STUDIES ON THE PHYLLOSTICTA LEAF SPOT OF GINGER

BY

T. PREMANATHAN

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
Kerala - India

1981

DEDICATED TO

THE FOND MEMORY OF MY FATHER

DECLARATION

I hereby declare that this thesis entitled "STUDIES ON THE PHYLLOSTICTA LEAF SPOT 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 September, 1981.

T. Premanathan

CERTIFICATE

Certified that this thesis is a record of research work done independently by Sri. T. Premanathan 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.

College of Horticulture,
Vellanikkara,
7th September, 1981

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

Approved by:

Chairman:

Dr. C.K. Peethambaran

Members :

1.Dr. Abi Cheeran

2.Dr. A.I. Jose

3.Sri. P.V. Prabhakaran

ACKNOWLEDGEMENTS

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

I am greatly indebted to Dr. Abi Cheeran, Professor and Head of the Department of Plant Pathology, College of Horticulture, Vellanikkara for his help, valuable advice and suggestions throughout the preparation of the thesis and also for having served as a member of the Advisory Committee.

I owe my gratitude to Sri. P.V. Prabhakaran, Associate Professor of Statistics and Dr. A.I. Jose, Professor i/c., Department of Agricultural Chemistry for their proper guidance, suggestions and help rendered for the preparation of the thesis and for serving as members of the Advisory Committee.

Thanks are also due to Sri. V.K.G. Unnithan, Assistant Professor of Statistics, members of the

staff of the Department of Plant Pathology, my friends and colleagues, who have put in a helping hand in this investigation.

I am also thankful to Dr. P.C.S. Nair, Director of Research, Kerala Agricultural University (former Associate Dean, College of Horticulture) and Dr. P.K. Gopalakrishnan, Associate Dean i/c., College of Horticulture for providing necessary facilities for conducting the research project.

The award of Junior Fellowship by the I.C.A.R. is gratefully acknowledged.

Vellanikkara,
7th September, 1981.

T. Premanathan

CONTENTS

		Page
INTRODUCTION	..	1
REVIEW OF LITERATURE	..	3
MATERIALS AND METHODS	..	18
RESULTS	..	34
DISCUSSION	..	81
SUMMARY	..	95
REFERENCES	..	i - vi
APPENDICES	..	I - VI
ABSTRACT	..	

LIST OF TABLES

Table No.		Page
1.	Effect of inoculation studies on injured leaves of ginger plants using spore suspension of *P. zingiberi*. ..	38
2.	Fortnightly averages of the disease index, number of leaves per plant and weather factors influencing Phyllosticta leaf spot of ginger. ..	42
3.	Correlation matrix between the intensity of Phyllosticta leaf spot and weather factors/plant parameter. ..	45
4.	Linear regression coefficient of factors influencing the Phyllosticta leaf spot disease of ginger. ..	46
5.	Per cent germination of pycnidiospores of *P. zingiberi* in different media at different intervals. ..	49
6.	Per cent production of double germ tubes by the pycnidiospores of *P. zingiberi* in different media at different intervals. ..	49
7.	Fortnightly averages of disease index of Phyllosticta leaf spot and rank position in different ginger types. ..	52
8.	Comparative ranking of ginger types against Phyllosticta leaf spot based on mean disease index. ..	57
9.	Comparative ranking of ginger types against Phyllosticta leaf spot based on aggregate rank. ..	59

Table No.		Page
10.	Growth measurement (in mm) of P. zingiberi by poison food technique with different concentrations of fungicides, on the sixth day.	62
11.	Per cent inhibition of growth of P. zingiberi by poison food technique with different concentrations of fungicides after six days incubation.	63
12.	Mycelial weight (in mg) of P. zingiberi in liquid potato dextrose media incorporated with different fungicides.	67
13.	Comparative efficacy of different fungicides in the control of Phyllosticta leaf spot disease of ginger.	70
14.	Effect of different fungicides against the Phyllosticta leaf spot disease of ginger.	71
15.	Increase in disease index, 3 weeks and 6 weeks after each spray in the fungicidal trial against Phyllosticta leaf spot of ginger.	75
16.	Effect of fungicide treatments on the intensity of disease and yield of ginger.	79

LIST OF PLATES

1. Score card for grading the intensity of Phyllosticta leaf spot of ginger.

2. Symptomatology of Phyllosticta leaf spot of ginger.

LIST OF FIGURES

1. Pycnidia of *Phyllosticta zingiberi* Ramakr.

2. Cross section of a pycnidium of *P. zingiberi*.

3. Conidia of *Phyllosticta zingiberi* Ramakr.

4. Effect of plant parameter (average number of leaves per plant) and weather factors on the intensity of Phyllosticta leaf spot disease.

5. Conidial germination of *Phyllosticta zingiberi* Ramakr.

6. Comparative ranking of ginger types against Phyllosticta leaf spot based on mean disease index.

7. Efficacy of different fungicides on the control of Phyllosticta leaf spot of ginger.

Introduction

INTRODUCTION

Ginger is an important seasonal spice of India. This contribute 12.88 per cent (9,464.5 tonnes) of spice export from India and 9.8 per cent (Rs. 13.6 crores) of export earnings from spices (Rs. 138 crores). India ranks first in the production of ginger, contributing roughly 50 per cent of the world production.

Although ginger is grown almost all over the country, Kerala is the most important ginger producing state in India. Till 1977-'78 Kerala used to contribute about 70 per cent of the production but with the development of ginger cultivation in Meghalaya, the share of Kerala in total production came down to 40 per cent. Kerala has 12,713 hectares under ginger producing 32,910 tonnes of dry ginger per year.

Ginger is subject to a number of diseases leading to varying degrees of crop damage and yield reduction. Soft rot caused by Pythium spp continues to be the most serious disease and losses to the tune of 50 per cent have been reported due to this disease. The other rhizome diseases of ginger namely yellows (Fusarium sp) and wilt (Bacteria) are not as destructive as the soft rot and are sporadic in nature.

The leaf spot disease caused by Phyllosticta zingiberi Ramakr. has been first reported from Godavari district of Andhra Pradesh and Malabar district of the erstwhile Madras State in 1942 by Ramakrishnan as a minor disease of ginger. However, recently Phyllosticta leaf spot has been found to cause extensive foliar destruction which directly leads to reduction in yield.

Being considered as a minor disease of ginger, extensive work on this has not been conducted. Information about the mode of perennation, entry of the pathogen into the host, varietal susceptibility and control of the pathogen are lacking. Hence the present study was initiated with the following objectives.

1. To study the symptomatology and causal organism of the leaf spot disease of ginger.
2. To study the disease development in the field and the environmental factors influencing the intensity of the disease.
3. To find out the mode of entry of the pathogen into the host leaves.
4. To find out the mode of perennation and survival of the pathogen.
5. Screening of ginger types against the disease.
6. To study the effect of different fungicides in the laboratory on the pathogen and to find out effective and efficient control measures by the fungicidal trial under field conditions.

Review Of Literature

REVIEW OF LITERATURE

A leaf spot disease of ginger caused by *Phyllosticta zingiberi* n. sp. was first reported by Ramakrishnan (1942) from Godavari district of Andhra Pradesh and Malabar district of the erstwhile Madras state. He noticed the occurrence of this disease since 1938. Since then this leaf spot disease has been reported in India by several workers - Jain *et al* (1960) and Shukla and Haware (1972) from Madhya Pradesh; Sohi *et al* (1964) and Gupta and Varma (1966) from Himachal Pradesh and Kaware (1974) from Maharashtra. In Kerala this disease was reported from CPCRI, Kasaragod (Anon 1974). Preliminary studies on this disease were conducted by Brahma and Nambiar (1976). The disease has also been reported from Phillipines (Chanliongco 1966 and Mailum and Divinagracia 1969), Mauritius (Anon 1971) and Sarawak (Anon 1972).

Symptomatology

Detailed symptomatology of Phyllosticta leaf spot of ginger was worked out by Ramakrishnan (1942). He reported that leaf spots produced by *Phyllosticta zingiberi* varied from roundish 1 mm/$\frac{1}{2}$ mm to oval or elongated 9 - 10 mm x 3 - 4 mm with white centre, dark

brown margins and yellowish halo. The central portion of older spots was thin and papery and more often torn up. In the central portion a number of minute blackish pycnidia were formed, first immersed in the tissues of the leaf under the epidermis. These later became erumpent and were seen distinctly on the surface as the mesophyll tissue collapsed and the leaf became thin in the affected areas. The spots were usually isolated but they also became confluent resulting in big patches. Sometimes a large number of spots developed on the leaf and the entire leaf turned brown and dried up. Sohi et al (1964) also described the symptoms of the disease as oval to elongate or sometimes irregular spots, varied from 2.0 to 15.0 mm in size. Mailum and Divinagracia (1969) observed shot hole symptom on infected leaves. According to Shukla and Haware (1972) the initial spots were half to one mm diam. in size, and enlarged gradually within seven to ten days to reach 8.0 - 10.0 mm x 3.5 - 4.0 mm in size.

Causal organism

Ramakrishnan (1942) found that pycnidium of

Phyllosticta zingiberi was black, measuring 78 µm to 150 µm in diameter and with a definite ostiole. According to Sohi et al (1964) pycnidia were ostiolate, amphigenous, subglobose to globose, dark brown, erumpent and measured 57.3 µm to 145 µm in diameter. Shukla and Haware (1972) also observed similar pycnidia, but the size ranged from 70 µm - 170 µm with a mean diameter of 94 µm. Ramakrishnan (1942) observed the characteristic liberation of worm like mass of spores from the ostiole. The spores were hyaline, oblong with rounded ends and often biguttulate, measured 3.7 - 7.4 µm x 1.2 - 2.5 µm with an everage of 4.3 µm x 1.6 µm. Sohi et al (1964) also described the spores as hyaline, unicellular, oval to oblong, biguttulate measuring 3.8 - 7.64 µm x 3.0 - 3.8 µm in size. The only difference between the descriptions of Ramakrishnan (1942) and Sohi et al (1964) was in the breadth of the spores. Shukla and Haware (1972) also described the spores as hyaline, unicellular, oblong with rounded ends measuring 3.7 - 7.5 µm x 1.5 - 3.5 µm with an average of 4.4 µm x 1.8 µm. They also described

the fungal hyphae as hyaline, septate, inter and intra cellular in parenchymatous tissue of host.

Ramakrishnan (1942) studied the growth characters of the fungus on different media. On french bean agar the fungus grew as thin, greyish white aerial mycelium with faintly visible zones. The pycnidia were produced in plenty on the surface or slightly immersed in the medium. The growth of the fungus on quacker oats agar appeared as a thick white aerial mycelium. The submerged portion was dark olive in colour. Plenty of pycnidia were produced but they were hidden by the aerial mycelium. On potato dextrose agar there was thick growth with smoke grey aerial and dark olive submerged mycelium with visible zones and Numerous pycnidia. On sterilized ginger leaves there was no aerial growth of the fungus but entire leaves were studded with numerous pycnidia. On culture media the pycnidial formation started on fourth or fifth day. The pycnidia were light in colour in the beginning, but with age the colour deepened and turned light to dark brown. They were isolated or in

groups. Each pycnidium was ostiolate, thin walled and very short necked. Ramakrishnan (1942) also observed pycnidium with two ostioles which according to him was formed by the fusion of two pycnidia. The pycnidia in culture with a size of 100 to 270 um diameter (average 177.6 um) were bigger than those in nature (78 to 150 um). Shukla and Waware (1972) observed pycnidial formation after seven days growth on potato dextrose agar medium. The pycnidia measured 100 to 250 um in diameter.

The hyphae were hyaline or coloured. Sometimes several of them united to form strands (Ramakrishnan 1942). Formation of coloured hyphae was common on potato dextrose agar, quacker oats and Richards agar whereas on French bean agar and sterilized ginger leaves it was rare. He also noted the swelling of hyphal cells into various shapes inside which round glistening bodies were formed. Even after keeping the culture for over three years no coloured spore was ever noticed in any of the cultures.

The optimum pH requirement for the fungus was found to be between 4.3 and 5.8 on Richard's agar

(Ramakrishnan 1942); 6.0 in P.D.A. (Shukla and Haware 1972) and 5.0 - 7.0 on organic media (Mallum and Divinagracia 1969).

Pathogenicity

The pathogenicity of the fungus on ginger leaves was proved by Ramakrishnan (1942). Successful infection by the fungus was obtained when the leaves were inoculated with spores and culture bits of the fungus in agar media. However infection was noticed only on wounded leaves. The first symptom on inoculated leaf surface was watersoaked spots which appeared on the third day after inoculation. Gradually the spots increased in size and pycnidia were formed within eight days. When inoculations were made using cultures grown on sterilized ginger leaves, within six months of isolation, successful infection was obtained on wounded ginger leaves after 60 hours and on unwounded ginger leaves after six days. But, when two years old culture of the same isolate was used, successful infection was obtained only when the leaves were wounded.

Host range

Phyllosticta zingiberi could attack a number of plants other than ginger. Turmeric was reported as a host of *P. zingiberi* by Ramakrishnan (1942), Sumanwar and Bhide (1962) and Pavgi and Upadhyay (1967). Mailum and Divinagracia (1969) reported *Curcuma domestica*, *Costus speciosus*, *Alpina sanderae*, *Hedychium coronarium*, *Cyperus rotundus* and several grasses as hosts of the fungi.

Spore germination studies

Spore germination studies of *Phyllosticta zingiberi* has not been carried out so far. Onesirosan (1976) found that the conidia of *Phyllosticta lycopersici* did not form germ tubes in distilled water alone, since C, N, and PO_4^{3-} were indispensible for spore germination. He observed that C and N were required for maximum spore swelling but germ tube formation required PO_4^{3-} as well. A wide spectrum of sugars could serve as C source. He also found that the rate of germination was increased in presence of Mg^{++}. Chowdhury (1937) observed that *Phyllosticta cajani* required a minimum relative humidity of

93.9 per cent for germination. Bootsma et al (1973) reported that the germination percentage in Phyllosticta maydis decreased from a maximum at 100 per cent to nil at 94 per cent relative humidity.

Entry of Phyllosticta zingiberi into ginger leaf

There are no reports on the mode of entry of Phyllosticta zingiberi into the leaf. However Jimenez-Diaz and Boothroyd (1976) observed the entry of Phyllosticta maydis into the maize seedlings. They observed over 90 per cent germination within 12 hours. The germinating conidia produced one or two unbranched germ tubes of variable length. Ingress occurred by direct penetration of an epidermal cell by a penetration peg which developed from an appressorium. He found the earliest penetration, six hours after inoculation and 30 per cent of the germinated conidia penetrated within 24 hours. Penetration was followed by the development of a bulbous to rod shaped primary hypha and then the secondary hyphae grew within epidermal cell and intercellularly in the mesophyll but not in vascular tissue.

Survival of the pathogen

Detailed studies on the survival of Phyllosticta zingiberi has not been conducted till recently. Brahma and Nambiar (1980) reported that the pycnidiospores and mycelia of Phyllosticta zingiberi remained viable for 14 months and 30 months respectively at laboratory temperatures (27-30°C). Under field conditions, the fungus survived in the leaf debris throughout the summer season (temperature 30-33°C). Pycnidiospores survived in soil even at 25 cm depth for six months. When unsterilized field soil was incubated with the infected leaves, the pathogen survived upto two months (March) and upto six months (July) when sterile field soil was inoculated. They also found the development of the disease in very young seedlings raised in pots, the surface of which was covered with infected leaf debris.

Screening of ginger types

A preliminary work on screening of ginger types was conducted by Nybe and Nair (1979). They found that out of the 25 types tested Tafingiva was the

best followed by Maran, Bajpai and Nadiya.

Fungicidal studies

Bioassay

Bioassay of fungicides using *Phyllosticta zingiberi* as a test organism has not been conducted so far. However, there are a few reports on the efficacy of different fungicides against a few species of *Phyllosticta*. Ristanovic (1972) working with *Phyllosticta prunicola* found that DNOC, zineb, captan, folpet, dithianon, zirem, copper oxychloride and Bordeaux mixture were fungistatic to pycnidiospores. Among the various antibiotics tried agrimycin 200 ppm alone was fungistatic, while all others failed to inhibit spore germination of the fungus. Deshpande *et al* (1973) observed that hinosan at 250 ppm concentration could completely inhibit the growth of *Phyllosticta elettariae*, the incitant of leaf spot of cardamom. However, 1,000 ppm of kocide or blitox was required to check the fungus completely. The fungicides captan 83 W, dithane Z-78, dithane M-22, plantvax and polyram, even though reduced the growth

rate, was not effective in completely inhibiting the growth even at 1,000 ppm concentration. In vitro studies of fungicides against Phyllosticta elattariae by Prasad et al (1978) showed that difolatan, hexaferb and thiram, even at the lowest doses tested (25 ppm), were inhibitory to the pathogen. Srivastava et al.(1975) found that, out of the eight different fungicides viz. bisdithane, cuman, brassicol, dithane M-45, dithane Z-78, captan (each in 2,000 ppm) and ceresan wet and blitox 50 (each in 3,000 ppm) tried in vitro against Phyllosticta sorghiphila, bisdithane, cuman and ceresan wet completely inhibited the fungal growth. Patel et al.(1975) evaluated the effect of fungicides and antibiotics on conidial germination and mycelial growth of Phyllosticta ricini in the laboratory. They observed that all the test compounds were fungistatic and captan, ziram, aureofungin, thiram and zineb at 200 ppm gave maximum inhibition of mycelial growth.

Field studies

Field studies on the control of Phyllosticta leaf

leaf spot of ginger was conducted by very few workers. Ramakrishnan (1942) opined that one or two sprays of one per cent Bordeaux mixture could control the disease. Chanliongco (1966) stated that treatment with zerlate, vancid Z-65 and dithane M-22 were effective in controlling the disease. Mailum and Divinagracia (1969) suggested crop sanitation and avoiding close planting, could reduce the disease severity. Sohi et al (1973) obtained good control of the disease by spraying the plants with 0.2 per cent dithane Z-78, six times at fortnightly intervals. They also recommended spraying of flit 406 (0.3 per cent), dithane M-22 (0.2 per cent) or Bordeaux mixture one per cent at fortnightly intervals for checking the disease.

