	Th	Ch	Ag	Th
39	Th	Ag	Ch	Th
40	*	*	*	*

Ch = Cheshunt compound
Ag = Agallol
Th = Thiride
x = No drenching
* = Drenching with water

Germination count was recorded 30 days after sowing. The ungerminated rhizomes were earthed up and examined for the pre emergence rotting. Disease incidence (post emergence rotting) was recorded at 15 day interval till the crop was harvested. Harvesting was done on the 245th day after planting when the aerial parts of the plant were dried completely. The final stand of the crop was recorded at the time of harvest. The fresh weight of rhizomes were recorded separately for each plot. The disease incidence (post emergence rotting) was correlated with rainfall during the cropping season.

Pot culture studies

Commercially made circular pots of size 30 cm diameter and 30 cm height were used for conducting pot culture experiment. Each pot was filled with 10 kg of soil. For filling up of pots, the soil was brought from the field where the ginger was grown earlier. Three rhizome bits having uniform size with one or two sprouted buds were sown in each pot. Cultural operations were carried out as per the Package of practice recommendations (Anonymous, 1978). All the treatments in the field experiment was repeated in the pot culture experiment also. Each pot was drenched with 300 ml of fungicide. Pre emergence rotting was recorded 30 days after sowing and post emergence rotting was recorded once in a fortnight till the crop was harvested. Final stand of the crop was recorded at the time of harvest.

Statistical analysis

All the data obtained were analysed statistically. Students 't' was used when the number of treatments were ten and below. When the treatment numbers exceeded ten, Tukey's method was followed for analysis. Only the best 10 treatments were compared with CD in the case of forty treatment analysis.

Results

RESULTS

Causal organism

The pathogen causing soft rot of ginger was isolated and it was brought into pure culture for detailed morphological studies. The morphological characters of the organism were as follows.

Mycelium hyaline, coenocytic with a width of 5.8 u. The growth of the fungus was rapid on oatmeal agar medium with cottony white in colour and covered 9 cm petridish within 48 hours. Sporangia were very rare in solid media, but abundant in the liquid oatmeal medium. Large number of sporangia were observed within 24 hours when a culture disc from solid media was transferred to aerated water. Sporangia were filamentous in the initial stages later swelled and produced lobulate inflated branches, cut off by a cross wall from the vegetative hyphae.

The size, shape and number of lobes of sporangia varied widely (Figs. 1 to 3b). It measured 23.9 to 76.9 x 7.8 to 73 μ and the number of lobes varied from one to twelve. A long emission tube ending in a vesicle was formed from the sporangium prior to zoospore formation. Number of zoospores in a vesicle varied from 15 to 46 depending on the size of

