FUNGAL DISEASES OF SESAMUM IN KERALA

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THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE
DOCTOR OF PHILOSOPHY
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT PATHOLOGY
COLLEGE OF AGRICULTURE
VELLAYANI - TRIVANDRUM

1989

DECLARATION

I hereby declare that this thesis entitled "Fungal diseases of sesamum in Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Fungal diseases of sesamum in Kerala" is a record of research work done independently by Smt. K.K. SULOCHANA under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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ACKNOWLEDGEMENT

The author wishes to place on record her deep sense of gratitude and indebtedness to:

Dr. S. Balakrishnan, Professor of Plant Pathology for suggesting the problem, guidance and supervision throughout the investigation,

Dr. M.Chandrasekharan Nair, Professor of Plant Pathology for the inspiration, critical suggestions and help during the investigation,

Dr. Sasikumar Nair, Professor of Microbiology, for encouragement and help during the investigation,

Dr. A. Visalakshy, Professor of Agricultural Entomology, Dr. P. Padmaja, Professor and Project Co-ordinator (Soil and Agronomy), members of the advisory committee for the valuable suggestions and constant help.

Her thanks are also due to Dr. K.I.Wilson, Professor and Head of the Department of Plant Pathology, Dr. C.K.Peethambaran, Associate Professor of Plant Pathology for their encouragement and help in the preparation of the thesis.

Thanks are also due to Dr. Alice Abraham, Professor of Agricultural Chemistry for the help rendered during chemical analysis and Sri P.V.Prabhakaran, Professor of Agricultural Statistics in designing the experiment and statistical analysis of the results and the staff and post graduate students of the Department of Plant Pathology for the co-operation and help rendered during the course of this investigation.

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF ILLUSTRATIONS

INTRODUCTION

INTRODUCTION

Sesamum (Sesamum indicum L.) is probably one of the most ancient oil seeds known and used by man. India accounts for nearly 47 per cent of the world's total sesamum in area and 30 per cent in production.

In Kerala, sesamum is cultivated throughout the State in an area of 16785 ha. Majority of the area under this crop in this state is confined to the Onattukara region of the districts of Quilon and Alleppey and in Palghat and Trivandrum districts.

Sesamum is cultivated as a third crop in the paddy fields and also as an inter crop in coconut gardens. In recent years the cultivation of sesamum is gaining importance as a major source of vegetable oil resulting in a steady increase in the area of cultivation. Intensified cultivation has led to the out-break of many diseases, of which fungal diseases are very much destructive resulting in considerable reduction in the yield of sesamum.

No systematic efforts have been made so far in Kerala to study the different aspects of various fungal diseases affecting the crop and to evolve proper control measures that can be adopted against these diseases. Detailed information on

the season of occurrence, symptomatology, methods of survival of the pathogens, resistance/susceptibility of different varieties, etc. are necessary for formulating suitable strategy for plant disease management. Considering these major objectives, the following items of work have been carried out in the present studies. ...

Survey on the occurrence of various fungal diseases of sesamum at different localities in different seasons.
Isolation, purification, identification and testing pathogenicity of the fungal pathogens.
Symptomatology of the fungal diseases.
Studies on seed-borne mycoflora of sesamum.
Mode of entry, histopathology and role of toxins, if any.
Survival of the fungal pathogens.
Screening of fungicides against the pathogens.
Residue of fungicide in sesamum plants.
Influence of fungicides on quality and yield of oil.
Screening of sesamum varieties for resistance against important fungal diseases.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Sesamum (Sesamum indicum L.) is usually affected by a number of fungal, bacterial and viral diseases, of which, many of the fungal diseases are very serious in most of the sesamum growing areas. A review of literature on the fungal diseases of sesamum is presented in this chapter.

2.1. Fungal pathogens of sesamum

2.1.1. Alternaria spp.

Dey (1948) conducted studies on leaf spot diseases of sesamum and recorded Alternaria leaf spot, from Kanpur, Benarus and Mirzapur.

A leaf blight disease of sesamum caused by Alternaria sesami was first reported in India by Mohanty and Behera (1958). Minz and Solel (1959) reported a leaf spot disease caused by Alternaria macrospora from Israel. A damping off of sesamum caused by Alternaria sesami was observed in United States and Berry (1960) compared the cultural variants of the fungus causing the disease in Kansas-10 sesamum seedlings inoculated by spraying culture suspensions of A.sesami in green house. Dark brown to black water soaked lesions were found to develop, followed by shrinkage of tissue on stems as well as leaves.

The leaf spots were two cm in dia in older plants and the intensity of symptoms varied with different isolates. The spores of all isolates were similar and born singly or occasionally in groups of two or three. Sesamum isolates of the fungus were non-pathogenic to other crop plants tested. It was found that A.solani from tomato and potato and A.cucumerina from cucurbits did not attack sesamum. All the sesamum isolates of Alternaria were suggested to be cultural variants of A.sesami.

The seed-borne nature of A.sesami was reported by Gobelez (1960) and Leppik and Sowell (1964). Mazzani (1966) gave description of an irregular leaf spot of sesamum caused by Alternaria sp. Malaguti and Ciccarene (1967) reported the importance of a brown angular leaf spot of sesamum caused by Cylindrosporium sesami in Venezuela and suggested that sometimes the infection by C.sesami was associated with irregular concentric leaf spot caused by A.sesami and white round spot caused by Cercospora sesami.

Malaguti (1973) conducted further studies on the leaf spot diseases of sesamum in Venezuela and described the symptoms and pathogens of zonate leaf spot (A.sesamicola), round white spot (Cercospora sesami) and angular brown spot (Cylindrosporium sesami).

The occurrence of cultural strains of A.sesami was observed by Despande and Shinde (1976).

A.sesami was found to attack sesamum plants under highly humid conditions (Mehta and Prasad, 1976). Mohapatra et al. (1977) studied the physiology of A.sesami causing leaf blight of sesamum.

The incidence of Alternaria leaf blight of sesamum in Karnataka was reported to be between 32.28 and 72.21 per cent (Dolle and Hegde, 1984, a). Visible symptoms of the disease were apparent three days after germination of seeds and disease development reached its peak when the crop was 35 days old. Evening humidity and maximum temperature were significant in the disease development of Alternaria leaf blight (Dolle and Hegde, 1984, b).

Bending of stem in sesamum plants as a symptom caused by A.alternata was reported by Rani et al. (1985). The affected plants in the field showed characteristic bending at the site of infection where an elliptical lesion was formed. Leaves, flowers and fruits were affected by the disease and the seed yield was reduced. Maiti et al. (1985)

reviewed major as well as minor diseases of sesamum in India.

2.1.2. Cercospora spp.

Snowden (1927) reported a Cercospora sp. in sesamum. Curzi (1932) observed C.sesami Zimm. var. Somalensis curzi producing sparse spots of 0.5 to 5 mm dia. The spots were at first minute, subround with a white centre surrounded by a blackish purple margin. Later they became larger, angular and distinctly zonate with alternately whitish and blackish purple. The amphigenous, chestnut, dimorphous conidiophores arise from prominent stromata in small bundles or singly. On the upper surface of leaves they usually arise in tufts and are conspicuously thickened at the base and tapering or geniculated at the apex, nonseptate or sparsely septate and measuring 27 to 40 x 3 to 7 µm. On the under surface they arise singly or in bundles of two or four and are straight, septate and frequently 3 to 4 µm in dia. The straight or flexuous cylindrical hyaline conidia are 5 to 6 septate and measuring 40 to 70 x 3 to 3.5 µm.

There are two main species of Cercospora, viz., C.sesami and C.sesamicola causing diseases in sesamum (Mohanty, 1958).

The occurrence of angular leaf spot of sesamum caused by C.sesamicola was recorded by Ferrer (1960) from Panama. The outbreak of the disease was severe causing burning of the leaves and considerably reducing yields. Descriptions of round spot symptoms on sesamum leaves caused by C.sesami was given by Mazzani (1966) and Malaguti and Ciccarone (1967).

2.1.3. Colletotrichum spp.

Snowden (1927) recorded Colletotrichum sp. from sesamum plants. Mehta (1951) reported an anthracnose disease in sesamum caused by Colletotrichum sp. from India and the detailed symptoms were described by Joshi (1961). He reported that later sown crops are severely affected. The green color of the plant is lost or changed to dirty or dull green on one side. The leaves on the other side withered. The cortical portion of the stem is destroyed and the inner portion exposed. The brownish discoloration at times may extend from base to top.

2.1.4. Corynespora cassiicola

Corynespora blight of sesamum caused by C.cassiicola was reported by Stone and Jones (1960). The disease caused

defoliation and death of sesamum plants. Cross inoculation to and from soybean was successful, but the conidia of both isolates were some what broader on sesamum. The fungus was found to be carried both on and within the seeds of both hosts. Singh et al. (1969) reported C.cassiicola causing leaf spot/blight disease in sesamum.

Subero (1975) reported the Corynespora blight caused by C.cassiicola from Venezuela and the incidence of the disease resulted in severe blighting and extensive spots on leaves, capsules and stems at flowering stage leading to defoliation.

Corynespora blight of sesamum caused by C.cassiicola was reported from India by Saksena and Singh (1975). They found that the fungus was pathogenic to tomato and Dolichos sp. and carried both on and within the seeds of affected plants and survived on host plant debris until the next crop season.

2.1.5. Fusarium spp.

Wilt disease of sesamum caused by Fusarium sp. was first reported in India by Butler (1926). Butler and Bisby (1931) reported F.vasinfectum on sesamum causing wilt diseases. A root rot disease caused by F.coeruleum and foot rot disease caused

by F.solani were reported (Joshi, 1961). Jaffe and Palti (1966) observed the occurrence of F.solani and F.oxysporum in association with the wilt of sesamum in Israel. They found that out of the nine species of Fusarium identified in 79 isolates from soil and plant material in association with 18 different hosts, F.solani and F.oxysporum were most prevalent in affected hosts and in many soil types. Mazzani (1966) reported the wilting type of symptoms in sesamum due to Fusarium sp.

The formation of macroconidia in F.oxysporum infecting sesamum was reported by Soloveva and Madumarov (1969). Buldeo and Rane (1978) reported a wilt of sesamum caused by Fusarium sp. and observed that Fusarium sp. was often associated with Macrophomina phaseolina.

Kang et al. (1985) observed that the incidence of Fusarium wilt of sesamum caused by F.oxysporum f. sp. vasinfectum in the variety Kwangsan was considerably influenced by sowing date and mean air temperature in the field during two to three years of continuous cropping. They found that the longer the growth period at lower temperature, the higher the infection.

2.1.6. Helminthosporium spp.

Parisi (1933) was the first to report H.sesami on sesamum. A leaf blotch or serial stem rot symptoms on sesamum plants due to H.sesami and leaf blotch and stem rot symptoms in sesamum caused by H.gigasporum sub sp. javanicum was reported (Joshi, 1961).

Stone (1959) found that H.sesami attacked sesamum plants causing blighting type of symptoms and a relatively long (60 to 72 h) exposure to 100 per cent humidity and a temperature of about 30°C resulted in considerable infection. Plants less than 21 days of age were the most susceptible.

2.1.7. Leveillula taurica

A disease caused by L.taurica in sesamum was reported by Patel et al. (1949) as mildew while Parra et al. (1976) reported L.taurica as woolly mould of sesamum. Etiology of the diseaseswere discussed by the authors.

2.1.8. Macrophomina spp.

Charcoal rot or stem rot or root rot of sesamum caused by M.phaseolina was first reported by Pearl (1923) followed by Mc Rae (1930), Sundararaman (1931), Mehta (1951) and Vasudeva (1961).

Ashby (1927) recorded an infection of M.phaseoli on the dry pods of sesamum. Sundararaman (1932) observed a wilt disease of sesamum caused by M.phaseoli which reduced the yield of sesamum by about 43 per cent. Jain and Kulkarni (1965) found that M.phaseoli caused a root and stem rot of sesamum and that the fungus remained viable in the soil during the severe heat also. It grew best in the laboratory at 25 to 35°C with maximum sclerotial production at 35°C and there was more incidence of the disease at 100 per cent humidity.

A root and stem rot of sesamum caused by M.phaseolina was reported by Gemawat and Verma (1974). Another report on a root rot disease was made by Vir et al. (1974) and they identified the causal agent as M.phaseoli.

2.1.9. Oidium spp.

A powdery mildew disease of sesamum caused by Oidium sp. was reported by Snowden (1927). Oidium attack made the leaves of sesamum more susceptible to infection by Macrophoma corchori (Mehta, 1951; Joshi, 1961).

Roy (1965) recorded the occurrence of powdery mildew of sesamum caused by O.erysiphoides. It was reported that powdery mildew disease of sesamum in the early stages of growth of the crop is due to O.acanthospermi and that the incidence of the disease decreases with age of the plants (Rabindran and Jeyarajan, 1983).

2.1.10. Phytophthora spp.

A stem canker of sesamum caused by Phytophthora sp. was recorded from Peru by Crandall and Dieguez (1948). Malaguti (1953) reported P.parasitica as the causal agent of stem rot of sesamum in Venezuela. The first symptom of stem rot is a damp blackish lesion on the collar at or below soil level. Later on, it spreads to the stem and branches either girdling the stem and strangling the basal part or extending in irregular vertical streaks. The leaves,

flowers and tips of branches wither and hang downwards. The plants may be attacked at any stage of growth, but mostly at the time of flowering.

Kumar et al. (1963) observed stem rot disease of sesamum caused by P.parasitica in Rajasthan resulting in severe losses, especially in regions with heavy soil and high rainfall. Initial symptoms of leaf blight caused by P.parasitica var. sesami are water soaked spots on leaves and stems. Under favourable conditions these spots enlarge and coalesce with each other resulting in premature leaf fall. Infected stems and branches appear brown initially and later turn black (Gemawat and Prasad, 1964).

Sehgal and Prasad (1966) conducted studies on Phytophthora spp. in sesamum and found that there were no morphological or physiological differences between isolates of P.parasitica var. sesami and P.nicotianae var. parasitica while they varied in pathogenicity. Gemawat and Prasad (1966) reported that sesamum plants of all stages of growth will get infected by P.nicotianae var. parasitica and the symptoms will appear within three to seven days after inoculation.

Mazzani (1966) recorded a collar rot disease of sesamum caused by Phytophthora sp. Brown rot disease in sesamum due to P.nicotianae var. parasitica was reported by El-Sheddi et al.(1976).

Under favourable conditions heavy mortality up to 79.8 per cent has been reported in the case of leaf blight caused by P.parasitica var. sesami (Singh et al., 1977).

Phytophthora blight of sesamum was recorded from Assam by Rathaiah (1985) and observed that the disease is more severe during the months of May and June.

2.1.11. Other fungi

Mitter and Tandon (1930) reported blight disease of sesamum caused by Cladosporium sp. and Macrosporium sp. Kawamura (1931) recorded a leaf spot of sesamum caused by Macrosporium sesami from Japan.

A white silk disease of sesamum caused by Corticium centrifugam and Phoma sp., wilt by Verticillium dahliae, powdery mildew by Sphaerotheca fuliginea, leaf spots by Cladosporium sp., Phyllosticta sesami and Cylindrosporium sesami have been recorded (Joshi, 1961).

A leaf spot disease of sesamum by Sphaeronema sesami was reported by Sehgal and Daftari (1966). They observed that the disease is characterised by small necrotic leaf spots which later enlarge and coalesce in severe cases affecting midribs and petioles.

A pre-emergence damping off of sesamum caused by Pythium aphanidermatum was recorded by Gemawat and Prasad (1966). Malaguti and Ciccarene (1967) reported an angular brown leaf spot caused by Cylindrosporium sesami. This severe leaf spot was characterised by brown spots of 2 to 20 mm dia in the veinal areas. Rarely it occurs on stems and capsules also. During rainy season the cultivation of sesamum becomes difficult due to the attack of C.sesami.

Gemawat and Verma (1972) reported a mildew disease of sesamum plants caused by Sphaerotheca fuliginea from Rajasthan. A damping off and root rot of sesamum caused by Thielavia terricola was described by Chakravarti et al.(1973).

Chaudhary and Singh (1975) reported a foot rot disease of sesamum caused by Corticium rolfsii. Kamal Singh (1976) found that, a wet rot of sesamum seedlings caused by Choanephora cucurbitarum results in severe losses to the crop.

A new species of hyphomycete, Pseudocercosporella sesami has been reported on sesamum by Purkayastha and Mallik (1976). Buldeo et al. (1979) reported a sclerotial disease of sesamum caused by Selerotium rolfsii. A mildew disease caused by Erysiphe cichoracearum was reported by Rao and Shanmugam (1983).

Kamaran (1985) isolated Verticillium dahliae from wilted stems of sesamum plants. Maiti et al. (1985) reviewed various fungal diseases of sesamum including many minor fungal diseases caused by Cercoseptoria sesami, Botryosphaeria ribis, Phoma exigua, P.variosporeae, Synchytrium sesami, S.sesamicola and Pellicularia filamentosa.

2.2. Seed-borne mycoflora and their influence on quality of sesamum seeds.

Among the different fungal diseases of sesamum, some are known to be caused by seed-borne fungi which cause reduction in the nutritive and other qualities of seeds as well.

Leppik and Sowell (1964) recorded Alternaria sesami as a seed-borne pathogen distributed all over the world through seeds. The dormant mycelium of the fungus usually occurs in the sub-epidermal layers of the seed coat.

Lalithakumari et al. (1971) reported the effect of seed-borne fungi on the physico-chemical properties of ground nut oil. They showed that Aspergillus flavus, Botryodiplodia sp. and Cladosporium herbarum invaded the ground nut seed and caused reduction in oil content. At the same time Rhizoctonia bataticola slightly increased the oil content. All the seed-borne fungi altered color of the oil and inflicted a bad odour. The color intensity of the oil extracted from seeds infected with R.bataticola and A.flavus was more after 15 days of incubation but decreased after 30 days of incubation. C.herbarum and Helminthosporium tetramera caused a slight fall in the intensity of color after 30 days storage period. Botryodiplodia sp. caused a decrease in the color intensity of oil only after 30 days of incubation. The oil extracted from seeds infected with A.flavus, C.herbarum and Botryodiplodia sp. emitted a rancid odour even with 15 days of incubation. In the case of R.bataticola, the rancidity was observed only after a month of incubation. H.tetramera infection did not cause any unpleasant odour of the oil. R.bataticola increased the saponification number of the oil to a greater extent. A.flavus, C.herbarum and Botryodiplodia sp. also caused increase in saponification number, but H.tetramera did not alter the value. Appreciable reduction in iodine value was observed in the seed samples infected with A.flavus

and C.herbarum while Botryodiplodia sp. caused negligible reduction. R.bataticola showed a slight increase and H.tetramera did not affect iodine value at all.

Singh et al. (1972) observed the seed-borne nature of Macrophomina phaseolina in sesamum seeds and reported the role of seed-borne pathogens in reducing the nutritive value of sesamum.

Mathur and Kabeere (1975) reported Alternaria solani, Corynespora cassiicola, Cercospora sesami, Fusarium moniliforme, F.oxysporum and Verticillium dahliae as seed-borne pathogens of sesamum in Uganda.

Shukla and Bhargava (1977) isolated Fusarium solani from sesamum seeds. The seed-borne nature of Macrophomina phaseolina associated with sesamum seeds has been observed and reported by Kushi and Khare (1978). They discussed the comparative efficacy of different methods to detect M.phaseolina associated with the sesamum seeds.

Philip and Abraham (1979) reported the changes in the quality of coconut oil due to storage of copra. The population of both fungi and bacteria were found to increase.

Oil extracted from copra infected by fungi and bacteria showed no appreciable changes for the first three months. Afterwards slight impairement in the quality of oil was noticed. A progressive reduction in the oil content of copra by microbial infection was reported by Paul et al. (1980). They observed that fungal attack reduced the quantity as well as quality of the oil. Among the physical properties, color and odour changed slightly. Acid value and iodine value of the oil showed an increase with the period of incubation.

Seed transmission and pycnidial formation in sesamum wilt caused by M.phaseoli has been reported by Abdou et al. (1980). Macrophomina phaseolina is a destructive pathogen of sesamum in Iraq causing typical wilt with dry root rot associated with discoloration of infected tissues due to sclerotial formation. Seeds of infected plants carry the fungus on and inside the testa, as sclerotia and stromatic mycelium.

Singh et al. (1980) recorded the seed-borne nature of Alternaria sesami in sesamum from India and found that in severely infected seeds the fungus invades all parts including the embryo and even sporulates within the seed.

The significance of seed-borne fungi in sesamum with special reference to Corynespora cassiicola was studied by Yu (1981). The predominant fungi in sesamum seeds were Alternaria sesami, A.sesamicola, A.tenuis (A.alternata) and Corynespora cassiicola.

Biodeterioration of sesamum oil in situ by fungi has been reported by Sharma (1981). Aspergillus niger and A.tamarii were the most active organisms which caused 58.4 and 26.2 per cent loss in total seed oil and they could increase the fatty acid content to 49.5 and 30.3 per cent respectively, after eight weeks of incubation. On the other hand, A.flavus, Penicillium citrinum and Cladosporium herbarum caused only 15.9, 11.6 and 8.8 per cent reduction respectively, in total oil, with an appreciable increase in the free fatty acid content. It was also pointed out that oil extracted from the fungus infected seeds showed lower iodine values, and increased saponification values. Increase in peroxidase content of oil was also noted.

The fungi associated with sesamum seeds have been studied by Kumar et al. (1984). Standard blotter method and agar plate method with PDA were used for the isolation of seed-borne fungi as recommended by ISTA.

The various fungi recorded include Aspergillus flavus, A.sacchari, A.candidus, A.terreus, A.niger, A.clavatus, Alternaria sesami, Fusarium moniliforme, Rhizopus nigricans, Curvularia lunata, Helminthosporium sitophila, Rhizoctonia bataticola, Memnoniella sitophila, M.echinata, Penicillium rubrum, etc.