The efficacy of different fungicides in controlling Phyllosticta leaf spots on various crop plants other than ginger was reported by various workers. Guba (1924) successfully controlled leaf blotch of apple by summer sprays of lime-sulphur at four, six and ten weeks after the fall of blossoms. Hooker (1924) tried different copper fungicides and

observed that copper hydroxide was 15 times more effective than Bordeaux mixture in controlling apple blotch on the basis of copper content. Schneiderhan (1932) obtained good control of apple blotch by using instant Bordeaux in north western greenings of West Virginia. The effectiveness of dithiocarbamate fungicides against apple blotch was proved by Mc Callan (1946). He got good control of the disease by using fermate and ferric dimethyl dithiocarbamate. Struble and Morrison (1961) reported a reduction in the apple blotch by fermate (2 lb/100 gal.) dithane Z-78 and parzate (1.5), orthocide 50 (2), thylate (1.5) and omadine (1.5) to an extent of zero, 1.4 and zero, 4 to 8, 3 and 5 per cent infection, when applied at fortnightly interval. Smolyakova (1968) found that phygon, vukhin (quinone group) maneb and dioxide (group of diene synthetics) were highly toxic against Phyllosticta mali. Ristanovic (1972) observed that DNOC, zineb, captan, folpet, dithianon, ziram, copper oxychloride and Bordeaux mixture could protect plum leaves from artificial and natural infections of Phyllosticta prunicola.

Tandon and Bilgrami (1957) were able to reduce the leaf spot disease of Artocarpus heterophyllus caused by Phyllosticta artocarpinae by spraying with 0.33 per cent perenox or 3:3:50 Bordeaux. Phyllosticta straminiella causing leaf spot disease of rhubarb was controlled by weekly sprays with 1:1:10 Bordeaux mixture (Anon 1960). Mietkiewski and Nowak (1972) successfully controlled Phyllosticta paviae causing reddish brown leaf spot of chestnut by using copper oxychloride (0.3 per cent) and zineb (0.2 per cent). The usefulness of bisdithane, dithane Z-78, captan, miltox and cuman in controlling Phyllosticta leaf spot of arhar caused by Phyllosticta cajani was recorded by Saksena and Kumar (1974). Rao and Naidu (1974) recommended 0.2 per cent difolatan spray at fortnightly interval to control nursery leaf spot disease of cardamom caused by Phyllosticta elettariae. Difolatan 0.2 per cent followed by bavistin (carbendazin) one per cent were the most effective of seven fungicides tried in controlling the nursery leaf spot of cardamom in a trial conducted by Ram and Rao (1978). Natarajan

and Srivastava (1975) obtained good control of chrysanthemum blight caused by Phyllosticta chrysanthemi by spraying 0.3 per cent captan or flit 406.

Materials and Methods

MATERIALS AND METHODS

All the laboratory experiments connected with the "Studies on the Phyllosticta leaf spot of ginger" were conducted at the Department of Plant Pathology and the field experiments in the farm attached to the College of Horticulture, Kerala Agricultural University, Vellanikkara during 1979-80.

The area is located between 10° 31' N latitude and 76° 15' E longitude at an altitude of 22.25 m above MSL. The climate prevailing in this area is typically humid tropical with heavy rainfall. The soil is lateritic, acidic, medium clay loam rich in organic matter.

Symptomatology of Phyllosticta leaf spot

Symptomatology of Phyllosticta leaf spot was studied in the ginger type Maran. Observations were taken on alternate days from the control plots of the fungicidal trial in the field.

Causal organism

The organism causing the leaf spot disease of ginger was isolated from the infected leaves by the

method described by Riker and Riker (1936). The pure culture of the pathogen was maintained in the potato dextrose agar medium and used for further studies.

All the microscopical works - measurements and drawings - were done using Olympus research microscope and its drawing apparatus under the maximum possible magnification. All the taxonomical description of the pathogen has been done from the infected leaves collected from the field and from the pure culture maintained in potato dextrose agar medium.

Studies on the disease development in the field

The ginger type Maran was selected for this study. The intensity of the disease was recorded at fortnightly intervals, in the untreated check plots of the fungicidal trial against Phyllosticta leaf spot using a score card having nine grades from zero to eight as given below.(Plate 1).

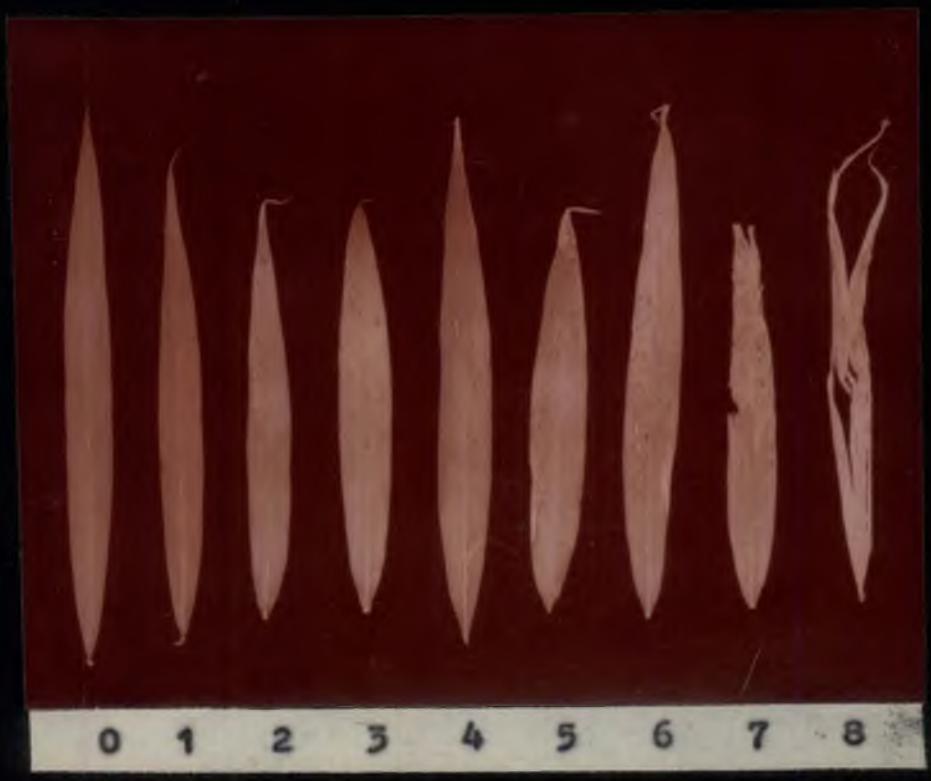


Plate 1. Score card for grading the intensity of Phyllosticta leaf spot of ginger.

Grade	% infection
0	No infection
1	2%
2	5%
3	10%
4	11-20%
5	21-35%
6	36-60%
7	61-85%
8	85%

Score card for grading the intensity of Phyllosticta leaf spot of ginger.

Grade	Intensity of the disease (per cent leaf area infected)
0	No infection
1	Less than 2 (1 or 2 spots)
2	Less than 5 (3 to 5 spots)
3	Less than 10 (6 to 9 spots)
4	11 to 20
5	21 to 35
6	36 to 60
7	61 to 85
8	More than 85

Inoculation studies

Koch's postulates were carried out on potted plants which were grown under the laboratory condition. Whenever the term plant is referred it indicates a clump of tillers. Inoculation studies were carried out by two methods. (1) Atomising heavy spore suspension on three months old ginger plants and covering with polythene bags for 48 hours. Control plants were sprayed with sterile distilled water instead of spore suspension. (2) The leaves of three

months old potted plants were pinpricked and heavy spore suspension was atomised. Control plants also received the same treatment except that sterile distilled water was sprayed, instead of spore suspension. Here also all the treated plants were covered by polythene bags for 48 hours.

All the inoculated plants were kept under observation for 15 days.

Spore germination studies

Spore germination studies were carried out by hanging drop technique by using sterilised slides and moist chamber. The rate of germination of the spores was studied in sterile distilled water, sterile tap water, 10,000 ppm sucrose solution in sterile distilled water and 20 per cent leaf extract. Initial germination studies were carried out to find out the minimum time required for germination. Later, germination counts were taken at 2 hours interval till 100 per cent germination was noticed.

The germination studies were conducted by counting the number of spores germinated, out of a total of 100 spores.

Entry of the pathogen

Mode of entry of the pathogen into the host leaves were studied using the "whole leaf clearing and staining technique" (Shipton and Brown 1962). The studies were conducted on fully matured leaves of six months old ginger plants. These leaves were surface sterilised with ethanol and cut into small bits of one cm^2 size. A drop of thick spore suspension prepared by crushing matured pycnidia from infected leaves was kept on each leaf bit. These leaf bits were kept in sterile moist chamber. The inoculated leaf bits were examined after 6, 12, 24, 36 and 48 hours.

Studies on the survival of the pathogen

The mode of survival of the pathogen on infected leaves were studied under semi field conditions in pots. The infected leaves, just before withering of the plants, were collected from the field, late in the season. Well developed spots before the formation of pycnidia and spots with well developed pycnidia were selected and placed on the surface of the soil and burried separately 5 cms and 15 cms below the soil

level in dry and moist conditions. The leaf samples were taken from the soil at fortnightly intervals and the viability of the fungs was studied by tissue isolation technique for seven months.

Screening of ginger types against the disease

The germplasm collection of ginger in the College of Horticulture was used for screening studies. The list of twenty-two ginger types used for the study are given below:

1. Arippa	2. Bajpai
3. Burdwan	4. Ernad-Chernad
5. Ernad-Manjeri	6. Himachal Pradesh
7. Jorhut	8. Juggijan
9. Karakkal	10. Maran
11. Nadiya	12. Narasapattam
13. Rio-de-Janeiro	14. Taiwan
15. Thingpuri	16. Thinladium
17. Tura	18. Valluvanad
19. Vengara	20. Wynad-Kunnamangalam
21. Wynad-local	22. Wynad-Manantoddy

For each type 48 sprouted seed rhizomes of uniform size were sown in a bed having 3 x 1 metre size. All

the cultivation operations and plant protection measures for soft rot of ginger were carried out as per the package of practice recommendations (Anon 1978).

The natural infection of the disease and its intensity on different types of ginger were recorded at fortnightly intervals. The disease intensity scoring was done by using the same score card used for grading the intensity of the disease.

For studying the intensity of infection, four clumps were selected from each bed using random numbers. These clumps were tagged and all the subsequent observations were taken from these clumps. All the leaves of the tagged clumps were graded for their intensity of disease and the disease index was calculated by a modified method of Mc Kinney's scale (1923).

$$\text{Disease index} = \frac{\text{(grade x number of leaves)}}{\text{Total number of leaves}} \times \frac{100}{\text{Maximum disease score}}$$

= per cent infection

Fungicidal studies

Bioassay studies in vitro

Bioassay studies were conducted using 12 fungicides by poison food technique (Zentmeyer, 1955) to find out

effectiveness of different fungicides against P. zingiberi. All the fungicides except Bordeaux mixture were tried in five concentrations, 100, 250, 500, 1,000 and 2,000 ppm, while Bordeaux mixture was tried only at 1% concentration. The trade name and active ingredient of the fungicides used are given below:

1. Antracol	Zinc-propylene-bis-dithiocarbamate
2. Bavistin	2- (Methoxy-carbamoyl)-benzimidazole
3. Bayer 5072	P-Dimethyl amino-benzene diazo-sodium sulfonate
4. Bordeauz mixture	Basic copper sulphate
5. Cuman	27% Zinc dimethyl dithiocarbamate
6. Difolatan	N-1, -1, 2, 2-tetrachloroethyl thio-cis-4-cyclohexene-1, 2-dicarboximide.
7. Dithane M-45	75% co-ordination product of zinc ion and manganous ethylene bis-dithiocarbamate
8. Dithane Z-78	75% ethylene bis-dithiocarbamate
9. Fycop A	40% copper oxychloride
10. Hinosan	O-ethyl-S, S-diphenyl dithiophosphate
11. Kitazin	48% O-O-diethyl-S-benzyl thiophosphate
12. Panolil	Guazatine-40% W/V. (Guanidated 9-aza-1, 17-diamino-heptadecane acetate salt)

Solid medium

Twenty ml of potato dextrose agar medium was taken in test tubes and sterilized in an autoclave under 15 lbs pressure for 20 minutes.

The fungicides from the stock solution were added to the potato dextrose agar medium taken in the test tubes, to get the required concentrations. This was mixed well and poured into the sterilized petri dishes. Five millimeter diameter inoculum discs of seven day old, uniformly grown culture was placed in the centre of the dish aseptically and incubated at room temperature. Media without the fungicide was taken as the control. For each treatment four replications were maintained. The growth of the organism on the media was measured every 24 hours till the organism completely covered the 90 mm petri dish in the control. The per cent inhibition of the growth of the organism was calculated by the formula (Vincent 1927).

$$I = \frac{100\ (C - T)}{C}$$

where I = Inhibition of fungal growth

C = growth in check

T = growth in treatment

Liquid medium

The bioassay studies were also conducted in liquid medium, using potato dextrose broth. The fungicides used and concentrations tried were the same as those used in the solid medium. For the study, 100 ml of the sterilized potato dextrose broth was taken in 250 ml conical flask and the fungicides were added into the madium from the stock solution to get the required concentrations. Potato dextrose broth without any fungicide was kept as the control. Fungal discs of five mm diameter taken from uniformly grown, seven day old culture were used for inoculation. The flasks were incubated at room temperature. The treatments were replicated thrice. After 15 da's growth, the dry weight of the fungal mycelium in each treatment was found out. The fungal mat was filtered through a previously weighed Whatman no. I filter paper. This was then oven dried at 60°C till two consecutive weights agreed. The dry weight of the fungal disc alone was also found out as above.

Fungicidal trial in the field

Moderately susceptible ginger type, Maran, was

selected for this study. The experimental area was ploughed well and raised beds of 3 x 1 metre size with 25 cm height were formed. The experiment was laid out in randomised block design with seven treatments and four replications. Each plot consisted of four beds. Between beds a spacing of 50 cm was given. Each plot was one metre apart seperated by a small bund to avoid possible drift of the fungicide and other treatment influences. Forty seed rhizomes of uniform size having one or two sprouted buds were sown in each bed with a spacing of 30 cm x 25 cm. These rhizomes were treated with 0.25% agallol-3 solution for 30 minutes before planting. Three plants from each bed were selected using random numbers for estimating the disease intensity. Thus 12 plants were selected from each plot as observational plants. The disease intensity was recordedusing the same score card used for grading the intensity of disease. Cultural operations were carried out as per the package of practice recommendations (Anonymous 1978). Sufficient control measures were taken against soft rot disease by soil drenching with cheshunt compound.

Treatments

Five fungicides which were found significantly effective in checking the growth of *P. zingiberi* in the bioassay studies viz. antracol, Bordeaux mixture, cuman, difolatan and panolil were used for the field experiment. Fycop, the copper oxychloride fungicide, even though did not give good result during *in vitro* studies, was also included in the field studies with a higher concentration of 0.25 per cent, as copper oxychloride is one of the most popular fungicide in Kerala. The concentrations of the fungicides used are given below:

Fungicide	Concentration
Antracol	0.2%
Bordeaux mixture	1%
Cuman	0.1%
Difolatan	0.2%
Fycop	0.25%
Panolil	0.05%

Each treatment, consisting of four plots, received 2.5 litres of the spray fluid per application. The fungicides were sprayed using a knapsack sprayer. In the control plots water was sprayed instead of

fungicide solution. Sufficient care was taken to avoid the drift effect of the spray fluid. Three fungicidal sprays were given at six weeks interval starting from six fortnights after planting the rhizomes. The first spraying was given immediately after the appearance of Phyllosticta leaf spots in the field. The observations were taken at three weeks interval. The last observation was taken just before withering of crop, one month before harvest.

Statistical analysis

The statistical analysis of the data on disease index for different fortnights of the screening trial of ginger types was carried out using the Analysis of Variance technique of the randomised block design.

Ranks were assigned to the types in each fortnight based on the disease index and the ranked data were analysed according to the method suggested by Walker and Lev (1965). The significance of the difference between the ranking of treatments over the different fortnights were tested using the Wallis-Kruskal H test*. The test criterion for the test is given below:

---

* H is found to follow a χ^2 distribution with degrees of freedom equal to (m - 1).

$$\chi^2 = \frac{12}{m(p)(p+1)} \left(\leq_{i=1}^{p} T_i^2 \right) - 3m (p+1)$$

where, m = number of fortnights

p = number of treatments (ginger types)

The analysis of the consolidated data of the fortnightly averages of disease index in different ginger types was carried out by using the ordinary analysis of variance technique of the randomised block design.

Data on per cent inhibition of growth of P. zingiberi by poison food technique with different concentrations of fungicides after six days incubation obtained from the result of the bioassay studies in solid medium were analysed according to the method suggested by Federer (1955). The data were transformed to angles by using the inverse sine transformation given by = $\text{Sin}^{-1}\sqrt{p}$ where is the angle corresponding to the per cent p. The variations between fungicides and between concentrations within fungicides were evaluated and tested for significance.

The data from the bioassay studies in liquid medium were analysed without effecting the transformation

because the observations were mycelial weights of the fungal growth in different treatments. The method of analysis followed was same as described above besides that the general effect of fungicides over control was tested for significance.

Data to determine the comparative efficacy of different fungicides in the control of Phyllosticta leaf spot disease of ginger during each period of observation were analysed by implying the analysis of variance technique of randomised block design.

The overall increase in disease index during the entire period of observation was calculated and the resulting observations were analysed statistically to measure the effects of different fungicides on the disease intensity. The average yield per plot was also recorded and subjected to statistical analysis.

The influence of weather parameters on the intensity of the disease was determined by working out the simple correlation coefficients. The correlation between the average number of leaves per plant in each fortnight and the intensity of the disease was also calculated. The partial regression coefficient were

computed to know the relative effects of the different independent variables on the disease index. The coefficient of determination (R^2) was calculated to measure percentage variation explained by the independent variables of the multiple regression equation.