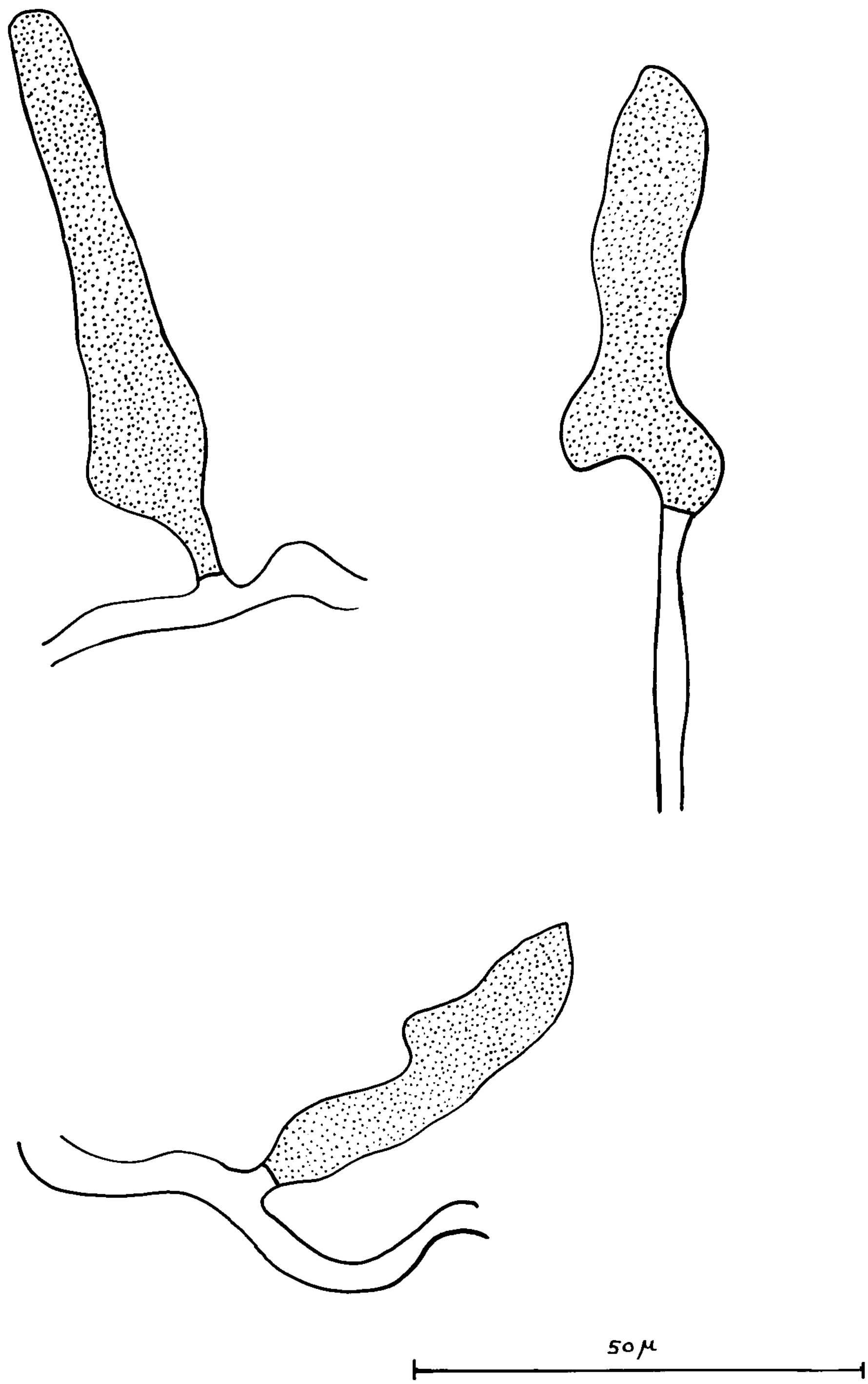


FIG. 1

Single lobed sporangia of *Pythium aphanidermatum*

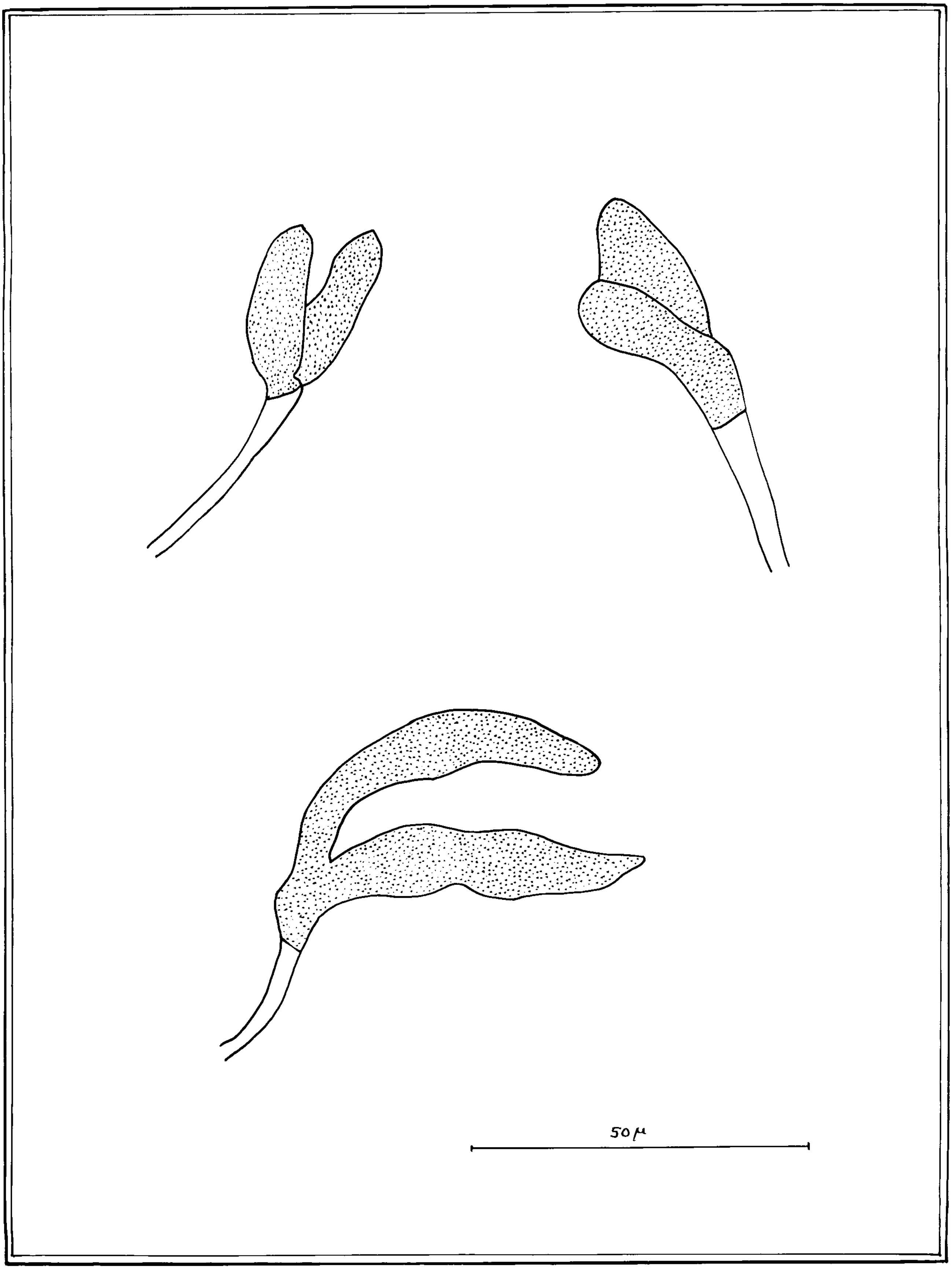


FIG 2

Bi-lobed sporangia of Pythium aphanidermatum

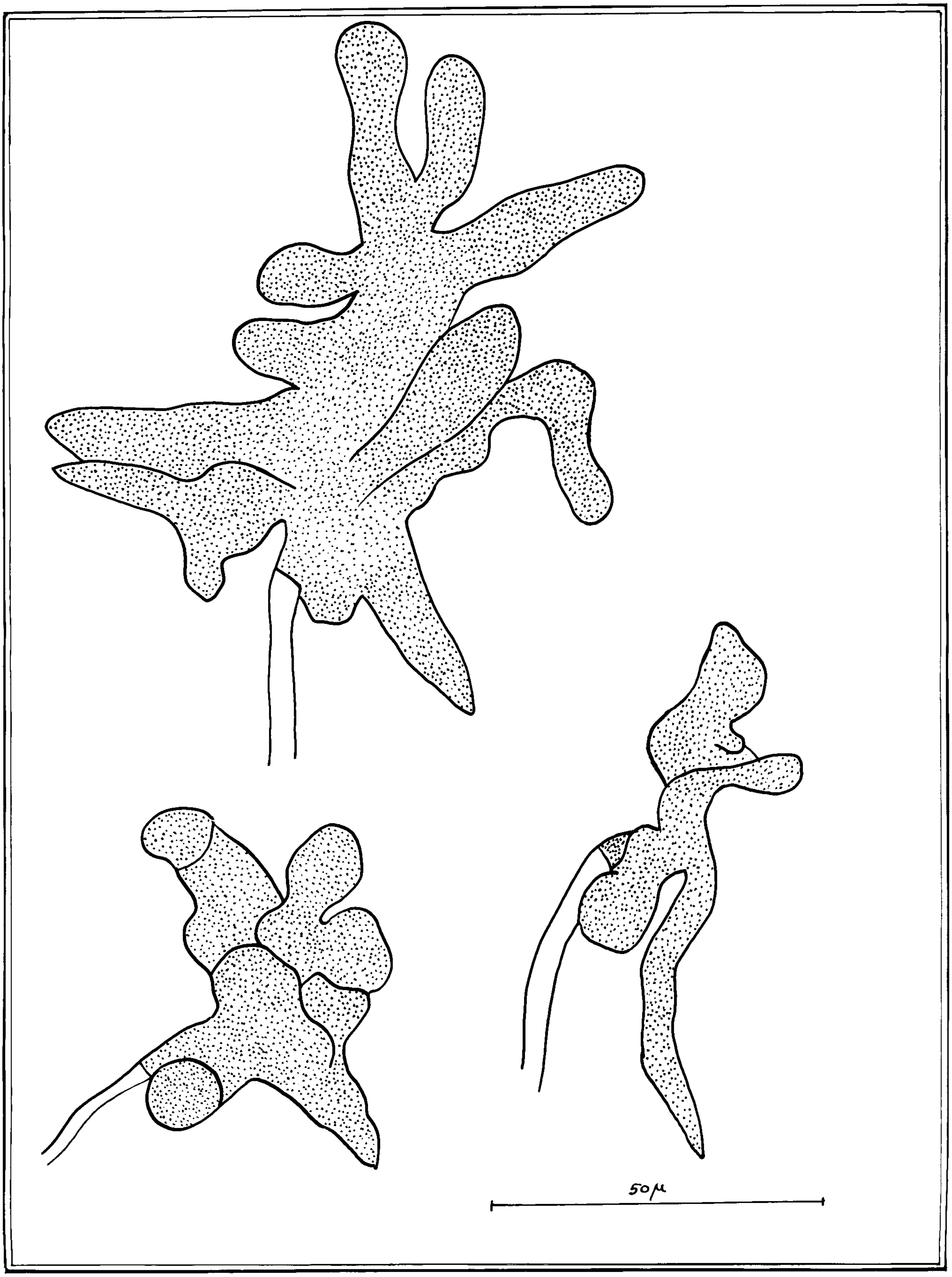


FIG 32

Multilobed sporangia of *Pythium aphanidermatum*

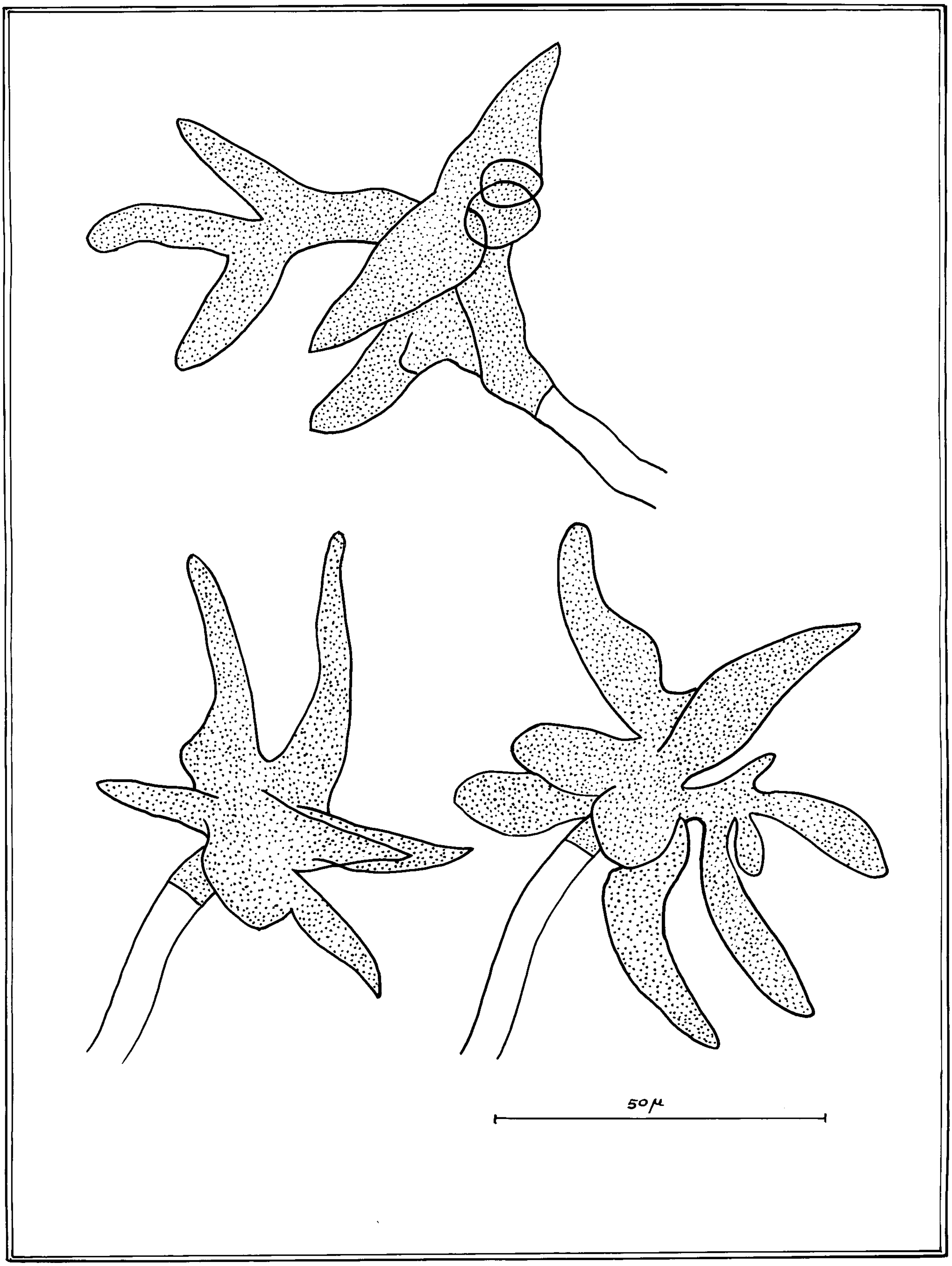


Fig 3b
Multilobed sporangia of Pythium aphanidermatum

sporangia. The zoospores were motile and the encysted zoospores measured 5.6 to 10.2 µ in diameter. The oogonia were terminal, smooth, spherical and the size varied from 20.8 to 28.5 µ in diameter (Fig. 4). Antheridia were stalked, hypogynal or diclinous, mostly terminal, rarely intercalary, barrel shaped or broadly clavate, 12.5 to 34.2 x 4.6 to 12.2 µ in size (Fig. 4). Oospores were spherical, smooth and measured 12.5 to 28.2 µ in diameter (Figs. 5 and 6).

The sporangia germinated in the temperature range of 20 - 32°C, the maximum at 28°C and no zoospores were produced above 28°C. Sporangia germinated directly by putting forward germ tube above 28°C. The motility of zoospore was vigorous for the first 20 minutes after liberation from the vesicle and decreased thereafter and encysted in about 1 to 2 hours in sterile distilled water. Based on the above characters the organism was found to be the same of that described by Fitzpatrick (1923) and identified as Pythium aphanidermatum (Edson) Fitzpatrick.

Pathogenicity test

The pathogenicity of P. aphanidermatum isolated from infected rhizomes, which was used for the present studies,