Vaidehi and Lalitha (1985) while studying the fungal successions in sesamum seeds, isolated 54 fungal species from the seeds. Among these Alternaria, Curvularia, Drechslera, Fusarium and Cladosporium were found to be abundant before harvest, and reduced afterwords. Aspergillus flavus and A.niger occurred in very low percentages.

Seed-borne fungi of some sesamum varieties were recorded by Valand et al. (1985). In their study they used four cultivars and isolated 16 different fungi including Macrophomina phaseoli, A.flavus and A.niger.

Singh (1987) reported the oil properties of sesamum seeds at different relative humidities under microbial infestation. During isolation studies, A.flavus, Drechslora hawaiiensis and Fusarium moniliforme were frequently found on sesamum seed surface. Environmental factors, especially relative humidity and temperature,

affect different properties of sesamum oil. At high relative humidities, percentage of oil and iodine value decreased while saponification value and fatty acids showed an increasing trend. At 33 and 55 per cent humidities, there was only a slight change in oil percentage, while it reduced considerably at 75 and 96 per cent humidities due to attack by A.flavus. At 75 and 96 per cent relative humidity the saponification value increased and the highest increase was due to infection by A.flavus. The iodine value was decreased by all the three fungi at 96 per cent humidity.

2.3. Physiology of parasitism

2.3.1. Mode of entry and histopathology

Marks et al. (1975) reported that the penetration of young leaves of Populus tremuloides by Colletotrichum gloeosporioides is by means of penetration pegs which successfully penetrated the epidermal walls within 24 to 48 h after inoculation.

Brown (1975) in his studies on the post harvest development of C.gloeosporoides on citrus plants found

that the spores germinated usually on the surface of citrus fruit and formed appressoria which in turn produced infection hyphae that remained latent. Such hyphae were thin, thread like, less than 1.0 µm in dia and were observed within or beneath the cuticle, intercellulary in the upper two to four cell layers.

Fahim and Shehedi (1966) reported the mode of penetration of Alternaria porri into onion leaves. The fungus entered directly through the epidermal cell wall and through the stomata. Munjal and Gupta (1965) made a comprehensive study of the host parasite relations of the anthracnose of celosia caused by C.gloeosporioides. They observed that the cells of the diseased tissue lost their shape and later the hyphae collected underneath the epidermis form stroma, from which conidiophores were produced. Moses and Govinda Rao (1969) in their studies on coriander anthracnose caused by Glomerella cingulata observed the presence of septate, intercellular hyphae which formed stroma at certain places and condiophores and conidia were produced. Cuticular penetration of the isolates of C.gloeosporioides in clove, nutmeg and cinnamon was reported by Karunakaran (1981).

The histopathological relationship of C.gloeosporioides on the weed, Aeschynomene was investigated by Tebeest et al. (1978). Inoculation of the seedlings with suspensions of C.gloeosporioides resulted in the formation of pin point lesions (0.5 to 1 mm dia) within 48 h after inoculation. Lesions formed within 48 h after inoculation produced spores which germinated and produced appressoria in 4 to 5 h and penetrated the host epidermis. They also found that mycelium grew within the cortex, cambium, xylem and pith tissues. The death of seedlings was caused by collapse of infected stem tissues. Coalescence of lesions enhanced girdling of stems and hastened death.

Singh et al. (1980) conducted histological studies of Alternaria sesamicola in sesamum seeds. In three white seeded sesamum seed samples, having very high and moderate incidence of A.sesamicola, the dormant mycelium of the fungus usually occurred in the sub epidermal layers of the seed coat and occasionally in the endosperm and embryo. In severely infected seeds it invaded all parts including the embryo, even sporulating within the seed. Heavy aggregation of mycelium in the hilum region suggested that it penetrated through this point, whereas, the thick inner cuticle of seed coat and the outer cuticle of the endosperm appeared

to resist its inward penetration. Watanabe (1939) studied histological changes in sweet potatoes as a result of invasion by Fusarium oxysporum and reported that in the xylem of diseased sweet potatoes, tylosis and vascular discoloration occurred in advance of the invading mycelium of the wilt fungus. The invasion of F.oxysporum in sweet potato and its cytological changes were also studied and reported by Mc lure (1950). He suggested that tylosis clogged vessels serve to prevent the invasion of the pathogen. Hyphae of the wilt fungus F.oxysporum pass through vessel element apertures and also through unobstructed pits. Callus formation is suppressed where the stele is infected with F.oxysporum. An auxiliary xylem is often found in infected plants and is developed centripetally from an internal cambium. This development of new cells internal to the stele is the cause of stem splitting found in Fusarium wilt infected plants. The fungus grows around tylosis barrier by passing through bordered pits into unclogged xylem elements. Histological changes including withering and collapse of necrotic regions as a result of invasion in clove, cinnamon and nutmeg leaves by C.gloeosporioides have been reported (Karunakaran, 1981).

2.3.2. Role of toxins produced by fungi

A number of fungi including leaf spot pathogens are known to produce toxins. The phytotoxic properties of alternaric acid in relation to etiology of plant diseases caused by Alternaria solani were described by Brian et al. (1952). Raistrick et al. (1953) reported alternaric acid and alternariol monoethyl ether as metabolic products of A.tenuis. The same compounds are reported to be produced by A.dauci also (Freeman, 1966).

Pero and Main (1970) reported the toxin produced by A.tenuis causing brown spot disease in tobacco plants and the metabolite isolated from the pathogen was alternariol monoethyl ether. It was isolated from the cultures of A.tenuis grown in autoclaved rice grains supplemented with yeast extract and Czapek's broth. A phytotoxic high molecular weight polysaccharide was also isolated from A.tenuis (Main and Pero, 1972). Kinoshita et al. (1972) reported tenuazonic acid from the Alternaria sp.

Toxin production by A.alternata the cause of a leaf spot disease of brinjal has been reported by Vijayalekshmi and Rao (1988). The toxin production by the pathogen was

tested by noting the reduction in seed germination and root length over control. Epinasty with increased rolling of the leaf lamina with necrotic areas were the symptoms observed on detached leaves of tomato which were treated with culture filtrate of the pathogen. Orschanskaya (1960) observed that the culture filtrate of Diplodia zeae inhibited germination of maize seeds to a considerable extent. Sengupta et al. (1966) isolated an antibiotic botryodiplodin from the culture filtrates of Botryodiplodia theobromae. The antibiotic was effective against Gram negative bacteria, but not against saprophytic fungi. The toxic effect of the metabolite produced by B.theobromae was reported by Dwivedi and Singh (1971).

Wolf and Flowers (1957) reported the production of toxin by Colletotrichum nicotianae causing anthracnose of tobacco. The production, physiological activity and chemical nature of colletotin, a toxin produced by C.fuscum was described by Goodman (1959).

Goodman (1960) reported that colletotin caused spotting of tomato foliage. Activity of this toxin was measured by the intensity of symptoms. It was reported that toxin production appeared on 11th day of incubation and its effect on tomoto foliage became more intense

by 17th and 18th days. Although colletotin affects plants which were not attacked by the pathogen C.fuscum, varieties of Digitalis more resistant to colletotin were also more resistant to the pathogen.

Production of toxin by C.gloeosporioides causing citrus die back occurred in Richard's solution after 22 days growth (Sharma and Sharma, 1969). The toxic metabolities of C.capsici infecting chillies were assayed on seeds, seedlings, leaves and fruit tissues of chillies and all the samples exhibited toxin injury (Narain and Das, 1970).

Nair and Ramakrishnan (1973) studied the production of toxic metabolites by C.capsici and its role in leaf spot disease of turmeric. The concentrated toxic metabolite from mycelium (endo toxin) and that from culture filtrate (exo toxin) were bioassayed on turmeric leaves. In treatments with endo toxin as well as exo toxin, visible signs of necrosis were noted within 4 h.

Kurosawa (1926) demonstrated that the culture filtrate of Fusarium moniliforme could produce bakanae symptoms on rice seedlings. Hemmi and Seto (1928) and Seto (1932) confirmed the phenomenon but noticed that the

culture filtrates of some isolates grown under similar conditions could not produce the bakanae symptoms. The conditions under which the fungus is grown also affect the nature of the filtrate. Ito and Shimada (1931) reported that production of the growth promoting substance is inhibited by the omission of KH_2PO_4 or $MgSO_4$ from the culture solution. They found the substance to be thermostable and neither enzymic nor volatile. Kurosawa (1932) found potassium in the medium to be essential for the formation of growth promoting substances.

Yabuta and Hayashi (1939) isolated two principal substances from the culture filtrate of F.moniliforme, viz., fusaric acid and gibberellin.

Stoll (1954) reported that fusaric acid and other compounds are produced most abundantly at 33°C in Richards' medium. Biological studies of the two substances showed that fusaric acid causes stunting symptoms and gibberellin causes elongation of many species of plants besides rice plants.

Hiroe and Nishimura (1956) conducted studies on watermelon wilt caused by F.oxysporum f. sp. niveum and reported that the toxic metabolite produced by the

organism is a steroid, phytonivein. It was also observed that 10 ppm of this compound when applied on plants produced wilt symptoms.

Nishimura (1957) reported the production of fusaric acid by a number of Fusarium species causing wilt diseases, including F.batatus, F.conglutinans, F.cubense, F.lini, F.lycopersici, F.niveum, F.orthoceras, F.vasinfectum, F.heterosporum and F.udum. In addition to fusaric acid, these fungi produce another toxic metabolite, dehydrofusaric acid, which also caused similar wilt symptoms. Bolten and Nuttall (1968) conducted pathogenicity studies with F.poae, causing necrosis and wilting symptoms in plants, and found that the culture filtrate of this fungus also induced necrosis and wilting symptoms.

Singh and Husain (1970) reported that F.lateritium f. cajani the causal agent of pigeon pea wilt, produces fusaric acid and dehydrofusaric acid.

The toxic metabolite production of some Fusarium species, viz., F.solani f. sp. pisi, F.martii, F.javanicum was suggested by Kern (1972). These organisms produced root and stem rot diseases in plants. The metabolites produced

by these species of Fusarium include naphthazarine derivatives, isomarticin, norjavanicin, novarubin, fusarubin and javanicum. These metabolites when applied to plants resulted in leaf necrosis and stem grooving.

Toxic metabolite production by F.oxysporum f.sp. lycopersici, F.oxysproum f. sp. melonis and F.oxysporum f. sp. vasinfectum was recorded by Camporota et al. (1973). The metabolites produced by these organisms as recorded by the authors include lycomarasmin, lycomarasmic acid and aspergillomarasmin A. These chemicals caused necrotic leaf spots in plants.

2.4. Survival of fungal pathogens

Singh et al. (1980) reported that Alternaria sesami survived in the sesamum seeds and the pathogen can even sporulate within the seed.

Bunting (1927) noted that Botryodiplodia theobromae isolated from maize cobs caused the development of typical lesions when inoculated on cocoa pods. Srivastava (1964) reported that spores of B.theobromae remained viable for fewer months and mycelia for 12 months on rubber seeds.

Chona and Nariani (1952) conducted studies to test the survival ability of Colletotrichum in soil. In their study they grew the organism in sterilized and unsterilized soil cultures and these soil cultures were from time to time inoculated into healthy canes of a susceptible variety. They found that C.falcatum can survive in soil or on soil compost mixture up to three months. In sterilized soil it can remain viable for five months and in sterilized soil-compost mixture up to six months. Survival of Colletotrichum in infested corn residues was studied by Lipps (1983). In the spring the number of acervuli of C.graminicola developing on corn residues buried by ploughing was significantly less than on residues left on the soil surface. C.graminicola was eliminated from infested corn stalks buried 1 to 2 cm below the soil surface.

Survival of Curvularia causing leaf spot disease in maize was studied by Mandokhot and Choudhary (1980). They studied the survival ability by burying the infected leaves in soil and by infesting sterilized and unsterilized soil with the pathogen. It was observed that the pathogen leads a saprophytic life in organic debris in soil producing sclerotia towards the end of growth period.

Lucas (1955) reported the saprophytic colonization of Fusarium in wheat straw. He showed that there was a progressive reduction in the saprophytic colonization of F.culmorum with increasing proportion of unsterilized soil. This indicates that Fusarium is a vigorous soil saprophyte with a high competitive saprophytic ability.

2.5. Chemical control of fungal diseases of sesamum

Many nonsystemic as well as systemic fungicides have been used for the control of fungal diseases of sesamum.

In green house and field trials conducted at Beltsville during 1954-58, Orthocide 75 at 0.25 - 2 oz/bushel gave the best control of pre-emergence damping off of sesamum seedlings associated with isolates of Pythium ultimum. In a field trial the mean percentage stand was increased from 4.8 to 34.8 as a result of the treatment. This and other seed treatments reduced the development of Alternaria leaf spot also (Thomas, 1959).

Gemawat and Prasad (1964) found effective control of leaf blight pathogen in sesamum, Phytophthora parasitica, by spraying thrice with 3:3:50 Bordeaux mixture.

Singh et al. (1969) found that among the nine fungicides tested against Corynespora cassiicola from sesamum, Antracol at 1500 ppm and Copper sandoz and Ceresan wet at 2000 ppm completely inhibited the growth of the fungus.

In the fungicidal screening experiments for the control of Alternaria blight of sesamum in Tamil Nadu, Samuel et al. (1971) found that spraying Bordeaux mixture and Dithane Z-78 gave satisfactory control of the pathogen.

Daftari and Verma (1973) studied the effect of aureofungin on seedling mortality and growth of two varieties of sesamum with seed-borne infection of Fusarium solani. They recommended seed treatment with aureofungin at the rate of 20 µg per milligram of seeds to reduce the seedling mortality by 90 per cent in susceptible varieties, and to increase germination percentage as well as seedling vigour.

Albeldawi et al. (1973) observed that in glass house experiments on the control of charcoal rot of sesamum with benomyl, the fungicide was absorbed by sesamum roots and translocated to the stem, where it prevented Macrophomina phaseoli previously added to the soil from attacking the plant.

Significant control was obtained even at 0.3 g Benlate per pot and no phytotoxic effects were observed. Shukla and Singh (1973) conducted studies on the effect of fungicidal seed treatment on Macrophomina root rot of sesamum, and found that seed treatment with captan (0.3 per cent) gave the best control of M.phaseoli and increased yield from 124 to 232 kg per ha. Use of captafol (Tripathi et al., 1977). carbendazim, thiram + captan (Shukla and Singh, 1973) and thiophanate methyl (Taneja and Grover, 1982) were also found to be effective against this pathogen.

Control of damping off and root rot of sesamum caused by Thielavia terricola var. minor by soil drenching with fungicides and antibiotics and the efficacy of these chemicals for seed treatment was reported by Chakravarti et al. (1974). They found that ziram and Brassicol were effective both for seed treatment as well as for soil drenching. They used Cupramar, Copper sandoz, Fytolan, Dithane Z-78, Ziram, Aureofungin and Brassicol for soil drenching. Seoud et al. (1975) conducted studies on the effect of soil application of fungicides on the incidence of root rot and wilt diseases of sesamum and reported that these diseases caused by Fusarium oxysporum, Rhizoctonia solani, Sclerotium bataticola and Phytophthora sp. were best controlled by soil treatments with Brassicol-75 during field trials over three seasons.

Shanmugam et al. (1976) observed that in two Kharif seasons, applications of sulphur dust gave the highest yields from powdery mildew infected plots of sesamum. But in the rabi season, when disease incidence was lower, Benlate was the best followed by wettable sulphur. When the mildew was severe, wettable sulphur was the best followed by Miltox and Benlate. Rao and Shanmugam (1983) found triadimefon and bilaxazol were effective against powdery mildew of sesamum. An integrated programme for controlling pests and diseases of sesamum has been suggested by Abraham et al. (1976). They reported that under condition of heavy powdery mildew incidence, Miltox gave best control at 0.25 per cent concentration. Light incidences of powdery mildew and leaf blight caused by Alternaria sesami were controlled by Dithane M-45 at 0.2 per cent concentration.

Wangikar and Kodmelwar (1977) conducted screening of various fungicides against F.oxysporum f. sp. sesami causing wilt of sesamum. Derosal, Bavistin, Tillex, Captaf, Ceresan, Thiram, Vitavax and Benlate completely inihibited the growth of the fungus at 2000 and 3000 ppm. Brassicol and Dithane M-45 were found to be less effective in controlling the growth of the fungus. The systemic fungicides, viz., Derosal, Bavistin, Benlate and Vitavax were observed to have better efficacy over other non-systemic fungicides.

Tripathi et al. (1977) reported the control of charcoal rot of sesamum caused by Rhizoctonia bataticola. In vitro trials with captafol, benomyl, thiophanate methyl, and S.7258 showed that the growth of R.bataticola was effectively inhibited by these fungicides. The concentration of all the fungicides was 1000 µg per g soil. In field tests captafol was the most effective fungicide followed by carbendazim and thiram + captan. Taneja and Grover (1982) studied the efficacy of benzimidazole and related fungicides against R.solani and R.bataticola and found that thiophante methyl is effective in inhibiting the growth of the fungi.

Ramaiah and Sastry (1983) noted maximum seedling emergence in sesamum seeds treated with captan and Bavistin. The seeds collected from different localities were mixed with 0.2 per cent each of nine different fungicides for the control of seed mycoflora. Captan and Duter gave a broad spectrum effect.

Sharma and Jain (1984) reported the in vitro evaluation of fungicides against Fusarium spp. Three fungicides, viz., Dithane M-45, Bavistin and MBC were screened against nine species/isolates of Fusarium. The species/isolates were sensitive to systemic fungicides tested and differed in their relative sensitivity.

Kumar and Singh (1984) could eliminate all seed-borne fungi except A.sesami, Curvularia lunata and Drechslera tetramera from sesamum seeds by seed treatment with Bavistin (0.2 per cent) and captan was next to Bavistin in effectiveness.

Reduction in the seed-borne mycoflora and increase in the germination of seeds of sesamum was obtained by seed treatment with carbendazim, captan, benomyl and thiram. Seed treatment with carbendazim or benomyl at 1500 ppm was very effective (Vyas et al., 1984).

Dolle and Hegde (1984, b) conducted field trials against A.sesami with different fungicides. Best control of the pathogen was achieved with Dithane M-45 at 0.3 per cent, applied at 30, 45 and 60 days after sowing.

Kumar and Singh (1986) reported that Bavistin 2 g per kg sesamum seed was found to be better than captan, thiram and Vitavax in improving germination and seedling emergence.

2.6. Losses due to important diseases

Sesamum crop is affected by a number of diseases. Eventhough no precise estimate has yet been made on the losses caused by most of the diseases, some attempts have been made to assess the yield losses in sesamum caused by some of the diseases.

Sundararaman (1932) estimated that the yield loss due to stem and root rot of sesamum caused by Macrophomina phaseolina as 57 per cent when the incidence of the disease was 60 per cent. Choudhury (1945) observed that there is 20 per cent yield loss due to leaf spot disease of sesamum caused by Cercospora sesami.

Murugesan et al. (1978) conducted field experiments during monsoon seasons of 1976 and 1977 to study the intensity on sesamum and yield loss due to diseases. The avoidable losses in the yield of sesamum during monsoon 1976 and summer 1977 were 110 kg and 111 kg per ha, respectively, which worked out to be 40 per cent. The multiple regression analysis of yield on diseases like phyllody, Alternaria blight, powdery mildew and charcoal rot revealed that 1 per cent increase

in the incidence of charcoal rot disease brought down the yield by 1.8 kg per ha whereas one per cent increase in phyllody brought down the yield by 8.36 kg. Siddaramaiah et al. (1981) estimated the yield losses due to pod spot of sesamum caused by A.sesami as ranging from 0.1 to 6.7 g seeds per 100 capsules. The number of shrivelled seeds depends on the severity of the disease.

2.7. Residues of Bavistin in crops

Although a number of fungicides are in use at present in India, the work done on residues of fungicides is very meagre. However the limited informations available in literature are presented here.

Most of the organic fungicides have low mammalian toxicities and problems of excess residues of the parent compound are generally not serious. Zaldivar et al. (1975) conducted studies on the fungicide residues on fresh pineapple after Bavistin treatment and residues were much below the internationally permitted levels.

Kannaiyan et al. (1975) conducted studies on seed treatment with 0.3 per cent benomyl on wheat. The root and shoot portions were analysed at 15 days interval for 60 days. But he could not detect benomyl on both root and shoot on TLC plates. Though, two of its degradation products, viz., methyl-2-benzimidazole carbamate and an unidentified compound were found up to 45 and 15 days respectively.

Consequent to the spray application of benomyl, carbendazim and thiophanate methyl, each at 100 g a.i./ha for the control of Cercospora leaf spot of sugarbeet, Bandyopadhay and Mukhopadhyay (1977) noticed that benzimidazole residue in sugarbeet leaves at harvest ranged between 3.15 and 6.20 ppm, which was far below the tolerance limit of 18.75 ppm of the fungicide in food stuffs.

Vaidya and Banerjee (1984) described a photometric method of estimation of carbendazim residues. The procedure employed involves the use of bromocresol green (BCG) and bromophenol blue (BPB) as the reagents. The method can be used for the estimation of carbendazim from commercially formulated products as well as from plant residues.

According to their methodology carbendazim contents present in the two plant samples, viz., jowar and peas foliage were 2.62 and 0.22 ppm with BCG and that with BPB were 2.7 and 0.26 ppm respectively when applied at the rate of 20 /ug per ml.

The maximum residue limits (MRL) of carbendazim on plants as per guide to Codex recommendations concerning pesticide residues/FAO/WHO, Rome is as follows (Sundararajan,1985).