Results

RESULTS

Symptomatology

The first infection in the field was observed only five fortnights after planting. The initial symptom of the disease was noticed on the physiologically active leaves as chlorotic specks on the infection court. Within 48 hours these chlorotic specks enlarged slightly and became dark brown in colour. These brownish spots measured 0.2 - 0.5 mm in size. These spots further enlarged with a definite margin. A well developed spot was oval or elongated, rarely circular in shape with a papery white holonecrotic area encircled by dark brown raised margin, surrounded by yellowish halo. The matured spots measured 6.0 - 10.0 mm x 2.0 - 6.0 mm in size. In few cases the holonecrotic area later dropped off resulting shot hole symptoms (Plate 2). Often the spots coalesced to form large patches.

The fructification of the fungus was noticed on the host tissue only on well developed spots which appeared in the field only after seven fortnights after planting in the month of September. During the later stages of the crop growth the fructifications of the fungus was noticed

Plate 2. Symptomatology of Phyllosticta leaf spot of ginger.

even in the developing spots. Pycnidia were found even 3 - 4 days after the production of the spots.

Causal organism

The pathogen causing the leaf spot disease of ginger was isolated and brought into pure culture on potato dextrose agar. Detailed studies on morphological characters of the organism were conducted. The organism was identified as Phyllosticta zingiberi Ramakr. (Ramakrishnan 1942). The description of the present collection is given below. Phyllosticta zingiberi Ramakr. Proc. Indian Acad. Sci. B. 15: 167-171, 1942.

Spots numerous, epiphyllous oval to elongated, holonecrotic area papery white, dark coloured raised margin, surrounded by an yellow halo, 5.0 - 10.9 mm x 3.0 - 4.0 mm in size, rarely resulting in shot holes.

Pycnidia numerous, amphigenous, gregarious, scattered over the holonecrotic area, at first completely covered with epidermal layer, later erumpent, dark brown in colour, subglobose to globose, ostiolate, leathery, wall composed of four to six

pseudoparenchymatous cells, 60 - 135 Aim in diameter, conidiogenous cells simple, aseptate, elongated to pyriform formed from the inner layer of the conidial wall 6.0 - 10.0 um x 3.5 - 4.5 µm. Conidia holoblastic, hyaline, unicellular, oval to oblong, biguttulate, smooth walled with a mucilaginous coating, 4.6 - 9.3 µm x 2.5 - 3.9 µm (Figs. 1, 2, and 3) on living leaves of Zingiber officinale Rosco., Vellanikkara, 20.10.1980, Premanathan, T.

The fungus was brought in pure culture. The morphological characters of the fungus on culture media were slightly different from those found in the natural substratum. The fungus grew well on potato dextrose agar medium with thick aerial growth. The hyphae were hyaline in the initial stage, later became dark coloured. On potato dextrose agar medium the fungus covered a 90 mm petri dish within a period of six days under laboratory conditions. Sometimes the interwoven mycelium formed sclerotia like structures in the culture.

On potato dextrose agar medium, pycnidial production was noticed from fourth day onwards. The pycnidia

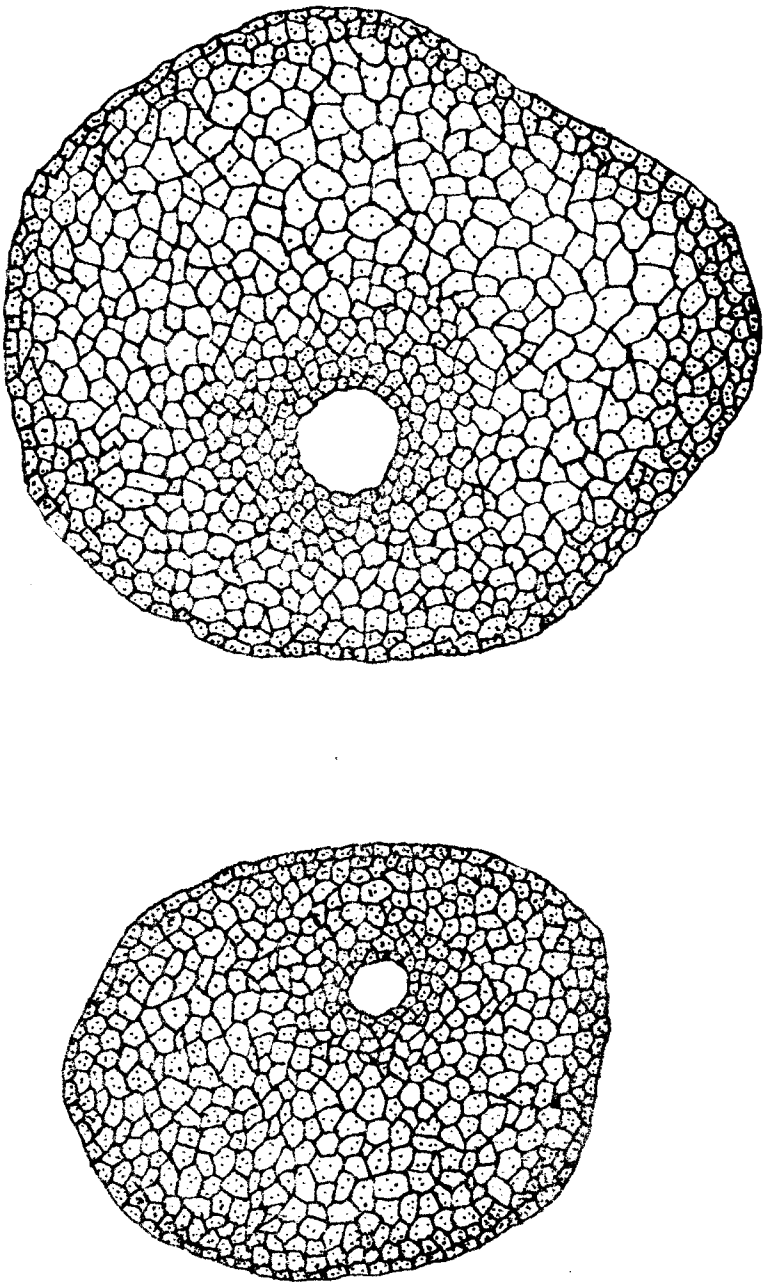


FIG. 1. PYCNIDIA OF *Phyllosticta gingiberi* Ramakr.

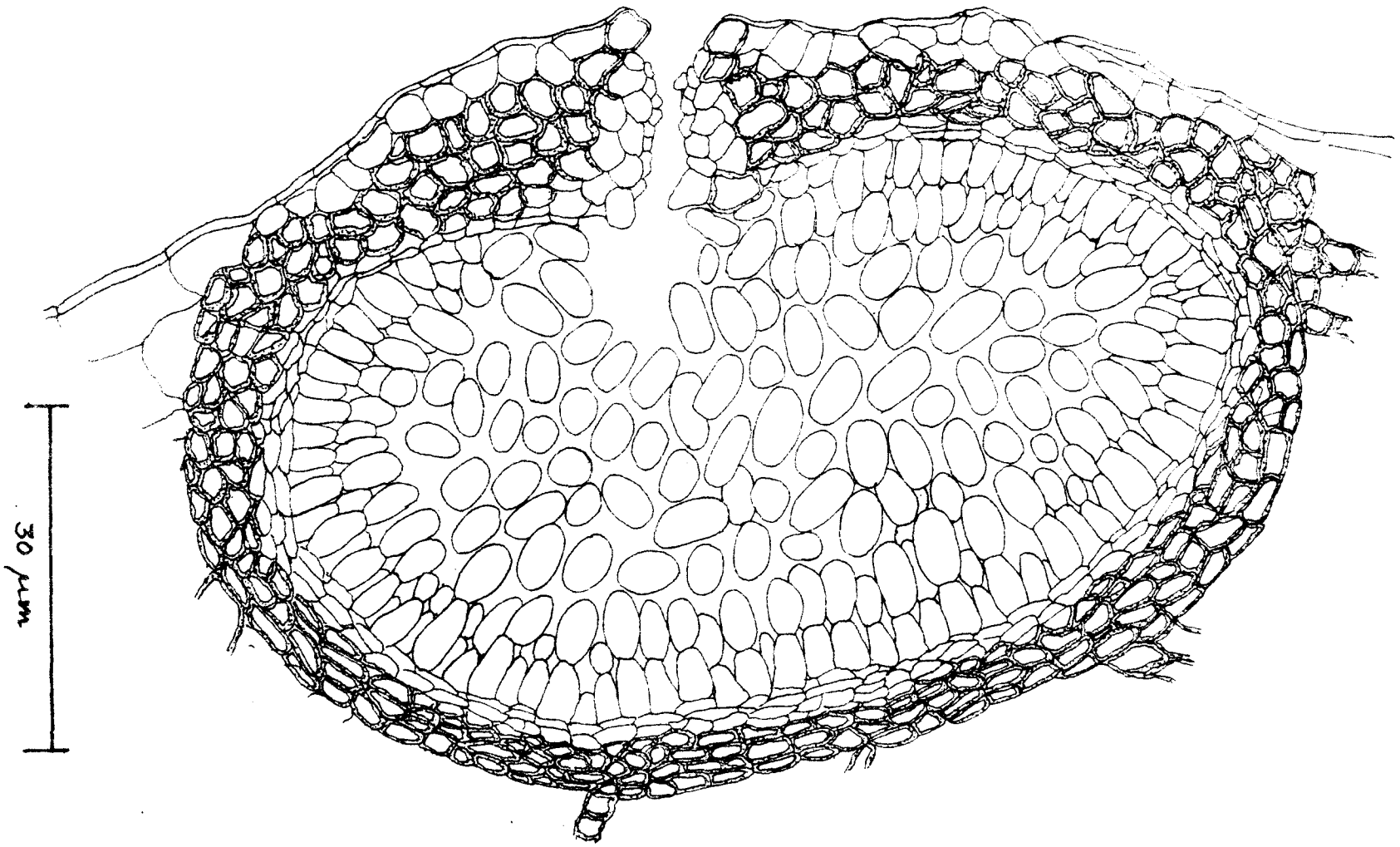


FIG. 2. C.S. OF PYCNIDIUM OF *Phyllasticta zingiberi* Ramakr.

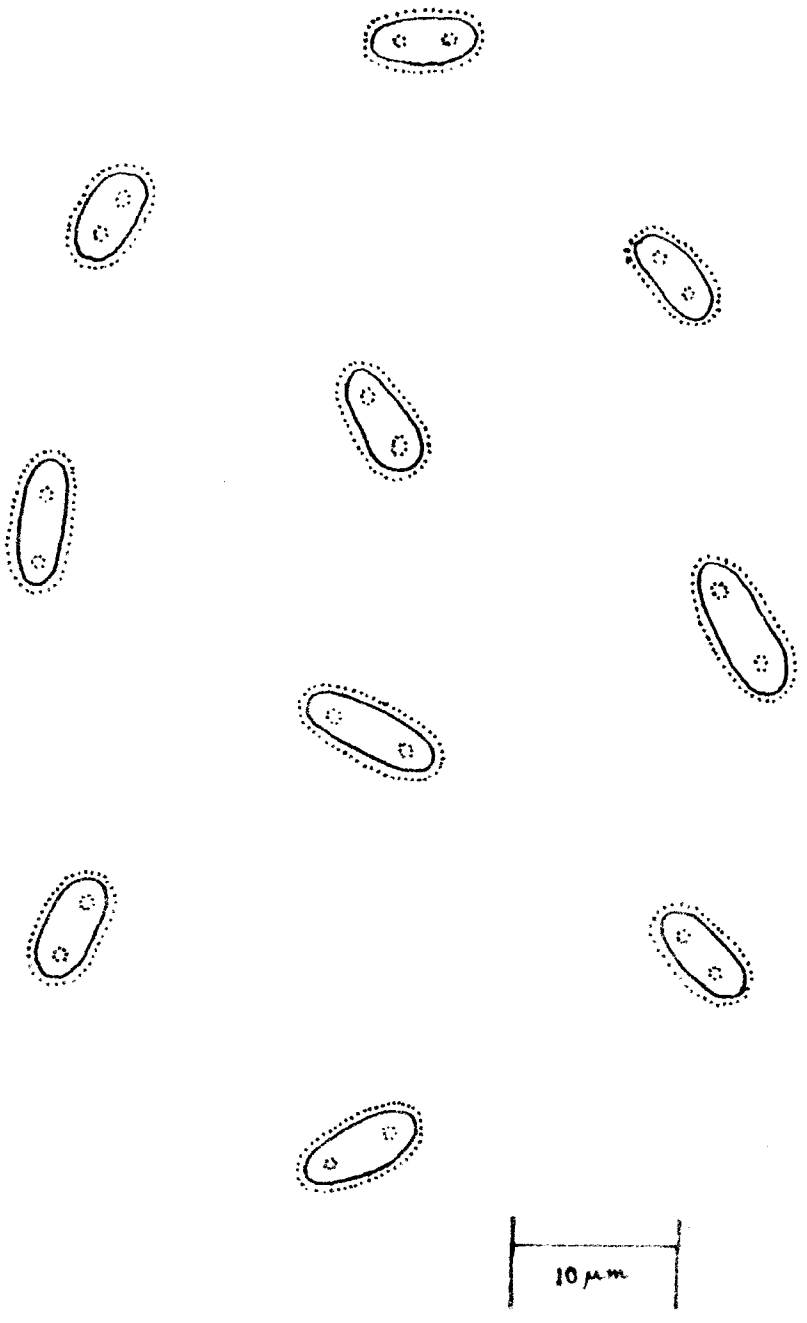


FIG. 3. CONIDIA OF *Phyllosticta zingiberi* Ramakr.

were abundant, gregarious, subglobose to globose, ostiolate, erumpent, dark coloured and thin walled with a size of 457.8 - 934.6 µm. The size of the pycnidia in artificial media was much higher than that seen in the natural substratum. Similarly the conidiogenous cells and conidia in culture were also larger than those noticed on the infected leaves. The conidiogenous cells measured 10 - 15 µm x 4.0 - 6.0 µm and the conidia measured 4.6 - 14.0 µm in length and 3.0 - 4.5 µm in breadth.

Inoculation studies

Inoculation studies revealed that uninjured leaves inoculated with the fungus did not take infection. However, when spore suspension was sprayed on injured leaves infection was obtained. Infection was not obtained on plants sprayed with sterile distilled water instead of spore suspension (Table 1).

On injured leaves infection was not obtained on the first three leaves from the top. All other leaves took infection on artificial inoculation. The infection obtained ranged from 81.63 - 88.24 per cent with an average of 84.69 per cent. The

Table 1. Effect of inoculation on injured leaves of ginger plants using spore suspension of *P. zingiberi*.

Sl. no.	Total no. of leaves	No. of leaves infected	Per cent infection
1	51	45	88.24
2	62	52	83.87
3	44	37	84.09
4	73	62	84.93
5	59	50	84.75
6	49	40	81.63
7	47	39	82.98
8	33	28	84.85
9	32	28	87.50
10	53	45	84.91
		Average infection	84.69

first visible symptom noticed was dark brown spots without any definite margin. Later on the spots enlarged and the holonecrotic area became grey white with a definite dark brown margin.

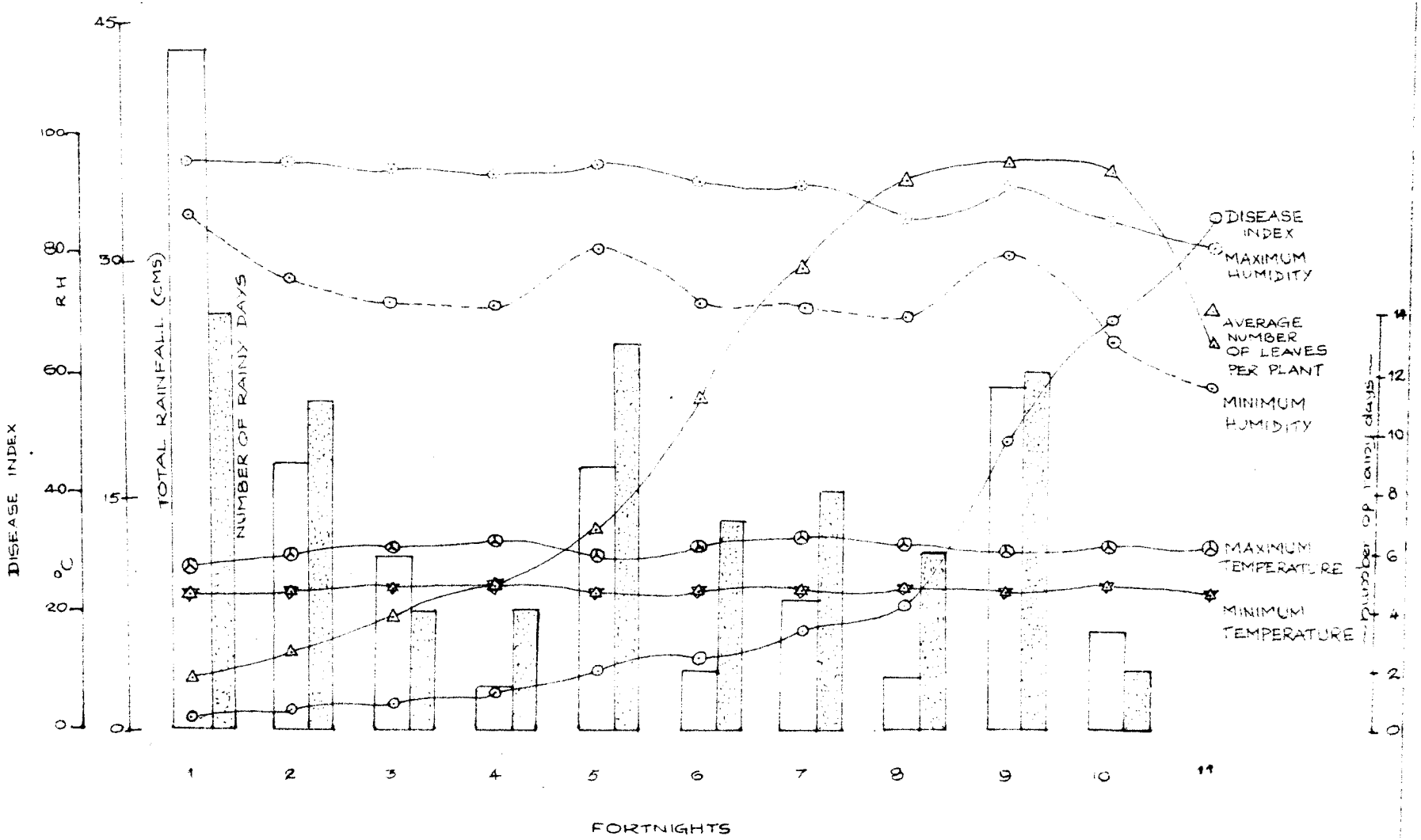
The development of the disease in the field

The intensity of the disease at periodic intervals, weather data and average number of leaves per ginger plant at fortnightly interval are given in table 2, and represented in figure 4.