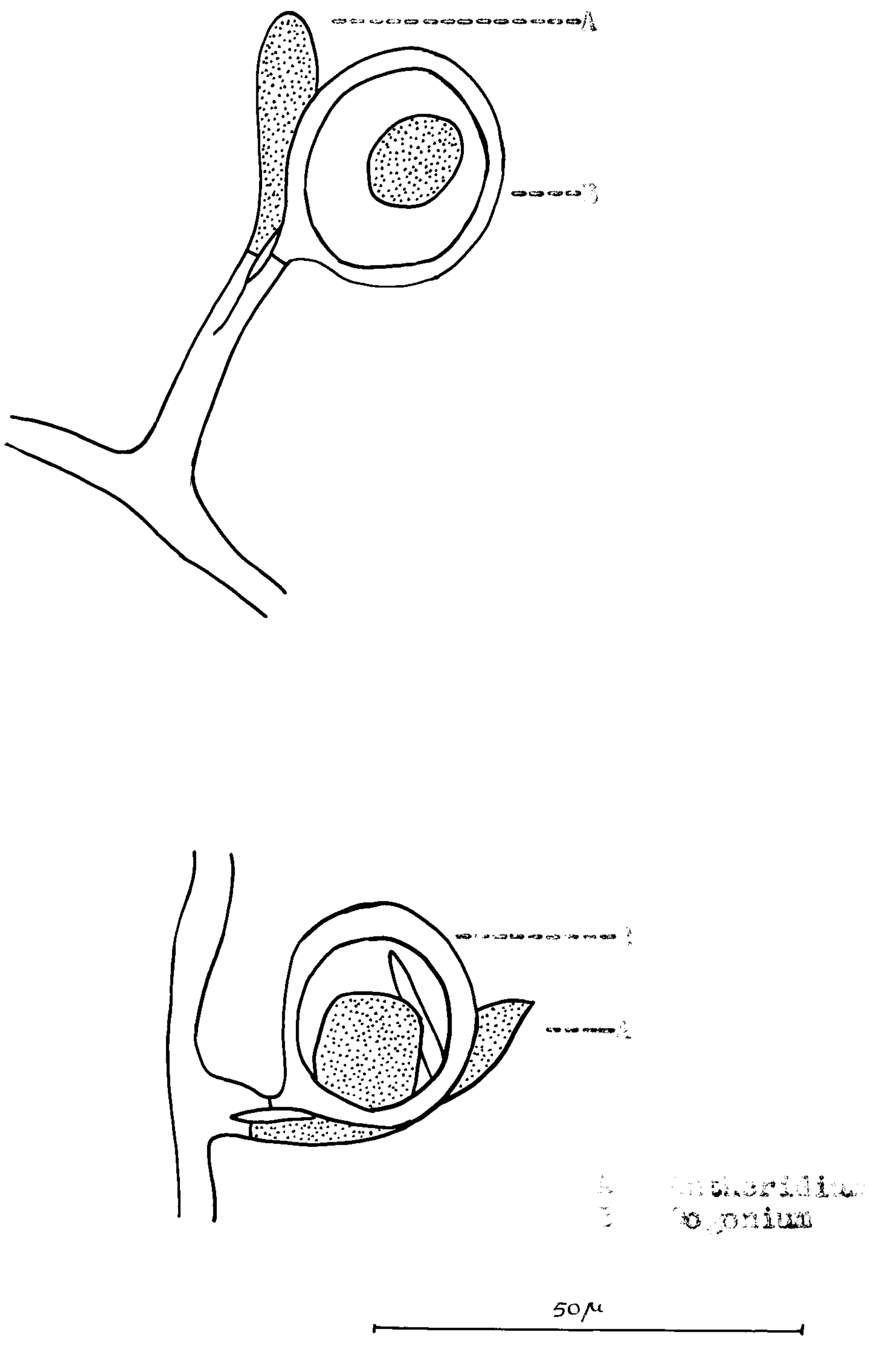


FIG 4

Sexual reproductive structures of *Pythium aphanidermatum*

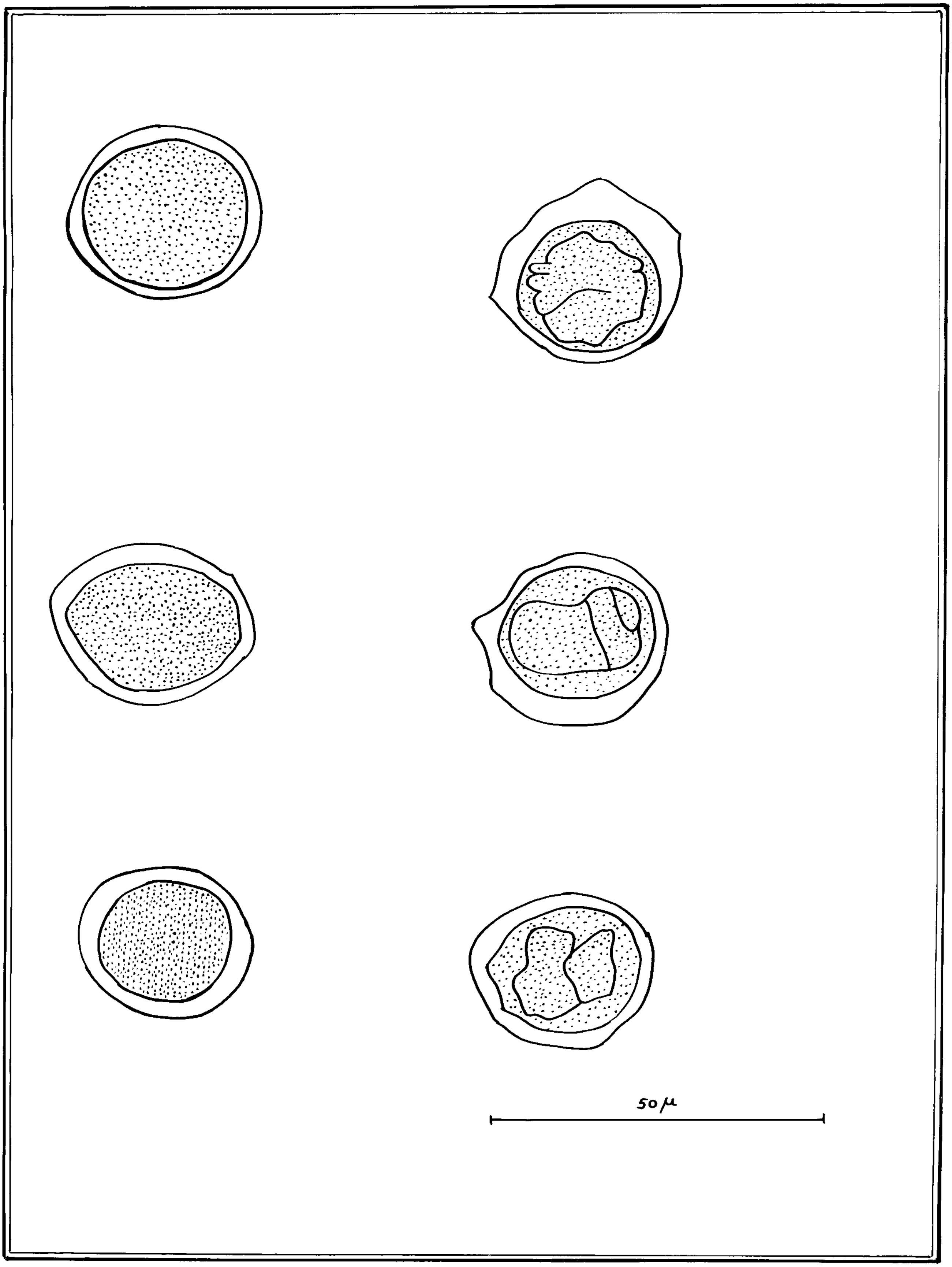


FIG 5

Oospores of Pythium aphanidermatum - different stages of maturity

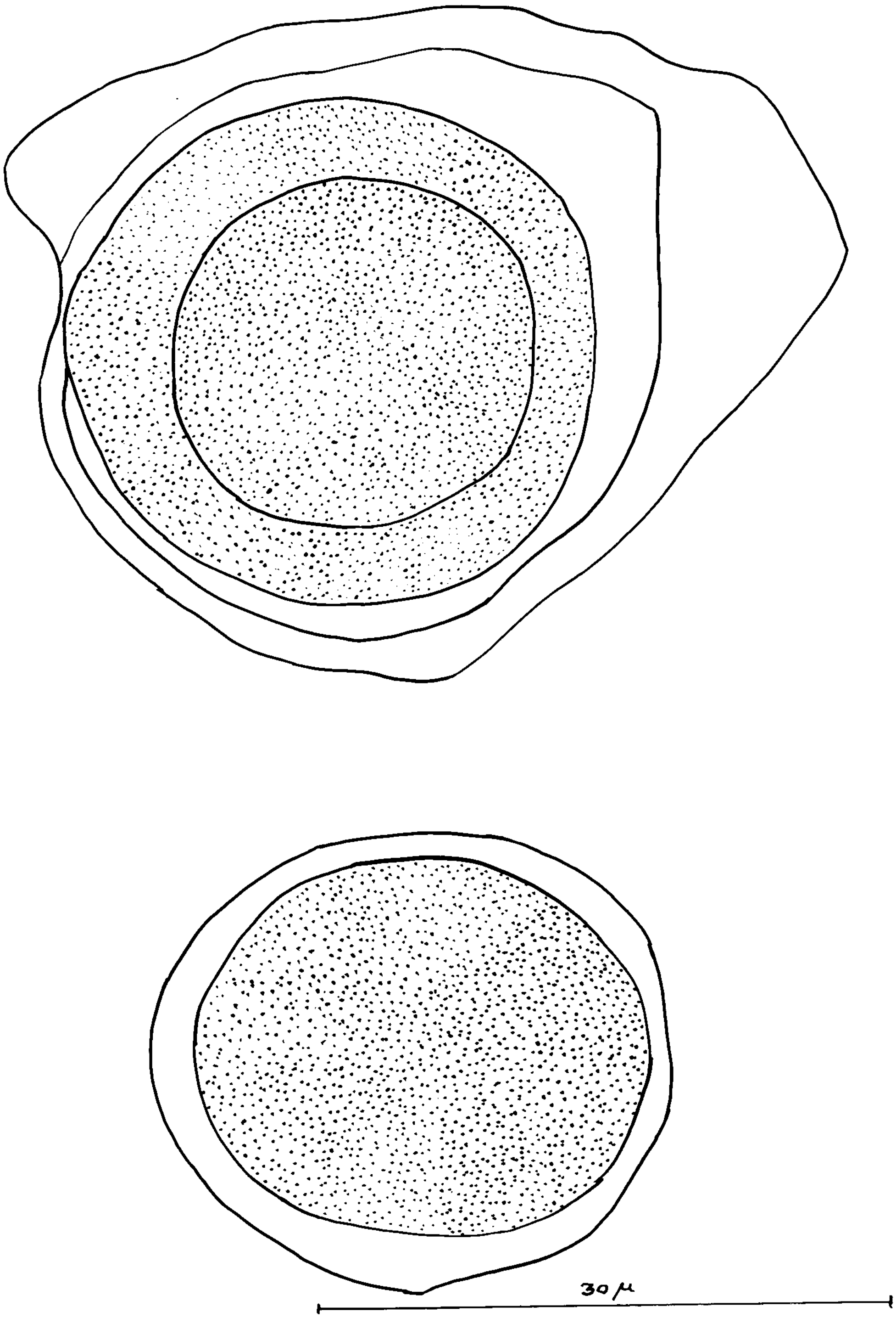


FIG 6

Enlarged oospores of *Pythium aphanidermatum* was proved on 'Rio-de-janeiro' and 'Maran' varieties of ginger. When the fungus was inoculated on rhizome bits, complete rotting of the rhizomes was observed within eight days after inoculation. In potted plants, the first symptom observed was the appearance of a light yellow colour at the tip of the leaves. This yellowing spread very fast and the entire leaf blade and leaf sheath turned yellow within a period of 12 days. Meanwhile, the basal portion of the plant at the point of attachment with the rhizome and soil surface showed pale translucent brown area which became water soaked in nature due to the destruction of host tissues. The shoot at this stage could be easily pulled out from the soil. The rhizome of the infected plants became smooth and started rotting within this period. The symptom development was hastened with high rainfall and delayed with low rainfall and high temperature.

Bio assay of fungicides

In order to find out the most effective fungicide against *P. aphanidermatum* a bio assay with different fungicides was carried out using poison food technique (Zentmayer, 1955). The results are given in tables 1 and 2. The results indicated that among the twelve fungicides tried in three different concentrations, 100 per cent inhibition was

Table 2. Per cent inhibition of growth of *P. aphanidermatum* on media incorporated with different fungicides after 7 days incubation.

Serial Number	Fungicides	Per cent inhibition Concentrations in ppm		
		100	250	500
1	Dithane Z-78	0	0	0
2	Dithane M-45	0	0	0
3	Ziride	0	0	0
4	Bayer 5072	0	0	0
5	Difolatan	0	0	61.11
6	Antracol	0	0	0
7	Brassicol	0	0	0
8	Benlate	0	0	0
9	Bavistin	0	0	0
10	Cheshunt compound	0	0	0
11	Agallol	0	68.89	100
12	Thiride	0	77.80	91.11

obtained only with agallol at 500 ppm. Thiride and difolatan at 500 ppm gave 91.11 and 61.11 per cent inhibition respectively. All other fungicides were not effective in controlling the mycelial growth of the fungus at the concentrations tried. To find out the minimum concentration of cheshunt compound, agallol and thiride required for the complete inhibition of the fungus, an experiment was conducted using different concentrations of the fungicides. Complete inhibition of the fungus in vitro was noticed when 2000 ppm of cheshunt compound or thiride or 500 ppm of agallol was used. Agallol and thiride below 250 ppm concentration and cheshunt compound below 2000 ppm was ineffective in inhibiting the growth of the fungus (Tables 3 and 4).

The results of the synergistic effect of cheshunt compound, agallol and thiride on P. aphanidermatum are presented in tables 5 and 6. It revealed that 100 ppm of agallol plus 100 ppm of thiride was the most effective among the different combinations tried, in inhibiting the mycelial growth of the fungus completely. Cheshunt compound plus agallol; and cheshunt compound plus agallol and thiride showed 100 per cent inhibition at 250 ppm concentration. However, cheshunt compound plus thiride combination exhibited complete inhibition only 15 500 ppm concentration.

Table 4. Per cent inhibition of growth of *P. aphanidermatum* on media incorporated with three fungicides in different concentrations after 7 days incubation.

Serial Number	Fungicides	Per cent inhibition								
		Concentrations in ppm								
		10	25	50	100	250	500	1000	2000	3000
1	Cheshunt compound	0	0	0	0	0	0	0	100	100
2	Agallol	0	0	0	0	68.89	100	100	100	100
3	Thiride	0	0	0	0	77.80	91.11	94.4	100	100

Table 6. Per cent inhibition of growth of P.aphanidermatum on media incorporated with different combinations of three fungicides after 7 days incubation.

Serial Number	Fungicidal combinations	Per cent inhibition – Concentrations in ppm - each				
		10	50	100	250	500
1	Cheshunt compound plus thiride	0	0	0	0	100
2	Cheshunt compound plus agallol	0	0	0	100	100
3	Agallol plus thiride	0	0	100	100	100
4	Agallol plus cheshunt compound plus thiride	0	0	0	100	100

Field studies

On the basis of bio assay studies, cheshunt compound, agallol and thiride were used for the field studies. They were tried in the field as per the details described under Materials and Methods.

Effect of seed treatment on pre emergence rotting

Seed treatment with 0.25 per cent agallol solution was not effective in reducing the pre emergence rotting of ginger. The pre emergence rotting in the control plot was 41.46 percentage for 'Rio-de-janeiro' and 38.02 percentage for 'Maran' (Tables 7 and 9).

Effect of fungicidal application on pre emergence rotting

The effect of fungicidal application on pre emergence rotting of ginger varieties 'Rio-de-janeiro' and 'Maran' is given in Tables 7, 8, 9 and 10. All the fungicidal applications reduced the pre emergence rotting, but there was no significant difference between the treatments.

Effect of cheshunt compound, its time and sequence of application on soft rot of ginger

Pre emergence rotting: Application of cheshunt compound was found effective in reducing the pre emergence

Table 7. Effect of fungicidal application on pre emergence rotting of variety 'Rio-de-janeiro'

Treatment numbers	Treatments	Number of rhizomes planted in 20 replications	Pre emergence rotting	Percentage of pre emergence rotting	Angular transformed values
1	Cheshunt compound	960	191	19.90	23.55
2	Agallol	960	162	16.88	22.21
3	Thiride	960	217	22.60	26.88
4	Control	960	398	41.46	40.00
	F ratio				11.01**
	C.D(0.05)				6.98

Each replication contains 48 plants.

** Significant at 1 per cent level.

Table 8. Effect of fungicidal applicati n on pre emergence rotting of variety 'Rio-de-janeiro'

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	13061.91	79		
Block	2130.54	19	112.13	1
Treatments	4009.44	3	1336.48	11.01
Error	6921.93	57	121.44	

Ranking <u>T2 T1 T3</u> T4

Table 9. Effect of fungicidal application on pre emergence rotting of variety 'Maran'

Treatment numbers	Treatments	Number of rhizomes planted in 20 replications	Pre emergence rotting	Percentage of Pre emergence rotting	Angular transformed values
1	Cheshunt compound	960	97	10.10	14.47
2	Agallol	960	133	13.85	19.54
3	Thiride	960	136	14.17	18.46
4	Control	960	365	38.02	37.83
	F. ratio				18.07**
	C.D (0.05)				6.93

Each replication contains 48 plants

** Significant at 1 per cent level

Table 10. Effect of fungicidal application on pre emergence rotting of variety 'Maran'

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	15407.74	79		
Block	2095.26	19	110.28	<1
Treatments	6490.14	3	2163.38	18.07
Error	6822.34	57	119.69	

Ranking T1 T3 T2 T4

rotting of ginger. The percentage of pre emergence rotting in the cheshunt compound treated plots were 19.90 and 10.10 respectively for 'Rio-de-jeneiro' and 'Maran' varieties, compared to 41.46 and 38.02 in control (Tables 7 and 9).

Post emergence rotting: A single application of cheshunt compound after germination of ginger was not effective, irrespective of the time of application and the infection rate ranged from 27.68 to 46.02 percentage. However, there is a significant reduction in the disease incidence, when atleast two applications of cheshunt compound were given after the germination. But there was no appreciable disease reduction in the plots where two or three applications of cheshunt compound was given after germination of ginger. The post emergence rotting in these treated plots were 6.41 and 10.13 percentages respectively (Tables 11 and 12).

Pre plus post emergence rotting: The effect of cheshunt compound on the control of soft rot of ginger is shown in Tables 11 and 13. Lowest disease incidence of 23.96 percentage was recorded in the treatment number 6 ie. Ch-Ch-Ch-x followed by treatment numbers 7 and 5 ie. Ch-Ch-Ch-Ch and Ch-Ch-x-x respectively. These two treatments viz. 7 and 5 were also on par with treatment number 1 ie Ch-x-x-x. Highest disease incidence of 69.79 percentage was noticed in the control followed by 68.23 percentage in the treatment number 4 ie. x-x-x-Ch. It is seen from the tables 11, 12 and 13 that cheshunt compound before planting as well as two or three times application, after germination of ginger, were necessary for effectively controlling the soft rot of ginger.

Effect of agallol, its time and sequence of application on soft rot of ginger

Pre emergence rotting: Application of agallol was found effective in reducing the pre emergence rotting of ginger. The percentage of pre emergence rotting in the agallol treated plots were 16.88 and 13.85 for 'Rio-de-janeiro' and 'Maran' varieties respectively compared to 41.46 and 38.02 for control (Tables 7 and 9).

Post emergence rotting: Single application of agallol after germination of ginger was not as effective as two or three times application of agallol after germination of ginger in reducing the post emergence rotting. The lowest disease incidence of 14.46 percentage was noticed when three applications of agallol was given after germination of ginger, while the highest incidence of 58.77 percentage was noticed in treatment number 3 ie. when agallol was applied only once

Table 11. Effect of cheshunt compound, its time and sequence of application on soft rot of giner

Treatment numbers	Treatments	Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre-emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Ch x x x	192	155	37	58	37.42	37.70	95	49.48	44.71
2	x Ch x x	192	117	75	48	41.20	39.81	123	63.02	53.04
3	x x Ch x	192	118	74	40	33.90	37.77	114	59.38	51.11
4	x x x Ch	192	113	79	52	46.02	43.22	131	68.23	56.18
5	Ch Ch x x	192	177	15	49	27.68	31.41	64	33.34	35.24
6	Ch Ch Ch x	192	156	36	10	6.41	14.83	46	23.96	27.30
7	Ch Ch Ch Ch	192	158	34	16	10.13	18.43	50	26.04	29.76
8	Control	192	115	77	57	49.57	46.63	134	69.79	57.77
	F ratio						4.48**			5.66**
	C.D. (0.05)						15.95			14.99

Each replication contains 48 plants.

**Significant at 1 per cent level.

Table 12. Effect of cheshunt compound, its time and sequence of application on post emergence rotting alone

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	6578.47	31		
Block	419.27	3	139.76	1.19
Treatments	3689.23	7	527.03	4.48
Error	2469.97	21	117.62	

Ranking T6 T7 T5 T1 T3 T2 T4 T8

Table 13. Effect of cheshunt compound, its time and sequence of application on soft rot of ginger

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	7352.68	31		
Block	1060.77	3	353.59	3.41
Treatments	4111.81	7	387.40	5.66
Error	2180.10	21	103.81	

Ranking T6 T7 T5 T1 T3 T2 T4 T8

three months after planting (Tables 14 and 15).

Pre plus post emergence rotting: Maximum reduction in the incidence of soft rot (26.04 percentage) was noticed, when four applications of agallol was given. The plots which received three or two applications of agallol ranked second and third with an infection percentages of 30.21 and 47.40 respectively. Treatments where only one application of agallol at different periods of time was given did not differ significantly from one another and from that of check (Tables 14 and 16).

Effect of thiride, its time and sequence of application on soft rot of ginger

Pre emergence rotting: Application of thiride was found effective in reducing the pre emergence rotting of 'Rio-de-janeiro' and Maran' varieties of ginger. The percentage of pre emergence rotting in thiride treated plots were 22.60 and 14.17 respectively for 'Rio-de-janeiro' and 'Maran' varieties, compared to 41.46 and 38.02 for control (Tables 7 and 9).

Post emergence rotting: Thiride was not effective in controlling the post emergence rotting of ginger. There was no significant difference between the control and the

Table 14. Effect of agallol, its time and sequence of application on soft rot of ginger.

Treatment numbers	Treatments	Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Ag x x x	192	160	32	74	46.25	43.94	106	55.21	48.23
2	x Ag x x	192	115	77	51	44.35	43.62	128	66.67	55.56
3	x x Ag x	192	114	78	67	58.77	50.04	145	75.52	60.56
4	x x x Ag	192	118	74	54	45.76	42.12	128	66.67	54.77
5	Ag Ag x x	192	151	41	50	33.11	35.24	91	47.40	43.53
6	Ag Ag Ag x	192	160	32	26	16.25	23.95	58	30.21	32.91
7	Ag Ag Ag Ag	192	166	26	24	14.46	22.11	50	26.04	30.40
8	Control	192	115	77	57	49.57	46.63	134	69.79	57.77
	F ratio						4.43**			5.77**
	C.D. (0.05)						14.56			13.98

Each replication contains 48 plants.

**Significant at 1 per cent level.

Table 15. Effect of agallol, its time and sequence of application on post emergence rotting alone

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	5413.55	31		
Block	317.12	3	105.71	1.08
Treatment	3038.02	7	434.00	4.43
Error	2058.41	21	98.02	

Ranking T7 T6 T5 T4 T2 T1 T8 T3

Table 16. Effect of agallol, its time and sequence of application on soft rot of ginger

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	5942.34	31		
Block	393.75	3	131.25	1.45
Treatments	3651.34	7	521.62	5.77
Error	1897.25	21	90.35	

Ranking T7 T6 T5 T1 T4 T2 T8 T3

various treatments. However, the treatments 7, 6 and 5 showed a tendency for better control of the post emergence rotting compared to check (Tables 17 and 18).