Commodity	MRL in mg/kg
Bananas (pulp)	0.5
Bananas (whole)	1.0
Grapes, peaches, cherries and citrus	10.0
Pineapple	20.0
Mango	2.0

Cheriyan (1987) conducted studies on the residue analysis of carbendazim on fruit samples of banana, mango and pineapple after the application of Bavistin at 500 ppm to protect them from post harvest decay. The residue of carbendazim was found to be 3.83 ppm in bananas, 1.45 ppm in mango and 1.00 ppm in pineapple fruits.

2.8. Influence of fungicides on oil quality and yield

Rajagopal and Vidhyasekaran (1983) reported that carbendazim, tin hydroxide, chlorothalonil, mancozeb and zineb controlled tikka leaf spot of ground nut. Chlorothalonil, carbendazim and mancozeb sprays increased the oil contsnt of ground nut kernels and reduced the free fatty acid content and saponification value of the oil. Captafol and carbendazim sprays increased the iodine value of the oil.

Singh and Kang (1984) reported the effect of carbendazim on amino acid composition of ground nut plants. They observed that besides fungicidal action, carbendazim (Bavistin) affects metabolism of the crop. They recorded the effect of Bavistin on the amino acid composition of ground nut leaves at various stages of the crop growth when applied to control the tikka disease caused by Cercospora spp. Spraying of Bavistin (at three concentrations i.e., 0.05, 0.10 and 0.15 per cent) was started when the crop was 51 days old. Three sprayings were given at 14 days interval. The amino acid metabolism of the leaves at 75 day old stage showed that application of Bavistin at shorter intervals tends to increase the amino acid content.

Effect of systemic fungicides on the physico-chemical properties of ground nut was reported by Lalithakumari et al. (1984). Foliar application of systemic fungicides and a growth regulator, cytozyme, revealed significant alteration in physico - chemical properties of ground nut plants. Among the fungicides tested, Baycor gave excellent control of leaf spot. The reduction in disease incidence due to Baycor was correlated with increase in protein, total nitrogen and total phenols and a decrease in total sugar.

Gupta et al. (1987) reported the fungicidal control of leaf spots and its influence on quality of ground nut. Unsprayed ground nut with a disease incidence of 43.73 per cent resulted in reduction of oil and protein content. But the free fatty acid content was increased. Maximum disease control was observed with thiophanate methyl, while copper oxychloride and zineb were least effective. Linoleic acid increased while oleic acid decreased in diseased samples. Among the treatments, copper oxychloride, zineb and captan decreased the oil content while benomyl + mancozeb combination significantly increased the oil contents. Protein content significantly declined with copper oxychloride and in control when compared with thiophanate methyl while in other treatments there was no appreciable change.

2.9. Varietal screening of sesamum

Gupta et al. (1963) conducted studies on performance of different sesamum varieties and suggested the possibilities of breeding resistant varieties.

Gemawat and Prasad (1965) conducted tests with different varieties of sesamum for resistance to Phytophthora blight. Of the 41 varieties of sesamum screened in the glass house against P.parasitica var. sesami, only 75 A/1-1/2-1 was resistant. Two others showed some tolerance and the rest were susceptible. Gemawat and Verma (1974) reported that varieties of sesamum ES-25, ES-105, ES-124, ES-156 and ES-190 were resistant to P.parasitica var. sesami causing blight disease in sesamum.

Jain and Kulkarni (1965) identified Rt-1, C-50, St-58 and Gwalior-5 as tolerant to charcoal rot/stem rot/root rot caused by Macrophomina phaseolina. Vir et al. (1974) conducted studies on varietal screening of sesamum against M.phaseoli, causal agent of root rot of sesamum. They found 18 sesamum varieties to be susceptible to root rot disease.

Kushwaha and Kushal (1970) studied the reaction of sesamum varieties to Cercospora leaf spot in Madhya Pradesh. Of the 31 sesamum varieties tested in the field 41, 41 A, 41 B, 128 and 128 B were found to be resistant to C.sesami and others were moderately resistant or susceptible.

Mazzani et al. (1975) succeeded in the incorporation of resistance to Phytophthora and Macrophomina in the sesamum variety Aceitera. This new sesamum variety resistant to P.nicotianae var. parasitica, M.phaseoli and Fusarium oxysporum f. sp. sesami was obtained by backcrossing with the African variety Ajemo Atar 55, resistant to Phytophthora spp. and Macrophomina spp. The yield and vegetative characters of the new variety resemble those of the original Aceitera, which is resistant to Fusarium sp.

Reaction of different sesamum varieties and seeding dates to charcoal rot caused by Sclerotium bataticola was studied by El-shamma (1976). The natural infection by M.phaseolina on local varieties in Iraq was also studied and it was found that red sesamum had the highest yield and the lowest percentage of infection at all three seeding dates tried. There was a significant negative correlation between seed yield and percentage of infection for all varieties.

Hiremath and Joshi (1980) conducted studies on varietal resistance in sesamum against leaf spot caused by Cercospora sesami, and they could not observe any variety as highly resistant in their screening trial. The incidence of leaf spot caused by C.sesami resulted in severe damage to the crop during Kharif season. Fifty varieties were screened for resistance against the disease during 1972 and 1974. Average percentage disease index varied from 12.1 to 63.5. None of the varieties was found immune. Four varieties were moderately resistant, with per cent disease index less than 15. Late maturing varieties appeared to be resistant and early maturing varieties susceptible. Varieties of medium maturity appeared to be moderate in reaction.

Variar and Pavgi (1981) reported varietal reaction of sesamum to gall disease caused by Synchytrium sesamicola. Resistance or susceptibility of 50 varieties of sesamum to infection by S.sesamicola was tested by artificial inoculation with zoospores. None of the varieties tested was found immune or highly resistant while two were resistant and the rest showed infection ranging between resistant and highly susceptible at the seedling and adolescent stages. Many of them varied in their susceptibility at the cotyledonary or mature leaf stages.

Use of resistant varieties against Alternaria sesami causing blight disease in sesamum has been suggested by many workers. Varieties so far identified as highly resistant to A.sesami are CVS No.4, JT.7, No.2, E.8, J.T.63-117, A.6-5, J.T.66-276, Anand-9, J.T.62-10, VT-43 and Anand-74 (Jeyarajan et al 1981; Siddaramaiah et al., 1981; Jayaramaiah et al., 1981). Dolle and Hegde, (1984, b) screened sesamum varieties against A.sesami and among the 22 cultivars tested under conditions of natural infection, X-7732/10-2 showed lowest incidence of disease.

Virk and Gemawat (1981) carried out evaluation of sesamum varieties for resistance to Fusarium wilt and observed differential disease reactions in varieties and exotic collections.

Resistant varieties of sesamum against powdery mildew disease was reported by Krishnaswami et al. (1984). Of the 28 sesamum varieties evaluated for reaction to Oidium acanthospermi under artificial inoculation and in the field during the rainy seasons of 1981 and 1982 at Coimbatore, Co-1 and TNAU-2 showed the lowest disease incidence in both the seasons.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1. Survey on the occurrence of fungal diseases of sesamum

A survey was conducted to find out the various fungal diseases affecting sesamum crop in Kerala. This work was conducted from 1981 to 1984 and covered the important sesamum growing areas of Trivandrum, Quilon, Alleppey and Palghat Districts. The various fungi obtained during the survey were recorded.

During the survey it was found that the incidence of five leaf spot diseases caused by *Alternaria sesami*, *Colletotrichum gloeosporioides*, *Curvularia lunata*, *Botryodiplodia theobromae* and *Fusarium oxysporum* f. sp. *sesami* were very severe in all the sesamum growing areas of Kerala during all the seasons. Hence detailed studies were conducted on these diseases and their causal agents.

3.2. Isolation, purification, testing pathogenicity and identification of fungi

3.2.1. Isolation

The diseased specimens of sesamum were collected from different locations for isolation of the pathogens. The fungal pathogens were isolated from the diseased parts following the standard procedure and cultures were maintained on potato dextrose agar (PDA) slants.

3.2.2. Purification

The various fungi isolated were purified by single spore isolation technique and maintained on PDA slants by periodical subculturing.

3.2.3. Pathogenicity

Pathogenicity of the fungi was tested by inoculating sesamum plants of different growth stages. Inoculations were done with and without injury by placing mycelial bits as well as by spraying spore suspensions. The concentration of spores in the spray suspension was adjusted to approximately 10^4 per ml in sterilized distilled water. The spraying was done using an atomizer. Controls consisted of sesamum leaves sprayed with sterilized distilled water. The plants were covered with polythene bags to

maintain high humidity. In the case of powdery mildew caused by Acrosporium acanthospermi only the natural incidence of the disease was examined.

The plants were kept for symptom development and the observations were recorded. The pathogens were reisolated from the artificially infected plants and purified. The morphological and cultural characters of the reisolated pathogens were compared with those of the original isolates.

3.2.4. Identification

The mycelial characters, asexual and sexual fruiting bodies, colony color, intensity of sporulation, spore measurements etc. of the fungi were studied. Morphological characters of all the organisms were studied by growing them in slide culture as described by Riddel (1950). The fungal pathogens were identified by comparing the characters with the details in published literature.

3.3. Symptomatology

Symptoms of the various fungal diseases were studied by observing the naturally infected sesamum plants in the field and also following the course of development of the disease in artificially inoculated plants.

3.4. Effect of diseases on germination of seeds

Effect of diseases on germination of seeds was determined by observing the germination percentage of seeds from infected pods collected from sesamum plants inoculated with Alternaria sesami, Colletotrichum gloeosporioides, Curvularia lunata, Botryodiplodia theobromae and Fusarium oxysporum f. sp. sesami. This was done by keeping surface sterilized sesamum seeds in large sterilized petri dishes. The petri dishes were lined with moist filter papers. Three replications were maintained for each fungus with 100 seeds for each replication. The plates with the seeds were incubated for three days under room temperature with control plates containing healthy seeds. The germinated seeds were counted from each plate, germination percentage recorded and the per cent inhibition of germination over control was determined.

3.5. Seed-borne fungi

The seed-borne fungi from the following ten sesamum varieties were isolated.

i) Kayamkulam-1	ii) T.C.30
iii) No.42	iv) Assam local
v) B.64	vi) Si.866
vii) Kayamkulam-2	viii) T.13
ix) Timbi-9	x) Trivandrum local

The seeds were supplied by the Department of Agronomy, College of Agriculture, Vellayani.

Standard blotter method and agar plate method with PDA were used for the isolation of seed-borne fungi (ISTA, 1976). Surface sterilized and unsterilized seeds were placed on sterilized moist blotter paper and on PDA. One hundred seeds of each variety were used for each method of isolation. Seed sterilization was done by using 0.1 per cent mercuric chloride. The observations were recorded after five days and the fungi associated with the seeds were isolated and identified.

3.6. Mode of entry

Cleared leaf technique (Crossan, 1967) was followed for this study. Sesamum leaves of different growth stages were collected from actively growing plants, thoroughly washed with distilled water and

placed in large sterile petri dishes. Spore suspensions of each of the five fungi viz., A.sesami, C.gloeosporioides, C.lunata, B.theobromae and F.oxysporum f. sp. sesami were prepared from ten day old cultures of the fungi. Small circles were marked on sesamum leaves and one drop each of the spore suspension was placed in each circle. The petri dishes were then covered with the lids lined with moist cotton to maintain high humidity. The plates were then incubated at room temperature. After 6, 12, 18, 24 and 48 h of incubation the leaf discs were cut out with a sterile cork borer from the marked areas, and placed in FAA for 24 h. The leaf discs were then transferred to 50 per cent lactic acid for clearing. Then they were mounted in lactophenol cotton blue and examined for spore germination and penetration into the leaf.

Drops containing conidial suspensions of all fungi were also placed on glass slides and incubated in petri dishes lined with moist cotton for comparison of the germination of spores with that on leaf discs.

3.7. Histopathology

Histopathological studies were conducted by taking transverse sections of sesamum leaves infected with the five

leaf spot fungi, viz., A.sesami, C.gloeosporioides, C.lunata, B.theobromae and F.oxysporum f. sp. sesami using a rotary microtome (Sass, 1964).

The histological changes brought about by the five species of fungi were observed and noted by comparing with the sections of healthy leaves.

3.8. Toxin production

A study on toxin production capacity of various fungi viz., Alternaria sesami, Colletotrichum gloeosporioides, Curvularia lunata, Botryodiplodia theobromae and Fusarium oxysporum f. sp. sesami was carried out.

3.8.1. Influence of various media on toxin production

The following liquid media were tried to assess their comparative effects in supporting the production of toxic metabolites by the pathogen.

1. Host leaf extract medium
2. Host leaf extract dextrose medium
3. Richards' medium
4. Czapek (Dox) medium
5. Potato dextrose medium

Compositions of media are given in Appendix 1. Each medium was prepared and dispensed in 250 ml conical flasks at the rate of 30 ml and sterilized by autoclaving at 1.05 kg/cm^2 for 15 minutes. The medium was inoculated with 5 mm dia discs of seven day old culture of each fungus. Three replications were maintained. The inoculated flasks were incubated at room temperature. After 15 days incubation, the cultures with the media were macerated in blender and filtered through Whatman No.I filter paper. The comparative toxic activity of each filtrate was studied by following the bioassay technique.

Sesamum leaves of uniform age were collected and placed inside sterilized petri dishes lined with moist cotton. On one half of the leaves 0.05 ml of the culture filtrate was placed and slightly pricked with sterilized needle through the liquid. On the other half of the same leaf sterilized water applied in the same manner served as control. Similarly on another leaf, on one half the culture filtrates and on the other half the respective medium were placed in the same manner. The petri dishes were incubated at room temperature and observations were recorded after 72 h. There were three replications for culture filtrates from each medium and averages were calculated and expressed in six grades according to the length of lesion produced on the leaf by each fungus.

3.8.2. Exo and endo toxin

The fungi, viz., A.sesami, C.gloeosporioides, C.lunata, B.theobromae and F.oxysporum f. sp. sesami were grown on respective medium which supported maximum production of toxin for a period of 15 days at room temperature and the mycelial growth was filtered through a previously weighed whatman No.I filter paper. This culture filtrate was used to test exotoxin production. The mycelium was homogenised in a blender by adding five times its weight of water. The homogenised mycelium was centrifuged at 1000 rpm for 15 minutes. The supernatant was taken and again centrifuged at 1000 rpm for 15 minutes and used for testing endo toxin production. These two test liquids (endo toxin and exo toxin) were assayed on sesamum leaves. The lesions developed on the assayed leaves were observed and recorded in six grades depending on the extent of lesion length. Two controls each with medium and sterilized water were also kept.

3.8.3. Effect of culture filtrates on germination of fungal spores.

All the five species of fungi, viz., A.sesami, C.gloeosporioides, C.lunata, B.theobromae and F.oxysporum f. sp. sesami were grown on their respective medium,

in which maximum toxin production was observed, for 15 days and the culture filtrates were taken to investigate the effect of each culture filtrate on spore germination of all the above fungi. Spore suspensions were prepared from ten day old cultures of the fungi in the test solution. The concentration of the spore suspension was adjusted to 10^4 spores per ml of the solution. A small quantity of the spore suspension (0.05 ml) was placed on clean, grease free sterile glass slides which were kept in petri dishes lined with moist cotton wool. Controls consisted of spore suspensions prepared in sterilized water and the respective media which supported maximum toxin production. All the petri dishes were incubated at room temperature and the observations were taken 48 h after incubation. The number of conidia germinated was counted from 20 random microscopic fields under low power objective and per cent inhibition was calculated.

3.9. Survival of the pathogens

The duration of survival of the five species of fungi was studied by burying the infected leaves in soil (Mandokhot and Chaudhary, 1980).

Infected leaves were cut into small pieces and buried at a depth of 5 cm in earthen pots containing garden soil. The pots were kept under natural conditions and were irrigated regularly. The viability of the organisms was observed at one month interval by digging out the infected leaf pieces and plating them on PDA, after several washings with sterile distilled water. When the buried material could not be traced, infested soil was plated on PDA by soil plate method (Warcup, 1950). The plates were incubated at room temperature and observed for the growth of fungi. When the colonies developed on the plates produced sufficient quantities of spores, they were harvested and spray inoculated on susceptible sesamum plants grown in pots and observed for the development of symptoms by each fungus. Sprayed plants were covered with polythene bags for 48 h to maintain high humidity.

3.10. Evaluation of fungicides against leaf spot diseases

3.10.1. <u>In vitro</u> evaluation of fungicides

The comparative efficacy of the following fungicides was tested under laboratory conditions at different concentrations as shown below.

Fungicide	Chemical name	Concentrations (ppm)		
1. Bavistin	Methyl-2-benzimidazole carbamate	250,	500,	1000
2. Bordeaux mixture		2500,	5000,	10000
3. Difolatan	Cis-N-(1,1,2,2-tetra-chloro ethylthio)-4 cyclohexane-1,2 dicarboximide	1000,	2000,	3000
4. Dithane M-45	Manganese ethylene bisdithiocarbamate and zinc ions	1000,	2000,	3000
5. Fytolan	Copper oxychloride	1000,	2000,	3000
6. Hinosan	O-ethyl-S,S-diphenyl dithiophosphate	500,	1000,	2000

The poisoned food technique (Zentmyer, 1955) was adopted to study the effect of different fungicides on growth of fungi. The required quantity of fungicides was added to 50 ml of sterilized Czapek (Dox) agar medium to give the necessary concentration, mixed well, and poured into sterile petri dishes at the rate of 15 ml per petri dish. After solidification, the mycelial discs of 5 mm dia cut out from actively growing culture were placed in the centre of plates in respect of all the five species of fungi. Controls consisted of unamended Czapek (Dox) agar medium inoculated in the same way. All the petri dishes were incubated at room temperature. Observations on colony dia were recorded

when the growth of the organisms has completely covered the plates in the control. Per cent inhibition of growth of different fungi over control was calculated by using the formula,

$$\text{Per cent inhibition} = \frac{C-T}{C} \times 100$$

where C = radial growth in control
T = radial growth in treatment

3.10.2. Field evaluation of fungicides and estimation of yield loss

The efficacy of three fungicides at two concentrations each, were tested under field conditions for the control of the five species of fungi causing leaf spot diseases on sesamum.

The trial was carried out at the Instructional Farm, College of Agriculture, Vellayani, during August-December season of 1987. The sesamum variety Kayamkulam-2 was used for the experiment. The experiment was laid out in split plot design with the following treatments.

Fungi

A_1 .. *Alternaria sesami*

A_2 .. *Colletotrichum gloeosporioides*

A_3 .. *Curvularia lunata*

A_4 .. *Botryodiplodia theobromae*

A_5 .. *Fusarium oxysporum* f. sp. *sesami*

Fungicides

B_1 .. 250 ppm Bavistin

B_2 .. 500 ppm Bavistin

B_3 .. 5000 ppm Bordeaux mixture

B_4 .. 10000 ppm Bordeaux mixture

B_5 .. 1000 ppm Dithane M-45

B_6 .. 2000 ppm Dithane M-45

B_7 .. Control

Spacing .. 20 x 15 cm

Plot size .. 1.8 x 1.5 m

Number of plants per plot .. 60

Number of replications .. 4

The field was prepared well and laid out into different plots. Fertilizers were applied according to package of practice recommendations of KAU. Seeds were sown in lines and watered regularly. When the plants were 40 days old,

they were sprayed with spore suspensions of the respective pathogens. High humidity was maintained by covering the entire plants with polythene bags. When the plants showed initial symptoms of the disease the bags were removed.

The plants were given two sprayings with the fungicides. The first spraying was given on 45th day and the second on 60th day of sowing. There were seven treatments including control and four replications for each disease. Thus there were a total of 140 treatment combinations.

Observations were taken randomly from 20 plants from each plot and the averages were calculated. Pre and post treatment observations on disease intensity by each fungus was recorded by using the following disease grades (Mayee and Datar, 1986).