The first visible symptom of the disease in the field was observed during the first week of August when average number of leaves was 14 per clump. During this fortnight 458.36 mm rainfall was received resulting in high relative humidity (average maximum 95.43 per cent and minimum 86.57 per cent) and low average temperature (average maximum 27.56°C and minimum 22.88°C). The disease intensity was only 1.94 per cent at this stage.

The intensity of rain was reduced during the second fortnight after symptom development and there were only 11 rainy days with 177.21 mm rainfall resulting in a lowering of average minimum relative humidity (76.21 per cent) though the average maximum relative

FIG-4 Effect of plant parameter (average number of leaves per plant) and weather factors on the intensity of Phyllosticta leaf spot



humidity was not changed appreciably. A slight increase both in average maximum and minimum temperatures was noticed during this period. Within this fortnight 11 new leaves were produced per clump and the disease intensity was increased to 2.81 per cent.

During the third fortnight after the appearance of the disease there was only four rainy with 116.12 mm rainfall. The low rainfall during this period resulted in a reduction of both average maximum and minimum relative humidity (average maximum 94.29 per cent and average minimum 71.86 per cent) and an increase in average maximum and minimum temperature (30.13°C and 23.59°C respectively). An average of 14 new leaves were produced in each clump during this period and the disease intensity increased to 4.00 per cent.

In the fourth fortnight after the appearance of the disease in the field, rainfall was very meagre (24.80 mm) which was received in four days. But this low rainfall did not cause any change in relative humidity (average maximum 93.50 per cent and minimum 71.57 per cent). The day and night temperature increased from 30.13°C and 23.59°C to 31.75°C and 24.16°C respectively.

During this period an average number of 48 leaves was noticed per clump and the disease intensity increased to 6.03 per cent.

In the fifth fortnight there was 13 rainy days with a total rainfall of 176.10 mm which increased the average minimum relative humidity and decreased the maximum and minimum temperature. During this fortnight 20 new leaves were produced and the disease intensity was 9.94 per cent.

During the subsequent three fortnights (sixth, seventh and eighth) the rainfall humidity and temperature pattern was almost similar and that was lower than the previous fortnight. There was a slight increase in the average maximum temperature. The number of leaves during this period increased continuously and the number of new leaves produced was 44, 44 and 29 respectively. The disease intensity during this period was 11.85, 16.56 and 20.89 per cent respectively.

During the nineth fortnight the north east monsoon was very active and there was 12 rainy days with a total rainfall of 230.88 mm resulting in an increase in the relative humidity and a decrease in temperature. Only five new leaves were produced during this period.

Table 2. Fortnightly averages of the disease index, number of leaves per plant and weather factors influencing Phyllosticta leaf spot of ginger.

Sl. no.	Disease index (%)		Temperature(°C)		Relative humidity(%)		Rainfall(mm)		Average no.of leaves per plant
	Average	Increase	Average maximum	Average minimum	Average maximum	Average minimum	Total rainfall	Rainy days	
1	1.94	1.94	27.56	22.88	95.43	86.57	458.36	14	14
2	2.81	0.87	29.32	23.04	95.29	76.21	177.21	11	25
3	4.00	1.19	30.13	23.59	94.29	71.86	116.12	4	39
4	6.03	2.03	31.75	24.16	93.50	71.57	24.80	4	48
5	9.94	3.91	29.22	23.24	95.07	81.21	176.10	13	68
6	11.85	1.91	31.01	23.65	92.50	72.00	40.00	7	112
7	16.56	4.71	32.60	23.66	91.57	70.29	87.00	8	156
8	20.89	4.33	31.76	24.11	86.00	69.43	36.90	6	185
9	48.74	27.85	30.11	23.36	91.71	80.14	230.80	12	190
10	69.82	21.08	31.27	24.08	85.78	64.44	64.00	2	189
11	85.07	15.25	31.16	22.71	79.86	57.43	---	---	130

The severity of the disease in the field suddenly increased from 20.89 to 48.74 per cent.

During the tenth fortnight there was only two rainy days with 64 mm total rainfall. The relative humidity both maximum and minimum decreased to 85.78 and 64.44 per cent respectively and there was a very slight increase in the maximum and minimum temperature when compared to the previous fortnight. No new flushes were produced during this period indicating that the crop has attained maturity. There was a marked increase in the disease intensity (48.74 to 69.82 per cent) during this period.

In the fortnight just before the harvest there was no rainfall and the actual winter season started indicating low humidity with low night temperature. As the plants attained the harvesting maturity now new flushes were produced and a large number of old leaves dried and there were only 130 leaves in each clump. During this period the disease intensity reached the maximum (85.07 per cent) and there was not even a single leaf without the leaf spot (Table 2 and Fig. 4).

Effect of weather parameters and plant parameter on the development of Phyllosticta leaf spot of ginger.

From the correlation matrix (Table 3) it is observed that maximum and minimum temperature, maximum and minimum relative humidity, total rainfall and number of rainy days were having no significant effect on the intensity of the disease. The number of leaves per plant was found to influence significantly the intensity of disease with positive correlation.

The corrected coefficient of multiple determination (R^2) was found to be 0.7103 indicating the goodness of fit and implying that 71.03 per cent of variation in the intensity of Phyllosticta leaf spot of ginger could be explained by the included independent variables (Table 4).

In this epidemiological studies the calculated values of minimum and maximum temperature, minimum and maximum relative humidity, total rainfall, rainy days and average number of leaves per plant were -0.1595, - 0.7416, 0.1466, 0.6121, -0.0276, -0.9574 and 1.7702 respectively. These would mean that a unit decrease in the maximum temperature would, ceteris paribus increase 0.1595 per cent incidence of Phyllosticta leaf spot, a decrease in

Table 3. Correlation matrix between the intensity of Phyllosticta leaf spot and weather factors/plant parameter.

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Y	1.0	0.14245^{NS}	-0.02270^{NS}	-0.51299^{NS}	-0.23683^{NS}	-0.04660^{NS}	-0.16701^{NS}	0.70157*
X_1		1.0	0.64413*	-0.51719^{NS}	-0.73681*	-0.86100*	-0.67253*	0.56379^{NS}
X_2			1.0	-0.03556^{NS}	-0.23483^{NS}	-0.50778^{NS}	-0.36321^{NS}	0.31755^{NS}
X_3				1.0	0.83490*	0.56169^{NS}	0.71896*	-0.65088*
X_4					1.0	0.84564*	0.93686*	-0.43539^{NS}
X_5						1.0	0.79953*	-0.37792^{NS}
X_6							1.0	-0.26986^{NS}
X_7								1.0

NS : Non significant

* Significant at 5% level

Y : Disease intensity (increase in disease index)

X_1 : Fortnightly average maximum temperature

X_2 : Fortnightly average minimum temperature

X_3 : Fortnightly average maximum humidity

X_4 : Average minimum humidity

X_5 : Fortnightly total rainfall

X_6 : Fortnightly total number of rainy days

X_7 : Average number of leaves per plant in each fortnight

Table 4. Linear regression coefficient of factors influencing the Phyllosticta leaf spot disease of ginger.

Variable	Partial regression coefficients (b)	S.E. of b	't' value
X_1	-0.9271	5.8124	-0.1595
X_2	-10.2192	13.7795	-0.7416
X_3	0.2653	1.8100	0.1466
X_4	1.5680	2.5616	0.6121
X_5	-0.0018	0.0649	-0.0276
X_6	-2.9636	3.0956	-0.9574
X_7	0.1591	0.0899	1.7702

Multiple correlation coefficient R = 0.8428* * Significant at 5% level

$R^2 = 0.7103$

$$Y = 644.6471 - 0.9271X_1 - 10.2192X_2 + 0.2653X_3 + 1.5680X_4 - 0.0018X_5 - 2.9636X_6 + 0.1591X_7$$

one °C in minimum temperature, ceteris paribus, would increase 0.7416 per cent incidence of the disease, a unit increase of maximum relative humidity would, ceteris paribus increase 0.1466 per cent, a unit increase in minimum relative humidity would, ceteris paribus make an upward variation in the incidence by 0.6121 per cent disease. A unit reduction in total rainfall and rainy days would, ceteris paribus result in the increase of 0.276 per cent and 0.9574 per cent respectively. A unit increase in the parameter, the average number of leaves per plant would, ceteris paribus increase the intensity of the disease by 1.77 per cent.

Spore germination studies

The minimum time required for the germination of spores was different in different media (Table 5). Among the four media used, the spore germination time was minimum in 10,000 ppm sucrose solution, followed by 20 per cent leaf extract, sterile tap water and sterile distilled water. The minimum time required for spore germination in these media was two hours, three and a half hours, three hours 45 minutes and four hours respectively. Since the minimum time required for initial germination was two hours,

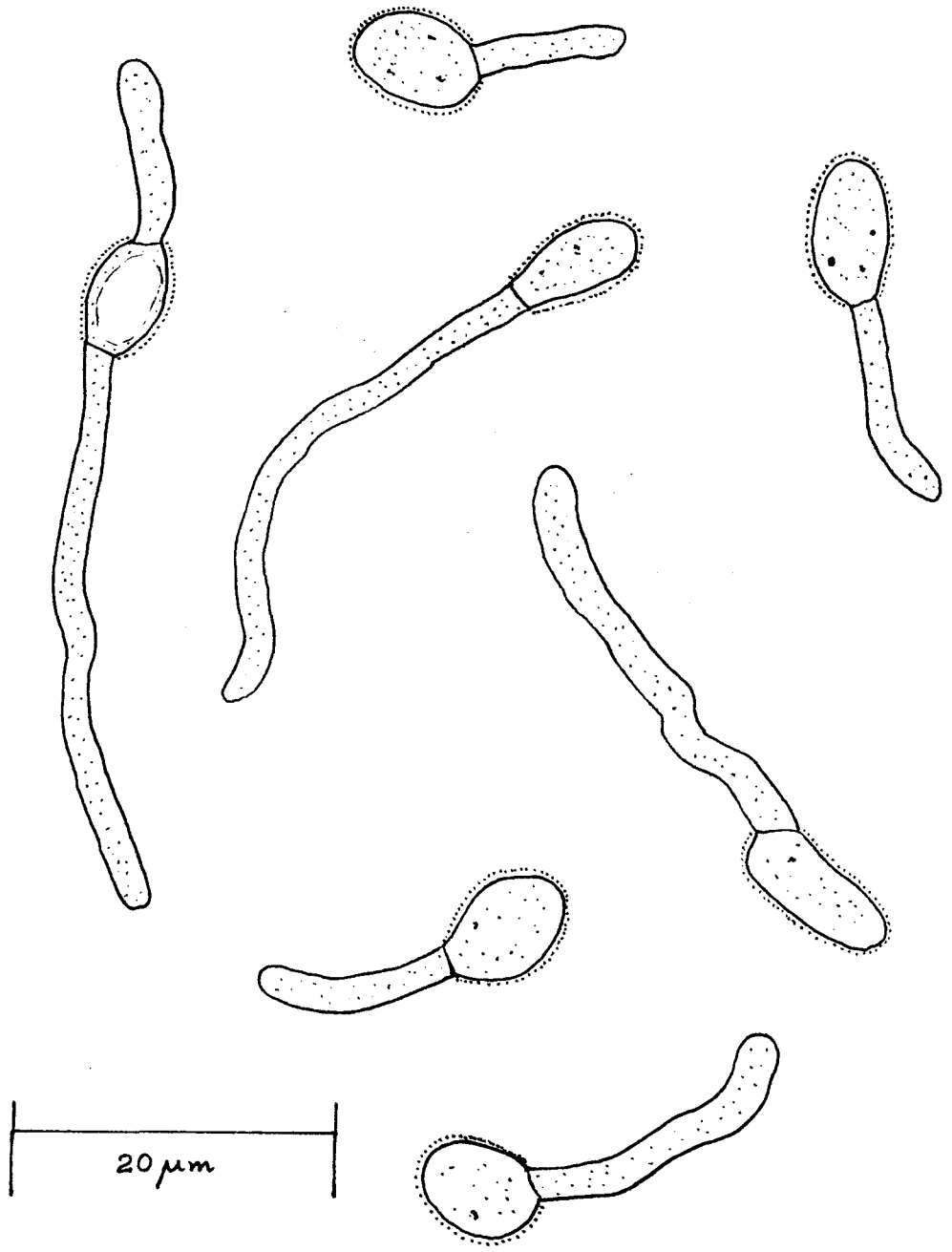


FIG. 5. CONIDIAL GERMINATION OF *Phyllosticta zingiberi* Ramakr.

the germination count was taken at an interval of two hours, till cent per cent germination was observed. Cent per cent germination of the spores was noticed within 12 hours in sterile distilled water and 10,000 ppm sucrose solution, while it took 14 hours in the case of sterile tap water and 20 per cent leaf extract (Table 5). In general spores of P. zingiberi germinated by putting forth a single polar germtube (Fig. 5) while some germinated by putting forth two germ tubes. In the initial stages of germination all the spores germinated by a single germ tube in all the media. The first double germ tube production was noticed in 10,000 ppm sucrose solution after six hours and it was only 3.3 per cent. This increased to 58.3 per cent after 14 hours. In tap water this phenomenon was observed only after eight hours. The double germination in this media was 2.3 per cent after eight hours and 31.7 per cent after 14 hours. In distilled water double germ tube formation was very meagre and was only 10 per cent even after 14 hours. This phenomenon was not observed in leaf extract (Table 6). In both cases the germ tubes were developed from the polar ends.

Table 5. Per cent germination of pycnidiospores of P. zingiberi in different media at different intervals.

Treatments	Time in hours						
	2	4	6	8	10	12	14
Distilled water	0.0	3.3	33.3	65.0	86.7	100	100
Tap water	0.0	8.3	30.0	58.3	78.3	91.7	100
10,000 ppm Sucrose solution	6.7	65.0	76.7	88.3	98.3	100	100
20% Leaf extract	0.0	33.0	52.0	65.0	81.7	93.3	100

Table 6. Per cent production of double germ tubes by the pycnidiospores of P. zingiberi in different media at different intervals.

Treatments	Time in hours						
	2	4	6	8	10	12	14
Distilled water	0.0	0.0	0.0	0.0	0.0	10.0	10.0
Tap water	0.0	0.0	0.0	2.3	15.0	28.3	31.7
10,000 ppm Sucrose solution	0.0	0.0	3.3	15.0	30.0	56.7	58.3
20% Leaf extract	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Entry of the pathogen

Entry of the pathogen into the ginger leaf was studied as described in the materials and methods. Conidia artificially inoculated on both surfaces of the leaf were found germinated. In all cases the spores were germinated within four hours and put forth the germ tube parallel to the leaf surface. After 48 hours well developed branched hyphae were noticed and they developed parallel to the leaf surface. These hyphae showed no affinity towards the stomata. From the germ tube no infection peg or appressoria were found to be developed. In some cases the germ tubes showed direct penetration into the leaf surface.

Survival studies

The mode of perennation of the fungus was studied with an aim to find out the survival pattern of the pathogen in the field. The infected leaves with and without pycnidia were kept on the surface and buried five and fifteen cm below the soil surface. A set of the above treatments was kept dry and another wet by controlled irrigation. The samples were drawn

at fortnightly intervals from all the treatments and viability of the fungus was studied by isolating the pathogen from the leaf bits. The leaves kept in and on the dry soil did not decompose and the whole leaves remained intact throughout the period of observation. When the leaves were kept wet, they decayed gradually and at the end of the experimental period it was difficult to get complete leaf bits. Decomposition was more in buried leaves under wet condition. However, the pathogen could be isolated throughout the period of observation (seven months) from the leaves containing pycnidia and from those which did not contain pycnidia. The growth of the fungus from the leaf bits were observed three days after culturing. There was no difference in cultural characters of the organism which was isolated from the leaf bits containing pycnidia and those which did not contain pycnidia.

Screening of ginger types against Phyllosticta leaf spot

Twenty two ginger types were screened against the disease in the field condition. The incidence of the disease was first noticed in the field during the first

fortnight of August, five fortnights after planting. The observations were taken at fortnightly intervals and the intensity of the disease was measured as described in the materials and methods. The final observation was taken when the plants started withering which was the sign of maturity of the crop. The intensity of the disease at fortnightly intervals is given in Table 7.

During the first observation, the minimum disease intensity was noticed in the ginger type, Himachal pradesh (0.28 per cent) followed by Burdwan (0.30 per cent) and Nadiya (0.46 per cent) while the maximum intensity was noticed in the type Jorhut (5.81 per cent) followed by Taiwan (5.27 per cent) and Rio-de Janeiro (3.77 per cent). Other types showed varying degrees of disease intensity between these extreme values.

A gradual increase in the intensity of disease in the different types was noticed with the maturity of the crop. The intensity of disease varied with the types. When the intensity of disease was observed at the end of the first fortnight of September (eight fortnights after planting) the type Himachal pradesh continued to show low disease intensity (1.82 per cent) compared to other types. The type Burdwan also showed a similar trend with a disease intensity of 2.23 per cent. The type Jorhut which showed the highest intensity of disease during the sixth fortnight of planting continued

to show highest disease index (8.28 per cent) after eighth fortnight of planting. However, the intensity of the disease in this type got reduced from 5.81 per cent found in the sixth to 4.06 per cent in the seventh fortnight. The maximum increase in disease index of 1.95 to 9.43 per cent was noticed in the type Juggijan (Table 7).

When the plants completed three fourth of the growth period (after 11 fortnights of growth, by October last) the pattern of disease development showed considerable change in the different types screened. At this stage, the type Maran showed the least disease intensity of 9.71 per cent followed by Burdwan (10.48 per cent), Karakkal (10.85 per cent) and Bajpai (10.94 per cent). The maximum intensity of disease observed at this stage was in the type Valluvanad (18.95 per cent) followed by Juggijan (18.82 per cent) and Tura (18.11 per cent)(Table 7).