Pre plus post emergence rotting: Soft rot incidence was high in the control and the treatments 2, 3 and 4 where pre emergence application of thiride was not given. The treatments 1, 5, 6 and 7 were not significantly different from one another (Tables 17 and 19).

Effect of pre and one post emergence fungicidal application (in rotation) on soft rot of ginger

Post emergence rotting: Except the treatment number 3, where thiride was applied after a basal application of agallol, all other treatments exhibited better control of the post emergence rotting than that of untreated check when the fungicides were applied one after the other in rotation (Tables 20 and 21).

Pre plus post emergence rotting: All fungicidal sequences gave better overall control of the soft rot of ginger than the untreated check except the Ag-Ch-x-x sequence, which was on par with control (Tables 20 and 22).

Table 17. Effect of thiride, its time and sequence of application on soft rot of ginger.

Treatment numbers	Treatments	Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Th x x x	192	158	34	62	39.24	39.48	96	50.00	44.91
2	x Th x x	192	119	73	45	37.82	37.64	118	61.46	51.69
3	x x Th x	192	116	76	44	37.93	38.24	120	62.50	52.65
4	x x x Th	192	112	80	50	44.64	41.91	130	67.71	55.75
5	Th Th x x	192	152	40	36	23.68	28.73	76	39.58	38.90
6	Th Th Th x	192	160	32	41	25.63	29.98	73	38.02	38.04
7	Th Th Th Th	192	159	33	34	21.38	27.39	67	34.89	40.00
8	Control	192	115	77	57	49.57	46.63	134	69.79	57.77
	F ratio						1.98			3.95**
	C.D. (0.05)						N.S.			12.72

Each replication contains 48 plants.

**Significant at 1 per cent level.

Table 18. Effect of thiride, its time and sequence of application on post emergence rotting alone

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	3425.15	31		
Block	101.49	3	33.83	<1
Treatments	1322.21	7	188.89	1.98
Error	2001.45	21	95.31	

Ranking N.S.

Table 19. Effect of thiride, its time and sequence of application on soft rot of ginger

Analysis of variance table

Source	S.S.	df.	variance	F.
Total	3865.09	31		
Block	221.89	3	73.96	<1
Treatments	2071.68	7	295.95	3.95
Error	1571.52	21	74.83	

Ranking T6 T5 T7 T1 T2 T3 T4 T8

Table 20. Effect of pre and one post emergence fungicidal application (in rotation) on soft rot of ginger.

Treatment Numbers	Treatments	Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Ch Ag x x	192	161	31	39	24.22	30.00	70	36.46	36.73
2	Ch Th x x	192	166	26	48	28.92	32.30	74	38.54	38.14
3	Ag Th x x	192	153	39	56	36.60	41.44	95	49.48	44.76
4	Ag Ch x x	192	177	15	42	23.73	31.22	57	29.69	32.57
5	Th Ch x x	192	153	39	43	28.10	30.96	82	42.71	40.76
6	Th Ag x x	192	151	41	40	26.49	30.73	81	42.61	40.07
7	Control	192	115	77	57	49.57	46.63	134	69.79	57.77
	F ratio						3.23**			3.19**
	C.D. (0.05)						10.83			13.43

Each replication contains 48 plants.

**Significant at 1 per cent level.

Table 21. Effect of pre and one post emergence fungicidal application (in rotation) on post emergence rotting alone

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	2573.39	27		
Block	586.93	3	195.64	3.68
Treatments	1030.13	6	171.68	3.23
Error	956.33	18	53.13	

*

Ranking T1 T6 T5 T4 T2 T3 T7

Table 22. Effect of pre and one post emergence fungicidal application (in rotation) on soft rot of ginger

Analysis of variance table

Source	S.S.	df.	variance	F.
Total	3469.09	27		
Block	431.15	3	143.72	1.76
Treatments	1566.18	6	261.03	3.19
Error	1471.76	18	81.76	

Ranking T4 T1 T2 T6 T5 T3 T7

<u>Effect of pre and two post emergence fungicidal application (in rotation) on soft rot of ginger</u>

<u>Post emergence rotting</u>: Effect of pre and two post emergence fungicidal application (in rotation) on post emergence rotting is shown in tables 23 and 24. The lowest disease incidence of 10.74 percentage was observed with Ag-Ch-x sequence. However, this treatment was not statistically different from other fungicidal sequences tried. All the fungicidal sequences tried were statistically significant than untreated check (Tables 23 and 24).

<u>Pre plus post emergence rotting</u>: In all the fungicidal sequences, the overall disease incidence was less than 50 per cent when compared to control. However, there was no significant difference between the fungicidal sequences tried (Tables 23 and 25).

<u>Effect of pre and three post emergence fungicidal application (in rotation) on soft rot of ginger</u>

<u>Post emergence rotting</u>: Eventhough all the fungicidal sequences tried were significantly better than the check, they were on par among themselves. The lowest post emergence rotting 8.28 percentage was noticed in Ag-Th-Ch sequence after germination (Tables 26 and 27).

Table 23. Effect of pre and two post emergence fungicidal application (in rotation) on soft rot of ginger

Treatment numbers	Treatments	Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Ch Ag Th x	192	174	18	34	19.54	26.31	52	27.08	30.81
2	Ch Th Ag x	192	161	31	24	14.91	22.69	55	28.65	32.36
3	Ag Th Ch x	192	157	35	28	17.83	24.82	63	32.81	34.84
4	Ag Ch Th x	192	165	27	32	19.39	26.23	59	30.73	33.21
5	Th Ch Ag x	192	162	30	29	17.90	25.18	59	30.73	[illegible]
6	Th Ag Ch x	192	149	43	16	10.74	19.24	59	30.73	32.97
7	Control	192	115	77	57	49.57	46.63	134	69.79	57.77
	F ratio						5.48**			3.92*
	C.D.(0.05)						11.27			14.23

Each replication contains 48 plants

** significant at 1 per cent level.
 * significant at 5 per cent level.

Table 24. Effect of pre and two post emergence fungicidal application (in rotation) on post emergence rotting alone

Analysis of variance table

Source	S.S.	df.	variance	F.
Total	2998.97	27		
Block	72.17	3	24.06	<1
Treatments	1891.20	6	315.20	5.48
Error	1035.60	18	57.53	

Ranking T6 T2 T3 T5 T4 T1 T7

Table 25. Effect of pre and two post emergence fungicidal application (in rotation) on soft rot of ginger

Analysis of variance table

Source	S.S.	df.	variance	F.
Total	3955.35	27		
Block	148.66	3	49.55	<1
Treatments	2156.20	6	359.37	3.92
Error	1650.49	18	91.69	

Ranking   <u>T1 T2 T6 T5 T4 T3</u> T7

Table 26. Effect of pre and three post emergence fungicidal application (in rotation) on soft rot of ginger.

Treatment numbers	Treatments	Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Ch Ag Th Ch	192	157	35	13	8.28	16.30	48	25.00	28.62
2	Ch Th Ag Ch	192	165	27	18	10.91	19.41	45	23.44	28.25
3	Ag Th Ch Ag	192	163	29	17	10.43	18.65	46	23.96	28.36
4	Ag Ch Th Ag	192	156	36	25	16.03	22.80	61	31.77	34.17
5	Th Ch Ag Th	192	160	32	21	13.13	21.00	53	27.60	30.30
6	Th Ag Ch Th	192	163	29	16	9.82	18.20	45	23.44	28.77
7	Control	192	115	77	57	49.57	49.63	134	69.79	57.77
	F ratio						7.09**			4.14**
	C.D. (0.05)						11.72			15.77

Each replication contains 48 plants.

** significant at 1 per cent level.

Table 27. Effect of pre and three post emergence fungicidal application (in rotation) on post emergence rotting alone.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	3972.70	27		
Block	205.73	3	68.57	1.10
Treatments	2647.09	6	441.18	7.09
Error	1119.88	18	62.22	

Ranking <u>T1 T6 T3 T2 T5 T4</u> T7

Pre plus post emergence rotting: All the fungicidal sequences tried were significantly different from that of check, however, they were not significantly different from one another in reducing the disease incidence of ginger (Tables 26 and 28). Ch-Th-Ag-Ch and Th-Ag-Ch-Th sequences showed the lowest disease incidence of 23.44 percentage.

Effect of pre and one post emergence fungicidal application (same sequence and rotation) on soft rot of ginger

Post emergence rotting: When two applications of the same fungicide one after the other, was compared with two applications of the fungicides in rotation for the control of post emergence rotting of ginger, the results were not significantly different from one another (Tables 29 and 30).

Pre plus post emergence rotting: The soft rot incidence was controlled significantly by applying the fungicides two times. But there was no significant difference between the treatments; whether the same fungicides were used two times or the different fungicides were used in rotation. The lowest incidence (57 out of 192) was noticed in Ag-Ch-x-x sequence and the highest incidence (95 out of 192) in Ag-Th-x-x sequence (Tables 29 and 31).

Table 28. Effect of pre and three post emergence fungicidal application (in rotation) on soft rot of ginger.

Analysis of variance table

Source	S.S.	df.	variance	F.
Total	5104.70	27		
Block	276.96	3	92.32	<1
Treatments	2798.50	6	466.42	4.14
Error	2029.24	18	112.74	

Ranking T2 T3 T1 T6 T5 T4 T7

Table 29. Effect of pre and one post emergence fungicidal application (same sequence and in rotation) on soft rot of ginger.

Treatment numbers	Treatments	Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Ch Ch x x	192	177	15	49	27.68	31.41	64	33.34	35.24
2	Ag Ag x x	192	151	41	50	33.11	35.24	91	47.40	43.52
3	Th Th x x	192	152	40	36	23.68	28.73	76	39.58	38.90
4	Ch Ag x x	192	161	31	39	24.22	30.00	70	36.46	36.73
5	Ch Th x x	192	166	26	48	28.92	32.28	74	38.54	38.14
6	Ag Th x x	192	153	39	56	36.60	37.27	95	49.48	44.76
7	Ag Ch x x	192	177	15	42	23.73	29.32	57	29.69	32.57
8	Th Ch x x	192	153	39	43	28.10	31.84	82	42.71	40.76
9	Th Ag x x	192	151	41	40	26.49	30.73	81	42.61	40.07
10	Control	192	115	77	57	49.57	46.63	134	69.79	57.77
	F ratio						1.64			2.48*
	C.D. (0.05)						N.S.			12.83

Each replication contains 48 plants.

*Significant at 5 per cent level.

Table 30. Effect of pre and one post emergence fungicidal application (same sequence and in rotation) on post emergence rotting alone.

Analysis of variance table

Source	S.S.	df.	variance	F.
Total	2992.40	39		
Block	68.72	3	22.91	<1
Treatments	1033.07	9	114.79	1.64
Error	1890.61	27	70.02	

Ranking N.S.

Table 31. Effect of pre and one post emergence fungicidal application (same sequence and in rotation) on soft rot of ginger.

Analysis of variance table

Source	S.S.	df.	variance	F.
Total	4061.69	39		
Block	198.07	3	66.02	<1
Treatments	1749.64	9	194.40	2.48
Error	2113.98	27	78.30	

Ranking T7 T1 T4 T5 T3 T9 T2 T6 T10

Effect of pre and two post emergence fungicidal application (same sequence and in rotation) on soft rot of ginger

Post emergence rotting: The lowest post emergence rotting of 6.41 percentage was observed when two applications of cheshunt compound after germination of ginger were given, while the highest incidence of 25.63 percentage was noticed where two applications of thiride after germination were given. However, the post emergence rotting in two times thiride treated plots after germination was significantly lower than in check (49.57 percentage) (Tables 32 and 33).

Pre plus post emergence rotting: All the plots which received three fungicidal applications was found to be superior to the untreated plots as far as overall disease incidence was concerned. Eventhough all the treatments were on par and significantly different from that of control, application of cheshunt compound three times had shown the lowest disease incidence of 23.96 percentage and the highest incidence of 38.02 percentage was observed where thiride was applied three times (Tables 32 and 34).

Effect of pre and three post emergence fungicidal application (same sequence and in rotation) on soft rot of ginger

Post emergence rotting: When the fungicides were applied three times either in same sequence or in rotation after

Table 32. Effect of pre and two post emergence fungicidal application (same sequence and in rotation) on soft rot of ginger

Treatment numbers	Treatments		Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Ch Ch Ch	x	192	156	36	10	6.41	14.80	46	23.96	27.30
2	Ag Ag Ag	x	192	160	32	26	16.25	23.95	58	30.21	32.90
3	Th Th Th	x	192	160	32	41	25.63	29.98	73	38.02	38.04
4	Ch Ag Th	x	192	174	18	34	19.54	26.31	52	27.08	30.81
5	Ch Th Ag	x	192	161	31	24	14.91	22.69	55	28.65	32.36
6	Ag Th Ch	x	192	157	35	28	17.83	24.82	63	32.81	34.84
7	Ag Ch Th	x	192	165	27	32	19.39	26.23	59	30.73	33.21
8	Th Ch Ag	x	192	162	30	29	17.90	25.18	59	30.73	33.13
9	Th Ag Ch	x	192	149	43	16	10.74	19.24	59	30.73	32.79
10	Control		192	115	77	57	49.57	46.63	134	69.79	57.77
	F ratio							6.39*			3.25**
	C.D. (0.05)							9.60			13.41

Each replication contains 48 plants.

**Significant at 1 per cent level.

* Significant at 5 per cent level.

Table 33. Effect of pre and two post emergence fungicidal application (same sequence and in rotation) on post emergence rotting alone.

Analysis of variance table

Source	S.S.	df.	Variance	F
Total	3763.16	39		
Block	60.13	3	20.04	<1
Treatments	2520.55	9	280.06	6.39
Error	1182.48	27	43.80	

Ranking T1 T9 T5 T2 T6 T8 T7 T4 T3 T10

Table 34. Effect of pre and two post emergence fungicidal application (same sequence and in rotation) on soft rot of ginger.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	5215.13	39		
Block	353.68	3	117.89	1.38
Treatments	2501.36	9	277.93	3.25
Error	2306.09	27	85.41	

Ranking

T1 T4 T5 T9 T2 T8 T7 T6 T3 T10

germination of ginger, they were significantly better in controlling the post emergence rotting than the untreated check. Among the treatments, three times thiride application after germination with a disease incidence of 21.38 percentage was found to be least effective. All other treatments were not significantly different from one another (Tables 35 and 36).