Grade		Description
0	..	Healthy leaves
1	..	1 per cent or less
3	..	1-10 per cent
5	..	11-20 per cent
7	..	21-50 per cent
9	..	51 per cent and above

(Figures 1, 2, 3, 4 and 5)

Fig. 1. Score chart for Alternaria leaf spot

Grade		Description
0	...	Healthy leaves
1	...	1 per cent or less
3	...	1 - 10 per cent
5	...	11 - 20 per cent
7	...	21 - 50 per cent
9	...	51 per cent and above

FIG. 1 SCORE CHART FOR *Alternaria* LEAF SPOT

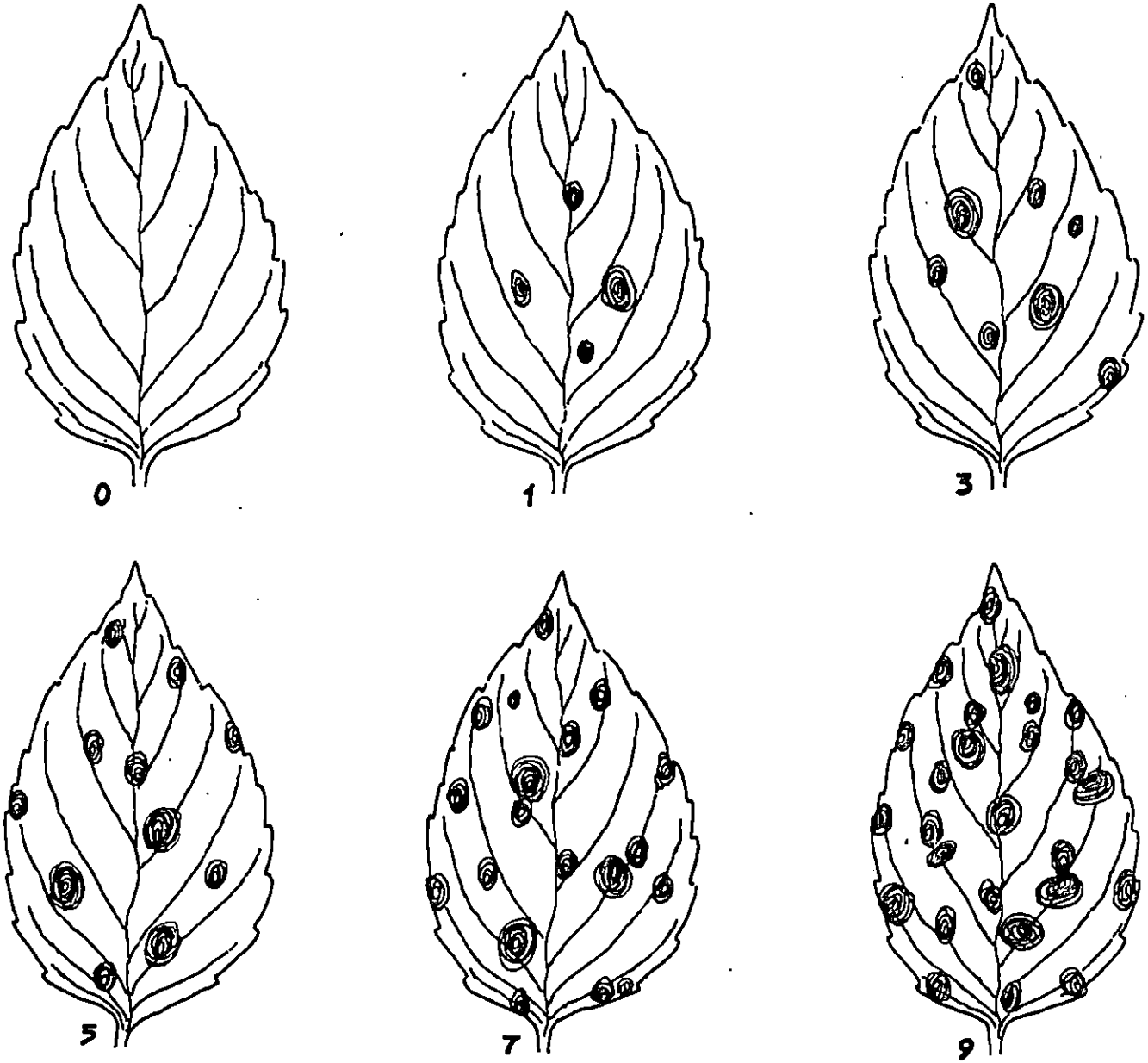


Fig. 2. Score chart for Colletotrichum leaf spot

Grade		Description
0	...	Healthy leaves
1	...	1 per cent or less
3	...	1 - 10 per cent
5	...	11 - 20 per cent
7	...	21 - 50 per cent
9	...	51 per cent and above

FIG.2 SCORE CHART FOR *Colletotrichum* LEAF SPOT

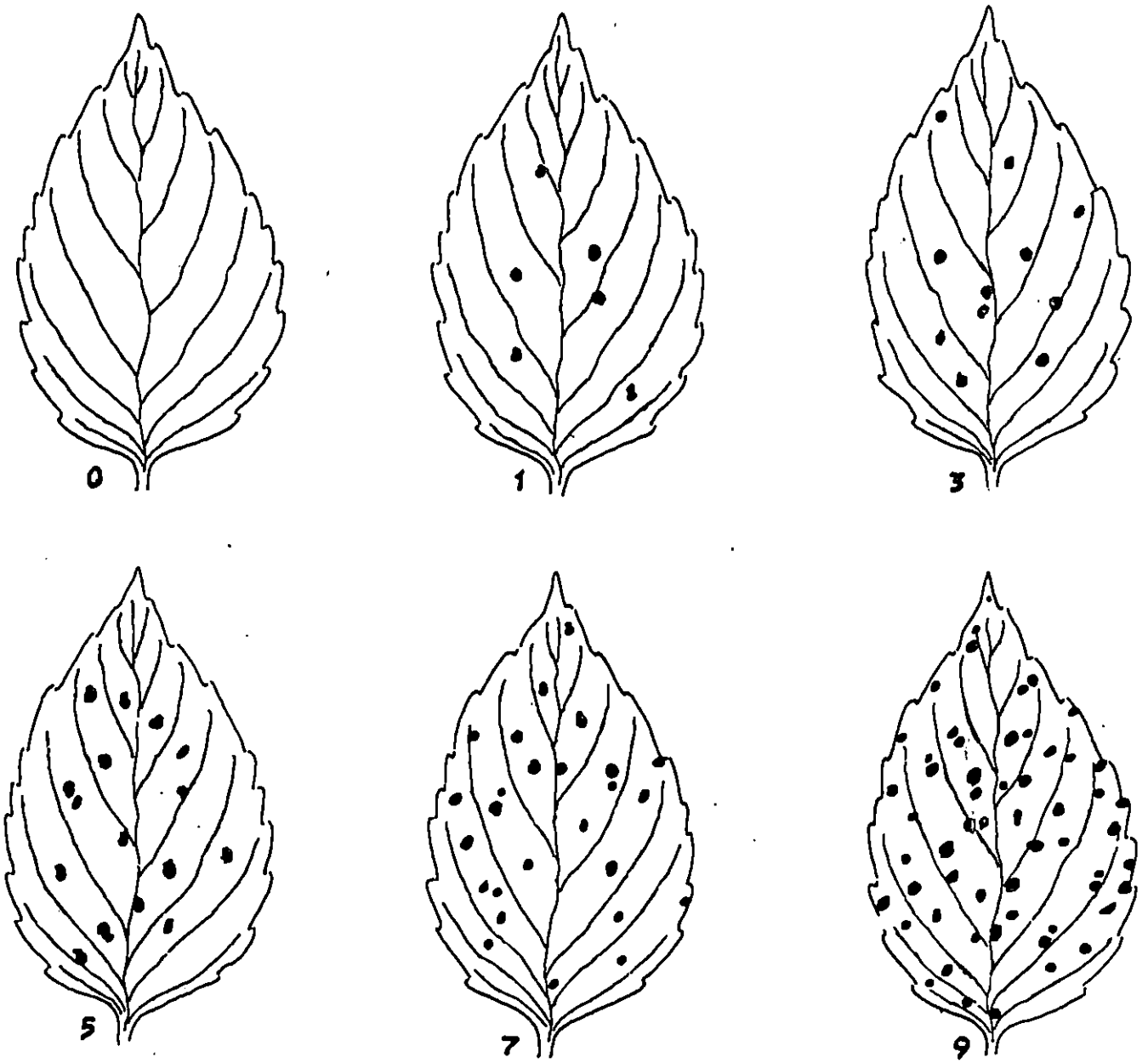


Fig. 3. Score chart for Curvularia leaf spot

Grade		Description
0	...	Healthy leaves
1	...	1 per cent or less
3	...	1 - 10 per cent
5	...	11 - 20 per cent
7	...	21 - 50 per cent
9	...	51 per cent and above

FIG. 3 SCORE CHART FOR *Curvularia* LEAF SPOT

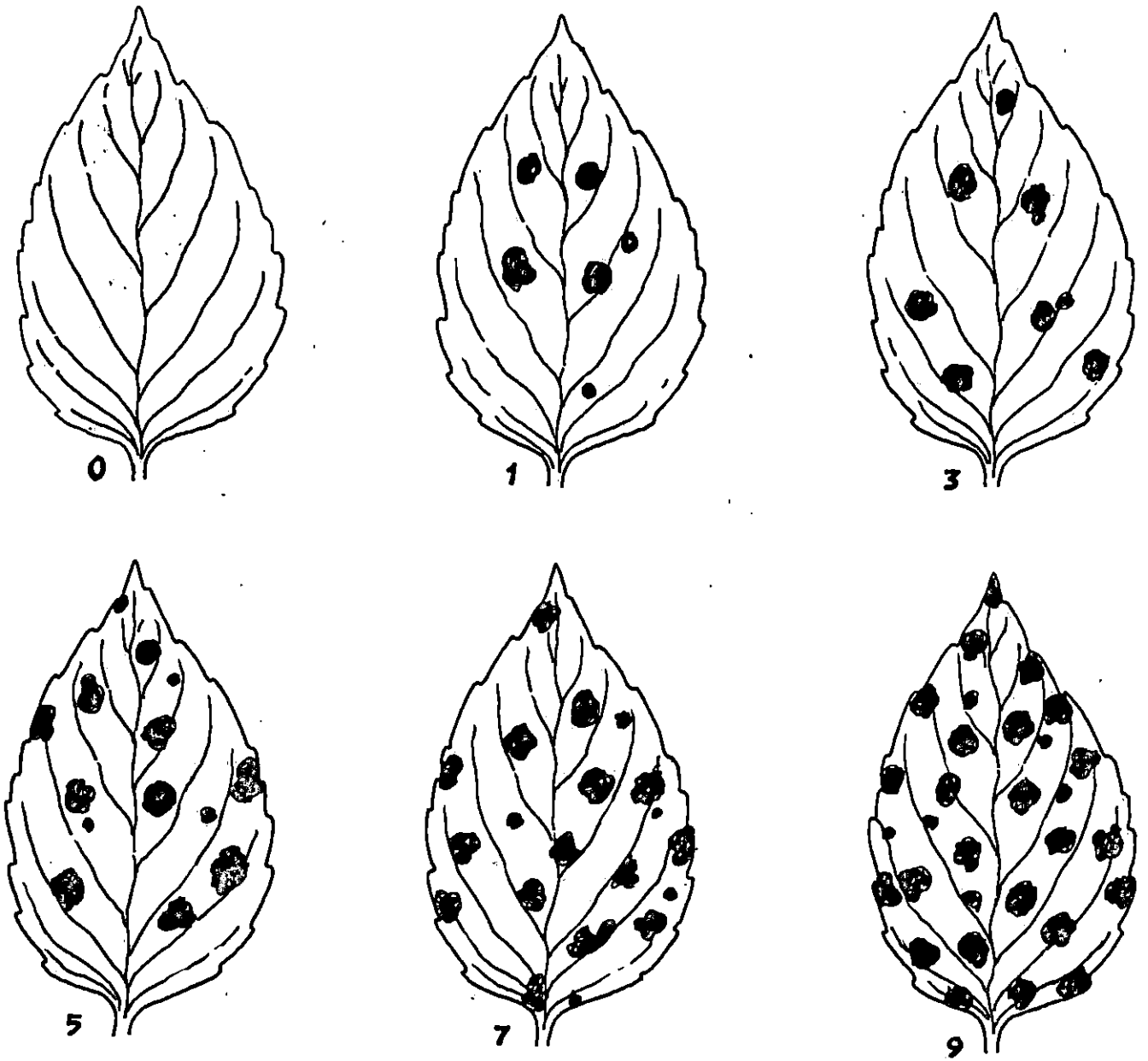


Fig. 4. Score chart for Botryodiplodia leaf spot

Grade		Description
0		Healthy leaves
1		1 per cent or less
3		1 - 10 per cent
5		11 - 20 per cent
7		21 - 50 per cent
9		51 per cent and above

FIG. 4 SCORE CHART FOR *Botryodiplodia* LEAF SPOT

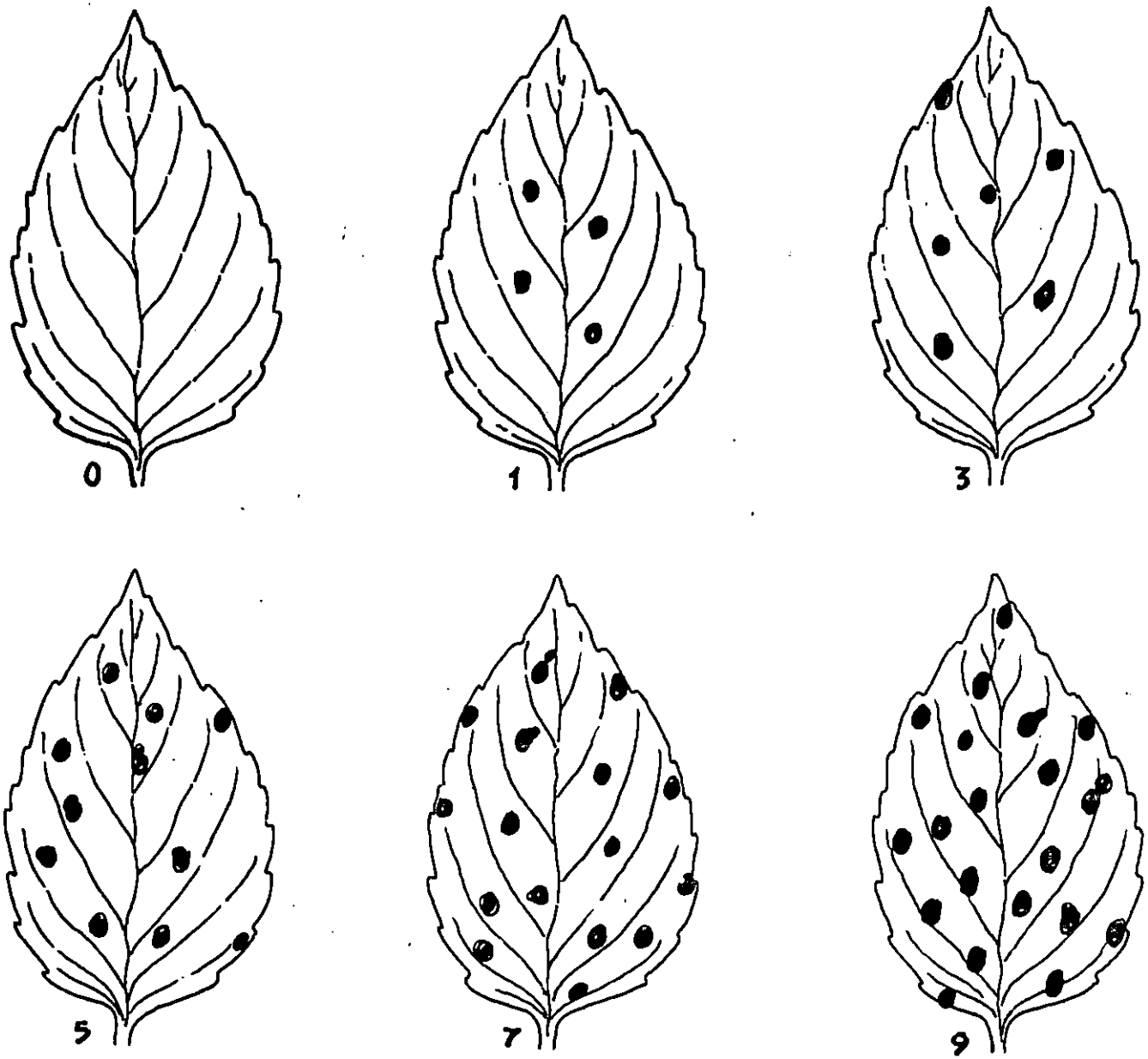
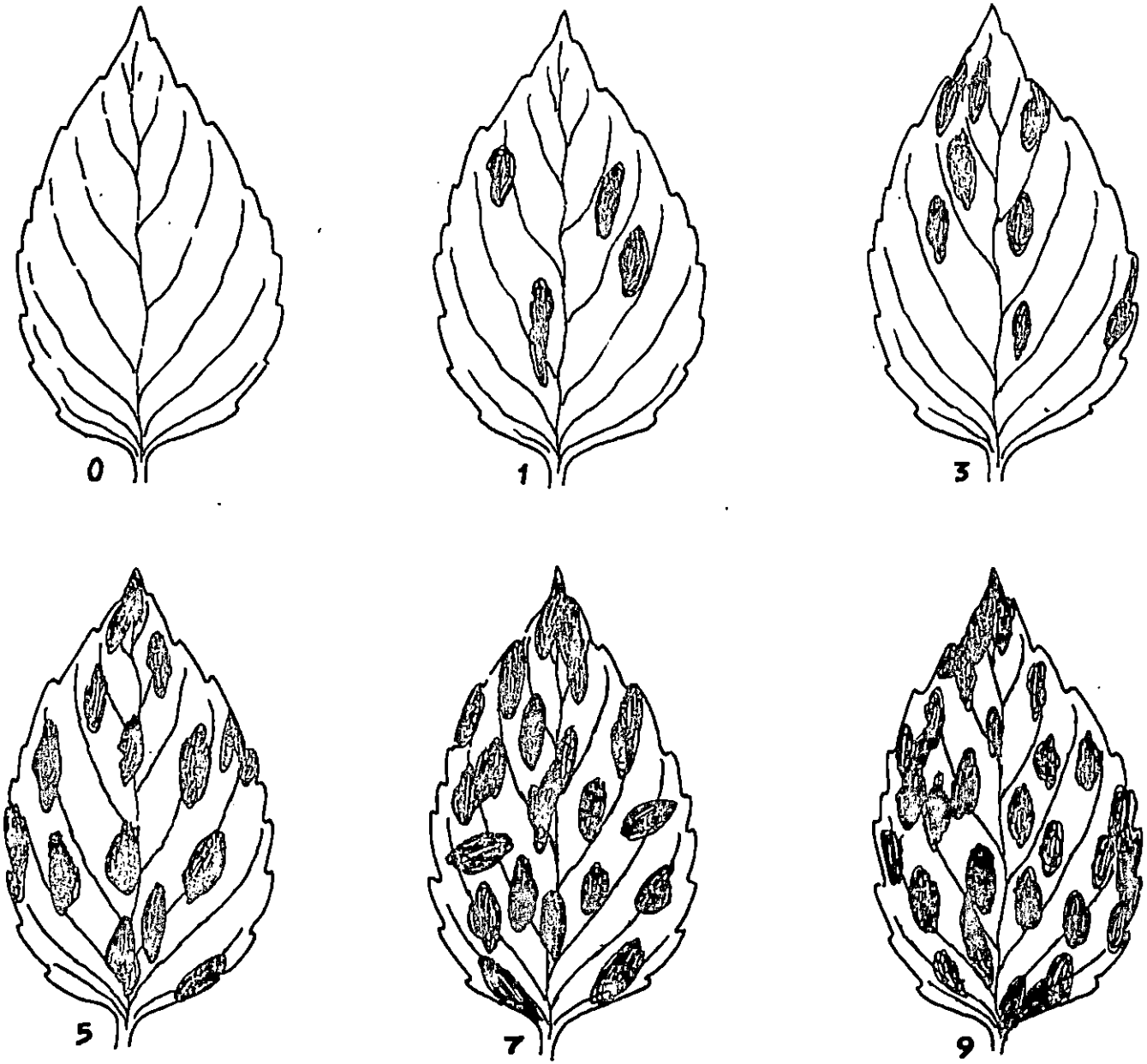


Fig. 5. Score chart for Fusarium leaf spot

Grade	Description
0	Healthy leaves
1	1 per cent or less
3	1 - 10 per cent
5	11 - 20 per cent
7	21 - 50 per cent
9	51 per cent and above

FIG. 5 SCORE CHART FOR *Fusarium* LEAF SPOT



All the leaves of 20 plants selected from each treatment were observed, the disease intensity was recorded and disease index was calculated using the following formula:

$$\text{Disease index (DI)} = \frac{\text{Sum of individual ratings x 100}}{\text{Total number of plants assessed x 9}}$$

Thousand seed weight and yield per plot were also taken. The data were analysed and per cent losses in yield were calculated. The losses in yield were recorded based on 1000 seed weight and per plot yield. Observations on stem infection, pod infection, percentage of healthy leaves and incidence of powdery mildew were also recorded.

3.11. Residual ~~toxicity~~ of Bavistin (Carbendazim)

The residue of Bavistin, which was found to be the most effective fungicide, was estimated.

The investigation was carried out during 1987 as a pot culture experiment in the upland sesamum cultivation season, at College of Agriculture, Vellayani. The experiment was laid out in completely randomised design with four replications. The package of practices recommendations of KAU were followed in raising the crop except the plant

protection schedule. The fungicide (250 and 500 ppm of Bavistin) was sprayed on 45th and 60th day of sowing.

Three samples were taken (both leaf and pod) at one week interval after the last fungicidal spraying. Residue analysis of Bavistin was conducted by the procedure supplied by BASF Ltd.

The sample (100 g) was macerated with 300 ml ethyl acetate. The supernatant organic phase was decanted into a one litre glass beaker and repeated the ethyl acetate extraction. The combined ethyl acetate extracts were desiccated over 5 to 10 g sodium sulphate and filtered into a round bottom flask. This was reduced to about 25 ml in a vacuum rotary evaporator. Then 25 ml of 1 N sulphuric acid was added and the flask was shaken vigorously for 2 min. The suspension was rinsed into a 250 ml separating funnel with 100 ml distilled water. The aqueous phase was run off into a separating funnel and neutralised with 30 ml saturated sodium bicarbonate solution. This was extracted twice with 25 ml chloroform. The chloroform extracts were combined and extracted with 10 ml of 1 N sulphuric acid in a separating funnel. The chloroform phase was discarded and the sulphuric acid extract was filtered into a 10 ml measuring cylinder

and was then read in Spectronic 2000 against 1 N sulphuric acid. The spectrum of carbendazim was recorded at 281 nm.

3.12. Influence of fungicides on quality and yield of oil

Samples collected from the field experiment described under 3.10.2 were used to determine the influence of fungicides on quality and yield of sesamum oil.

3.12.1. Oil quality

The following properties of the oil were determined to study the influence of the sprayed fungicides, viz., Bavistin, Bordeaux mixture and Dithane M-45 on quality of sesamum oil.

3.12.1.1. Acid value

Seed samples were collected from the field experiment after the fungicidal application. The oil was extracted by hot percolation method (A.O.A.C., 1960). The acid value of extracted oils was assessed by heating the oil with neutralized 95 per cent alcohol. The contents were then cooled and titrated against 0.1 N KOH using phenolphthalein as as indicator (A.O.A.C., 1960).