During the month of November there was a sudden increase in the disease intensity in all the types. At this stage the disease intensity in the type Maran increased from 12.01 per cent during first fortnight of November to 31.85 per cent in the second fortnight.

Similarly the type Karakkal showed an increase from 12.31 to 32.57 per cent, Nadiya 15.24 to 39.21 per cent and Bajpai 13.28 to 39.24 per cent. The maximum increase in the disease intensity of 36.21 was observed in type Vengara (20.23 to 56.44 per cent) followed by Taiwan (19.25 to 54.12 per cent), Jugijan (20.85 to 53.14 per cent) and Valluvanad (19.84 to 52.89 per cent)(Table 7).

From last fortnight of November to the final observation in December, there was a marked increase in the disease development. However it was not as pronounced as was noticed during first to second fortnight of November. During the final observation (15th fortnight after planting) the type Maran exhibited the minimum disease intensity (53 per cent) followed by Karakkal (55 per oent),Bajpai (65.25 per cent) and Narasapattam (68.25 per cent). The maximum disease intensity during the same period was observed in the type Vengara (94.50 per cent) followed by Taiwan (92.13 per cent), Arippa (86 per cent) and Wynad-local (84.25 per cent)(Table 7).

The progress in the disease development of different types varied with time. This variation was different in different types. The type Maran which showed least disease index at the final stage of

observation was ranked only seventh during the initial stage of disease development, 12th after three fortnights and then the intensity got reduced. From second fortnight of October (11 fortnight after planting) till the final stage Maran was ranked first. When the disease index in other types suddenly increased during the 13th fortnight the intensity of increase was only 19.84 per cent in Maran compared to 36.21 per cent in type Vengara which showed the maximum disease index. Karakkal, which was ranked second at the end of last observation was ranked 10th during the sixth fortnight. The type Bajpai which showed a higher rank in the initial stage of the disease development (18th rank) did not show high disease intensity in later stages of crop growth. This type was better than Maran and Karakkal during eighth, ninth and tenth fortnights. During the final observation it was ranked third (Table 7). The type Vengara which showed the maximum disease intensity during the last three fortnights was ranked fifth during the first observation. The disease gradually developed in this type and it was found to be one of the most susceptible type during the final stages ot

Fig. 6. Comparative ranking of ginger types against Phyllosticta leaf spot based on mean disease index.

Rank no.	Type
1	Maran
2	Karakkal
3	Bajpai
4	Nadiya
5	Narasapattam
6	Burdwan
7	Ernad-Manjeri
8	Ernad-Chernad
9	Wynad-Kunnamangalam
10	Thingpuri
11	Thinladium
12	Himachal pradesh
13	Rio-de-Janeiro
14	Arippa
15	Jorhat
16	Wynad-local
17	Wynad-Manantoddy
18	Valluvanad
19	Tura
20	Vengara
21	Juggijan
22	Taiwan

FIG: 6 COMPARATIVE RANKING OF GINGER TYPES AGAINST PHYLLOSTICTA LEAF SPOT BASED ON MEAN DISEASE INDEX

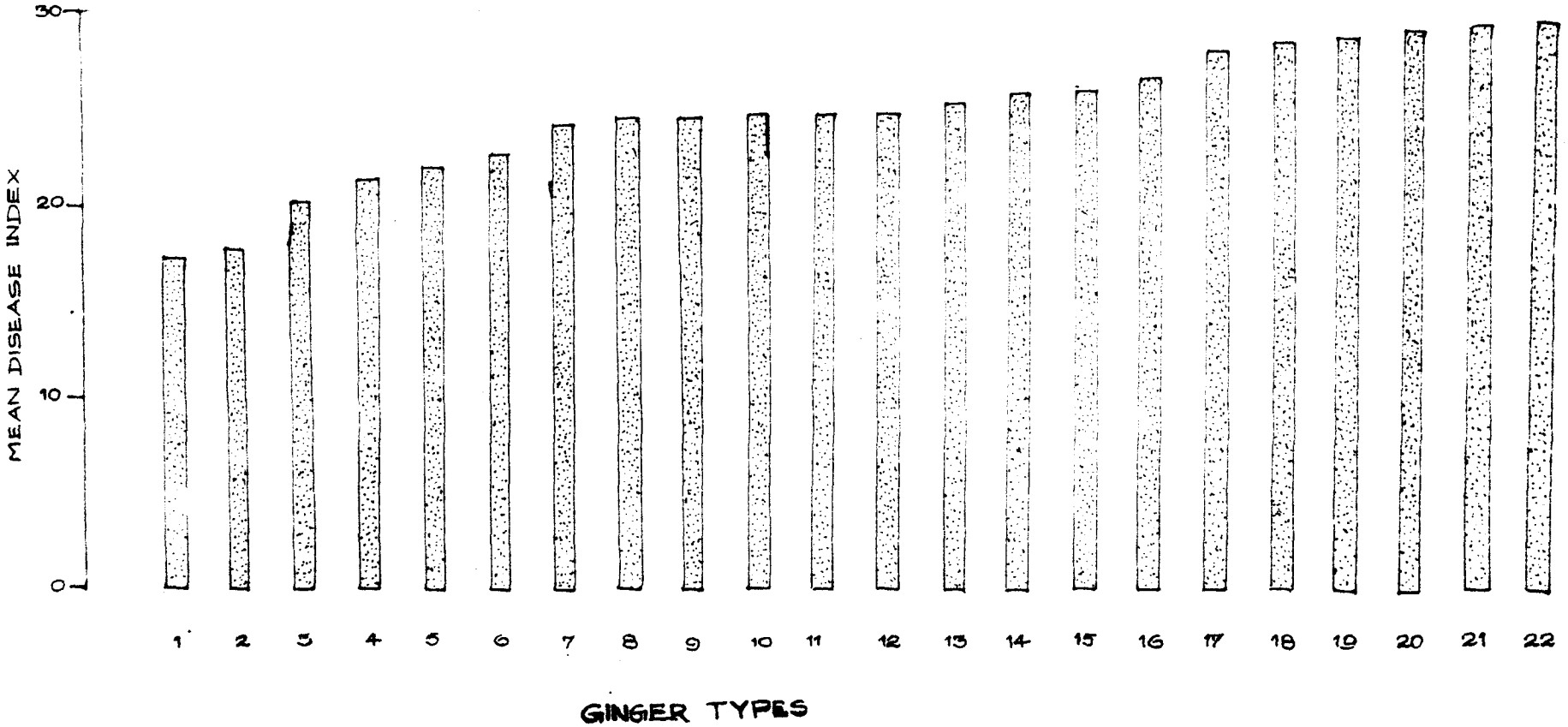


Table 8. Comparative ranking of ginger types against Phyllosticta leaf spot based on mean disease index.

Rank No.	Type	Mean disease index
1	Maran	17.16
2	Karakkal	17.72
3	Bajpai	20.10
4	Nadiya	21.36
5	Narasapattam	21.91
6	Burdwan	22.51
7	Ernad-Manjeri	24.06
8	Ernad-Chernad	24.32
9	Wynad-Kunnamangalam	24.53
10	Thingpuri	24.60
11	Thinladium	24.64
12	Himachal pradesh	24.68
13	Rio-de-Janeiro	25.29
14	Arippa	25.74
15	Jorhut	25.91
16	Wynad-local	26.53
17	Wynad-Manantoddy	27.80
18	Valluvanad	28.28
19	Tura	28.57
20	Vengara	28.90
21	Juggijan	29.08
22	Taiwan	29.16

CD (0.05)

its growth.

The data of the mean disease index based on pooled analysis of the disease index during the crop growth are given in Table 8 and Fig. 6. The type Maran exhibited the minimum disease incidence (17.16) which was on par with the type Karakkal (17.72). The types Bajpai, Nadiya and Narasapattam though on par were significantly inferior to the types Maran and Karakkal. Taiwan with a mean disease index of 29.16 was the most susceptible type. The types Juggijan, Vengara, Tura, Valluvanad and Wynad-Manantoddy were on par with Taiwan.

X^2 test was employed to find out the significance of the difference between the rankings of the ginger types over different fortnights. The test was found to be significant (X^2 = 737.34). Hence a pooled estimate of the true rankings of the ten fortnights after the incidence of the disease in the field was carried out. The lowest total rank was found in type Burdwan (43) followed by Maran and Nadiya (46) which were found to be less susceptible to the disease when compared to other types. The rank totals below 100 were found in types Bajpai (57),

Table 9. Comparative ranking of ginger types against Phyllosticta leaf spot based on aggregate rank.

Rank No.	Type	Total of ranks
1	Burdwan	43
2	Maran	46
3	Nadiya	46
4	Bajpai	57
5	Karakkal	61
6	Narasapattam	75
7	Ernad-Chernad	88
8	Himachal pradesh	94
9	Thingpuri	99
10	Arippa	99
11	Ernad-Manjeri	111
12	Wynad-Kunnamangalam	112
13	Thinladium	129
14	Rio-de-Janeiro	134
15	Wynad-local	142
16	Vengara	144
17	Jorhut	154
18	Valluvanad	167
19	Wynad-Manantoddy	171
20	Tura	180
21	Taiwan	182
22	Juggijan	196

Karakkal (61), Narasapattam (75), Ernad-Chernad (88), Himachal pradesh (94), Thingpuri and Arippa (99). The most susceptible type Juggijan had a maximum total rank of 196 followed by Taiwan (182), Tura (180), Wynad-Manantoddy (171), Valluvanad (167) and Jorhut (154). The total ranks of the other types were in between 100 and hundred and fifty (Table 9).

Fungicidal studies

Bioassay

The effectiveness of 12 different fungicides was evaluated in the laboratory against *P. zingiberi* by poison food technique (Zentmeyer, 1955). The fungicides were tried in different concentrations, from 100 ppm to 2,000 ppm.

Solid medium

P. zingiberi took six days to completely cover a 90 mm diameter petridish in the untreated check. Hence the per cent inhibition was calculated based on the sixth day growth of the fungus in various treatments. The inhibition of growth of the fungus varied in different concentrations of different fungicides (Tables 10 and 11).

Among the fungicides tried, bavistin, Bayer 5072, fycop and panolil did not show any inhibition at 100 ppm concentration and the growth rate noticed in the media incorporated with the above fungicides were similar to the untreated media. All other fungicides showed varying degrees of inhibition. Difolatan induced the maximum fungistatic property with 92.86 per cent inhibition. None of the fungicides tried showed complete inhibition of growth at the lowest concentration.

In the next higher concentration, 250 ppm the maximum inhibition of growth was observed in difolatan (93.15 per cent) followed by antracol (78.27 per cent) and panolil (77.38). Bavistin, even at this concentration did not show any inhibition of growth. Bayer 5072 (19.94), fycop (23.81) and dithane Z-78 (46.56) gave only less than 50 per cent inhibition of the fungal growth. Even in 500 ppm concentration bavistin (5.95) was found to be least effective in checking the growth of the fungus. This was followed by fycop (38.99). All other fungicides gave more than 50 per cent inhibition. Panolil, which failed to inhibit the fungal growth at 100 ppm completely inhibited the growth at 500 ppm concentration. Difolatan (93.48) caused the maximum

Table 10. Growth measurement (in mm) of P. zingiberi by poison food technique with different concentrations of fungicides, on the sixth day.

Sl. no.	Fungicide	Growth measurement (in mm) Concentration in ppm				
		100	250	500	1,000	2,000
1	Antracol	29.25	24.25	16.25	16.00	5.00
2	Bavistin	90.00	90.00	85.00	80.00	73.75
3	Bayer 5072	90.00	73.25	35.00	14.50	5.00
4	Cuman	65.00	33.75	18.25	14.25	8.50
5	Difolatan	12.00	11.75	11.50	11.25	11.00
6	Dithane M45	32.50	29.75	23.00	20.00	20.00
7	Dithane Z-78	59.00	54.25	43.75	27.75	17.00
8	Fycop	90.00	70.50	57.25	27.75	20.00
9	Hinosan	37.00	35.75	32.00	31.00	24.00
10	Kitazin	73.75	43.50	28.25	19.25	19.00
11	Panolil	90.00	25.00	5.00	5.00	5.00
12	Bordeaux mixture 1%	5.00				
13	Control	90.00				

Diameter of the disc planted 5 mm.

Table 11. Per cent inhibition of growth of P. zingiberi by poison food technique with different concentrations of fungicides after six days incubation.

Sl. no.	Fungicide	Concentrations in ppm					Mean
		100(A)	250(B)	500(C)	1,000(D)	2,000(E)	
1	Antracol	72.34 (58.28)	78.27 (62.09)	87.80 (69.58)	88.10 (69.83)	100.00 (84.44)	85.30 (68.85)
2	Bavistin	0.00 (1.40)	0.00 (1.40)	5.95 (14.12)	11.90 (20.18)	19.35 (26.11)	7.44 (12.64)
3	Bayer 5072	(0.00 (1.40)	19.94 (26.53)	65.48 (54.01)	89.88 (71.44)	100.00 (84.44)	55.06 (47.56)
4	Cuman	29.76 (33.04)	66.96 (54.91)	85.42 (67.52)	90.18 (74.84)	97.02 (80.04)	73.87 (61.45)
5	Difolatan	92.86 (74.51)	93.15 (74.81)	93.45 (75.15)	93.75 (75.53)	94.05 (75.88)	93.45 (75.17)
6	Dithane M-45	68.45 (55.83)	71.73 (57.88)	79.76 (63.28)	83.33 (65.90)	83.33 (65.89)	77.32 (61.76)
7	Dithane Z-78	36.90 (37.41)	42.56 (40.71)	55.06 (47.91)	74.11 (59.41)	86.90 (68.78)	59.11 (50.85)
8	Fycop	0.00 (1.40)	23.81 (29.22)	38.99 (38.65)	74.11 (59.41)	83.33 (65.98)	44.05 (38.94)
9	Hinosan	63.10 (52.59)	64.58 (59.48)	69.05 (56.22)	70.44 (56.96)	78.57 (62. 44)	69.11 (56.34)
10	Kitazin	19.34 (26.10)	55.36 (48.09)	73.51 (59.02)	84.23 (66.60)	84.52 (66.81)	63.39 (53.32)
11	Panolil	0.00 (1.40)	77.38 (61.62)	100.00 (84.44)	100.00 (84.44)	100.00 (84.44)	75.48 (63.27)
12	Bordeaux mixture 1%						100.00 (84.44)

(Figures given in parenthesis are the angular transformed values)

CD (0.05) between fungicides excluding Bordeaux mixture : 2.23

CD (0.05) between concentrations within fungicides : 0.50

CD (0.05) for comparing Bordeaux mixture with other fungicides : 3.87

12 5 1 11 6 4 9 10 7 3 8 2

(Table Contd....)

(Table 11 Contd.....)

Difolatan	E	D	C	B	A	Kitazin	E	D	C	B A
Antracol	E	D	C	B	A	Dithane Z-78	E	D	C	B A
Panolil	E	D	C	B	A	Bayer 5072	E	D	C	B A
Dithane M-45	E	D	C	B	A	Fycop	E	D	C	B A
Cuman	E	D	C	B	A	Bavistin	E	D	C	B A
Hinosan	E	D	C	B	A					

inhibition followed by anthracol (87.80) and cuman (85.42). In 1,000 ppm, only panolil induced cent per cent inhibition. All other fungicides, except bavistin (11.90), gave more than 70 per cent inhibition. In the highest concentration (2,000 ppm) cent per cent inhibition was noticed with antracol, Bayer 5072 and panolil. Even in the highest concentration bavistin caused only 19.35 per cent inhibition. All other fungicides tried gave more than 75 per cent inhibition in the highest concentration.

Bordeaux mixture was tried only at one per cent concentration. At this concentration complete inhibition of *P. zingiberi* was observed.

On comparing the efficacy of different fungicides, one per cent Bordeaux mixture was found to be the best followed by difolatan and antracol. Panolil, which was found to be the best in concentrations above 500 ppm when compared with other fungicides, was on par with dithane M-45 and cuman.

There were significant differences among the different concentrations of the same fungicide in inhibiting the fungal growth. Highest concentration of difolatan, 2,000 ppm though was on par with 1,000 ppm

was significantly superior to 500 ppm. In general in difolatan the difference between the effects of two subsequent concentrations were on par while there was significant difference between the effects of alternate concentrations. Antracol at 2,000 ppm completely inhibited the fungal growth while 1,000 ppm and 500 ppm were on par which in turn were better than the lower concentrations. There was no significant difference between the effects of 2,000 and 1,000 ppm concentrations of dithane M-45. These concentrations were significantly superior to the lower concentrations. Complete inhibition of the fungal growth was noticed at 500, 1,000 and 2,000 ppm concentrations of panolil. At 250 ppm the inhibition was only 77.38 per cent while the fungicide failed to inhibit the growth at 100 ppm concentration. In all other fungicides higher concentrations were significantly better than the lower ones in inhibiting the fungal growth.

Liquid medium

The fungus grew well in liquid medium and gave a dry weight of 808 mg in the untreated control (Table 12). The extent of inhibition in fungicide incorporated liquid medium was more than in the corresponding fungicide incorporated solid medium.

Table 12. Mycelial weight (in mg) of P. zingiberi in liquid potato dextrose media incorporated with different fungicides.