Pre plus post emergence rotting: All the fungicidal treatments were statistically significant from the untreated check in controlling the soft rot of ginger (Tables 35 and 37). The treatment number 1 (four times cheshunt compound application) was found superior followed by the treatment number 2 (four times agallol application). Maximum infection (34.89 percentage) was noticed in the treatment number 3 (four times thiride application).

Effect of pre and post emergence fungicidal application in different sequences and intervals on soft rot of ginger

Post emergence rotting: The effect of fungicidal application in different sequences and intervals on post emergence rotting is given in Tables 38 and 39. The lowest percentage of rotting (8.28) was seen in treatment number 13 (Ag-Th-Ch sequence after germination). But it was on par

Table 35. Effect of pre and three post emergence fungicidal application (same sequence and in rotation) on soft rot of ginger.

Treatment numbers	Treatments	Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Ch Ch Ch Ch	192	158	34	16	10.13	18.43	50	26.04	18.43
2	Ag Ag Ag Ag	192	166	26	24	14.46	22.11	50	26.04	22.11
3	Th Th Th Th	192	159	33	34	21.38	27.39	67	34.89	35.99
4	Ch Ag Th Ch	192	157	35	13	8.28	15.80	48	25.00	28.62
5	Ch Th Ag Ch	192	165	27	18	10.91	19.41	45	23.44	28.23
6	Ag Th Ch Ag	192	163	29	17	10.43	18.65	46	23.96	28.36
7	Ag Ch Th Ag	192	156	36	25	16.03	22.80	61	31.77	34.17
8	Th Ch Ag Th	192	160	32	21	13.13	21.00	53	27.60	30.30
9	Th Ag Ch Th	192	163	29	16	9.82	18.20	45	23.44	28.77
10	Control	192	115	77	57	49.57	46.63	134	69.79	57.77
	F ratio						6.33**			5.55**
	C.D. (0.05)						10.24			13.07

Each replication contains 48 plants.

**Significant at 1 per cent level.

Table 36. Effect of pre and three post emergence fungicidal application (same sequence and in rotation) on post emergence rotting alone.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	4358.88	39		
Block	170.80	3	56.93	1.14
Treatments	2840.92	9	315.66	6.33
Error	1347.16	27	49.89	

Ranking T4 T9 T1 T6 T3 T8 T2 T7 T5 T10

Table 37. Effect of pre and three post emergence fungicidal application (same sequence and in rotation) on soft rot of ginger.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	6629.22	39		
Block	383.43	3	127.81	1.57
Treatments	4054.08	9	450.45	5.55
Error	2191.71	27	81.17	

Ranking T1 T2 T5 T6 T4 T9 T8 T7 T3 T10

Table 38. Effect of pre and post emergence fungicidal application in different sequences and intervals on soft rot of ginger.

Treatment numbers	Treatments	Number of rhizomes planted in 4 replications	Number of rhizomes germinated	Pre emergence rotting	Post emergence rotting	Percentage of post emergence rotting	Angular transformed values	Total number of infected plants	Percentage of total infection	Angular transformed values
1	Ch Ag x x	192	161	31	39	24.22	30.00	70	36.46	36.73
2	Ch Th x x	192	166	26	48	28.92	32.28	74	38.54	38.14
3	Ag Th x x	192	153	39	56	36.60	37.27	95	49.48	44.76
4	Ag Ch x x	192	177	15	42	23.73	29.32	57	29.69	32.57
5	Th Ch x x	192	153	39	43	28.10	31.84	82	42.71	40.76
6	Th Ag x x	192	151	41	40	26.49	30.73	81	42.61	40.07
7	Ch Ag Th x	192	174	18	34	19.54	26.31	52	27.08	30.81
8	Ch Th Ag x	192	161	31	24	14.91	22.69	55	28.65	32.36
9	Ag Th Ch x	192	157	35	28	17.83	24.82	63	32.81	34.84
10	Ag Ch Th x	192	165	27	32	19.39	26.23	59	30.73	33.21
11	Th Ch Ag x	192	162	30	29	17.90	25.18	59	30.73	33.13
12	Th Ag Ch x	192	149	43	16	10.74	19.24	59	30.73	32.97
13	Ch Ag Th Ch	192	157	35	13	8.28	15.80	48	29.00	28.62
14	Ch Th Ag Ch	192	165	27	18	10.91	19.41	45	23.44	28.23
15	Ch Th Ag Ch	192	163	29	17	10.43	18.65	46	23.96	28.36
16	Ag Ch Th Ag	192	156	36	25	16.03	22.80	61	31.77	34.17
17	Th Ch Ag Th	192	160	32	21	13.13	21.00	53	27.60	30.30
18	Th Ag Ch Th	192	163	29	16	9.82	18.20	45	23.44	28.77
19	Control	192	115	77	57	49.57	46.63	134	69.79	57.77
	F ratio						5.50**			2.30*
	C.D. (0.05)						14.33			20.93

Each replication contains 48 plants.
**Significant at 1 per cent level.
* Significant at 5 per cent level.

Table 39. Effect of pre and post emergence fungicidal application in different sequences and intervals on post emergence rotting alone.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	6468.78	75		
Block	94.63	3	31.54	<1
Treatments	4124.82	18	229.16	5.50
Error	2249.33	54	41.65	

Ranking T13 T18 T15 T12 T14 T17 T8 T6 T9 T11 T10 T7

T4 T1 T6 T5 T2 T3 T19

with other treatments except the treatment number 3 (Th-x-x sequence after germination) and control.

Pre plus post emergence rotting: The treatment number 14 (Ch-Th-Ag-Ch sequence) was found superior in controlling the soft rot of ginger than control. But this treatment was on par with all other fungicidal treatments. The plots receiving two times fungicidal application except the treatment numbers 1 and 4 (Ch-Ag-x-x and Ag-Ch-x-x sequences respectively) were on par with control (Tables 38 and 40).

Effect of fungicidal application on soft rot and yield of ginger

Post emergence rotting: All the fungicidal treatments were statisfically significant than the untreated check in controlling the post emergence rotting of ginger. The least post emergence rotting (6.41 per-centage) was seen in treatment number 6 which received two times application of cheshunt compound after germination. But it was on par with all the treatments where three times fungicidal application (in rotation) after germination was given except the treatment number 37(Ch-Th-Ag sequence after germination). Three times application of cheshunt compound (treatment number 7), agallol

Table 40. Effect of pre and post emergence fungicidal application in different sequences and intervals on soft rot of ginger.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	8581.84	75		
Block	105.88	3	35.29	<1
Treatments	3675.45	18	204.19	2.30
Error	4800.51	54	88.90	

Ranking T14 T15 T13 T18 T17 T7 T8 T4 T12 T11 T10 T16 T9 T1 T2 T6 T5 T3 T19 (treatment number 14) and Th-Ag-x sequence (treatment number 29) after germination of ginger were also on par with the treatment number 6 (Tables 41 and 42).

Pre plus post emergence rotting: All the fungicidal treatments were found statistically significant than the untreated check in controlling the overall disease incidence of ginger. Among the treatments, three times cheshunt compound application was found to be superior. But it was on par with four times fungicidal application (in rotation) except the treatment number 37 (Ag-Ch-Th-Ag sequence). Four times application of cheshunt compound, agallol, Ch-Ag-Th-x sequence and Ch-Th-Ag-x sequence were also on par with treatment number 6 (Tables 41 and 43).

Yield of ginger: All the fungicidal treatments increased the yield of ginger compared to the control (Tables 41 and 44). The treatment number 6 (Three times application of cheshunt compound) gave the maximum yield (5.780 kg) followed by three times application of agallol (5.640 kg). But they were on par with treatment numbers 34, 35, 36, 38, 39, 25 and 28.

Table 42. Effect of fungicidal application on post emergence rotting alone.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	20984.16	159		
Block	191.28	1	191.28	3.24
Treatments	13824.73	39	354.48	6.01
Varieties	22.20	1	22.20	< 1
Interaction	2287.29	39	58.65	< 1
Error	4658.66	79	58.97	

Ranking T6 T34 T39 T7 T36 T33 T35 T38 T29 T40

Table 43. Effect of fungicidal application on soft rot of ginger.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	26330.69	159		
Block	21.84	1	21.84	<1
Treatments	15057.21	39	386.06	4.13
Varieties	233.32	1	233.32	2.50
Interaction	3641.89	39	93.38	1.00
Error	7376.43	79	93.37	

Ranking T6 T35 T36 T34 T39 T7 T38 T14 T29 T40

Table 44. Effect of fungicidal application on yield of ginger.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	440.41	159		
Block	0.72	1	0.72	<1
Treatments	217.14	39	5.57	3.59
Varieties	59.10	1	59.10	38.13
Interaction	41.26	39	1.06	<1
Error	122.19	79	1.55	

Ranking

Fungicides <u>T6 T13 T39 T35 T34 T38 T36 T7 T25 T28</u> T40

The incidence of post emergence rotting of ginger at monthly intervals and rainfall received during the period.

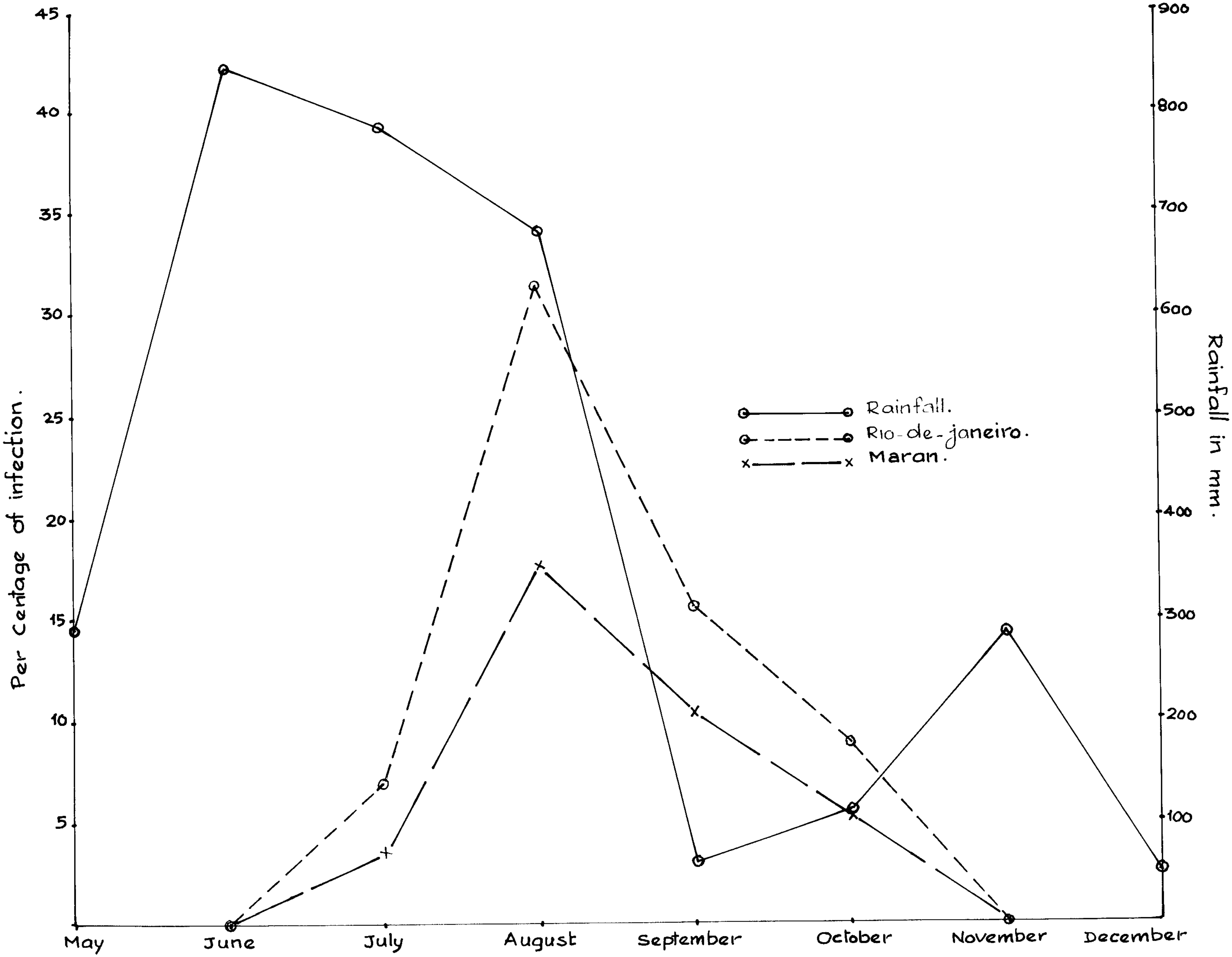
The incidence of soft rot of ginger at monthly intervals and rainfall received during that period is given in Table 45. It is clear from the table and the graph (Fig. 7) that the disease started appearing from July onwards and maximum infection was observed during August. There was a direct correlation between the rainfall and the disease incidence. From July to August there was a continuous increase in the disease incidence. This was followed by a gradual reduction and no fresh infection was noticed after October. The variety 'Rio-de-janeiro' was more susceptible than 'Maran'.

Pot culture studies

The disease incidence, both pre emergence and post emergence rotting was very meagre, in the pot culture experiment hence it was not possible to arrive at any conclusion (Table 46). There was no significant difference in the yield of ginger in the fungicide treated and in control pots (Tables 46 and 47).

Table 45. Incidence of soft rot of ginger at monthly intervals and rainfall received during the period May - December 1978.

Months	Rainfall in mm	Per centage of disease incidence		Total disease incidence
		Rio-de-janeiro	Maran	
May	287.5	—	—	—
June	848.5	—	—	—
July	790.4	7.02	3.51	10.53
August	679.5	31.58	17.54	49.12
September	68.3	15.79	10.53	26.32
October	114.1	8.77	5.26	14.03
November	284.2	—	—	—
December	43.9	—	—	—



Per Centage of infection.
45
40
35
30
25
20
15
10
5
Rainfall in mm.
900
800
700
600
500
400
300
200
100
Rainfall.
Rio-de-janeiro.
Maran.
May
June
July
August
September
October
November
December

Table 47. Effect of fungicidal application on yield of ginger in pots.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	568289.84	159		
Treatments	124521.09	39	3192.85	1.01
Varieties	115831.41	1	115831.41	36.65
Interaction	75074.84	39	1925.00	<1
Error	252862.50	80	3160.78	

Ranking: NS.

Discussion

DISCUSSION

Pythium species have been reported to cause several diseases such as rhizome rot, foot rot, pre emergence and post emergence damping off of various cultivated plants. Soft rot of ginger is caused by different species of *Pythium*.