3.12.1.2. Iodine value

Iodine value of each sample of the oil was assessed by dissolving weighed quantity of oil in chloroform and treating it with iodine solution. The reaction was allowed to continue for 30 min in darkness with occasional shaking. The excess of iodine in the reaction mixture was estimated by titration against 0.1 N sodium thiosulphate solution using starch as indicator. When blue color disappeared the flask was stoppered and shaken after adding a few ml of potassium iodide solution (A.O.A.C., 1960).

3.12.1.3. Saponification value

Saponification value of the oil was assessed by boiling the oil for 30 min after adding alcoholic potash. The contents were titrated with 0.5 N HCl using phenolphthalein as indicator and the saponification value was calculated (A.O.A.C., 1960).

3.12.2. Oil yield

Oil yield of sesamum after fungicidal applications, was determined by A.O.A.C. method (1960).

3.13. Varietal screening for resistance against the leaf spot diseases

The following ten sesamum varieties were screened for resistance/tolerance against the leaf spot diseases caused by Alternaria sesami, Colletotrichum gloeosporioides, Curvularia lunata, Botryodiplodia theobromae and Fusarium oxysporum f. sp. sesami in a pot culture experiment.

1. Kayamkulam-1
2. B-64
3. Si-866
4. T-13
5. Kayamkulam-2
6. IC-284
7. Timbi-9
8. Si-44
9. Trivandrum local
10. North Kerala local No.24

The experiment was laid out in a completely randomised design with four replications. The plants were raised in earthen pots of 30 cm dia. When the plants attained the age of 45 days, they were spray inoculated with spore suspensions of all the five species of fungi. The inoculated plants were given high humidity by covering with polythene bags. The bags were removed when the inoculated plants showed initial symptoms of the diseases. Observations on disease index, percentages of stem infection and pod infection were recorded.

RESULTS

4. RESULTS

4.1. Survey on the occurrence of fungal diseases of sesamum, isolation, purification, testing pathogenicity and identification of the fungi

During the survey, the occurrence of fungal diseases was recorded and the following fungal pathogens were isolated, purified and their pathogenicity tested. They were identified by studying their characters and comparing these with those recorded in literature.

4.1.1. Name:

Acrosporium acanthospermi (Chidd.) Subram.

4.1.1.1. Locality:

Neyyattinkara, Parassala, Vellayani, Attipra in Trivandrum district and Kayamkulam, Haripad, Chepad etc. in Alleppey district.

4.1.1.2. Season:

August - December and December - April.

4.1.1.3. Major symptoms:

Symptoms appear as small white spots on the upper surface of the leaves (Plate 1). Corresponding areas on the lower surface of the leaves have a water soaked appearance. Whitish powdery growth of the fungus coalesced to form large patches and cover the entire leaf lamina, severely infected leaves rolled inwards and found drooping. Defoliation and death occurred in severe cases.

4.1.1.4. Susceptible stage:

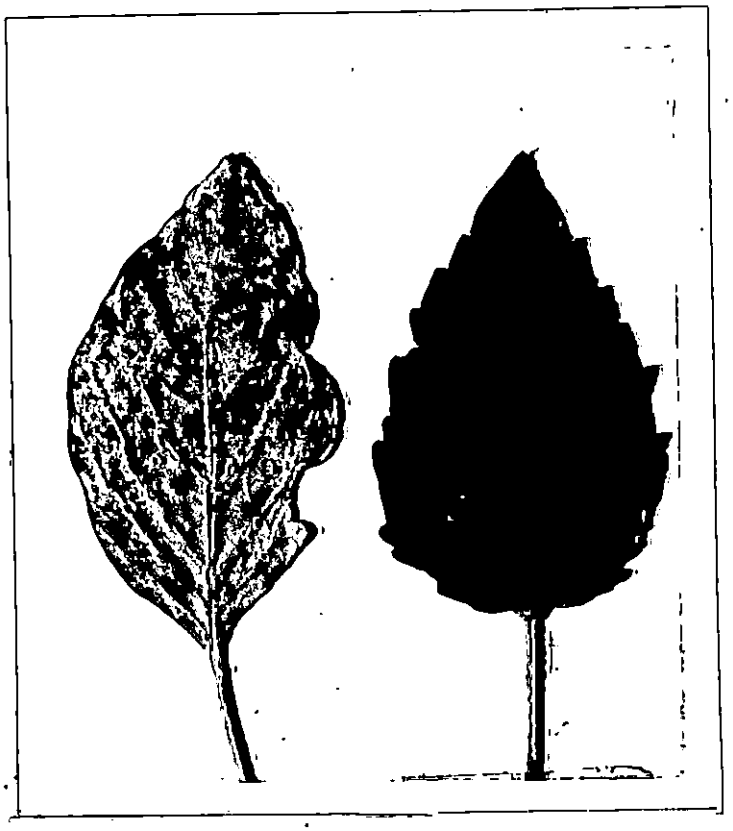
Pod formation and pod ripening stages.

4.1.1.5. Pathogenicity:

Infection occurred towards the end of crop season.

4.1.1.6. Characters of the pathogen:

Mycelium superficial on host surface, creeping, in mass appeared as white and hyphae are hyaline, septate, and branched. Conidiophores erect, simple, upper portion of the conidiophore increase in length as conidia are formed from this point. Conidia are hyaline, one celled, cylindrical or elliptical with round ends. Conidia measured 20.64 to 30.84 x 10.7 to 20.2 µm. Haustoria globular to slightly conical in shape.



Diseased Healthy

Plate 1. Powdery mildew caused by *Acrosporium acanthospermi*

4.1.2. Name:

Alternaria sesami (Kaw.) Mohanty & Behera

4.1.2.1. Locality:

All the sesamum growing areas in Trivandrum, Quilon and Alleppey Districts.

4.1.2.2. Season:

August - December.

4.1.2.3. Major symptoms:

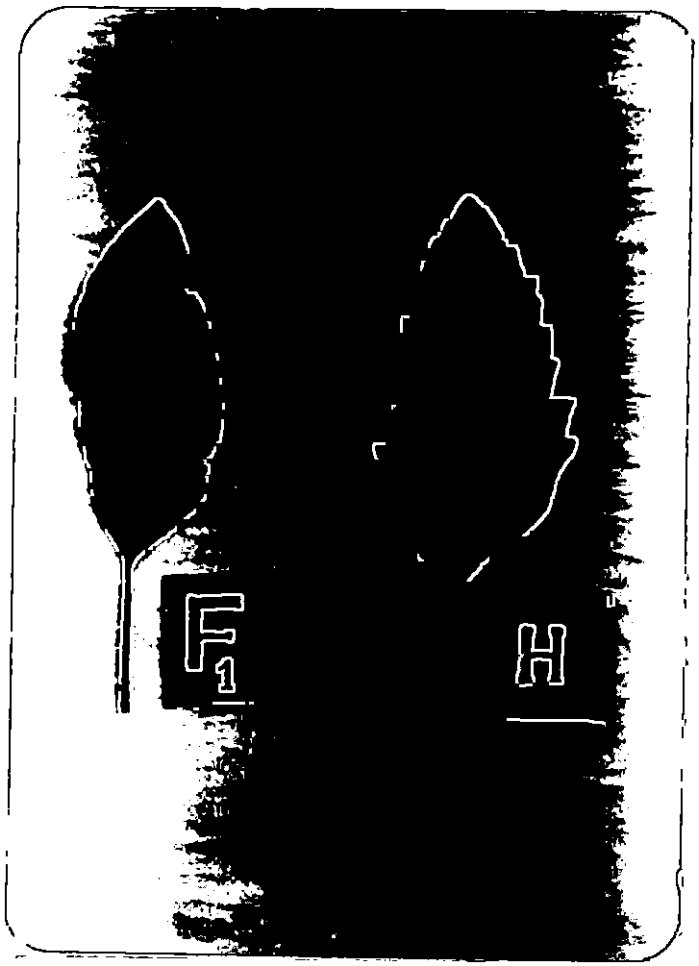
Leaf spots and occasionally leaf blight resulting in defoliation. Pod spot is also noticed. Spots initiate as water soaked lesions, later observed as typical concentric zonations inside the water soaked area (Plate 2). In the case of severely infected seeds the pathogen invaded all parts including the embryo.

4.1.2.4. Susceptible stage:

Flowering stage.

4.1.2.5. Pathogenicity:

Both injured and uninjured tissues are infected. Inoculation with spore suspension as well as culture bits gave positive results. Typical symptoms are produced within 4 to 7 days of inoculation.



F_1: Diseased H: Healthy

Plate 2. Leaf spot caused by *Alternaria sesami*

4.1.2.6. Characters of the Pathogen:

Color of the colony on PDA was ashy grey, mycelium septate, conidiophores simple, erect, somewhat flexuous, pale brown or yellowish brown. Conidia are yellowish brown, obclavate, having 3-6 septa, both longitudinal and transverse, constricted at the septa. Usually conidia are not in chains (Plate 3). Each conidium has long hyaline beak. Conidia measured 20.64 to 31.45 µm x 9.21 to 18.27 µm. (excluding the beak). Conidia from host tissues were shorter with more number of transverse septa than those from culture. The fungus could be isolated from seeds of infected pods also. Beak of the conidia are sometimes thickened and chlamydospores are formed (Plate 4).

4.1.3. Name:

Botryodiplodia theobromae Pat.

4.1.3.1. Locality:

All sesamum growing areas in Trivandrum, Quilon and Alleppey Districts.

4.1.3.2. Season:

December - April

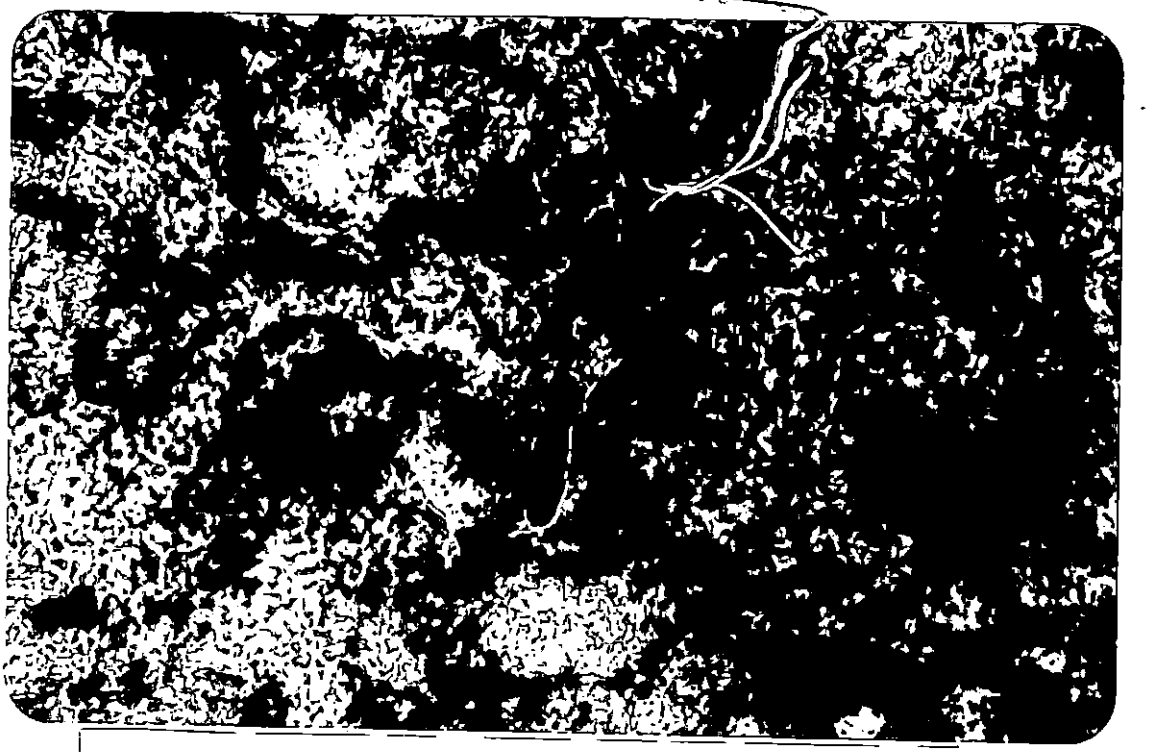


Plate 3. Conidia of *A.sesami* (X 750)

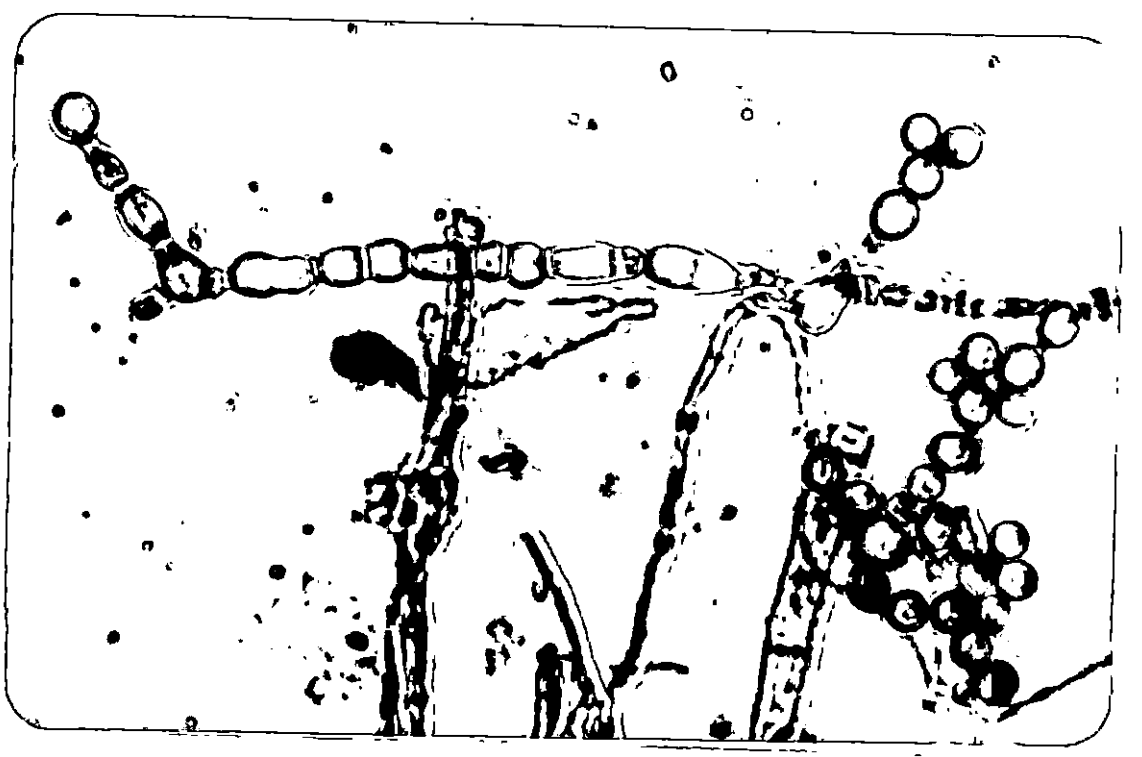


Plate 4. Chlamydospore formation in *A.sesami* (X 1500)

4.1.3.3. Major symptoms:

Initiate as small brown leaf spots. As disease advances, the spots enlarge and become leaf blight, followed by defoliation (Plate 5).

4.1.3.4. Susceptible stage:

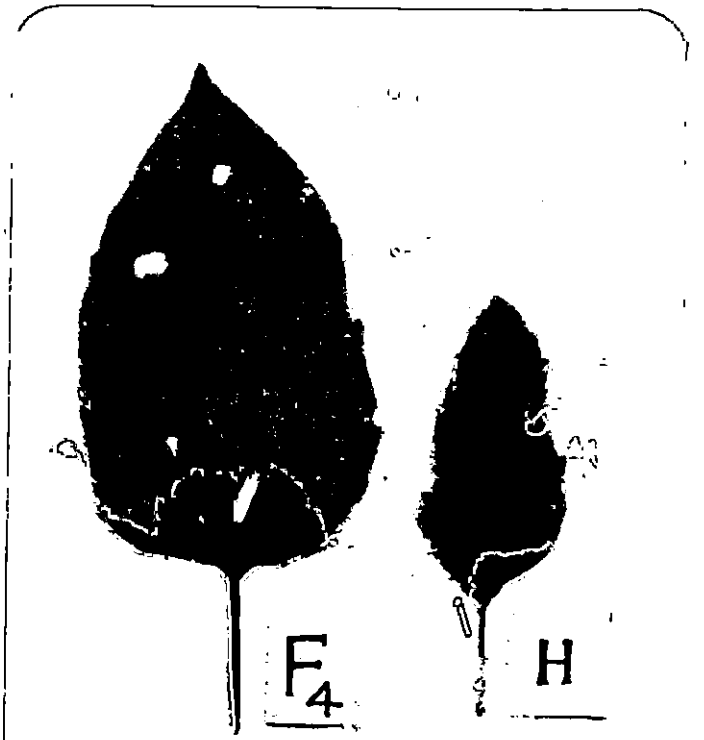
Branching stage.

4.1.3.5. Pathogenicity:

Inoculation trials were positive with spore suspension as well as with culture bits on both injured and uninjured tissues. Inoculam as culture bits hastened symptom development.

4.1.3.6. Characters of the pathogen:

The color of the colony on PDA was dark grey or blackish. Mycelium septate, conidiophores s[redacted], usually erect and hyaline. Conidia are hyaline [redacted]one celled when young and at maturity they become two celled, and are deep brown in color ovoid to subovoid or sometimes elongated. Mature conidia are relatively thick walled (Plate 6). They measured 14.38 to 22.21 x 7.32 to 12.70 µm. Pycnidia are observed in old cultures as black knots which are ovoid or



F_4: Diseased H: Healthy

Plate 5. Leaf spot caused by Botryodiplodia theobromae

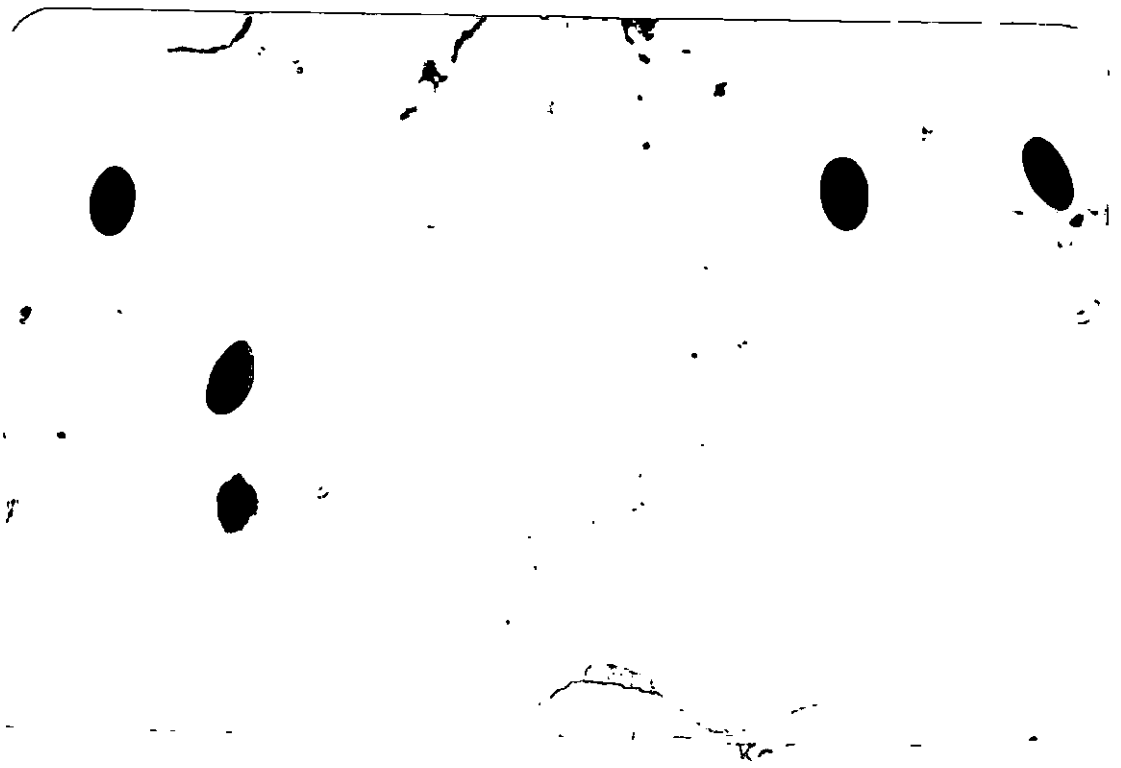


Plate 6. Conidia of B.theobromae (X 750)