Sl. no.	Fungicide	Concentrations in ppm					Mean
		100(A)	250(B)	500(C)	1,000(D)	2,000(E)	
1	Antracol	169	139	136	111	67	124.40
2	Bavistin	105	95	73	73	62	81.60
3	Bayer 5072	432	105	82	73	62	150.80
4	Cuman	144	71	65	63	63	81.20
5	Difolatan	150	130	118	93	77	113.60
6	Dithane M-45	171	126	109	108	110	124.47
7	Dithane Z-78	195	158	107	83	82	125.13
8	Fycop	603	283	148	105	98	247.40
9	Hinosan	207	118	112	96	77	122.00
10	Kitazin	107	94	76	70	69	83.20
11	Panolil	185	132	95	83	73	113.73
12	Bordeaux mixture 1%						62.00
13	Control						808.00

(Weight of the fungal disc used = 62 mg)

CD (0.05) between fungicides excluding Bordeaux mixture : 1.95

CD (0.05) between concentrations within fungicides : 4.37

CD (0.05) for comparing Bordeaux mixture with other fungicides : 3.38

CD (0.05) for comparing control with fungicides : 3.38

12 4 2 10 5 11 9 1 6 7 3 8

Cuman EDCBA Difolatan EDCBA Antracol EDCBA Dithane Z-78 EDCBA
Bavistin EDCBA Panolil EDCBA Dithane M-45 DCEBA Bayer 5072 EDCBA
Kitazin EDCBA Hinosan EDCBA Fycop EDCBA

Fycop was least effective in inhibiting the fungal growth in liquid medium. The dry mycelial weight in fycop incorporated medium was 603, 283 and 148 mgs in 100, 250 and 500 ppm concentrations of the fungicide respectively. Even at the highest concentration of 2,000 ppm, this fungicide failed to inhibit the growth completely. Bordeaux mixture completely inhibited the growth of the fungus at one per cent concentration. Bavistin, Bayer 5072 and cuman also completely inhibited the growth at the highest concentration of 2,000 ppm. All other fungicides showed only fungistatic property even at the highest concentration - antracol (67 mg), kitazin (69 mg), panolil (73 mg), difolatan and honosan (77 mg) followed by dithane Z-78 (82 mg) and fycop (98 mg). Among the different fungicides tried at 2,000 ppm, the maximum fungal yield was obtained in dithane M-45 incorporated medium. Cuman showed fungicidal property even in 500 ppm concentration. All other fungicides showed varying degree of fungistatic property in the lowest concentrations.

When the mean mycelial dry weight of the fungus in media incorporated with different fungicides were compared Bordeaux mixture one per cent was found to be

superior to all other fungicides followed by cuman and bavistin which were on par. The next better fungicide was kitazin which was on par with bavistin. Difolatan and panolil were found to be superior to the remaining fungicides and they were on par. All the fungicides are found to be better than the control.

Field studies

The fungicides which were found to give high degree of inhibition of growth in in vitro studies were selected for field trial for controlling the Phyllosticta leaf spot disease of ginger. Fycop (copper oxychloride) eventhough found less effective in in vitro trials was also included in the field trial because it is a cheaper, readily available and popular fungicide in the market.

The intensity of disease in the field before the fungicidal spray was recorded. Disease intensity ranged from 0.94 per cent to 2.07 per cent and the difference between the treatments was not statistically significant (Tables 13 and 14 and Fig. 7).

The first fungicidal spray was given six fortnights after planting. Three weeks after the first spray the maximum disease incidence (5.31 per cent) was noticed in

Table 13. Comparative efficacy of different fungicides in the control of Phyllosticta leaf spot disease of ginger.

Treatment no.	Fungicides	Disease index during each observation							Average disease index
		pre spraying (1)	3 weeks after 1st spray (2)	6 weeks after 1st spray (3)	3 weeks after 2nd spray (4)	6 weeks after 2nd spray (5)	3 weeks after 3rd spray (6)	6 weeks after 3rd spray (7)	
T_1	Antracol	1.16	1.48	5.73	9.17	16.98	32.74	75.25	20.36
T_2	Bordeaux mixture	2.07	1.88	4.94	7.16	12.74	22.81	60.29	15.98
T_3	Cuman	1.32	1.63	4.53	4.83	10.39	19.15	57.53	14.20
T_4	Difolatan	0.94	1.26	7.43	8.73	15.81	29.71	70.47	19.20
T_5	Fycop	1.72	1.92	6.84	9.15	16.43	31.85	74.82	20.39
T_6	Panolil	1.59	2.83	6.67	8.39	14.24	26.32	63.21	17.57
T_7	Control (no fungicide)	1.94	3.31	8.25	11.27	18.94	37.72	85.07	23.80

The results of the statistical analysis and the ranking of fungicides in each observation and the pooled data are given in table 14.

Table 14. Effect of different fungicides against Phyllosticta leaf spot disease of ginger.

Observation period	Se_m	CD	Comparison
1st observation		NS	T_4 T_1 T_6 T_3 T_5 T_7 T_2
2nd observation	0.28	0.84	T_4 T_1 T_3 T_2 T_5 T_6 T_7
3rd observation	0.97	2.88	T_3 T_2 T_1 T_6 T_5 T_4 T_7
4th observation	0.82	2.44	T_3 T_2 T_6 T_4 T_5 T_1 T_7
5th observation	0.38	1.12	T_3 T_2 T_6 T_4 T_5 T_1 T_7
6th observation	0.72	2.14	T_3 T_2 T_6 T_4 T_5 T_1 T_7
7th observation	3.12	9.27	T_3 T_2 T_6 T_4 T_5 T_1 T_7
Pooled analysis	0.59	1.76	T_3 T_2 T_6 T_4 T_1 T_5 T_7
Overall increase in disease index	3.20	9.49	T_3 T_2 T_6 T_4 T_5 T_1 T_7

NS indicate non significance

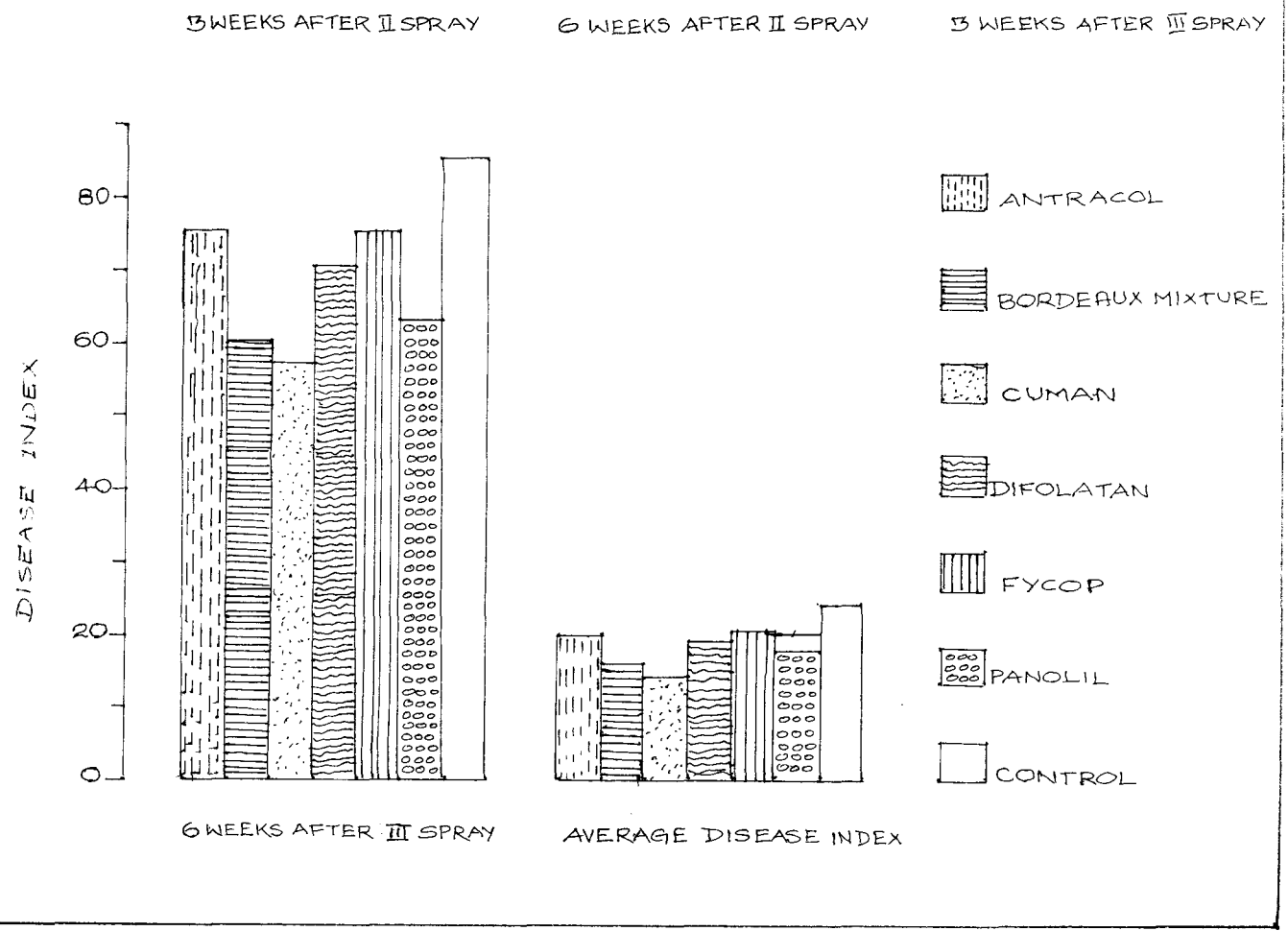
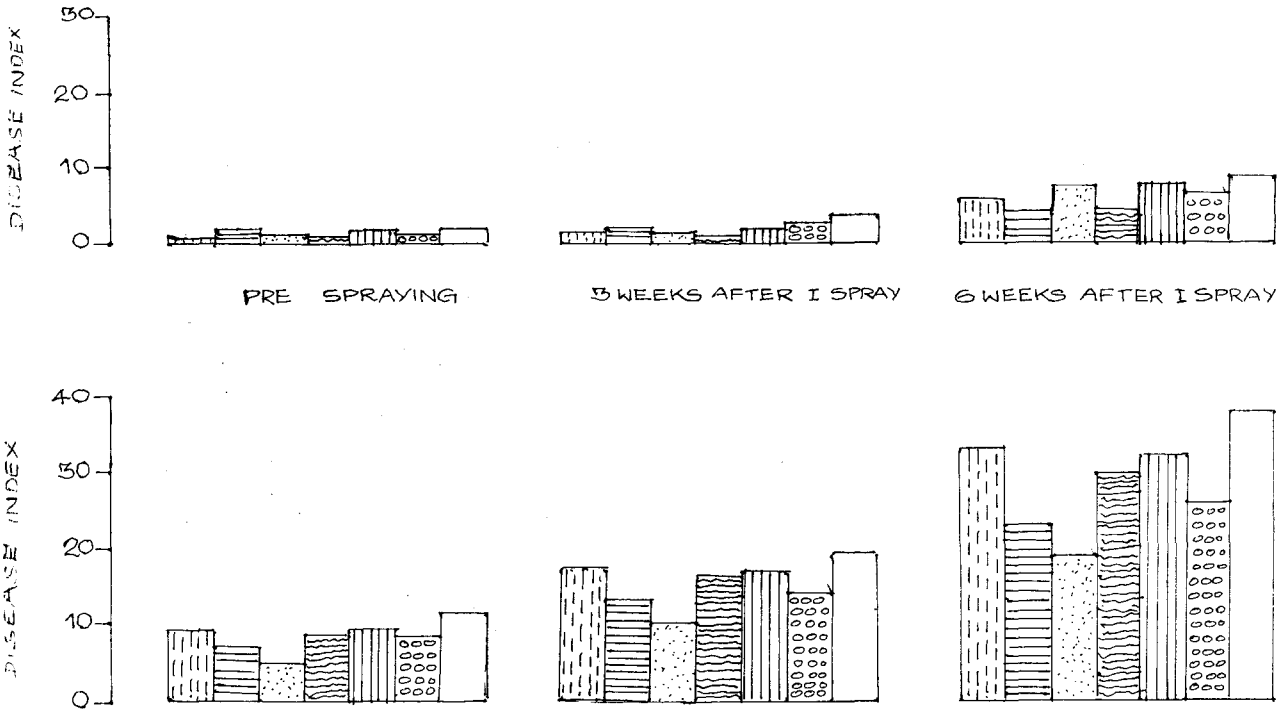

3 WEEKS AFTER II SPRAY
6 WEEKS AFTER II SPRAY
3 WEEKS AFTER III SPRAY
DISEASE INDEX
80
60
40
20
0
ANTRACOL
BORDEAUX MIXTURE
CUMAN
DIFOLATAN
FYCOP
PANOLIL
CONTROL
6 WEEKS AFTER III SPRAY
AVERAGE DISEASE INDEX

FIG. 7. EFFICACY OF DIFFERENT FUNGICIDES ON THE CONTROL OF PHYLLOSTICTA LEAF SPOT OF GINGER



the untreated check plots ad the minimum disease intensity (1.26 per cent) was noticed in plots, sprayed with difolatan. All the plots treated with fungicides except that with panolil were on par and significantly superior to the untreated check while plots treated with panolil and check were on par. A general increase in the disease intensity except in plots treated with Bordeaux mixture sprayed plots, where there was a reduction of 0.19 per cent disease intensity (Table 15). During this period the maximum increase was noted in untreated check plots (1.37 per cent) followed by Panolil (1.24). In all other treatments the disease increase was not much pronounced, which ranged from 0.20 to 0.32 per cent.

Six weeks after the first spray, the minimum disease intensity was noted in cuman treated plots (4.53 per cent). This was followed by Bordeaux mixture (4.94 per cent). The maximum was in untreated check plots (8.25 per cent). The disease index of plots treated with antracol, panolil, fycop and difolatan were found to be on par with the untreated check. Cuman and Bordeaux mixture were found to be superior to control though they were on par with antracol, panolil and fycop.

There was a general increase in the disease intensity in all the plots, from three to six weeks after the first spray. The minimum increase was in plots sprayed with cuman (2.90 per cent) and the maximum in plots treated with difolatan (6.17 per cent) followed by untreated check (4.94 per cent), fycop (4.92 per cent), antracol (4.25 per cent) and panolil (3.84 per cent).

The second spray was given six weeks after the first spray. The disease intensity three weeks after the second spray was found to be maximum in the untreated check plots (11.27 per cent) followed by those with antracol (9.17 per cent) and fycop (9.15 per cent) and minimum in plots sprayed with cuman (4.83 per cent) followed by Bordeaux mixture (7.16 per cent), difolatan (8.73 per cent) and panolil (8.39 per cent). There was significant difference between the treatments. Cuman was found to be superior to all other treatments though it was on par with Bordeaux mixture. The plots which received Bordeaux mixture, panolil, difolatan, fycop and antracol were on par. Fycop and antracol were on par with the untreated check.

Increase in the intensity of the disease was maximum in antracol treated plots and in untreated check (3.44 and 3.02 per cent respectively). The minimum increase

in the disease intensity was noticed in cuman treated plots (0.30 per cent) and panolil (1.72 per cent). But the plots which received Bordeaux mixture had shown an increase of 2.22 per cent and those with fycop an increase of 2.31 per cent (Table 15).

Six weeks after the second spray the disease incidence was found to be minimum (10.39 per cent) in cuman sprayed plots while it was maximum in the untreated check (18.94 per cent) followed by plots treated with antracol (16.98 per cent), fycop (16.43 per cent), difolatan (15.81 per cent) and panolil (14.24 per cent) and Bordeaux mixture (12.74 per cent). Difolatan and fycop were found on par and they were superior to antracol.

The increase in the disease intensity during three to six weeks after the second spray was minimum in cuman (5.56 per cent), Bordeaux mixture (5.58 per cent) and panolil (5.85 per cent) sprayed plots. The increase was maximum in antracol treated plots (7.81 per cent) followed by untreated check (7.57 per cent), fycop (7.28 per cent) and difolatan (7.08 per cent) treated plots.

All the treated plots had significantly lower disease incidence compared to the check (37.72 per cent) when the observation was taken three weeks after the

Table 15. Average increase in disease index, 3 weeks and 6 weeks after each spray in the fungicidal trial against Phyllosticta leaf spot.

Treatment no.	Fungicides	Increase in disease index					
		3 weeks after 1st spray	6 weeks after 1st spray	3 weeks after 2nd spray	6 weeks after 2nd spray	3 weeks after 3rd spray	6 weeks after 3rd spray
T_1	Antracol	0.32	4.25	3.44	7.81	15.76	42.51
T_2	Bordeaux mixture	-0.19	3.06	2.22	5.58	10.07	37.48
T_3	Cuman	0.31	2.90	0.30	5.56	8.76	36.38
T_4	Difolatan	0.32	6.17	1.30	7.08	13.90	40.76
T_5	Fycop	0.20	4.92	2.31	7.28	15.42	42.97
T_6	Panolil	1.24	3.84	1.72	5.85	12.08	36.89
T_7	Control (no fungicide)	1.37	4.94	3.02	7.67	18.78	47.35

third spray. Cuman treated plots continued to show significantly low disease index (19.15 per cent) followed by plots sprayed with Bordeaux mixture and panolil. Difolatan (29.71 per cent) and fycop (31.85 per cent) were statistically on par followed by antracol (32.74 per cent) which was on par with fycop sprayed plots.

The increase in the disease intensity was minimum (8.76 per cent) in cuman treated plots, three weeks after the third spray while the increase was maximum in untreated check (18.78 per cent). Among the fungicide treatments antracol gave the maximum increase (15.76 per cent)(Table 15).

A similar trend was noticed when the observation was taken six weeks after the third spray. However, during this period cuman, Bordeaux mixture and panolil treated plots did not exhibit significant difference among them.

The disease intensity suddenly increased during three to six weeks after the third spray. An increase upto 47.35 per cent (in the untreated check) was observed during this period. In all the fungicides sprayed plots this trend was observed; the minimum in plots treated with cuman (36.38 per cent) and maximum

plots sprayed with fycop (42.97 per cent)(Table 15).

The mean disease index of the seven observation were taken for comparing the efficacy of different fungicides against the disease. All the fungicide treatments were significantly superior to untreated check. Among the fungicide treated plots the minimum disease infection was noticed in those with cuman (14.20 per cent) and it was superior to all other fungicide treatments. Cuman was followed by Bordeaux mixture (15.98 per cent) which was on par with panolil (17.57 per cent). Panolil was on par with difolatan (19.20 per cent). Among the fungicide treated plots the disease infection was maximum in plots sprayed with fycop (20.39 per cent) followed by those with antracol (20.36 per cent) which was on par with those with difolatan. Untreated check gave the maximum intensity of 27.80 per cent (Tables 13 and 14).