In the present investigation *Pythium* sp. isolated from infected rhizomes of ginger was found to cause typical soft rot symptoms on artificial inoculation both in *in vitro* and *in vivo*. The characters of this species agreed with the descriptions of *P. aphanidermatum* given by Fitzpatrick (1923). The ability of *P. aphanidermatum* to bring about pathogenesis on ginger was reported by several workers (Butler, 1907; Subramaniam, 1919; Sen, 1930; Park, 1937; Thomas, 1938; Uppal, 1940; Bertus, 1942 and Indrasenan, 1972). Apart from *P. aphanidermatum*, four other species of *Pythium* viz. *P. myriotylum* (Uppal, 1940; Park, 1941 and Bertus, 1942), *P. graminicolum* (Park, 1935), *P. deliense* (Haware and Joshi, 1974) and *P. vexans* (Ramakrishnan, 1949) were also reported to cause soft rot of ginger. However, these species of *Pythium* were not found associated with the soft rot of ginger in the acid lateritic soils of Vellanikkara.

In the present investigation 12 commonly available fungicides were tested using bio assay method and the fungicides which were found to be the best were further tested in the field.

Several methods are employed to study the fungicidal ability of a chemical *in vitro*. Among the different methods, bio assay is considered to be a simple and comparatively effective method. The bio assay studies carried out with different fungicides using *P. aphanidermatum* as the test organism showed that the fungal growth could be inhibited by agallol, thiride and difolatan (Tables 1 and 2). Out of the five fungicides tested *in vitro* against *P. myriotylum*, Sharma and Joshi (1979) got good control of the fungus growth using dithane M-45, bavistin, ceresan and kitazin, while benlate was not effective. In the present investigation also benlate was found ineffective in checking the growth of the fungus. Similar results were obtained by Indra Malhan *et al.* (1975) working with *P. butleri*. This was mainly because of the absence of a proper site for the action of benlate on *Pythium* and other Phycomycetes fungi. But contradictory to the findings of Sharma and Joshi (1979), in the present investigation dithane M-45 and bavistin were found ineffective against *P. aphanidermatum*. However, our finding is in full agreement with the findings of Seema Wahab and Sharma (1976). The fungicide Bayer 5072 (dexon) was not effective upto 500 ppm concentration. It may be due to photodecomposition that Bayer 5072 became ineffective against _P. aphanidermatum_ in the present studies. Munnecke (1967) reported that dexon decomposes quickly when exposed to sunlight.

The fungicide brassicol (PCNB) was ineffective in checking the growth of the fungus. This is in agreement with the findings of Gibson _et al._ (1961) and Sivan _et al._ (1978). Kreutzer (1963) had shown that brassicol (PCNB) was not effective against members of _Pythium_, _Fusarium_, _Colletotrichum_, _Verticillium_, _Typhula_ and _Tilletia_.

The bio assay studies indicated that agallol, thiride and difolatan at 500 ppm were effective in checking the growth of the fungus at varying degrees. However, only the fungicides which gave more than 90 per cent inhibition viz. agallol and thiride were selected for further studies. Cheshunt compound, a fungicide which is being widely used by the farmers against soft rot of ginger, was also included to compare its efficacy with agallol and thiride.

The results of the present investigation showed that cheshunt compound was not effective even upto 1000 ppm concentration. This might be due to the low copper content of cheshunt compound which may not be enough to kill the fungus. Complete inhibition of P. aphanidermatum was possible when 500 ppm of agallol was incorporated in the medium. Soumini Rajagopalan (1961) got complete control of P. aphanidermatum only when 1000 ppm of ceresan was used, while Seema Wahab and Sharma (1976) observed complete control of the fungus even at a concentration of 700 ppm of ceresan. Sivan et al. (1978) found that 500 ppm of aretan gave 100 per cent control of P. debaryanum. This difference, in the concentration of fungicides required to kill the fungus completely, observed by these workers is due to the difference in the amount of mercury present in the fungicide used. Complete inhibition of the fungus was obtained only with 2000 ppm of thiride was incorporated in the medium. However, Sivan et al. (1978) obtained 100 per cent inhibition of P. debaryanum with 1000 ppm of thiram.

When two or more fungicides are mixed and applied against a pathogen, the fungitoxicity may be increased or decreased. In the present investigation, a study was carried out to find out the synergistic/antagonistic effect of cheshunt compound, agallol and thiride at different concentrations against P. aphanidermatum in vitro. The study revealed that (Tables 5 and 6) complete inhibition of the fungus was possible when 100 ppm of agallol and 100 ppm of thiride were mixed together, while it required 500 ppm of agallol or 2000 ppm of thiride to get 100 per cent inhibition of the fungus when they were used separately. This is a clear indication of synergistic action of these fungicides. Similarly cheshunt compound plus agallol at 250 ppm each; cheshunt compound plus agallol and plus thiride at 250 ppm each could also check the fungal growth completely. The observation that cheshunt compound plus agallol and plus thiride required 250 ppm each of the fungicide to effect a 100 per cent inhibition of the fungus was contradictory to the finding that agallol plus thiride at 100 ppm each could check the fungal growth completely. This indirectly indicates that, in a mixture of cheshunt compound, agallol and thiride; cheshunt compound is playing some role, which reduced the fungicidal efficacy of other two chemicals. This observation is reached from the finding that cheshunt compound plus agallol at 250 ppm each could control the fungus completely while it required the some concentration eventhough cheshunt compound, agallol and thiride were applied together. The reason for reduced fungicidal nature of cheshunt compound plus agallol and thiride mixture may be due to incompatibility and production of some unfavourable compounds. Nene (1971) reported that thiride was not compatible with copper fungicides. Richardson (1973) demonstrated that mixtures of chloroneb and thiram (1 : 1 ratio 2.5 g mixture/kg seed) applied to pea seeds gave more effective control of seed rot and damping off (*P. ultimum*) than when individual fungicides were applied separately.

Once the fungicide has proved effective in *in vitro*, its ability to check the disease must be proved under field conditions. With that aim a field experiment was conducted to find out efficacy of fungicides in controlling soft rot of ginger. Several workers (Park, 1935; Thomas, 1941; Bhagwat, 1960; Shahare and Asthana, 1962; Kothari, 1966 and Haware and Joshi, 1974) had undertaken similar studies, but their results are not in full agreement with each other due to the fact that the differences in soil and agroclimatic factors. The present study is mainly an attemtp to find out a good fungicide which is suitable for acid lateritic soil receiving high rainfall. Three fungicides namely cheshunt compound, methoxy ethyl mercury chloride (agallol) and tetra methyl thiuram disulphide (thiride) were used as soil fungicides. These fungicides were selected because they were found highly effective in checking the growth of *P. aphanidermatum*, the causal agent of soft rot of ginger, under *in vitro* studies. These fungicides were applied in different intervals and different sequences.

Soft rot of ginger is comprised of two types of rotting namely pre emergence and post emergence rotting. In pre emergence rotting, the sprouted rhizomes decayed even before it emerges out of the soil and perished. This might be due to presence of the pathogen in the sprouted rhizomes or it might have been attacked by the active pathogen available in the soil. In post emergences rotting, the rhizomes get infected by the pathogen available in the soil causing death of the plant. Eventhough post emergence rotting is more during the early stages of the growth of ginger it can infect even fully matured plants when the conditions are favourable.

The first aerial symptom noticed in the post emergence rotting was the yellowing of the leaves. The yellowing was first appeared at the tip of the leaves which later on spread to other parts of the leaf, and leafsheath. Meanwhile the collar region of the affected plant became watery and destruction of host tissues took place followed by toppling of the plant at this point. Later on, the rhizome also got decayed and formed a watery mass of putrefying tissues. The entire plant was killed within a period of one week when the climatic conditions are favourable.

All the seed rhizomes used for the field studies were treated with 0.25 per cent agallol solution prior to storage to prevent the damage during storage. For planting, only germinated rhizome were used. The pre emergence rotting in the control plots, where no fungicides were drenched was very severe and it was 41.46 and 38.02 percentage respectively for 'Rio-de-jeneiro' and 'Maran' varieties (Tables 7 and 9). From the study it is clear that seed treatment alone is not effective in checking the rhizome not of ginger in the field. This finding is in full agreement with Shahare and Asthana (1962). They also observed that seed treatment alone was not effective to control the rhizome rot in the field. A similar result was obtained by Anonymous (1953). They reported that treatment of rhizomes with 0.1 per cent mercuric chloride was effective in preventing storage rot, but not on the incidence of disease in the field. Further, Mundkur (1949) reported that external application of fungicides alone might not be quite effective in killing the pathogen as the mycelium and fruiting bodies were located inside the rhizomes. Therefore it can be reasonably presumed that seed treatment helped to check the rotting only during storage. But there are reports that the seed treatment alone could check the soft rot of ginger (Park, 1935; Thomas, 1939, 1941;

Anonymous, 1953; Bhagwat, 1960; Kothari, 1966 and Sharma and Dohroo 1980).

The present study has clearly shown that the seed treatment at the time of storage did not have any influence in checking the disease incidence in the field. This may be due to various reasons viz. the rhizomes might have carried some hibernating propagule very deep in the host tissues which might not have been destroyed by the seed treatment or the field might have contained sufficient potential inoculum for infecting the growing plant.

Pre emergence rotting was reduced considerably when the plots were drenched with the different fungicides before planting. But there was no difference between the fungicides. This shows that single soil drenching before planting with any one of the three fungicides tried can check the pre emergence rotting to a great extent. There are reports about the reduction in the pre emergence rotting by the application of copper fungicides (Bhagwat, 1960) and mercury fungicides (Soumini Rajagopalan, 1961). However, there are no reports about the usefulness of thiram in reducing the pre emergence rotting of ginger. The ability of thiram to reduce pre emergence damping off of tomato and egg plant was reported by Ramakrishnan *et al.* (1973). Therefore presowing drenching of the soil with any one of the above mentioned fungicides is highly essential to get a good check of the disease.

Application of fungicides at different intervals after germination gave varying degrees of control. A single application of cheshunt compound, agallol or thiride was not effective in checking the disease throughout the crop growth compared to two or three applications after germination. Except for agallol other two fungicides gave a better control than the check when a single application of fungicide was given one month after planting (Table 41).

Similarly a single fungicidal application three months after planting did not reduce the disease incidence when compared to two or three applications after emergence of plants. The incidence of disease in agallol treated plot was even higher than the check (Table 41) and the single treatment of agallol was ineffective. Munnecke (1961) reported that organo mercurial fungicides were lost by leaching at a faster rate compared to thiram. During the present investigation, there was a continuous rainfall from May to August (Table 45). During this period, the fungicide agallol which was applied might have leached away from the soil thus reducing the fungicidal concentration to such a low level which might not have been effective in killing the pathogen.

A single application of any one of the three fungicides four months after planting (ie. September) did not considerably reduce the post emergence rotting compared to control (Table 41). In the absence of a fungicidal application in the soil, the inoculum of the pathogen might have built up during May to August and caused severe infection during this period. Hence, just a single application of fungicide during September cannot in no way check the disease during the most susceptible period of the crop growth viz. July to September. Shahare and Asthana (1962) reported that once the disease has established in the field, it is very difficult to check the spread even by fungicidal application. Hence a single application of fungicides, four months after planting is not helpful in checking the spread of the disease. The incidence of the disease after south-west monsoon was very limited since the climatic and soil conditions were not favourable for the infection and spread of the pathogen. Further, with the maturity of the crop, it also developed some resistance against the pathogen.

The lowest disease incidence and highest yield of ginger was obtained when three applications of cheshunt compound was given (Tables 11 to 13, 32 to 34, 41 to 44).

Effect of cheshunt compound for the control of soft rot of ginger was reported by several workers. Bhagwat (1960) got good control of the disease by drenching cheshunt compound eight days before planting and three fortnightly applications after germination. Similarly Anonymous (1953) also obtained good control of the disease and highest yield of ginger by drenching cheshunt compound. The usefulness of cheshunt compound in controlling Pythium damping off of various crops was reported by several workers viz. Buddin and Wakefield (1924) on pelargonium, Shephered (1934) on tea, Chesters and Hickmann (1939) on viola and pansy, Hopkins (1939) and Orian (1953) on tobacco, Rafay et al. (1942) on sugarcane, Wallace (1944) on papaw, Singh and Singh (1953) on cucurbits, Singh and Srivastava (1953) on tomato and Ramakrishnan and Soumini (1954) on turmeric. The results of the present investigation clearly indicate that among the three fungicides tried, cheshunt compound is the best fungicide to control soft rot of ginger in the acid lateritic soils receiving high rainfall. Thus, to get a good control of the disease in the field, soil drenching with cheshunt compound before planting and two post emergence drenchings are highly essential.

Application of agallol two or three times after germination reduced the incidence of rotting considerably

(Tables 14, 15, 16). Three times application of agallol was the next best to cheshunt compound when the yield of ginger was taken into account (Tables 41 and 44). Though a single drenching of agallol after a preplanting drenching was found to be superior than the untreated check in reducing the soft rot incidence, it was inferior to two or three times application of agallol after the emergence of the plant (Tables 14, 15 and 16).

Single application of agallol was not effective because the fungicide might have been leached away under heavy rainfall conditions (Munnecke 1961) or it might have been degraded due to fungal action (Spanis _et al_. 1962). As a result of leaching a gradual reduction in the mercury level in the soil took place and this reduced level might have been ineffective to destroy the pathogen available in the soil. The behaviour of mercury fungicides in the soil was reported by several workers. Gibson (1956) reported that low dosages of ethyl mercury fungicides resulted in an increased incidence of damping off of pine seedlings due to _Pythium_ and _Rhizoctonia_ spp. Kimura and Miller (1964) observed that a large part of organic mercury applied to soil remained in the same form for a period of 30 to 50 days, later there was a gradual decomposition of the compound. In the present study two, three and four times application of agallol was found effective mainly because the gap between two successive applications was less than 60 days. Thus the level of fungicidal property of agallol was maintained to such a concentration which was toxic to the fungus. The ability of organo mercury fungicides in controlling the damping off was reported by Phillips et al. (1959) and Grover and Dutt (1972). However, Bhagwat (1960) reported that ceresan was not effective against soft rot of ginger.