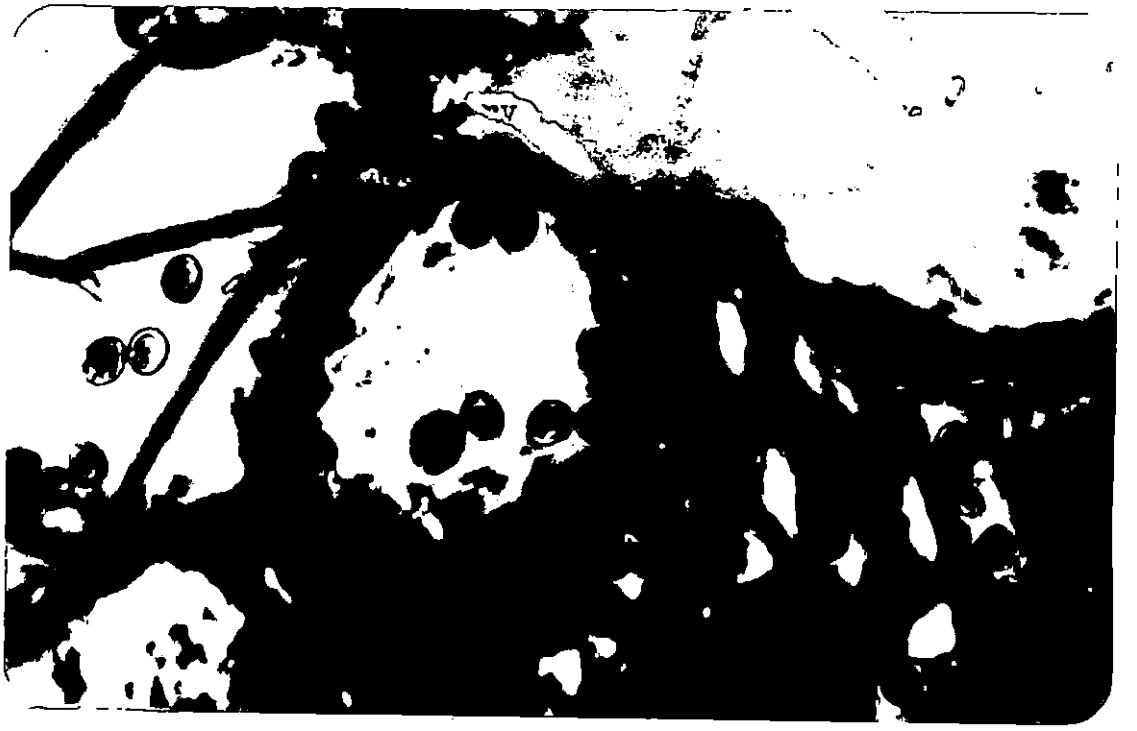


Plate 7. Pycnidium of B.theobromae (x 1500)

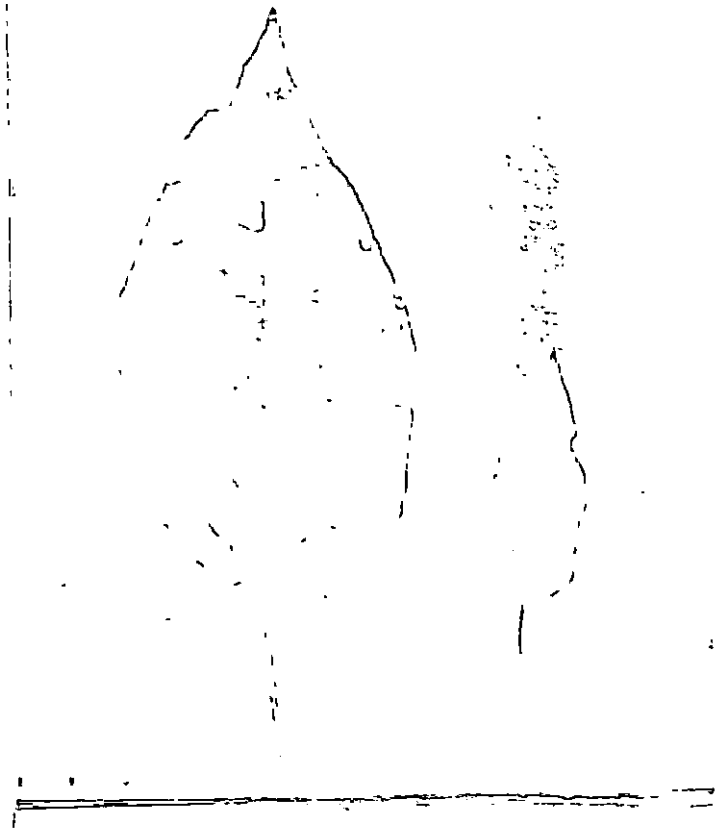


Plate 8. Leaf spot caused by *Cercospora apii*

Plate 9. Section of sesamum leaf showing conidiophores and conidia of C.apii (x 1500)

4.1.4.4. Susceptible stage:

Capsule ripening stage.

4.1.4.5. Pathogenicity:

On injured tissues symptoms started within 48 h after inoculation and uninjured took 5 to 6 days to initiate symptoms, when culture bit was inoculated, With spore suspension, the injured tissues showed symptoms after 3 to 4 days and in uninjured after one week.

4.1.4.6. Characters of the pathogen:

On host leaf extract agar, the colony color was pale grey to dirty white. But in carrot leaf agar the color was dark grey. Mycelium are irregularly septate and are immersed, thick walled and brown in colour. Conidiophores are produced in bundles of 20 to 25, usually emerge through the stomata (Plate 9). They were slight brown initially, but at maturity they became dark brown in color. They were unbranched and straight mostly, but some times geniculate and slightly swollen at the basal portion. Conidiophores measured 38.5 to 97 x 2.8 to 4.0 µm. Conidia are colorless, long septate (mostly 7-10) broad at the base and tapering towards the apex and measured 8.3 to 98.7 x 2.7 to 4.2 µm.

4.1.5. Name:

Colletotrichum gloeosporioides (Penz.) Penz.& Sacc.

4.1.5.1. Locality:

Vellayani and Balaramapuram both in Trivandrum district, Yakkara and Nenmara in Palghat district.

4.1.5.2. Season:

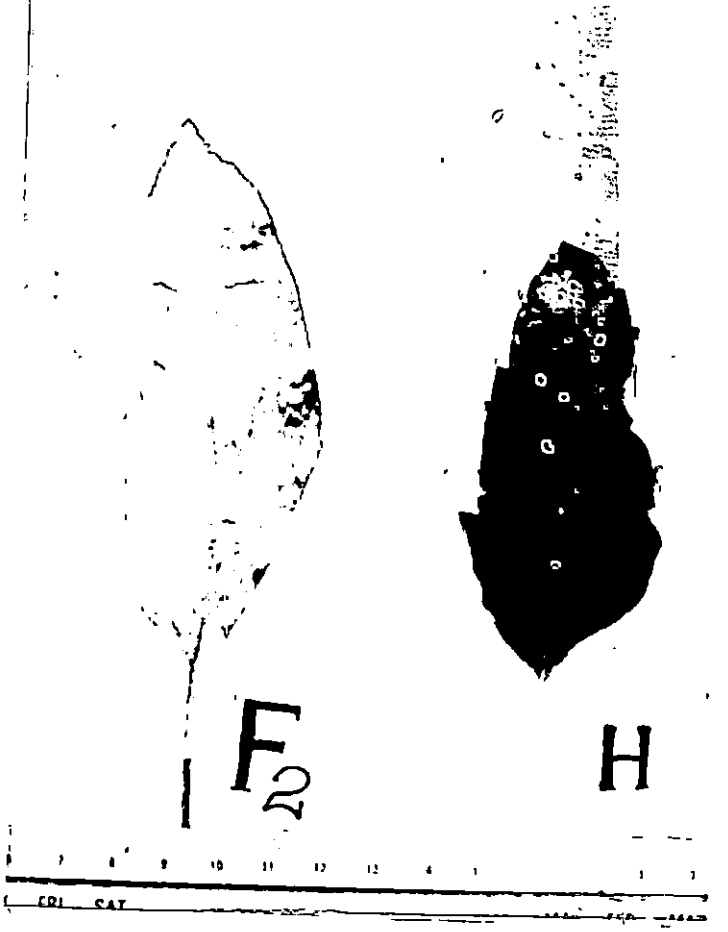
August - December.

4.1.5.3. Major symptoms:

Initiate as dull green areas on leaf surface, which enlarge and became necrotic. Shape of the spots more or less round which are brown or purplish brown in color (Plate 10). Often Anthracnose symptoms noticed which if occurs, cortical portion was found destroyed. The brownish discoloration continuous from foot to top when infection was very severe. But at times it was not found continuous. The disease affected the setting of the pods and affected plants destroyed before maturity of pods.

4.1.5.4. Susceptible stage:

Capsule ripening stage.



F_2: Diseased H: Healthy

Plate 10. Leaf spot caused by Colletotrichum gloeosporioides

Plate 11. Conidia of C.gloeosporioides (x1500)

4.1.5.5. Pathogenicity:

Spray inoculated plants developed symptoms within 4 to 6 days when injured. But with culture bits symptom expression was after about a week even with injury. Inoculation with culture bit developed symptoms after 48 h and with spore suspension after 5 days, both in injured and uninjured tissues.

4.1.5.6. Characters of the pathogen:

The color of the colony on PDA was ashy grey, mycelium branched and septate, hyphae hyaline and collected underneath the epidermis at certain places to form a mat like stroma. Conidiophores were hyaline, simple, cylindrical and nonseptate. They are arranged compactly in rows. Conidia are hyaline, cylindrical or oblong with round ends and one celled (Plate 11). In culture, the spore mass have a brick red or creamy coloration. They have thin walls with granular protoplasmic contents inside with oil globules. The perfect state of the organism - Glomerella cingulata (Stonem) Spauld. & Schrenk could be observed in the inoculated sesamum leaf bits. In most cases the perithecia could be observed only in cultures of more than 10 days old. Dense acervuli could be observed over the necrotic lesions of the infected areas as dark brown or blackish spines or dots. They are subepidermal. Inside the perithecium a number of asci could be observed. Asci are globose or subglobose or clavate in shape and brown in color.

Asci were found in groups. Inside each ascus, light ascospores were seen and they measured 14.79 to 15.12 x 3.97 to 4.24 µm. Conidial size varied from 20.23 to 23.67 x 4.74 to 4.96 µm.

4.1.6. Name:

Corynespora cassiicola (Berk & Curti) Wei.

4.1.6.1. Locality:

All sesamum growing areas in Kerala.

4.1.6.2. Season:

Occurs during both the seasons but severe during December - April.

4.1.6.3. Major symptoms:

First appears on the leaves as minute brown/purple dots, which gradually increases to 10 mm or sometimes much more in dia (Plate 12). The spots are irregular in outline and when in large numbers, they coalesce forming large patches. Sometimes the spots have concentric zonations inside. The spots could be observed on both surfaces of leaves. From leaves the disease extends to stem also. On stems reddish purple dots/spots appeared which in due course enlarged in size to form elliptical purplish brown spots

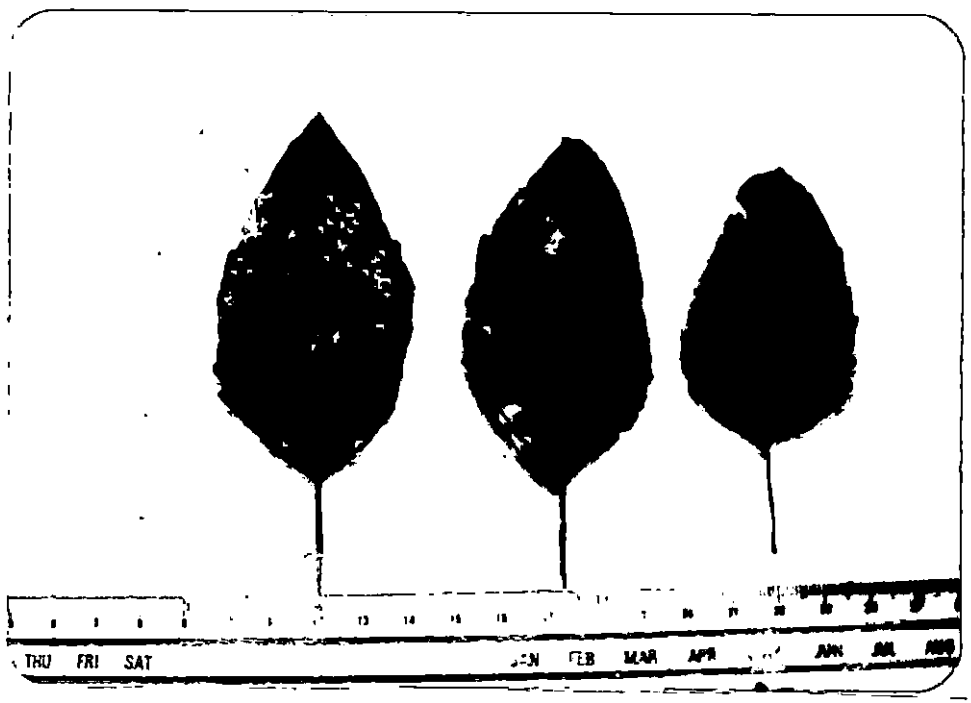


Plate 12. Leaf spot caused by *Corynespora cassiicola*

with a lighter centre. When such numerous spots occur on the stem they run into each other to form purple streaks. When such plants bear fruits, the characteristic spots could be observed on pods also. The spots varied in size from less than 1 mm to 2-3 mm. Heavily infected plants are killed.

4.1.6.4. Susceptible stage:

Any stage of the crop. However symptoms initiated first on plants towards maturity.

4.1.6.5. Pathogenicity:

Infection initiated first on culture bit inoculated plants i.e., 4 to 6 days after inoculation, but spore suspension inoculation took 7 days to initiate symptoms with injury. When the inoculations were done without injury it took 7 and 8-9 days respectively in culture bit and spore suspensions.

4.1.6.6. Characters of the pathogen:

On PDA, the colonies were pale grey in color at first, turned to deep grey when old. Mycelium was mostly immersed, composed of branched subhyaline to pale brown, septate and smooth walled. On infected leaves, the mycelium is internal. Conidiophores emerge through the epidermis,

slightly swollen at apex, which are simple, but some times branched. They are straight or slightly flexuous. Conidia were terminal and single in most cases, sometimes found inchains, pale olivaceous brown in color. They were smooth, several celled, obclavate to cylindrical in shape. They have colorless thick exospore and prominent dark basal scar with several (3-18) pseudosepta. Spores measured 26.72 to 92 x 4.7 to 17.0 µm.

4.1.7. Name:

Curvularia lunata (Wakker) Boedijn.

4.1.7.1. Locality:

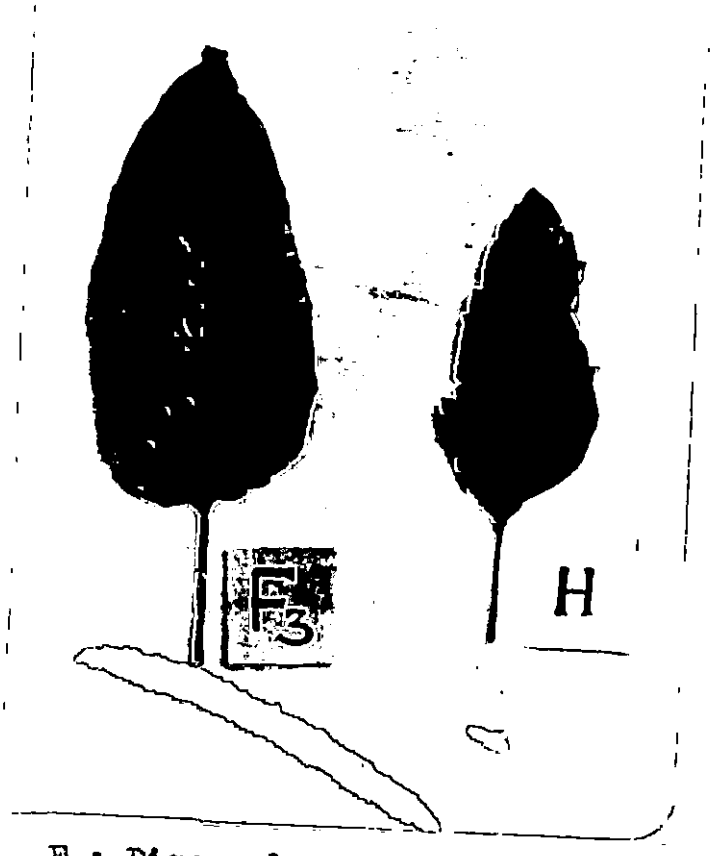
Vellayani in Trivandrum and Kayamkulam in Alleppey district.

4.1.7.2. Season:

August - December and December - April.

4.1.7.3. Major symptoms:

Small water soaked lesions are developed in the initial stages. These lesions later turned to brown in color (Plate 13). A large number of such spots could be



F_3: Diseased H: Healthy

Plate 13. Leaf spot caused by Curvularia lunata

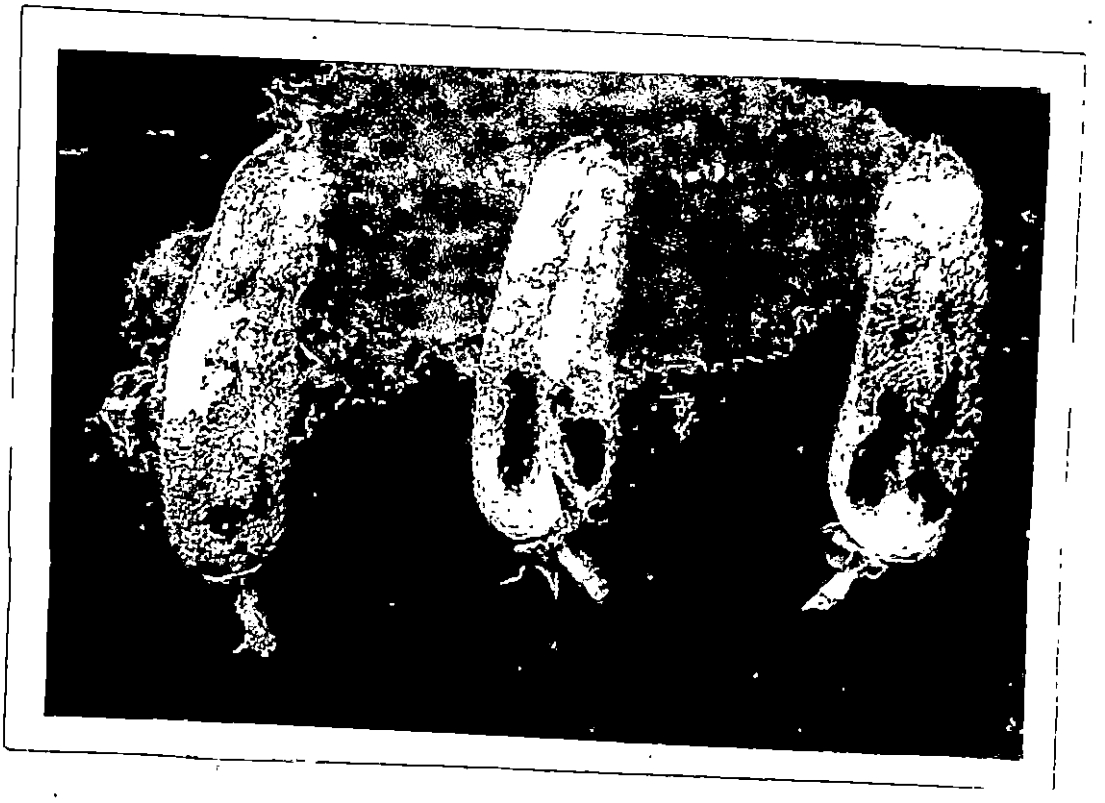


Plate 14. Pod spot caused by C.lunata

noticed on a single leaflet. Severe attack resulted in the shedding of leaves and water soaked lesions could be noticed on pods also (Plate 14).

4.1.7.4. Susceptible stage:

Towards seed maturity.

4.1.7.5. Pathogenicity:

Injured and uninjured leaves developed symptoms, but when injured, the symptom spread was rapid i.e., on injured the symptoms started within 4 to 5 days, while in uninjured it took one week.

4.1.7.6. Characters of the pathogen:

The color of the colony on PDA was dark ashy grey. Mycelium septate, profusely branched, subhyaline to light brown. Conidiophores were dark brown and unbranched. Conidia were dark brown, boat shaped, 3 septate, usually third cell from the base conspicuously larger, broader and darker than the others. Typical bending observed on the third cell (Plate 15). Apical cell of the conidium was subhyaline and round in shape. The basal cells are also subhyaline which bears a scar indicating the point of attachment to the conidiophores. The spores measured 35 to 41.2 x 12.4 to 13.4 µm. Conidia are usually found at the apical part of conidiophores in groups.

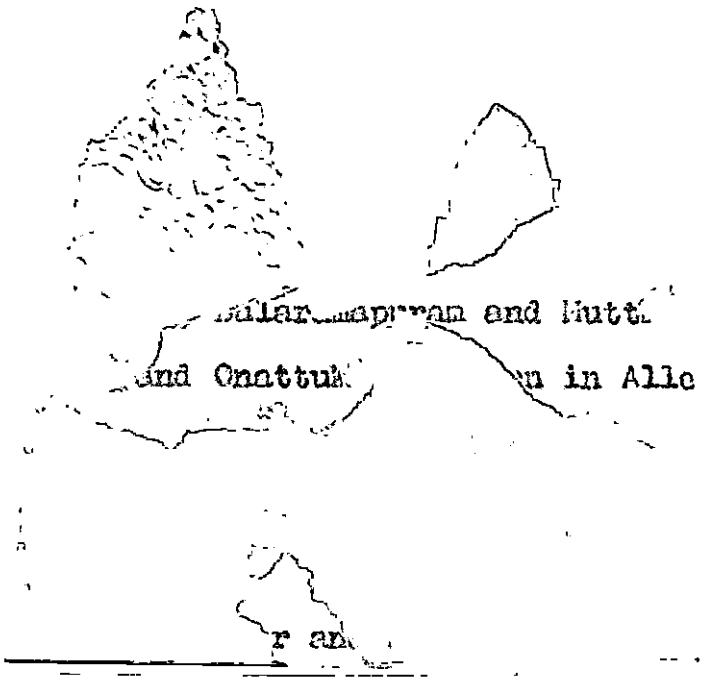
Plate 15. Conidia of C.lunata (x 1500 .)

4.1.8.3. Major symptoms:

Symptoms characterised by yellowing, withering and drooping of leaves. On leaves dull green areas appeared which later turned to blighted appearence (Plate 16). Complete destruction occured if the infection was in the seedling stage. The top of the plant dried up and bent over. Brown discoloration of the xylem vessels observed from root to apex. Death of plants occurred in severe cases causing typical wilt symptoms.