When the overall increase in the disease intensity was worked out from the pre-spraying to the final observation the treatments were found significantly different. Out of the six fungicides cuman showed the minimum increase in the disease intensity (56.21 per cent) followed by Bordeaux mixture (58.22 per cent) and panolil

(61.92 per cent) which were not significantly different from one another. The maximum increase in disease intensity was showed by the untreated check plots (83.13 per cent) which was on par with antracol treated plots. Plots treated with fycop (73.10 per cent) and difolatan (69.53 per cent) were on par with those with antracol (74.09 per cent)(Table 16).

Effect of fungicide treatment on the yield

Effect of fungicide treatment on the control of Phyllosticta leaf spot and the rhizome yield of ginger was worked out. Overall increase in the disease index due to the treatment effect and the per cent decrease over control (untreated check) was found out from the average disease index. Similarly from the yield data average yield per plot and the per cent increase of yield over the control as a result of the fungicide application was calculated (Table 16).

The maximum decrease in disease intensity over the control was observed in cuman sprayed plants (32.30 per cent) followed by plots treated with Bordeaux mixture (29.97 per cent), panolil (25.51 per cent), difolatan (16.36 per cent), fycop (12.07 per cent) and antracol (10.87 per cent). Variation in the average rhizome yield

Table 16. Effect of fungicide treatments on the intensity of disease and yield of finger.

Sl. no.	Treatment	Overall increase in disease index	% decrease over control	Average yield per plot in kg	% increase over control
1	Antracol	74.09	10.87	28.240	20.48
2	Bordeaux mixture	58.22	29.97	29.960	27.82
3	Cuman	56.21	32.38	31.640	34.98
4	Difolaten	69.53	16.36	29.840	27.30
5	Fycop	73.10	12.07	24.600	4.95
6	Panolil	61.92	25.51	28.000	19.45
7	Control (no fungicide)	83.13	—	23.440	—

per plot was not statistically significant. However, the variation in the yield was directly proportional to the efficay of the fungicide on the disease control. Cuman treated plots gave the maximum average yield (31.640 kg green ginger per plot) followed by plots sprayed with Bordeaux mixture (29.960 kg), difolatan (29.840 kg), antracol (28.240 kg), panolil (28.000 kg) and fycop (24.600 kg). The lowest average yield of 23.440 kg was recorded in the control plots.

The maximum per cent increase in yield over the control was obtained in cuman treated plots (34.98) followed by plots sprayed with Bordeaux mixture (27.82) and difolatan (27.30). The minimum increase was observed in fycop (4.95 per cent).

Discussion

DISCUSSION

The Phyllosticta leaf spot of ginger is an important disease of ginger, causing complete drying of the leaves during the later stages of the crop growth. The symptoms of the disease has been studied by several workers in India, Ramakrishnan (1942), Sohi *et al* (1964) and Shukla and Haware (1972). The detailed symptoms observed during the study are similar to that observed by earlier workers except that in the present study shot hole symptoms were noticed. However, Mallum and Divinagracia (1969) recorded shot hole symptom from Philippines. The shot hole symptom was not very common and it appears mostly during the dry period. This may be the reason why the earlier Indian workers did not observe this symptom.

The morphological characters of the pathogen, *Phyllosticta zingiberi* has been studied in detail by earlier workers, Ramakrishnan (1942), Sohi *et al* (1964) and Shukla and Haware (1972). In the present study the shape and texture of the pycnidia are found to be similar to that already described by the earlier workers. However, in the size, there is a slight variation and

it was observed to be smaller (60 - 135 um) when compared to that observed by earlier reports. This slight variation may be because the measurement of pycnidia was taken from the type Maran which is proved to be comparatively resistant to Phyllosticta leaf spot (Table 8). Levine (1923 and 1928) working with the uredospores of rust fungi have shown that the spores produced in the resistant plant are smaller.

The pycnidiospores observed on the type species measured 3.7 - 7.4 um x 1.2 - 2.5 µm (Ramakrishnan 1942). In the present study the pycnidiospores from the natural substratum measured 4.6 - 9.3 µm x 2.5 - 3.9 µm and there was no difference in the shape, guttulation and other characters of the spore. The size of the spores observed in the present study were larger than that described by Ramakrishnan (1942). Sohi et al. (1964) and Shukla and Haware (1972) have observed spore size of this pathogen in between the type species and the present observation. This slight difference in the spore measurement does not warrant any taxonomical rearrangement of the pathogen because slight variation in the size and shape of fungal spores may occur due to the influence of the environmental factors.

The cultural characters of the pathogen in potato dextrose agar were similar to that observed by Ramakrishnan (1942). The production of pycnidia in the culture started from fourth day onwards and well matured pycnidia were observed after seven days. However, Shukla and Haware (1972) observed the pycnidial production only after seven days. This variation may be due to the difference in the media and other incubation conditions. The size of the pycnidia and pycnidiospores in the media are found to be much larger when compared to that observed in the natural substratum. In the artificial media the pycnidia measured 457.8 - 934.6 µm and that of the pycnidiospores were 4.6 - 14.0 x 3.0 - 4.5 µm. There are no reports regarding the measurement of the pycnidiospores from the culture. Ramakrishnan (1942) and Shukla and Haware (1972) observed that the size of the pycnidia in the culture measured 100-270 µm and 100-250 µm diameter respectively. In the present investigation the size of the pycnidia observed in culture was much higher. Similar observation has also been observed in the same pathogen which was isolated from the leaf spot of turmeric by Sumanwar and Bhide (1952). They found that in the host the

pycnidiospores were 3.0 - 5.8 x 1.5 - 4.1 µm and on PDA 4.5 - 9.0 x 3.0 - 4.5 µm respectively. This variation in the natural substratum and the culture may be due to the fact that the organism is getting readily available rich nutrients and relatively non disturbant humidity conditions in artificial medium under laboratory conditions. From the above findings the organism causing the leaf spot disease of ginger is further confirmed to be Phyllosticta zingiberi Ramakr. by the present work.

Susceptible plants in a vulnerable state, disease causing parasites in an infective stage and favourable environmental conditions are the three important factors that act in close harmony for the establishment of plant diseases (Miller 1953). The present studies on the infection and development of Phyllosticta leaf spot of ginger reveals that if sufficient inoculum potential is available, the availability of sufficient number of matured leaves is the most important condition for the development of disease in the host. There was a significant positive correlation between the number of matured leaves per plant and the intensity of the disease (Table 3). This is in agreement with the concept of Yarwood (1959)

that "the age of plants and the conditions under which they grow affect their susceptibility to disease, is called pre-disposition, which is the tendency of non genetic conditions, acting before infection, to affect the susceptibility of plants to disease".

The climatic factors also have a direct effect on the intensity of the disease in the field. The severity of the disease in field was found to be high with a reduction of maximum and minimum temperature and an increase in the relative humidity. Thakur (1973) also observed that infection of Hibiscus cannabinus by Phyllosticta hibiscina could become severe with high moisture, damp cloudy weather and a temperature range of 25 - 30°C. The insignificance of the individual weather factors on the disease development in the present study may be because ginger, being a seasonal spice, is growing in a favourable environmental condition for the pathogen throughout the crop growth.

The age and number of leaves are the two important factors for the infection and development of disease in the field. This may be the reason for the low disease index during the early stages of crop growth eventhough the weather factors were favourable for the

infection during this period (Table 2). The inoculation studies have also shown that only physiologically active and mature leaves take infection. This can be attributed to high tannin and phenolic content in the tender and young leaves giving resistance against the fungal infection and development. This explains the low disease intensity during the early stages of crop growth.

When the crop attains maturity there was an increase in the disease index (Table 2). This can be attributed to several reasons. There was a high inoculum in the field during the later stages of the crop growth. This could cause disease on all the available leaves. Secondly, almost all the leaves reached physiological maturity and as was proved in the inoculation studies, the leaves took infection easily. The disease indexing was done by grading all the leaves in each observation. Hence, even if there was no new infection, the older infected leaves gave a higher index with the development and spread of the already existing leaf spots.

A possible reason for low intensity of disease in the field during the early stages of crop growth may be the low inoculum. The initial inoculum should multiply

and only after reaching a proper inoculum potential it can cause disease. Since ginger was not cultivated in the field before, the inoculum should come from the neighbouring fields where the inoculum remained on infected leaves of the previous crop present in the soil or from collateral hosts.

Usually in tap water and distilled water the conidia of Phyllosticta germinate by putting forth a single germtube. However, a very low percentage (10 per cent) of bipolar germination was noticed after 12 hours in distilled water in the present study. Bipolar germination in tap water was more than in distilled water and it was 2.3 per cent after eight hours and 31 per cent after 14 hours. The bipolar germination phenomena was not observed in the leaf extract. The inhibitory effect of the leaf extract may be due to phenols and other inhibitory products present in the leaf sap. Maximum bipolar germination was observed in sucrose solution (10,000 ppm) where it was 3.3 per cent after six hours and 58.3 per cent after 14 hours. The sucrose solution also initiated early germination of the spores and within six hours more than 75 per cent of the spores germinated. Onesirosan (1976) observed that carbon source increase the swelling

of the spores and hasten the germination of conidia of Phyllosticta lycopersici. The increased germination of the conidia in sucrose solution may be because of the stimulating effect of carbon source in sucrose solution. Ekundayo (1965) found that the sugar solution enhanced the germination of fungal spores by inducing plasticity of spore wall. The increased bipolar germination in sucrose solution in the present study may be due to additional energy and materials for the formation of new inner walls which precedes germtube formation were supplied by sucrose. A similar observation was made by Ekundayo (1965) working with Rhizopus spores.

It can generally be assumed that the primary source of inoculum for a disease like leaf spot disease of ginger usually comes either from a perennial collateral host or from a hibernating stage of the pathogen. In the present studies an attempt has been made to study the primary source of inoculum of Phyllosticta leaf spot. The pathogen has been found to survive on the infected plant parts either in the form of hibernating mycelium or its fructification, pycnidia. The pathogen in the infected leaves burried upto a depth of 15 cm or present on the soil surface has been found to survive

for more than seven months (from harvest to the development of symptoms in the next season). Most part of this period in Kerala (January-July) is usually a dry period and the soil temperature may go even upto 40°C. These observations support the findings of Brahma and Nambiar (1980) who reported that the pycnidiospores and mycelia of Phyllosticta zingiberi remained viable for 14 and 30 months under laboratory conditions. They also found that under the field conditions the pathogen survive in the burried leaves in the summer months (February to May). This clearly proves that the pathogen could survive in the soil either in dry or wet condition and serve as primary inoculum in the field.

All the 22 ginger types screened against the Phyllosticta leaf spot were found to be susceptible to the disease in varying degrees. Among the 22 types of ginger screened Maran was found to be the least susceptible and Vengara the most susceptible. A preliminary study conducted by Nybe and Nair (1979), showed Tafingiva to be the most resistant type followed by Maran and Taiwan the most susceptible one. Tafingiva was not included in the present study. In the present investigation Vengara was highly susceptible

followed by Taiwan.

However in the rank analysis, Maran came second to Burdwan. This is because of the high rank position of Maran in the initial stages of observation. In the early stages of crop growth Maran did not show its superiority over the other types but when it attained half maturity it showed high degree of resistance and the disease index was the least. More or less a similar trend has been observed in the type Karakkal. Unlike these two types, Burdwan which has shown a low disease index in the early stages of the crop became highly susceptible as it grew old. The type Bajpai has shown almost same degree of susceptibility from the beginning to the last.

In all the 22 types, the disease intensity showed a progressively increasing trend with an increase in the number of leaves per clump. The least susceptible type Maran had a disease index of 0.67 six fortnights after planting and at the final observation it was 53.00 per cent, followed by 0.86 to 55 per cent for Karakkal. The corresponding figures for the most susceptible type Vengara was 0.49 and 94.50. This indicate that some biochemical substances which induce or inhibit the development of the disease in the

plant, might have developed in the different stages of growth of the host plant.

In the bioassay studies conducted during the present investigation out of the 12 fungicides tried Bayer 5072 at 2,000 ppm and Bordeaux mixture one per cent gave cent per cent inhibition in both solid and liquid medium. Antracol 2,000 ppm and panolil 500, 1,000 and 2,000 ppm gave cent per cent inhibition in the solid medium while in liquid medium there was some growth.

The fungistatic ability of Bordeaux mixture, DNOC, Zineb, Captan, Folpet, Dithianon, Ziram and Copper oxychloride on pycnospores of P. prunicola was reported by Ristanovic (1972). Even though in the present study Hinosan and Fycop was not fungicidal even at the highest concentration of 2,000 ppm in solid and liquid medium, Deshpande et al. (1973) working with Phyllosticta elettariae found these fungicides to be highly effective at 250 and 1,000 ppm respectively. This may be due to the species difference of the fungus. Prasad et al. (1978) observed that difolatan even at the lowest doses (25 ppm) was inhibitory to the pathogen of cardamom leaf spot caused by Phyllosticta elettariae. In the present study,

in solid medium, a similar result was obtained. Even at the lowest concentration of 100 ppm, there was 92.86 per cent inhibition of fungal growth over the control. However, complete inhibition of the fungus was not obtained even at 2,000 ppm (93.45 per cent). A similar result was obtained in liquid medium also (Tables 11 and 12). In liquid medium bavistin 2,000 ppm and cuman 500 ppm and above, gave cent per cent inhibition of growth of the fungus though they supported some growth of the fungus in solid medium. This can be attributed to the uniform dispersal of the fungicides in liquid medium than in solid medium.

The efficacy of six different fungicides viz., antracol, Bordeaux mixture, cuman, difolataan, fycop and panolil, in controlling the leaf spot disease was tested in the field. Three sprays of fungicides at six weeks intervals were given. In general, a definite reduction in the disease index as a result of fungicide spraying is seen from the results. There is significant difference between the effect of different fungicides in checking the disease.

Plots sprayed with difolatan and antracol were found to show minimum disease, three weeks after the first spray. This shows the efficacy of these two

fungicides in checking the disease in a protective manner. The efficacy of difolatan against Phyllosticta was also proved by Rao and Naidu (1974) and Ram and Rao (1978). They observed reduction of the nursery leaf spot of cardamom caused by Phyllosticta elettariae by difolatan. The effect of these two fungicides was found reduced, six weeks after the first spray as indicated by the increase in the disease intensity and the rank position from one and two to six and three respectively (Tables 13 and 14). This may be due to the less persistent nature of difolatan and antracol.

Cuman and Bordeaux mixture were found to be very effective in controlling the disease throughout. They were on par with difolatan and antracol, three weeks after the first spray and afterwards they showed maximum efficacy in checking the disease. This can be attributed to the very good persistent action of these fungicides on Phyllosticta as was shown by (Schneiderhan, 1932; Mc Callan, 1946; Tandon and Bilgrami, 1957; Ristanovic, 1972; Sohi et al, 1973 and Saksena and Kumar, 1974).

Fycop, eventhough a copper fungicide was not effective in controlling the disease which is indicated by the high disease intensity from the beginning to the

end of the experiment, the rank position being five during all the observation.

Panolil was found to have less protective action, which is evident from the fact that it ranked sixth three weeks after the first spray and was on par with the untreated check. However, therapeutic effect of the fungicide can be visualised as there was a reduction in the disease intensity during the subsequent periods of observation and it became on par with cuman; six weeks after the second spray (Tables 14 and 15). Three weeks after the third spray, panolil ranked third based on minimum disease intensity and retained the same position throughout. This may be due to the cumulative and therapeutic action of the fungicide. Therapeutic action of panolil was observed by Shah (1979). The rank position of plots, treated with different fungicides, based on the average disease index remained same from three weeks after the second spray onwards. This is, because being a leaf spot disease, once the disease has set in, the further development of the leaf spot could not be checked effectively. The study emphasizes the need for giving prophylatic spray of fungicides, cuman or Bordeaux mixture which are found to be very effective because of their protective and persistent action.

Summary

SUMMARY

1. The study entitled "Studies on the Phyllosticta leaf spot of ginger" was conducted at the College of Horticulture, Vellanikkara during 1979-1981. The field experiments on screening of ginger types and fungicidal trial against the Phyllosticta leaf spot disease were conducted at the Instructional Farm of the College of Horticulture. The laboratory experiments were conducted at the Department of Plant Pathology.

2. The first visible symptom of the disease was noticed on the physiologically active leaves as chlorotic specks. The well developed spots were oval or elongated, rarely circular in shape with a papery white holonecrotic centre encircled by dark brown raised margin surrounded by yellowish halo measuring 6.0 - 10.0 mm x 2.0 - 6.0 mm in size. Rarely shot-hole symptoms were observed. Often the spots coalesced to form large patches.

3. The causal agent of the disease was found to be *Phyllosticta zingiberi* Ramakr. Koch's postulates were established. Artificial inoculation was successful only on injured leaves inoculated with the

fungus. Even on injured leaves artificial inoculation was not successful on the first three leaves. Fructification (pycnidia) of the fungus was more during the later stages of crop growth.

4. The detailed study on the plant and environmental factors influencing the disease development in the field revealed that the average number of matured leaves per plant had a significant positive correlation with the disease intensity in the field.

5. An increase in the relative humidity and a decrease in the maximum and minimum temperature influenced the disease development positively.

6. Spore germination was faster and maximum in 10,000 ppm sucrose solution. Bipolar germination was noticed more in 10,000 ppm sucrose solution when compared to tap water and distilled water.

7. The pycnidiospores and mycelia of the fungus were found to survive for a period of more than seven months in soil under different depths and at different moisture conditions. This period was the maximum time the fungus should remain in a hibernating condition between the harvest of the crop and symptom appearance in the subsequent crop.

8. None of the 22 ginger types screened was found to be resistant to the Phyllosticta leaf spot. The type Maran was found to be the least susceptible followed by Karakkal and Bajpai. Type Vengara was the most susceptible one.

9. One per cent Bordeaux mixture and 2,000 ppm bayer 5072 gave cent per cent inhibition of the fungal growth in both solid and liquid medium when bioassay studies were conducted using 12 fungicides.

10. Antracol 2,000 ppm and panolil 500 ppm and above gave cent per cent inhibition in the solid medium.

11. Bavistin 2,000 ppm and cuman 500 ppm and above gave cent per cent inhibition of growth of the fungus in liquid medium.

12. All the fungicides tried in the field reduced the disease incidence compared to the untreated check.

13. Cuman was found to be the most effective fungicide in controlling the Phyllosticta leaf spot of ginger, followed by Bordeaux mixture and panolil.