When one, two or three application of thiride was given after pre planting drenching, a reduction in the incidence of the disease was noticed compared to control (Tables 17 and 19). However, these treatments did not differ significantly from one another. Though thiride treatment was better than the control, it was inferior to cheshunt compound and agallol in reducing the disease (Tables 32 to 37). This finding is in full agreement with Nene(1971) who reported that thiram does not compete well with organic mercurials in controlling soil borne diseases. Ramakrishnan et al.(1973) found that drenching the soil with 0.2 per cent thiram reduced only pre emergence damping off of tomato and egg plant. Several other workers also reported the ineffectiveness of thiram (McKeen, 1950 and Cesaroni, 1954). However, Shumilenko (1964) got good control of *Pythium* by using thiram, because he used a very high concentration of the fungicide (500 kg/ha). The poor performance of thiride against Pythium may be due to several factors. Pythium itself could degrade thiram (Munnecke, 1967). Thiram degraded at a faster rate in nonsterile soil (Wood cock, 1971 and Raghu et al. 1974) and in soil containing less of clay (Nesheim and Linn 1968) and more of organic matter (Richardson, 1954). The soil in which ginger was cultivated in the present study contained less of clay and more of organic matter and this might have enhanced the decomposition of the fungicide. Temperature, also influenced the decomposition of thiride. Raju and Chatrath (1978) found that thiride degraded faster when third treated wheat seeds were stored at 20 - 25°C. The temperature, during the early stages of the cultivation of ginger in the present study was from 21.6°C to 30.9°C. Thus when compared to cheshunt compound and agallol, thiride is not a good fungicide to control the soft rot of ginger in the acid lateritic soils receiving heavy rainfall.

The ability of soil fungi to develop resistance against fungicides is high, since in soil, fungi are so intimately associated with fungicides (Brook and Chesters, 1957; Parry and Wood, 1958, 1959; Grover and Moore, 1961 and Elsaid and Sinclair, 1964). An experiment was conducted to find out whether *P. aphanidermatum* developed resistance against fungicides due to continuous application of the same fungicide to control soft roft of ginger. Fungicides were applied in different rotations and they were compared with the treatments receiving the same fungicide again and again. The plots receiving two applications of fungicides either in the same sequence or in rotation did not differ significantly from each other (Tables 29 and 31). The same trend was noticed in plots receiving three and four times fungicidal application also (Tables 32 to 36). However, the treatments with Ag-Ch, Ch-Ch, Ch-Ag in two times application; Ch-Ch-Ch, Ch-Ag-Th, Ch-Th-Ag in three times application and Ch-Ch-Ch-Ch, Ag-Ag-Ag-Ag and Ch-Th-Ag-Ch in four times application showed a better disease reduction compared to other treatments.

These findings clearly indicate that the fungus *P.aphanidermatum* did not develop any resistance against the fungicides, even when they are applied continuously. The results also indicated that incorporation of thiride in the rotation containing cheshunt compound and agallol is not very effective. This was expected since the findings showed that thiride when applied to soil decomposes at a faster rate compared to agallol and cheshunt compound. In the bio assay studies it was found that agallol plus thiride and agallol plus cheshunt compound inhibited the fungal growth better, when these compounds were mixed together, rather than when they were used separately. These combinations were effective even at a very low concentration. This enhanced antifungal action of agallol plus thiride and agallol plus cheshunt compound was not noticed in the field studies. This may be due to the fact that these fungicides eventhough applied one after the other, was not applied together. With the result, by the time when the second fungicide was applied, the first applied fungicide might have been degraded in the soil. The usefulness of the application of fungicides in definite intervals and rotations to control soft rot of ginger was not experimented upon by any of the previous workers. From this study it is clearly shown that application of same fungicides again and again at different intervals was found superior in controlling the disease than by applying them in rotation.

Application of fungicides was shown to reduce growth of the plant and yield in ginger (Anonymous, 1953 and Kothari, 1966). When the average yield of individual plants in fungicide treated and untreated plots were observed (Table 41) it was found that there was no significant variation in the yield between the treated and untreated plants. This shows that the fungicides cheshunt compound, agallol and thiride did not reduce the yield of ginger when it was drenched in the soil.

The environmental conditions play an important role in the development of soft rot disease of ginger. In the present study, the post emergence rot started appearing from July. The peak infection was noticed in August followed by a sharp decline in the disease incidence and no fresh infection was noticed after October. This variation in the disease incidence can be directly correlated with the rainfall and maturity of the plant. The most susceptible period of the crop was its early stages of growth (July to September). Further, continuous rainfall during south-west monsoon helped the multiplication and spread of the pathogen by creating a waterlogged condition for a prolonged period in the cultivated land. Under this slightly anaerobic condition, the ability of the plant to resist the infection was reduced and the plants got infected easily. There was no continuous showers during the north-east monsoon. Eventhough there was heavy rainfall during November, fresh infection was not noticed, that may be due to the fact that the soil was not soaked completely for a prolonged period and so, no anaerobic condition prevailed at that time and also the ginger plants were in advanced stages of maturity. The same trend was noticed in 'Rio-de-janeiro' and 'Maran' varieties of ginger. The influence of rainfall on soft rot was observed by Mc Rae (1911), Bhagwat (1960) and Shahare and Asthana (1962). The present study strengthens the observations already stated by these above-mentioned workers.

The incidence of soft rot in pot culture experiment was very low. Hence the efficiency of fungicides could not be studied. Eventhough the pots were filled with the sick soil, collected from the field where ginger was cultivated earlier, the disease was very low. This may be due to various factors such as compactness of soil, good drainage etc. Of this, the good drainage available in the pots resulting good aeration might have been adversely affected the growth of the pathogen and increased the resistance of the plants against the disease.

Summary

SUMMARY

1. 'Studies on the control of soft rot of ginger' was conducted at the Instructional Farm, attached to the College of Horticulture, Vellanikkara, Trichur.

2. 'Rio-de-janeiro' and 'Maran' varieties of ginger were used for the present investigation.

3. The causal organism of the disease (soft rot) was found to be *Pythium aphanidermatum* (Edson) Fitzpatrick. Koch's postulates were established.

4. Out of the 12 fungicides tested *in vitro*, agallol, thiride and difolatan were found to be better than the other fungicides in checking the growth of *P. apahanidermatum*.

5. Hundred per cent inhibition of the fungus *in vitro* was noticed with 2000 ppm, 500 ppm and 2000 ppm of cheshunt compound, agallol and thiride respectively.

6. Among the different combinations of cheshunt compound, agallol and thiride, 100 ppm of agallol plus 100 ppm of thiride was the most effective combination in inhibiting the mycelial growth of the fungus *in vitro*.

7. Seed treatment alone was not effective in checking the soft rot disease in the field.

8. Soil drenching before planting with any one of the three fungicides checked the pre emergence rotting of ginger to a great extent.

9. Single soil application of any one of the three fungicides one month after planting reduced the disease incidence to some extent. But single application either three months or four months after planting was not effective in controlling the disease.

10. Application of cheshunt compound before planting and two post emergence application were found very effective in controlling the disease.

11. Among the different treatments, cheshunt compound application three times ie. one pre emergence and two post emergence applications gave the best yield.

12. One application of agallol before planting and at least two post emergence applications were necessary for getting a satisfactory control of the disease.

13. One application of thiride before planting and two post emergence applications reduced the disease incidence to

some extent. Compared to cheshunt compound and agallol, thiride was not that much effective in controlling the disease.

14. Fungicidal drenching before planting as well as three post emergence drenchings at different intervals, whether in same sequence or in rotation, showed the highest percentage of disease control. However, soil drenching before planting and two post emergence applications within three months after emergence of plants gave sufficient control of the disease in the field.

15. Application of same fungicides again and again at different intervals was found to be superior in controlling the disease than by applying them in rotation.

16. P. aphanidermatum did not develop any resistance against the fungicides when they were applied continuously.

17. Adverse effect on the development of ginger rhizomes was not noticed when the fungicides were applied against soft rot of ginger.

18. The soft rot disease started appearing even before the emergence of the plants in the field and the post emergence rotting started appearing only in July. The

peak period of disease incidence was noticed in August, ie. immediately after the continuous heavy rain, followed by a sharp decline and no fresh infection was noticed after October.

19. 'Rio-de-janeiro' was more susceptible to the disease than 'Maran'.

20. There was a direct correlation between the disease incidence and continuous rainfall.

References

REFERENCES

Anonymous. 1953. Detailed reports of the Subordinate Officers of Department of Agriculture, Madras, for 1943-44, 1944-45, 1948-49, 1949-50, 1950-51, 521 pp.

Anonymous. 1978. Package of Practices Recommendations. Directorate of Extension Education, Kerala Agricultural University, Kerala, 143 pp.

Balagopal, C.; Devi, S.B.; Indrasenan, G. and Wilson, K.I. 1975. Varietal reactions of ginger (Zingiber officinale R.) towards soft rot caused by P. aphanidermatum (Edson) Fits. Agric. Res. Jour. Kerala, 12: 113-116.

Bertus, D.D. 1942. Report of the work of the Plant Pathology Division. Admn. Rep. Dis. Agric., Ceylon, 1941.

Bhagwat, V.Y. 1960. Control of soft rot of ginger. Poona Agric. Coll. Mag., 51: 47-49.

Booer, J.R. 1944. The behaviour of mercury compounds in soil. Ann. Appl. Biol., 31: 340-359.

Brook, M. and Chesters, C.G.C. 1957. The growth of Botrytis cineria Pers., Fusarium caerulum (Lib.) Sacc., and Phoma foveata Foister in the presence of tetrachloro nitrobenzene isomers. Ann. Appl. Biol., 45: 498-505.

Boswell, V.R.; Doolittle, S.P. and Patts, L.M. 1952. Pepper production, disease and insect control. Fmrs. Bull., U.S. Dep. Agric., 30 pp.

Buddin, W. and Wakefield, E.M. 1924. 'Blackleg' of Pelargonium cuttings. Gard. Chron., 25: 25.

Butler, E.J. 1907. An account of genus Pythium and some Chytridiaceae. Mem. Dep. Agric. India (Bot. Ser.), 1: 70.

Butler, E.J. 1918. Fungi and Disease in Plants. Thacker, Spink & Co., Calcutta, 348-352.

Butler, E.J. and Bisby, G.R. 1931. The fungi of India. Sci. Mongr., 1: I.C.A.R., New Delhi, Indian Govt. Cent. Publ., 153 pp.

*Cesaroni, F. 1954. Fungicidal soil treatments and seed dressing in the anti-parasitic defence of sugar beet. *Notiz. malatt. Piante*, **28**: pp 64-73.

Chesters, C.G.C. and Hickman, C.J. 1939. Preliminary report on stem and root rot of Viola and Pansy. Reprint from *Nat. Viola and Pansy Soc.*, 1938: 8.

*Chiu, W.F., Cheng, N.T. and Wu, T.T. 1945. Studies on *Pythium aphanidermatum* (Edson) Fitz. in China. *Lingnan. Sci. J.*, **21**: 45-62.

Crosier, W.F., Nash, G.T. and Crosier, D.C. 1970. Differential reaction of *Pythium* sp. and five isolates of *Rhizoctonia solani* to fungicides on pea seeds. *Pl. Dis. Reptr.*, **54**: 349.

*Domsch, K.H. 1959. Die wirkung von Boden fungiciden III. Quantitative Veranderungen der Boden flora. *Pflanzenschutz*, **66**: 17-26. *Z.PflanzenkrankL.*

*Domsch, K.H. 1960 a. Die wirkung von Boden fungiciden.IV. Veranderungen im spektum der Bodenpilze. *Z. PflanzenkrankL. Pflanzenschutz*, **67**: 129-150.

*Domsch, K.H. 1960 b. Die wirkung Von Boden fungiciden V. Enpfindlichkeit Von Bodenorganizmen *in vitro* *Z. PflanzenkrankL. Pflanzenschutz*, **67**: 211-216.

Drechsler, C. 1925. *Pythium* infection of cabbage heads. *Phytopathology*, **15**: 482-485.

Edson, H.A. 1915. *Rheosporangium aphanidermatus*, a new genus and species of fungus parasite on Sugar Beet and Raddishes. *Jour. Agric. Res.*, **4**: 279.

Elsaid, H.M. and Sinclair, J.B. 1964. Adapated tolerence to organic fungicides by isolates of *Rhizoctonia solani* from seedling cotton. *Phytopathology*, **54**: 518-522.

Fawcett, C.H.; Spencer, D.M. and Wain, R.L. 1957. Investigations on fungicides. II. Aryloxy and arylthio-alkanecarboxylic acids and their activity as fungicides and systemic fungicides. *Ann. Appl. Biol.*, **45**: 158-176.

Fitzpatrick, H.M. 1923. Generic concepts in the Pythiaceae and Blastocladiaceae. *Mycologia*, **15**: 166.

*Gardner, M.W. 1925. Indiana Plant Diseases, 1923. *Proc. Indiana Acad. Sci.*, **34**: 297.

Gattani, M.L. and Kaul, T.N. 1951. Damping off of tomato seedlings - its cause and control. *Indian Phytopath.*, **4**: 156-161.

George, C.K. and Vellappan, E. 1980. Production and Development of Ginger and Turmeric in India. *National Seminar on ginger and turmeric 1980*, 162 pp.

Gibson, I.A.S. 1956. An anomalous effect of soil treatment with ethyl mercury phosphate on the incidence of damping off in pine seedlings. *Phytopathology*, **46**: 181-182.

Gibson, I.A.S., Ledger, M. and Boehm, E. 1961. An anomalous effect of penta chloro nitrobenyene on the incidence of damping-off caused by a *Pythium* spp. *Phytopathology*, **51** : 531-533.

Gottieb., M. and Butler, K.D. 1939. A *Pythium* root-rot of cucurbits. *Phytopathology*, **29**: 624-628.

Grover, R.K. and Dutt, S. 1972. Seed and soil treatments with fungitoxicants for control of damping off of tomatoes caused by *Pythium aphanidermatum*. *Indian Journal of Mycology and Plant Pathology*, **2**: 98-102.

Grover, R.K. and Moore, J.D. 1961. Adaptation of *Sclerotinia fructicola* and *Sclerotinia laxa* to higher concentrations of fungicides. *Phytopathology*, 51: 399-401.

Harper, F.R. 1968. Control of root rot in garden peas with a soil fungicide. *Pl. Dis. Reptr.*, **52**: 776.

Haware, M.P. and Joshi, L.K. 1974. Studies on soft rot of ginger from Madhya Pradesh. *Indian Phytopath.*, **27**: 158-161.

Hopkins, J.C.F. 1939. Report of the Branch of Plant Pathology for the year 1938. Rhod. Agric. J., 36: 589-597.

Hoppe, P.E. 1966. Pythium species still viable after twelve years in air dried muck soil. Phytopathology, 56: 1141.