4.1.8.4. Susceptible stage:

Seedling stage (Cotyledonary stage).



F_5: Diseased H: Healthy

Plate 16. Leaf spot caused by Fusarium oxysporum f. sp. sesami

Plate 17. Micro and macro conidia and mycelium of F.oxysporum f. sp. sesami (x 750)

4.1.8.5. Pathogenicity:

Injured tender portions of stems got infected rapidly than uninjured portions. Symptoms developed within three days of inoculation with culture bits and four to six days with spore suspension.

4.1.8.6. Characters of the pathogen:

The color of the colony on PDA was pure white, mycelium very fluffy, septate, simple and hyaline, conidiophores are simple or branched, short, stout and hyaline. Two types of conidia are produced inside sporodochia and also in a scattered manner on the aerial mycelium. The larger spores - macroconidia - are born on elaborately branched conidiophores. They are hyaline, 3 to 5 septate, thin walled, fusiform or falcate in shape with pointed ends (Plate 17). Macroconidia measured 12.74 to 48.28 X 2.02 to 3.21 µm. The small spores - microconidia are mostly one celled, hyaline, ovoid or oblong. They are found produced singly from the tips of the phialides.

4.1.9. Name:

Helminthosporium sesami Miyake

4.1.9.1. Locality:

Vellayani, Kadakkavur and Uzhamalakkal in Trivandrum district.

4.1.9.2. Season:

August - December.

4.1.9.3. Major symptoms:

The symptoms appear on the leaves as small flecks of one mm dia to larger lesions which are sunken. The brown colored spots appear also on petioles and stem and later on the pods. The spot size reached upto 20 mm in severe infections, resulting in blight symptoms (Plate 18).

4.1.9.4. Susceptible stage:

Capsule dehiscence stage.

4.1.9.5. Pathogenicity:

Both injured and uninjured tissues developed symptoms of the disease. In injured spore suspension sprayed plants, the symptoms of the disease appeared within three to four days, whereas in uninjured spore suspension sprayed it took about one week. In the case of culture bit inoculated injured plants symptom development occurred on the third day itself but it delayed by two days in uninjured ones.

Plate 18. Leaf blight caused by Helminthosporium sesami

4.1.9.6. Characters of the pathogen:

The color of the colony on PDA was grey to ashy grey. As the culture became older, the color changed to deep grey or blackish. Mycelium is brown and septate. Conidiophores are tall, erect, single and brown colored. Conidia are subhyaline to brown, arise through small pores laterally. Apex of the conidiophores were free as they grew further. Conidia subhyaline to brown, smooth, pseudoseptate, (5-10 celled), slightly curved with a bulge in the centre and tapering at the top. Conidiophores bear this conidia at regular intervals, on the upper part in a sympodial manner. Thus on the conidiophores several bends and scars could be observed at regular intervals. This gave the conidiophores a characteristic shape. Conidia measured 33.7 to 98.74 x 7.2 to 14.94 µm.

4.1.10. Name:

Pestalotia sp.

4.1.10.1. Locality:

Vellayani and Anayara in Trivandrum district.

4.1.10.2. Season:

December - April.

4.1.10.3. Major symptoms:

Appear on the leaves as small purple colored spots with varying diameter of one mm to 7 mm. As the disease advanced, the purple color became more prominant towards the periphery and centre with grey color (Plate 19). Minute black dots could be observed on the grey centre representing the acervuli of the pathogen.

4.1.10.4. Susceptible stage :

Branching stage.

4.1.10.5. Pathogenicity:

Infection developed on all the plants inoculated with and without injury. Injured plants started the production of symptoms within 4 to 5 days, whereas uninjured took one week with spore suspension inoculation. But when the plants were inoculated with culture bit, the symptoms developed within two days in injured and 4-5 days in uninjured.

4.1.10.6. Characters of the pathogen:

On PDA, the colonies were white and leathery. In old cultures black dots could be observed in the white mycelium, representing the fruiting body of the fungus, the acervuli. They are discoid or cushion/saucer shaped and

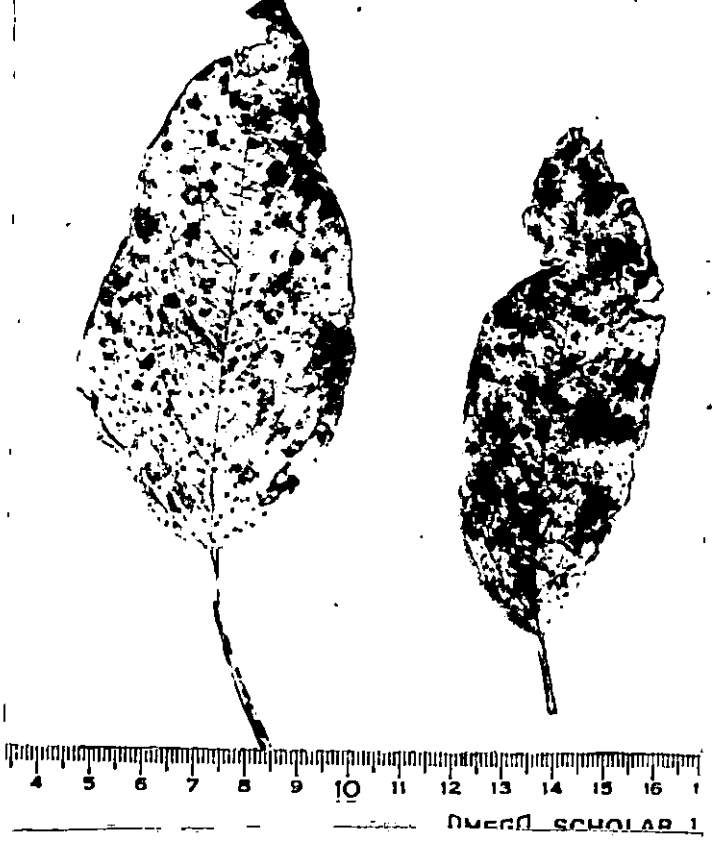


Plate 19. Leaf spot caused by Pestalotia sp.

Plate 20. Conidia of Pestalotia sp. (x 1500)

subepidermel on the host surface. Conidiophores were hyaline short and cylindrical formed on stroma. Conidia were dark colored, five celled usually, constricted at the septa. The middle three cells were darker and the end cells were found hyaline. Hyaline apical appendages were observed. In many of the spores only one apical appendage could be observed, rarely spores with three hyaline appendages could be noticed. There was one basal appendage for each spore. Size of conidia was 15.29 to 26.71 x 5.12 to 7.71 µm without appendage (Plate 20).

4.1.11. Name:

Phytophthora parasitica var. sesami Dastur.

4.1.11.1. Locality:

Vellayani and Chirayinkil in Trivandrum district and Haripad and Kayamkulam in Alleppey district.

4.1.11.2. Season:

August - December and December - April; but severe during December - April season.

4.1.11.3. Major symptoms:

Initial symptoms are water soaked spots on leaves and stems. Under favourable conditions these spots enlarge

rapidly and may coalesce with each other resulting in leaf blight. Pre-mature leaf fall occurs, infected stems and branches look brown initially but turn to black when mature. In humid weather, white mycelial growth of the fungus may be seen on the surface of affected parts. Root rot symptoms are noticed especially in seedlings and the severely infected seedlings destroyed the crop (Plate 21).

4.1.11.4. Susceptible stage:

Seedling and flowering stages.

4.1.11.5. Pathogenicy:

Stem rot symptoms developed in injured plants sprayed with culture suspension within five to six days and in uninjured within seven to eight days. Culture bit inoculated plants developed symptoms earlier than the spore suspension sprayed. i.e., in the case of injured tissues within three to four days and in uninjured within five to six days.

4.1.11.6. Characters of the pathogen:

On PDA, the colony color was white, smooth and cottony, mycelium coenocytic, hyaline, and freely branching. Many sporangiophores were produced bearing numerous sporangia. Sporangia are hyaline, lemon shaped and thin walled (Plate 22). Oospores were round and thick walled compared to sporangial wall.

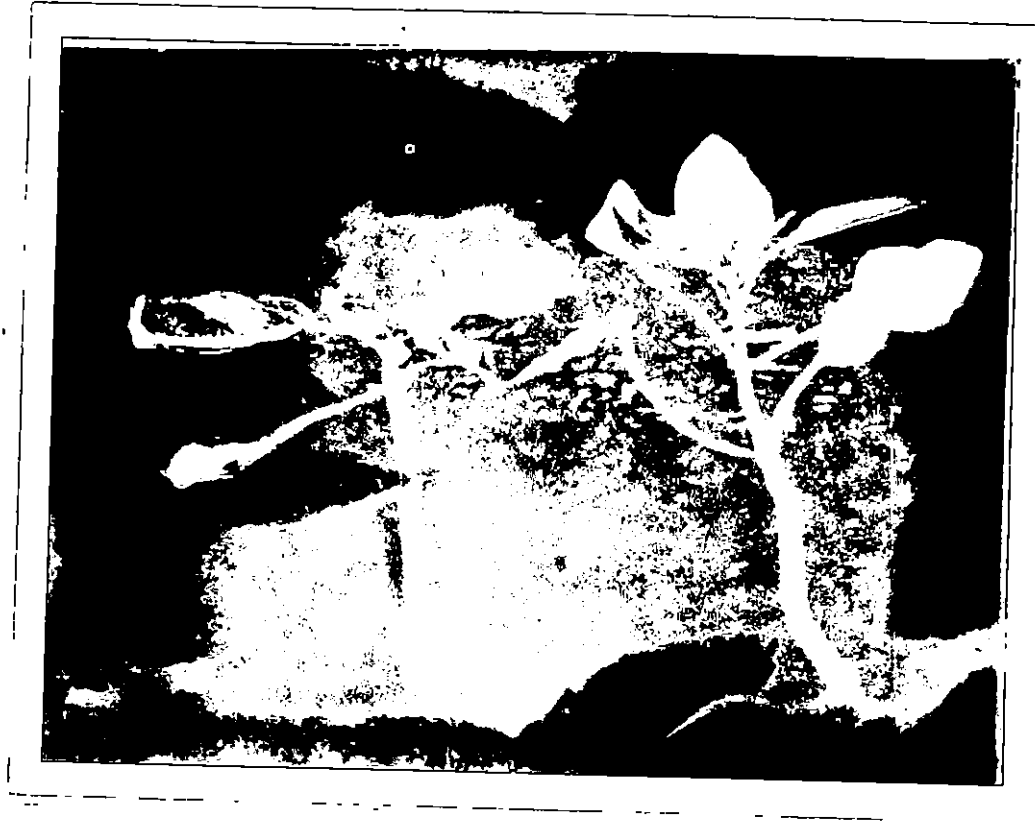


Plate 21. Stem rot caused by Phytophthora parasitica

Plate 22. Sporangia of P.parasitica (x 1500

4.1.12. Name:

Rhizoctonia bataticola (Taub.) Butl.

4.1.12.1. Locality:

Vellayani and Attingal in Trivandrum district and Pathiyoor in Alleppey district.

4.1.12.2. Season:

December - April mostly.

4.1.12.3. Major symptoms:

Rotting of the collar region was the initial symptom which spreads along the stem (Plate 23). On affected parts whitish growth of mycelium could be observed. After four to five days, small whitish dots on the infected areas representing the sclerotia of the organisms could be noticed. These sclerotia later turned to brown structures. High humid conditions especially at the time of maturity resulted in severe attack.

4.1.12.4. Susceptible stage:

Seedling stages are more susceptible.

Plate 23. Collar rot caused by Rhizoctonia bataticola

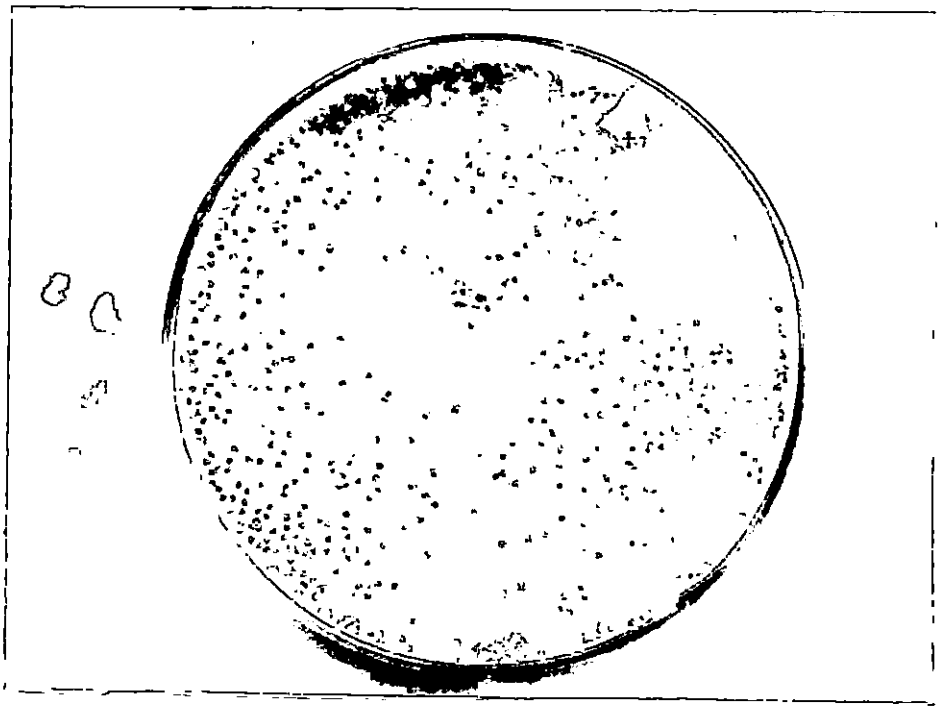


Plate 24. Culture of R.bataticola showing

4.1.12.5. Pathogenicity:

Symptoms developed in plants inoculated at various stages of growth with injury by using spore suspensions as well as dry culture bit inoculation, within four to five days. But in uninjured it took five and seven days respectively with culture bit and spore suspension inoculated.

4.1.12.6. Characters of the pathogen:

On PDA the colonies were white which was connected by thread like mycelial mat. Within four to five days small white dots representing the sclerotia of the organism could be observed (Plate 24). Later these white structures turned to light brown to deep brown in color composed of free, thick walled cells. Sclerotia varied in size and shape; globose, oval, oblong or elliptical. Sclerotia measured 22.2 x 37.72 µm.

4.2. Effect of diseases on germination of seeds:

Effect of the diseases on germination of seeds of sesamum was determined by noting the germination percentage of seeds from infected pods of diseased sesamum plants. It was found that the minimum germination percentage was in seeds from pods infected with A.sesami.

The percentage of inhibition over control in this case was 57.76. The maximum germination percentage was in the seeds from pods infected with C.gloeosporioides with 13.38 percentage of inhibition (Table 1).

4.3. Seed-borne fungi

Among the two methods used viz., standard blotter method and agar plate method, the latter was found to be better than the other since more species of fungi were isolated by this method. In general the predominant fungi were Rhizopus nigricans, Aspergillus flavus, Mucor haemalis, Aspergillus niger, Penicillium chrysogenum and Alternaria sesami. (tables 2 and 3).

Among the ten varieties of sesamum seeds tested, Kayamkulam-1, T.C.30, No.42, and Assam local were, in general, found to harbour more number of fungal propagules.

Table 1. Effect of fungal diseases on germination of sesamum seeds.

Fungi	Mean germination percentage	Percentage of inhibition over control
1. *Alternaria sesami*	34.72	57.76
2. *Colletotrichum gloeosporioides*	71.20	13.38
3. *Curvularia lunata*	41.20	49.87
4. *Botryodiplodia theobromae*	44.70	45.62
5. *Fusarium oxysporum* f. sp. *sesami*	42.28	48.56
6. Control	82.20	..

Table 2. Per cent incidence of fungi associated with seeds of ten varieties of sesamum by blotter method

Varieties	Fungi isolated																	
	Sterilized									Unsterilized								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1. Kayamkulam-1	16	9	4	3	-	-	41	29	21	21	18	8	5	-	8	54	32	38
2. T.C.30	4	16	-	10	-	-	21	16	18	19	23	6	18	-	27	32	11	33
3. No.42	10	4	-	-	-	-	8	7	9	16	19	-	-	-	-	14	7	19
4. Assam local	16	10	12	4	-	-	18	17	21	24	35	21	2	9	-	24	35	43
5. B.64	7	2	-	-	4	-	5	4	6	12	11	2	-	4	-	11	7	21
6. Si.866	-	7	8	11	2	-	26	-	19	2	15	4	-	7	-	11	-	29
7. Kayamkulam-2	7	-	-	32	16	2	-	-	-	11	4	-	26	-	-	26	-	-
8. T.13	5	-	14	-	-	-	11	-	8	5	1	21	-	5	-	7	-	21
9. Timbi-9	-	-	7	-	21	-	-	-	-	-	-	11	-	44	-	-	2	6
10. Trivandrum local	14	21	7	-	4	2	14	-	35	20	32	-	-	1	2	-	-	2
	79	69	52	60	44	4	144	73	137	130	157	73	51	70	37	179	94	212

1. Aspergillus niger
2. Aspergillus flavus
3. Alternaria sesami
4. Curvularia lunata
5. Botryodiplodia theobromae
6. Fusarium oxysporum f. sp. sesami
7. Mucor hiemalis
8. Penicillium chrysogenum
9. Rhizopus nigricans

Table 3. Per cent incidence of fungi associated with the seeds of ten varieties of sesamum by agar plate method

Varieties	Fungi isolated																	
	Sterilized									Unsterilized								
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1. Kayamkulam-1	28	14	8	6	-	4	22	29	44	34	28	10	7	5	7	29	32	50
2. T.C.30	13	24	7	9	-	-	28	30	52	22	34	11	18	3	-	35	44	61
3. No.42	24	16	-	-	-	-	16	21	19	32	28	-	-	-	11	20	12	32
4. Assam local	21	24	32	15	-	-	2	23	11	36	34	2	16	-	7	24	36	28
5. B.64	14	7	5	-	-	-	-	7	9	21	9	16	-	2	-	12	16	19
6. Si.866	2	7	-	14	-	-	-	2	4	2	10	18	-	14	19	29	-	-
7. Kayamkulam-2	12	21	4	4	-	4	-	12	4	19	41	-	4	6	-	12	-	7
8. T.13	5	-	14	2	3	2	19	7	8	9	14	21	-	4	-	24	16	10
9. Timbi-9	2	1	10	-	6	-	-	21	30	6	4	16	3	6	3	2	-	19
10. Trivandrum local	21	30	4	-	2	4	6	2	4	30	31	2	2	-	-	10	12	29

1. Aspergillus niger
2. Aspergillus flavus
3. Alternaria sesami
4. Curvularia lunata
5. Botryodiplodia theobromae
6. Fusarium oxysporum f. sp. sesami
7. Mucor haemalis
8. Penicillium chrysogenum
9. Rhizopus nigricans

4.4. Mode of entry

4.4.1. *Alternaria sesami*

Majority of the spores of *A.sesami* germinated within 24 h. In many of the spores two germ tubes could be observed. The germ tube from some spores grew up to 3-4 times the spore length. Other germ tubes grew only for short distances before entering the plant tissue. In many cases appressoria were formed. Successful penetration was established after 48 h.

4.4.2. *Colletotrichum gloeosporioides*

The spores of *C.gloeosporioides* started germination within 6-8 h. A large number of spores were found germinating forming germ tubes, but entry into the host tissue occurred only in very few. The germ tubes ended by forming appressoria. Entry occurred in most cases directly through the cuticle of the host forming very minute infection pegs. But in most cases infection peg could not be identified. Penetration of the host tissues took place only after 24-36 h of germination of the spores.

4.4.3. *Curvularia lunata*

Spore germination took place 12-18 h of incubation. Germ tube penetrated through stomata after forming appressoria from which small infection pegs could be observed. Only in very few cases direct penetration through the cuticle was observed. The mode of entry of the pathogen was mainly through the stomata of the host leaves.

4.4.4. *Botryodiplodia theobromae*

Majority of the spores germinated within 24 h and each spore produced two germ tubes mostly from the two sides. Later the germ tube elongated 2-3 times the length of the spore and formed appressorium. Entry of the pathogen into leaf tissues could be observed both through the cuticle as well as through stomata of leaf. But main mode of entry was through the cuticle.

4.4.5. *Fusarium oxysporum* f. sp. *sesami*

Germination of the spores started after 12 h of incubation. The entry of the fungus into the host tissues was mostly through the stomata by germ tubes only. Appressorium could not be observed.

4.5. Histopathology

The histological changes brought about by the fungal pathogens, viz., A.sesami, C.gloeosporioides, C.lunata, B.theobromae and F.oxysporum f. sp. sesami on the host were studied by taking thin sections of the infected leaves and comparing with the healthy ones.

4.5.1. Alternaria sesami

Mycelium of the fungus was observed in the epidermal layers of the diseased leaves. In few cases the mycelium ramified deeper into the tissues of the leaves. The presence of mycelial structures inside the tissues was characterised by blackish discoloration. (Plate 25).

4.5.2. Colletotrichum gloeosporioides

The mycelial mat is found underneath the epidermis of the infected leaves. The adjacent cells turned black. Mycelium ramified through the parenchymatous tissues both inter and intracellularly. The entire tissues were in a disorganised state (plate 26). The infected tissues became necrotic.