14. Maximum average rhizome yield was noticed in cuman treated plots followed by Bordeaux mixture.

References

REFERENCES

* Anonymous (1960). Diseases of Rhubarb. Agric. Gaz. N.S.W., 71(9): 470-473.

* Anonymous (1971). Plant Pathology. Rep. Agric. Mauritius, 1967. 99-108.

* Anonymous (1972). Annual report of the Research Branch, Dept. of Agriculture, Sarawak; 191 pp.

Anonymous (1974). Annual report 1973. Central Plantation Crops Research Institute, Kasaragod. 149-151.

Anonymous (1978). Package of Practices Recommendations. Directorate of Extension Education, Kerala Agricultural University, Trichur 144 pp.

Bootsma, A., Gillespite, T.J. and Sutton, J.C. (1973). Germination of Phyllosticta maydis conidia in an incubation chamber with control of high relative humidities. Phytopathology 63 (9): 1157-1161.

Brahma, R.N. and Nambiar, K.K.N. (1976). Leaf spot disease of ginger. Annual Progress Report 1976, CPCRI, Kasaragod, 121 pp.

Brahma, R.N. and Nambiar, K.K.N. (1980). Survival of Phyllosticta zingiberi Ramakr., causal agent of leaf spot disease of ginger. Status papers and abstracts, National Seminar on ginger and turmeric, 8-9 April, 1980 ICAR, CPCRI, Regional Station, Calicut: 67.

* Chanlionco, R.C. (1966). Leaf spot disease of ginger - Agric. at Los Banos 6 (2): 16-18.

Chowdhury, S. (1937). Germination of fungal spores in relation to atmospheric humidity. Indian J. Agric. Sc., 7(4): 653-657.

Cochrane, V.W. (1960). Spore germination in Plant Pathology- An Advance Treatise Vol. II (Eds. Horsfall J.G. and A.E. Dimond) 167-202.

Deshpande, R.W., Viswanath, S. and Anilkumar, T.B.(1973). In vitro assay of fungicides against Phyllosticta elettariae, the leaf spot pathogen of cardamom. Mysore Journal of Agricultural Sciences 7 (2): 330-331.

* Ekundayo, J.A. (1965). Studies on germination of fungal spores, with special reference to the sporangiophores of Rhozopus arrhizus. Ph.D thesis, University of Ibidan, Nigeria 123 pp.

Federer, W.T. (1955). Experimental design New York, Macmillan.

Guba, E.F. (1924). Phyllosticta leaf spot, fruit blotch and canker of the Apple; its etiology and control. Phytopathology 14 (5): 234-237.

Gupta, G.K. and Verma, B.R. (1966). Fungal foes that menace ginger crop. Indian Frmg. 16: 15.

* Jain, A.C., Nikam, B.G., Kulkarni, S.N. and Sharma, O.P.(1960). Fungi of Gwalior and Indore region. The Vikram 4: 181-187.

Jimenez-Diaz, R.M. and Boothroyd, C.W. (1976). Suscept-pathogen relationship in maize affected by yellow leaf blight. Phytopathology 66 : 1169-1173.

Kaware, M.T. (1974). Studies on leaf spot of ginger caused by Phyllosticta zingiberi. M.Sc. Thesis. 53 pp + IV. Punjabrao Krishi Vidyapeeth, Akola, India.

Kaiser, V.J. and Lukezic (1966). Occurrence, sporulation and pathogenicity studies with Glomerella cingulata associated with crown rot of boxed bananas. Mycologia 58: 395-405.

* Levine, M.N.(1923). A statistical study of the comparative morphology of biologic forms of Puccinia graminis. J. Agri. Research, 24: 539-567.

Levine, M.N.(1928). Biometrical studies on the variation of physiologic forms of Puccinia graminis tritici and the effect of ecologic factors of the susceptibility of wheat varieties. Phytopathlogy 18: 7-123.

* Mallum, N.P. and Divinagracia, C.G. (1969). Leaf spot of Ginger in the Phillippines. Philipp. Agric., 53(3-4): 202-217.

* Mc Callan, S.E.A. (1946). Dithiocarbamate fungicides. Agric. Chemicals, 1 (7): 15-18 and 55.

Mc Kinney, (1923). Influence of soil temperature and moisture on the influence of wheat seedings by Helminthosporium sativa. J. Agrl. Res., 26: 195-217.

* Mietkiewski., R. and Nowak, A. (1972). Reddish brown leaf spot of chestnut in parks and gardens in Szizecin. Rocznik Sakcji Dendrologicznej Polskiego Towarzystwa Botanicznego, 26: 131-133.

Miller, P.R. (1953). The effect of weather on disease. In Plant Diseases the Year Book of Agriculture, United States Department of Agriculture, Washington, D.C. 83-93.

Natarajan, K. and Srivastava, D.N. (1975). Studies on the fungi associated with Chrysanthemum leaf blight and its control. Indian Phytopath., 28(4): 525-527.

Nybe, E.V. and Nair, P.C.S. (1979). Field tolerance of Ginger types to important pests and diseases. Indian Cocoa, Arecanut and Spices Journal 2 (4): 109-111.

* Onesirosan, P.T. (1976). Nutritional requirements for germination of the conidia of Phyllosticta lycopersici. Mycopathologia 59(3): 131-135.

Ostle, Bernard. (1966). Statistics in Research, Oxford and IBH Pub. Co. 234-236.

* Pavgi, M.S. Upadhyay, R. (1967). Some parasitic fungi on Turmeric from India. Sydowia, 21 (1-6): 100-104.

* Patil, A.S., Deshpande, M.V., Ranade, D.R. and Goobole, S.H. (1975). Laboratory evaluation of some fungicides and antibiotics with respect to their effect on conidial germination and mycetial growth of Phyllosticta ricini E. Mastr. causing leaf spot of Castor (Ricinus communis L.). Labdev. B 13 (314): 105-108.

Prasad, A.S.A., Siddaramaiah, A.L., Kulkarni, S. and Vidyasekhar, T.S. (1978). In vitro studies of fungicides against Phyllosticta elettariae Chowdhury. Curr. Res. 11 : 193-194.

Ramakrishnan, T.S. (1942). A leaf spot disease of Zingiber officinale caused by Phyllosticta zingiberi n. sp. Proc. Indian Acad. Sci. B 15(4): 167-171.

Ram, B. and Rao, D.G. (1978). Efficacy of fungicides for the control of nursery leaf spot and Cercospora leaf spot of cardamom. Pesticides 12 (10): 35-36.

Rao, D.G. and Naidu, R. (1974). Chemical control of nursery leaf spot disease of cardamom caused by Phyllosticta elettariae Chowdhury. 42(1): 14-16. J. Plantn. Crops,

* Ristanovic, M. (1972). Contribution to the study of the control of Phyllosticta prunicola (Opiz.) Secc. parazitasljive. Zastita Bilja 23 (111/120): 139-145.

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

Saksena, H.K. and Kumar, K. (1974). Some aspects of epidemiology and control of Phyllosticta leaf spot of arhar (Cajanus cajan (L.) Millsp.) 399-406.

* Schneiderhan, F.J. (1932). Instant Bordeaux. West Virginia Agric. Exper. Stat. Circ. 60: 8.

Shah, S.E. (1979). Studies on the efficacy of new fungicides against crop disease. M.Sc. (Ag) Thesis, Tamil Nadu Agricultural University, Coimbatore pp 86.

Shipton, A.W. and Brown, J.F. (1962). A whole leaf clearing and staining technique to demonstrate host-pathogen relationships of wheat stem rust. Phytopathology 52: 1313.

Shukla, B.N. and Naware, M.P. (1972). Phyllosticta leaf spot of Ginger (Zingiber officinale) in Madhya Pradesh. Indian J. Mycol. Plant Pathol. 2 (1): 93.

* Smolyakova, V.M. (1968). Selection of preparations for combating Phyllostictosis of Apple. Abs. in Referat. Zh Rasten 11 : 877.

Sohi, H.S., Jain, S.S., Sharma, S.L. and Verma, B.N. (1964). New records of plant diseases from Himachal Pradesh. Indian Phytopath. 17 (1): 42.

Sohi, H.S., Sharma, S.L. and Verma, B.N. (1973). Chemical control of Phyllosticta leaf-spot of Ginger (Zingiber officinale) Pesticides, 7 : 21-22.

Srivastava, S.S.L., Shukla, H.P. and Singh, P.N. (1975). Studies on the sorghum leaf spot caused by Phyllosticta sorghiphila. Indian J. Mycol. Plant Pathol. 5(2) ; 187-188.

Struble, F.B. and Morrison, L.S. (1961). Control of Apple blotch with fungicides. Plant. Dis. Rep. 45(6): 441-443.

Sumanwar, A.S. and Bhide, V.P. (1962). Leaf spot of Turmeric (Cucurma longa L.) caused by Phyllosticta zingiberi Ramakr. J. Indian Bot. Soc. 41(2): 313-315.

Tandon, R.N. and Bilgrami, K.S. (1957). Leaf spot disease of Artocarpus heterophyllus caused by Phyllosticta artocarpina. Proc. Acad. Sci. India, B, 27(4): 204-209.

* Thakur, K.R. (1973). Studies on some factors affecting incidence of Phyllosticta leaf spot of mesta. Rivistia di Pathologia vegetable IV: 9(1): 11-12.

* Togashi, K. (1949). "Biological characters of Plant Pathogens. Temperature Relations" Meibundo, Tokyo, 478 pp.

Vincent, J.M. (1927). Distribution of fungal hyphae in the presence of certain inhibitors. Nature. 159: 850.

Walker, H.M. and Lev, Joseph. (1965). Statistical inference. Oxford and IBH Pub. Co. 438-440.

Yarwood, C.E. (1959). Pre-disposition in Plant Pathology an Advanced Treatise Vol. I (Ed. Horsfall, J.G. and Dimond, A.E., Academic Press, New York, 521-562.

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

* Originals not seen

Appendices

APPENDIX I

Fortnightly averages of disease index of Phyllosticta leaf spot and rank position in different ginger types.

Analysis of variance table

Fortnight ending on	Source	df	Mean square	F
	Total	87		
17--8--1979	Block	3	6.06	1.66^{NS}
(1)	Treat	21	9.17	2.51^{NS}
	Error	63	3.65	
	Total	87		
31--8--1979	Block	3	7.67	3.94**
(2)	Treat	21	4.23	2.17^{NS}
	Error	63	1.94	
	Total	87		
14--9--1979	Block	3	73.66	4.21**
(3)	Treat	21	17.46	1.00^{NS}
	Error	63	17.51	
	Total	87		
28--9--1979	Block	3	68.13	3.58**
(4)	Treat	21	51.94	2.73^{NS}**
	Error	63	19.02	
	Total	87		
12-10--1979	Block	3	0.64	0.58^{NS}
(5)	Treat	21	51.77	47.17**
	Error	63	1.10	

(Contd.....)

(Appendix I Contd....)

Fortnight ending on	Source	df	Mean square	F
	Total	87		
26-10-1979	Block	3	0.87	0.52^{NS}
(6)	Treat	21	33.27	19.88**
	Error	63	1.67	
	Total	87		
9-11-1979	Block	3	0.63	0.19^{NS}
(7)	Treat	21	29.82	8.95**
	Error	63	3.33	
	Total	87		
23-11-1979	Block	3	1.68	1.72^{NS}
(8)	Treat	21	169.18	17.32**
	Error	63	9.77	
	Total	87		
7-12-1979	Block	3	39.19	2.10^{NS}
(9)	Treat	21	293.89	15.72**
	Error	63	18.69	
	Total	87		
21-12-1979	Block	3	159.84	1.06^{NS}
(10)	Treat	21	411.13	2.72^{NS}
	Error	63	151.08	

NS : Non significant

** : Significant at 5% level

CD are given in table 7

APPENDIX II

Analysis of consolidated data of the disease index at fortnightly intervals of different types of ginger against the Phyllosticta leaf spot.

Analysis of variance table

Source	df	Mean square	F
Total	87		
Block	3	1.02	0.38^{NS}
Treat	21	47.88	17.67**
Error	63	2.71	

NS : Non significant

** : Significant at 1% level

CD (0.05) : 2.33

APPENDIX III

Per cent inhibition of growth of *P. zingiberi* by poison food technique with different concentrations of fungicides after six days incubation.

Analysis of variance table

Source	df	Mean square	F
Total	227		
Fungicides	12	5,997.75	44,526.73**
Within Antracol	4	401.97	3,092.08**
" Bavistin	4	493.23	3,794.08**
" Bayer 5072	4	4,544.95	34,961.15**
" Cuman	4	1,338.50	10,296.15**
" Difolatan	4	1.20	9.23**
" Dithane M-45	4	86.76	667.38**
" Dithane Z-78	4	686.96	5,284.31**
" Fycop	4	2,655.16	20,424.31**
" Hinosan	4	59.88	460.62**
" Kitazin	4	1,159.27	8,917.46**
" Panolil	4	5,175.14	39.808.77**
Error	171	0.13	

** Significant at 1% level

CD between fungicides excluding Bordeaux mixture : 2.23

CD between concentrations within fungicides : 0.50

CD for comparing Bordeaux mixture with other fungicides : 3.87

APPENDIX IV

Mycelial weight (in mg) of *P. zingiberi* in liquid potato dextrose media incorporated with different fungicides.

Analysis of variance table

Source	df	Mean square	F
Total	170		
Fungicides	11	30,271.5	3,983.10**
Within Antracol	4	4,358.4	573.50**
" Bavistin	4	944.4	124.26**
" Bayer 5072	4	75,150.9	9,888.28**
" Cuman	4	5,729.6	490.74
" Difolatan	4	2,532.9	333.28**
" Dithane M-45	4	2,163.8	284.71**
" Dithane Z-78	4	7,402.8	974.05**
" Fycop	4	1,35,147.9	17,782.60**
" Hinosan	4	7,531.5	990.99**
" Kitazin	4	833.1	109.62**
" Panolil	4	6,245.1	821.72**
Control vs. Treat	1	13,82,282.0	1,81,879.21**
Error	114	7.60	

** Significant at 1% level

CD between fungicides excluding Bordeaux mixture : 1.95

CD between concentrations within fungicides : 4.37

CD for comparing Bordeaux mixture with other fungicides : 3.38

APPENDIX V

Comparative efficacy of different fungicides in the control of Phyllosticta leaf spot disease of ginger.

Analysis of variance table

Observation period	Source	df	Mean square	F
1st observation (pre spraying)	Total	27		
	Block	3	0.16	0.28^{NS}
	Treat	6	0.71	1.27^{NS}
	Error	18	0.56	
2nd observation 3 weeks after 1st spray	Total	27		
	Block	3	0.72	2.32^{NS}
	Treat	6	2.25	7.26**
	Error	18	0.31	
3rd observation 6 weeks after 1st spray	Total	27		
	Block	3	5.48	1.46^{NS}
	Treat	6	7.47	3.71**
	Error	18	3.76	
4th observation 3 weeks after IInd spray	Total	27		
	Block	3	4.81	1.78^{NS}
	Treat	6	15.87	5.88**
	Error	18	2.70	

(Contd.....)

(Appendix V Contd.....)

Observation period	Source	df	Mean square	F
5th observation 6 weeks after IInd spray	Total	27		
	Block	3	0.37	0.65^{NS}
	Treat	6	32.65	57.28**
	Error	18	0.57	
6th observation 3 weeks after IIIrd spray	Total	27		
	Block	3	0.62	0.30^{NS}
	Treat	6	160.09	77.34**
	Error	18	2.07	
7th observation 6 weeks after IIIrd spray	Total	27		
	Block	3	69.77	1.79^{NS}
	Treat	6	381.70	9.80**
	Error	18	38.96	
Pooled analysis	Total	27		
	Block	3	1.61	1.15^{NS}
	Treat	6	40.53	28.95**
	Error	18	1.40	

NS : Non significant

** : Significant at 1% level

CD are given in table 14

APPENDIX VI

Effect of fungicide treatments on the intensity of disease and yield of ginger.

Analysis of variance table

Effect on	Source	df	Mean square	F
Overall increase in disease index	Total	27		
	Block	3	69.27	1.69^{NS}
	Treat	6	377.30	9.23**
	Error	18	40.87	
Average yield per plot	Total	27		
	Block	3	41.19	2.16^{NS}
	Treat	6	35.25	1.85^{NS}
	Error	18	19.08	

NS : Non significant

** : Significant at 1% level

STUDIES ON THE PHYLLOSTICTA LEAF SPOT OF GINGER

BY

T. PREMANATHAN

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
Kerala - India

1981

ABSTRACT

Laboratory and field experiments of "The studies on the Phyllosticta leaf spot of ginger" were conducted at the College of Horticulture Campus, Vellanikkara during 1979-1981.

The first visible symptom of the disease was observed as chlorotic specks. Fructification was more during the later stages of crop growth.

The detailed study on the plant and environmental factors influencing the disease development in the field revealed that the average number of leaves per plant has a significant positive correlation with the disease intensity.

Koch's postulate and morphological studies proved that the pathogen causing the disease is Phyllosticta zingiberi Ramakr.

Uninjured leaves and first three leaves, even after injury, failed to exhibit the symptoms on inoculation.

Conidia germinated by putting forth single or double germtubes. Sucrose solution (1,000 ppm) supported faster and maximum spore germination and the bipolar germination noted was maximum in this solution.

The fungus entered the leaf by direct penetration of epidermal cells without appressoria formation.

The pycnidiospores and mycelia of the pathogen were found to survive even after seven months in soil under different depths and moisture conditions.

The type Maran was found to be the least susceptible followed by Karakkal and Rajpai, whereas type Vengara was the most susceptible one.

Out of the 12 fungicides tried, one per cent Bordeaux mixture and 2,000 ppm Bayer 5072 gave cent per cent inhibition of the fungal growth in both solid and liquid media. Antracol 2,000 ppm and panolil above 500 ppm in solid medium; bavistin 2,000 ppm and cuman above 500 ppm in liquid medium gave cent per cent inhibition of fungal growth.

In the field trial cuman, was found to be the most effective fungicide in controlling the disease, followed by Bordeaux mixture and panolil.

Maximum rhizome yield was noticed in cuman treated plots followed by Bordeaux mixture.