Indra Malhan; Tyagi, P.D. and Grover, R.K. 1975. Laboratory evaluation of Benomyl against some plant pathogenic fungi. Indian Phytopath., 1: 76.

Indrasenan, G. 1972. Studies on the soft-rot of ginger (Zingiber officinale Rosc.) caused by Pythium aphanidermatum (Edson) Fitz. with special reference to the physiology of parasitism. M.Sc.(Ag.) thesis, Kerala University. 118 pp.

Indrasenan, G. and Paily, P.V. 1974. Studies on the soft rot of ginger (Zingiber officinale Rosc.) caused by Pythium aphanidermatum (Edson) Fitz. Agric. Res. Jour. Kerala, 11: 53-56.

Jharia, H.K., Khare, M.N. and Amar Chand. 1977. Efficacy of fungicides in the control of fungal diseases of chillies. Indian Phytopath., 30: 341-343.

Kimura, Y. and Miller, V.L. 1964. The degradation of organo-mercury fungicides in soil. Agr. Food Chem., 12: 253-257.

Kothari, K.L. 1966. Effect of fungicides on the germination and growth of ginger plants. Sci. Cult., 32: 48-49.

Kreutzer, W.A. 1963. Selective toxicity of chemicals to soil microorganisms. Ann. Rev. Phytopathol., 1: 101-126.

Lakshmanachar, M.S. 1980. Marketing of ginger and turmeric in India. National Seminar on Ginger & Turmeric, 1980, 162 pp.

Lockwood, J.L. 1960. Lysis of mycelium of plant pathogenic fungi by natural soil. Phytopathology, 50: 787-789.

Luna, L.V. and Hine, R.B. 1964. Factors influencing saprophytic growth of Pythium aphanidermatum in soil. Phytopathology, 54: 955-959.

Mc Keen, C.D. 1950. Arasan as a seed and soil treatment for the control of damping-off in certain vegetables. Sci. Agr., 30: 261-270.

Mc Rae, W. 1911. Soft rot of ginger in the Rangpur district, Eastern Bengal. Agric. J. India, 6: 139-146.

Mitra, M. and Subramanian, L.S. 1928. Fruit-rot disease of cultivated cucurbitaceae caused by Pythium aphanidermatum (Eds.) Fits. Mem. Dep. Agric. India (Bot. Ser.), 15: 79-84.

Mundkur, B.B. 1949. Fungi and Plant Disease. Mc Millan and Co. Ltd., London.

Munnecke, D.E. 1961. Movement of nonvolatile, diffusable fungicides through columns of soil. Phytopathology, 51: 593-599.

Munnecke, D.E. 1967. Fungicides in the soil environment. Fungicides - An advanced treatise, Vol.I. D.C.Torgeson (Ed.), 525 pp.

Munnecke, D.E. and Mickail, K.Y. 1967. Thiram persistence in soil and control of damping off caused by Pythium ultimum. Phytopathology, 57: 969-971.

Nene, Y.L. 1971. Fungicides in Plant disease control. Oxford and IBH Publishing Co., 385 pp.

Nesheim, O.N. and Linn, M.B. 1968. The fungitoxicity of thiram, captan and chemagro 2635 in relation to organic matter and clay content of soil. Trans. Ill. St. Acad. Sci., 61: 26-30.

Orian, G. 1953. Botanical Division. Rep. Dep. Agri., Mauritius, 1952: 37-40.

Park, M. 1934. Report of the work of the Mycological division. Ceylon Administration Reports. Rep. Dir. Agric., Ceylon, 1933, 126-133.

Park, M. 1935. Report on the work of the Mycological Division. Adm. Rep. Din. Agric., Ceylon, 1934,124-131.

Park, M. 1937. The seed treatment of ginger. Trop. Agric. Ceylon, 39: 3-7.

Park, M. 1941. Report of the Division of Plant Pathology. Adm. Rep. Div. Agric., Ceylon, 1939, 20-22.

Parry, K.E. and Wood, R.K.S. 1958. The adaption of fungi to fungicides: Adaptation to copper and mercury salts. Ann. Appl. Biol., 46: 446-456.

Parry, K.E. and Wood, R.K.S. 1959. The adaptation of fungi to fungicides: Adaptation to captan; adaptation to thiram, ziram, ferbam, nabam, and zineb. Ann. Appl. Biol., 47: 1-16.

Peethambaran, C.K. 1975. Studies on the comparative survival of Pythium spp. in soil. Ph.D. thesis, G.B. Pant University of Agriculture and Technology. 227 pp.

Peethambaran, C.K. 1977. Population dynamics of Pythium aphanidermatum (Edson) Fitz. in soil treated with different fungicides. Agric. Res. Jour. Kerala, 15: 80-82.

Phillips, G.F., Dixon, B.E. and Lidsey, R.G. 1959. The volatility of organomercury compounds. J. Sci. Food Agr., 10: 604-610.

*Pordesimo, A.N. and Raymundo, S.A. 1963. Rhizome rot of ginger and its control. Coff. Cacao. J., 5: 240.

Rafay, S.A.; Padmanabhan, S.Y. and Khanna, K.L. 1942. Control of sugarcane seedling disease and nematode injury. Proc. Indian. Sci. Congr., 24: 218.

Raghu, K.; Murthy, N.B.K. and Kumarasamy, R. 1974. Proc. Delhi Atomic Energy Symp. Use of Plant Productivity, 267 pp.

Raju, T.N. and Chatrath, M.S. 1978. Persistence of thiram on stored wheat seed. Indian Phytopath., 31: 323.

Ramakrishnan, T.S. 1949. The occurrence of Pythium vexans de Bary in South India. Indian Phytopath., 2:27-30.

Ramakrishnan, T.S. and Sowmini, C.K. 1954. Rhizome and root rot of Turmeric caused by Pythium graminicolum. Sub. Indian Phytopath., 7: 152-159.

Ramakrishnan, L.; Thamburaj, S.; Kamalanathan, S. and Krishnamurthy, C.S. 1973. Studies on the control of damping off (Pythium apahanidermatum (Eds.) Fitz.) disease in certain solanaceous vegetable crops. Madras Agric. J., 60: 537-538.

Richardson, L.T. 1954. The persistence of thiram in soil and its relationship to the microbiological balance and damping-off control. Can. J. Botany, 32: 335-346.

Richardson, L.T. 1973. Synergism between chloroneb and thiram applied to peas to control seed rot and damping-off by Pythium ultimum. Pl. Dis. Reptr., 57: 3.

Riker, A.J. and Riker, R.S. 1936. Introduction to research on plant diseases. John Swift Co., St. Louis, Chicago.

*Rosenberg, M.M. 1963. Report of the Hawaii Agricultural Experiment Station for the biennium ending June 30, 1962. Honolulu Univ., Hawaii.

Seema Wahab and Sharma, B.B. 1976. Evaluation of fungicides against cottony leak of cucurbit fruits due to Pythium aphanidermatum. Indian Phytopath., 29: 437-439.

Sen, T.N. 1930. Appendix IV Mycology. Ann. Rept. Dept. of Agric. Assam, 1929-30: 57-59.

Shahare, K.C. and Asthana, R.P. 1962. Rhizome rot of ginger and its control. Indian Phytopath., 15: 77-78.

Sharma, S.L. and Dohroo, N.P. 1980. Efficacy of chemicals in controlling rhizome rot of ginger. National Seminar on Ginger and Turmeric, 1980: 65.

Sharma, O.P. and Jain, A.C. 1966. Assay of Bordeaux mixture as soil fungicide. Indian Phytopath., 19: 246-249.

Sharma, N.D. and Joshi, L.K., 1979. In vitro evaluation of certain fungicides against eleven seed borne fungi and control of rhizome rot of ginger during storage. Pesticides, 13: 37-39.

*Shepherd, E.F.S. 1934. Botanical and Mycological division. Ann. Rept. Mauritius. Dept. of Agric., 1933:21-23.

*Shumilenko, E.P. 1964. Pathogenic mycoflora of ornamentals in the central Urals. Zap. Sverdlov. Otd. Vser. bot. Obschch. 3: 167-173.

Singh, B. and Singh, K. 1953. Fruit rot of cucurbits. Sci. and Cult., 18: 489-491.

Singh, B. and Srivastava, H.C. 1953. Damping-off of tomato seedlings. J. Indian. bot. Soc., 32: 1-16.

Sivan, D.; Kumaran, S. and Subramanian, D. 1978. Effect of certain fungicides on the in vitro growth of Pythium deparyanum (Hesse) (Seed and Seedling rot of Rice). Agri. Dig., 4: 46.

Soumini Rajagopalan. 1961. Studies on Phycomycetes in agricultural soils with special reference to Pythiaceae. M.Sc. (Ag.) thesis, Madras University, India. 186 pp.

Spanis, W.C.; Munnecke, D.E. and Solberg, R.A. 1962. Biological breakdown of two organic mercurial fungicides. Phytopathology, 52: 455-462.

Stanghellini, M.E. and Nigh, E.L. 1972. Occurrence and survival of Pythium aphanidermatum under arid soil conditions in Arizona. Pl. Dis. Reptr., 56: 507-510.

Subramaniam, L.S. 1919. A Pythium disease of ginger, tobacco and papayas Mem. Dep. Agric. India (Bot. Ser.), 10: 181-194.

*Takeuchi, H. and Ide, H. 1958. Studies on the soil fungicides I. Fungicidal action of the organic mercury compounds in the soil. Ann.Phytopath. Soc.Japan, 22: 197-200.

*Teakle, D.S. 1965. Fusarium rhizome rot of ginger in Queensland. *Qd. J. agric. Sci.*, **22**: 262-272.

Thomas, K.M. 1938. *Adm. Rep. Govt. Mycologist*, Madras, 1937-38, 21 pp.

Thomas, K.M. 1939. Detailed Administration Report of the Government Mycologist, Madras for the year 1939-40. 18 pp.

Thomas, K.M. 1941. Detailed Administration report of the Government Mycologist for the year 1940-41. *Rep. Dept. Agric., Madras*, 1940-41, 53-74.

Trujillo, E.E. 1963. Fusarium Yellows and rhizome rot of ginger. *Phytopathology*, **53**: 1970-1971.

Trujillo, E.E. and Hine, R.B. 1965. The role of papaya residues in papaya root rot caused by *Pythium aphanidermatum* and *Phytophthora parasitica*. *Phytopathology*, **55**: 1293-1298.

Trujillo, E.E. and Marclay, M. 1966. Effect of soil temperature and soil moisture on survival of *Phytophthora parasitica* and *Pythium aphanidermatum*. *Phytopathology*, **56**: 9.

Uppal, B.N. 1940. Appendix K. - Summary of the work done under the Plant Pathologist to the Government of Bombay, Poona, 1938-1939. *Rep. Dep. Agric.*, Bombay.

Vaughan, R.E. 1924. Disease of field and vegetable crops of United States in 1923. *Plant Dis. Reptr.*, **34**: 149-243.

Venkata Rao, A. and Kannaiyan, S. 1974. *Pythium* root rot of rice. *Farm Sci.*, **1**: 3.

Vincent, J.M. 1927. Distortion of fungal hyphae in the presence of certain inhibitors. *Nature*, **159**: 850.

*Wallace, G.B. 1944. Diseases of Papaws. *E. Afr. agric. J.*, **9** : 175-176.

Wood cock, D. 1971. In Soil Biochemistry (A.D. Meharen and J. Skujins, Eds.) Vol.2, Marcel Dokker, New York, 337 pp.

Wright, J. 1930. Root-rot of colo-yam. Gold Coast Dept. of Agric. Year Book, 184-197.

Zentmayer, G.A. 1955. A laboratory method for testing some fungicides with Phytophthora cinnamomi as test organism. Phytopathology, 45: 398.

*Originals not seen.

STUDIES ON THE CONTROL OF SOFT ROT OF GINGER

BY

V. KURUCHEVE

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the

Requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

Department of Plant Pathology

College of Horticulture

VELLANIKKARA :: TRICHUR

1980

ABSTRACT

The present investigation 'Studies on the control of soft rot of ginger' was conducted at the Instructional Farm, attached to College of Horticulture, Vellanikkara, Trichur during the year 1978-79. Two varieties of ginger viz. 'Rio-de-janeiro' and 'Maran' were used for the investigation.

The objectives of the investigations were 1) to find out the causal organism of soft rot of ginger in the acid lateritic soils of Vellanikkara 2) to find out suitable control measures against the disease 3) to know whether the fungus could develop resistance against continuous application of fungicides and 4) to find out any adverse effect on the development of ginger rhizomes when the fungicides were applied for controlling the disease.

The pathogen responsible for the disease was found to be <u>Pythium aphanidermatum</u> (Edson) Fitzpatrick. More than 90 *per* cent inhibition of the fungus was observed by agallol, thiride and difolatan at 500 ppm concentration <u>in vitro</u>. Hundred per cent inhibition of the fungus was possible only with 2000 ppm of cheshunt compound or thiride and with 500 ppm of agallol <u>in vitro</u>. Among the different combinations of cheshunt compound, agallol and thiride, 100 ppm of agallol plus 100 ppm of thiride was the most effective combination in inhibiting the mycelial growth of the fungus.

Seed treatment with 0.25 per cent agallol solution alone was not effective in reducing the disease incidence in the field. The fungicides which were proved very effective in *in vitro* studies, were again tested under field conditions. They were cheshunt compound, agallol and thiride. Soil drenching before planting with the above mentioned fungicides reduced the pre emergence rotting considerably. Single application of fungicides either in one, three or four months after planting was not adequate in controlling the disease.

A minimum of two post emergence applications ie. one month and three months after planting either with cheshunt compound or agallol, in addition to pre planting soil drenching were necessary for controlling the disease as well as for getting good yield. *P. aphanidermatum* did not develop any resistance against the fungicides when they were applied continuously in the field. Adverse effect on the development of ginger rhizomes was not noticed when the fungicides were applied for controlling the soft rot of ginger.

The present investigation showed that extent of control varied with the sequence and number of fungicidal applications. Treatments agallol - cheshunt compound, cheshunt compound - cheshunt compound and cheshunt compound - agallol in two times application; cheshunt compound - cheshunt compound - cheshunt compound; cheshunt compound - agallol - thiride and cheshunt compound - thiride - agallol in three times application and cheshunt compound - cheshunt compound - cheshunt compound - cheshunt compound; agallol - agallol - agallol - agallol and cheshunt compound - thiride - agallol - cheshunt compound in four times application showed a better disease reduction compared to other treatments.

The post emergence rotting started appearing from July and peak infection was noticed during August. The variety 'Maran' was more resistant to the disease. There was a direct correlation between the disease incidence and continuous rainfall.