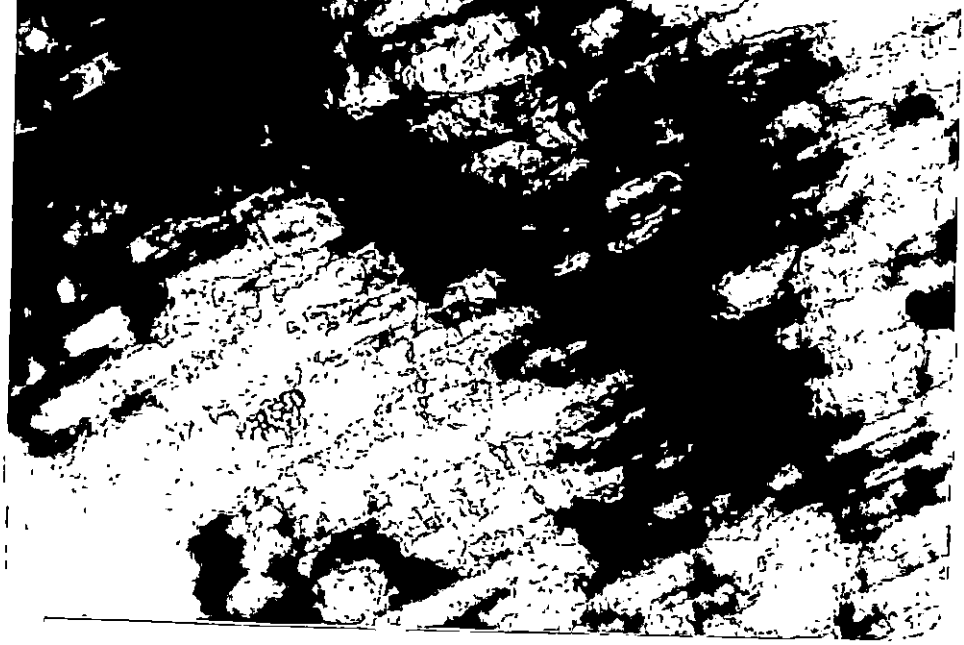


Plate 25. Histological changes in sesamum leaves caused by A.sesami (x 1500)

Plate 26. Histological changes in sesamum leaves caused by C.gloeosporioides (x 1500).

4.5.3. Curvularia lunata

The epidermal cells of the host tissues were the chief site of infection. The infected epidermal cells turned black and appeared in a collapsed condition. Due to the accumulation of mycelium inside the leaf tissues, the cells lost its original size and shape and appeared larger than the healthy ones.

4.5.4. Botryodiplodia theobromae

The cork layers as well as the subepidermal layers were invaded by the fungus and they appeared denser and darker than the healthy ones. The epidermal cells near the cork layers were found disintegrated.

4.5.5. Fusarium oxysporum f. sp. sesami

Due to the invasion of the pathogen inside the leaf tissues, vascular discoloration was observed. The adjacent cells near the necrotic areas turned darker and lost their original shape.

4.6. Toxin production

4.6.1. Influence of culture media

The toxin production capacity of the five fungal pathogens of sesamum as assessed by lesion length on sesamum leaves is given in table 4.

4.6.1.1. A.sesami

Maximum length of lesion was obtained with culture filtrate from Richards' medium followed by that from Czapek (Dox) and potato dextrose medium.

4.6.1.2. C.gloeosporioides

Maximum production of toxin by C.gloeosporioides was in Richards' and potato dextrose media.

4.6.1.3. C.lunata

Czapek (Dox) and potato dextrose media supported maximum toxin production by C.lunata as assessed by the lesion length on host leaves.

Table 4. Influence of culture media on toxin production by the five leaf spot fungi

Fungi	Culture filtrates of														
	Host leaf extract			Host leaf extract dextrose			Richards'			Czapek (Dox)			Potato dextrose		
	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
1. A.sesami	2	2	0	3	3	2	4	5	4	5	4	3	3	4	3
2. C.gloeosporioides	3	2	2	4	2	4	3	5	5	3	4	3	4	4	5
3. C.lunata	3	2	3	2	3	2	2	2	3	4	3	4	4	3	4
4. B.theobromae	2	3	4	2	3	2	1	3	2	4	3	3	5	5	5
5. P.oxysporum f.sp.sesami	2	2	2	4	5	4	3	3	2	2	3	2	3	4	3

0. no lesion
1. lesion length less than 1 cm
2. lesion length between 1-2 cm
3. lesion length between 2-3 cm
4. lesion length between 3-4 cm
5. lesion length more than 4 cm

4.6.1.4. B.theobromae

Maximum production of toxin by B.theobromae was in potato dextrose medium. This was followed by Czapek (Dox) medium.

4.6.1.5. F.oxysporum f. sp. sesami

Host leaf extract dextrose medium was the most favourable medium for toxin production by F.oxysporum f.sp.sesami followed by potato dextrose medium.

4.6.2. Exo and endo toxins

The observations on the effect of exo and endo toxins on lesion development on host leaves are presented in table 5. The fungi were grown on the respective medium which supported the maximum production of toxins.

The exo and endo toxins obtained from the respective medium were bioassayed on sesamum leaves. In both the cases necrotic lesions were discernible 8-10 h after inoculation. Observations were recorded after 48 and 72 h of inoculation as maximum lesion development was observed by this time. The results showed that the necrotic lesion development on sesamum leaves with exo and endo toxins varied with each fungus.

Table 5. Effect of exo and endo toxin production by the five species of leaf spot fungi on sesamum leaves

Fungi	Exo toxin						Endo toxin					
	48 h			72 h			48 h			72 h		
	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
1. A.sesami	3	2	2	3	2	3	3	2	3	5	3	4
2. C.gloeosporioides	2	3	2	3	3	2	3	3	4	4	4	5
3. C.lunata	2	2	3	3	5	4	2	3	3	3	3	3
4. B.theobromae	2	2	2	2	3	2	4	3	4	4	3	5
5. F.oxysporum f.sp. sesami	2	2	3	3	4	4	2	2	3	3	2	2

0. no lesion
1. lesion length less than 1 cm
2. lesion length between 1-2 cm
3. lesion length between 2-3 cm
4. lesion length between 3-4 cm
5. lesion length more than 4 cm

It was observed that among the exo and endo toxins produced by A.sesami, C.gloeosporioides and B.theobromae, the lesions caused by the endo toxins were found to be larger than those caused by the exo toxins. But in the case of C.lunata and F.oxysporum f. sp. sesami the maximum lesion development was noticed after 72 h by endo toxins.

4.6.3. Effect of culture filtrates on germination of fungal spores

Culture filtrates of the five species of fungi viz., A.sesami, C.gloeosporioides, C.lunata, B.theobromae and F.oxysporum f. sp. sesami were used to test their effects on the spore germination of each of the fungi. Germination of spores was recorded 48 h after incubation (table 6). Maximum inhibition of spore germination in the culture filtrate of A.sesami was recorded in the case of C.gloeosporioides (12.1) and minimum in C.lunata. With the culture filtrate of C.gloeosporioides also the maximum inhibition of spore germination was noticed in C.gloeosporioides (8.0) but minimum was in B.theobromae, while the culture filtrate of C.lunata showed maximum inhibition of spore germination in B.theobromae (8.7) and minimum in F.oxysporum f. sp. sesami.

Table 6. Effect of culture filtrates of the five species of fungi on germination of their respective spores

Fungi	Percentage of germination									
	SW	A_1-CF	A_2-CF	A_3-CF	A_4-CF	A_5-CF	RM	CM	PDM	HEDM
A_1	70.4	15.9	10.5	8.9	10.4	14.7	40.6	..	..	..
A_2	80.5	12.1	8.0	14.8	18.2	12.2	58.2	..	..	..
A_3	90.8	22.3	16.2	12.4	7.9	9.6	..	70.8	..	..
A_4	77.0	20.0	20.5	8.7	14.2	17.7	..	..	41.7	..
A_5	86.7	18.2	13.8	15.6	10.6	18.2	..	..	..	46.4

A_1 .. A.sesami
A_2 .. C.gleosporioides
A_3 .. C.lunata
A_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

SW .. Sterile water
RM .. Richards' medium
CF .. Culture filtrate
PDM .. Potato dextrose medium
CM .. Czapek (Dox) medium
HEDM .. Host extract dextrose medium

The culture filtrate of B.theobromae showed maximum inhibition in the case of C.lunata (7.9) and minimum in C.gleosporioides. Culture filtrate of F.oxysporum f. sp. sesami showed highest inhibition also in C.lunata (9.6) and minimum in F.oxysporum f. sp. sesami. In all the five species of fungi tested spore germination was maximum in sterile distilled water which ranged from 70.4 (A.sesami) to 90.8 (C.lunata).

4.7. Survival of the pathogens

This study was conducted by burying the infected leaves in soil.

4.7.1. A.sesami

The pathogen could be isolated directly from the leaf debris up to three months. But it could be isolated from the infested soil up to a period of five months. Sesamum plants inoculated with the fungus produced leaf spot symptoms after five days of inoculation.

4.7.2. C.gloeosporioides

The organism could be isolated from the buried leaf tissues up to a period of four months while from the infested soil it could be isolated even up to seven months. Acervuli were also observed on the leaf debris. As the duration of

burial period increased, the number of acervuli decreased. Sesamum plants sprayed with the conidial suspension of the organism produced typical leaf spot symptoms within four to six days.

4.7.3. C.lunata

The pathogen could be isolated from the leaf debris buried in the soil up to a period of four months. However, from the infested soil the pathogen could be isolated up to six months. Sesamum plants on inoculation with the conidial suspension of the pathogen produced typical symptoms of the disease within six days.

4.7.4. B.theobromae

The pathogen could be isolated from the buried leaf debris up to a period of five months, and from the infested soil up to seven months. Inoculated host plants produced symptoms within four days.

4.7.5. F.oxysporum f. sp. sesami

The pathogen could be isolated from the buried leaf pieces up to five months and from the infested soil it could be isolated up to eleven months. Both macroconidia and microconidia were produced on the medium. Inoculated plants developed leaf spot symptoms within one week. Wilting type of symptoms were also noticed when culture suspension was mixed in the soil in pots where the plants were raised, after five to six days of incorporation of the culture.

4.8. Evaluation of fungicides against leaf spot diseases

4.8.1. In vitro evaluation

The results of the effect of various fungicides on the radial growth of the five fungi causing leaf spot diseases in sesamum are presented in table 7.

4.8.1.1. A.sesami

Among the six fungicides, there was complete inhibition of growth of the fungus on Bavistin 250 ppm, 500 ppm and 1000 ppm, Bordeaux mixture 5000 and 10,000 ppm and Captafol 2000 and 3000 ppm.

Table 7. *In vitro* evaluation of fungicides against the leaf spot fungi in sesamum

Fungi	Bavistin			Bordeaux mixture			Captafol			Dithane M-45			Fytolan			Hinosan			C.D. (0.05)
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
A. sesami	250	0	100	2500	28	69	1000	25	72	1000	67	26	1000	67	26	500	51	43	
	500	0	100	5000	0	100	2000	0	100	2000	44	51	2000	52	42	1000	24	73	
	1000	0	100	10000	0	100	3000	0	100	3000	18	80	3000	44	51	2000	0	100	34.69
C.gloeosporioides	250	0	100	2500	27	70	1000	23	74	1000	14	84	1000	69	23	500	20	78	
	500	0	100	5000	12	87	2000	0	100	2000	0	100	2000	71	21	1000	0	100	
	1000	0	100	10000	0	100	3000	0	100	3000	0	100	3000	60	33	2000	0	100	4.89
C.lunata	250	25	72	2500	90	0	1000	22	76	1000	40	56	1000	90	0	500	35	61	
	500	0	100	5000	90	0	2000	19	79	2000	0	100	2000	80	11	1000	22	76	
	1000	0	100	10000	62	31	3000	0	100	3000	0	100	3000	34	62	2000	14	84	7.41
B.theobromae	250	0	100	2500	68	24	1000	0	100	1000	0	100	1000	85	6	500	23	74	
	500	0	100	5000	45	50	2000	0	100	2000	0	100	2000	72	20	1000	15	83	
	1000	0	100	10000	38	58	3000	0	100	3000	0	100	3000	62	31	2000	0	100	10.03
F.oxysporum f. sp. *sesami*	250	0	100	2500	0	100	1000	15	83	1000	64	29	1000	70	22	500	27	70	
	500	0	100	5000	0	100	2000	11	87	2000	58	36	2000	56	38	1000	21	78	
	1000	0	100	10000	0	100	3000	12	88	3000	56	38	3000	51	43	2000	0	100	6.50

A = Concentration (ppm) B = Mean colony dia (mm) C = Per cent inhibition over control

4.8.1.2. C.gloeosporioides

Bavistin at all concentrations tried (250, 500 and 1000 ppm), Bordeaux mixture at 10,000 ppm, Captafol at 2000 and 3000 ppm, Dithane M-45 at 2000 and 3000 ppm and Hinosan 1000 and 2000 ppm completely inhibited the growth of C.gloeosporioides. Fytolan failed to completely check the growth of the fungus in all the three concentrations tried. There was no significant differences between the effects of 5000 ppm Bordeaux mixture and 1000 ppm Dithane M-45.

4.8.1.3. C.lunata

There was complete inhibition of growth of the fungus with Bavistin at 500 and 1000 ppm, Captafol at 3000 ppm and Dithane M-45 at 2000 and 3000 ppm. Hinosan 2000 ppm was found superior to captafol 2000 ppm in inhibiting the growth of the fungus.

4.8.1.4. B.theobromae

Bavistin, Captafol and Dithane M-45 completely inhibited the growth of B.theobromae, at all the three concentrations tried. These three fungicides were significantly superior to Bordeaux mixture, Fytolan and Hinosan. Hinosan at 2000 ppm also completely inhibited growth of B.theobromae. Least effectives was shown by Fytolan at 2000 and 1000 ppm.

4.8.1.5. *P.oxysporum* f. sp. *sesami*

Complete inhibition of growth of the fungus was caused by Bavistin and Bordeaux mixture at all the three concentrations, and Hinosan at 2000 ppm. Dithane M-45 was found to be least effective.

4.8.2. Field evaluation of fungicides and estimation of yield loss

The efficacy of three fungicides, viz., Bavistin, Bordeaux mixture and Dithane M-45 at two concentrations each, was tested against the five leaf spot diseases in sesamum in the field. The pre and post treatment disease index values with respect to the five species of fungi are presented in table 8 and 9. Bavistin at both the concentrations (250 and 500 ppm) was found to be effective against all the five leaf spot diseases and was superior to the other fungicides. However, all the fungicides in both the concentrations tried in the present study have significantly reduced the disease index in all the leaf spot diseases.

Table 8. Pre-treatment observations on the intensity of leaf spot diseases of sesamum

Fungi	1	2	3	4	5	6	7	Marginal means of A CD=0.33 (0.05)
A_1	8.61 (3.10)	10.98 (3.46)	10.88 (3.45)	10.39 (3.37)	9.30 (3.21)	9.21 (3.20)	11.35 (3.51)	10.08 (3.33)
A_2	9.46 (3.23)	11.61 (3.55)	8.27 (3.04)	10.82 (3.44)	9.46 (3.23)	11.64 (3.56)	9.99 (3.32)	10.15 (3.34)
A_3	10.14 (3.34)	10.17 (3.34)	12.91 (3.73)	7.69 (2.95)	8.65 (3.11)	9.06 (3.17)	8.75 (3.12)	9.57 (3.25)
A_4	7.84 (2.97)	10.14 (3.34)	9.51 (3.24)	9.42 (3.23)	8.33 (3.05)	8.68 (3.11)	6.77 (2.79)	8.64 (3.10)
A_5	6.99 (2.83)	9.48 (3.24)	6.44 (2.73)	9.89 (3.30)	8.02 (3.00)	8.81 (3.13)	7.93 (2.99)	8.19 (3.03)

Figures in parentheses indicate transformed values

A_1 .. A.sesami
A_2 .. C.gloeosporioides
A_3 .. C.lunata
A_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

Table 9. Effect of fungicides on the intensity of leaf spot diseases of sesamum.

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD=0.30 (0.05)
A_1	6.86 (2.8)	7.38 (2.84)	9.11 (3.18)	8.18 (3.03)	6.54 (2.75)	7.42 (2.90)	13.34 (3.79)	8.30 (3.05)
A_2	5.78 (2.6)	9.07 (3.17)	5.96 (2.60)	7.24 (2.87)	6.91 (2.81)	9.01 (3.16)	12.96 (3.74)	8.00 (3.0)
A_3	7.53 (2.91)	7.76 (2.96)	9.46 (3.23)	4.59 (2.37)	6.49 (2.74)	8.07 (3.01)	12.34 (3.65)	7.90 (2.98)
A_4	5.23 (2.50)	7.29 (2.88)	7.06 (2.80)	7.69 (2.95)	6.91 (2.81)	7.04 (2.84)	12.33 (3.65)	7.54 (2.92)
A_5	3.81 (2.19)	4.83 (2.42)	4.62 (2.87)	7.21 (2.86)	6.41 (2.82)	5.87 (2.62)	13.67 (3.83)	6.38 (2.72)
Marginal menas of B CD=0.33 (0.05)	5.78 (2.6)	7.21 (2.86)	7.13 (2.85)	6.93 (2.82)	6.65 (2.77)	7.45 (2.91)	12.92 (3.73)	AB CD=0.74 (0.05)

Figures in parentheses indicate transformed values

A_1 .. A.sesami
A_2 .. C.gloeosporioides
A_3 .. C.lunata
A_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 ..10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

Percentages of reduction in disease index from the pre-treatment index values are presented in table 10. The maximum percentage reduction in disease index from pre-treatment values was obtained in the case of C.gloeosporioides followed by F.oxysporum f. sp. sesami, A.sesami, C.lunata and B.theobromae.

4.9. Estimation of loss due to important diseases

Loss in sesamum yield was calculated on 1000 seed weight basis as well as on per plot yield basis.

4.9.1. Seed weight basis

Infection by the various fungi, viz., A.sesami, C.gloeosporioides, C.lunata, B.theobromae and F.oxysporum f.sp.sesami were found to reduce yield of the crop on 1000 seed weight basis. Maximum reduction was caused by infection with A.sesami and least with C.lunata. Among the fungicides tested, Bavistin (250 ppm) was the best treatment in increasing the seed weight under field conditions. In general, the plots received Bavistin spray gave the maximum seed weight of 2.86 g (table 11) and this was superior to treatments with Bordeaux mixture and Dithane M-45.

Table 10. Percentage of reduction in disease index from pre-treatment values after application of fungicides

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD=0.60 (0.05)
A_1	-3.39 (13.10)	31.21 (14.36)	6.44 (13.47)	19.32 (13.94)	34.38 (14.47)	19.88 (13.96	-22.23 (12.36)	11.73 (13.66)
A_2	40.50 (14.68)	21.00 (14.00)	32.94 (14.42)	33.22 (14.43)	25.79 (14.17)	21.84 (14.03)	-35.99 (11.79)	19.12 (13.93)
A_3	24.09 (14.11)	23.81 (14.10)	27.21 (14.22)	40.21 (14.67)	24.37 (14.12)	10.50 (13.62)	-66.84 (10.40)	10.11 (13.61)
A_4	31.78 (14.38)	26.64 (14.20)	25.79 (14.17)	18.21 (13.90)	17.38 (13.57)	19.32 (13.94)	-109.05 (8.12)	-0.08 (13.23)
A_5	44.63 (14.82)	48.80 (14.96)	32.36 (14.40)	26.64 (14.20)	19.88 (13.96)	-33.80 (14.45)	-85.61 (9.56)	14.45 (13.76)
Marginal means of B CD=0.83 (0.05)	27.21 (14.22)	30.06 (14.32)	24.94 (14.14)	27.49 (14.12)	24.37 (14.12)	21.00 (14.00)	-65.8 (10.45)	AB CD=1.85 (0.05)

Figures in parentheses indicates transformed values

A_1 .. A.sesami
A_2 .. C.gloeosporoides
A_3 .. C.lunata
A_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

Table 11. Effect of application of fungicides on yield of sesamum (1000 seed weight basis)

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD=0.26 (0.05)
A_1	3.14	2.20	1.91	2.05	2.09	1.98	1.92	2.18
A_2	3.01	2.03	1.92	2.13	2.75	2.28	2.23	2.34
A_3	2.92	2.43	3.32	2.86	2.45	2.57	1.97	2.65
A_4	2.74	2.85	3.11	2.64	2.84	2.57	1.95	2.64
A_5	2.50	2.99	2.33	2.34	2.34	2.33	2.08	2.47
Marginal means of B CD=0.24 (0.05	2.86	2.50	2.52	2.40	2.49	2.38	2.03	AB CD=0.55 (0.05)

A_1 .. A.sesami
A_2 .. C.gloeosporioides
A_3 .. C.lunata
A_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10,000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

4.9.2. Per plot basis

Infection due to all the five species of fungi, viz., A.sesami, C.gloeosporioides, C.lunata, B.theobromae and F.oxysporum f. sp. sesami affected the yield of the crop assessed on per plot basis also. In this case also maximum reduction was caused by infection with A.sesami and least with C.lunata. Among the fungicides tested, Bavistin 500 ppm resulted in the effective control of the diseases which reflected on the yield. In general, the plots sprayed with Bavistin 500 ppm recorded the highest yield of 106.75 g (table 12) which was superior to the yields from plots sprayed with Bordeaux mixture and Dithane M-45. There was no significant difference between fungi with regard to yield reduction due to infection.

4.10. Stem infection

Among the five species of fungi inoculated, the maximum incidence of stem infection was caused by C.gloeosporioides followed by A.sesami. Incidence of stem infection caused by these two species of fungi were found significant when compared to the other three. Bavistin at both the concentrations (250 and 500 ppm) was found to be more effective than the other two fungicides for the control of stem infection caused by all the five species of fungi (table 13).

Table 12. Effect of application of fungicides on yield of sesamum (per plot yield basis)

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD=14.10 (0.05)
A_1	66.50	101.75	72.50	77.00	63.50	62.00	54.00	71.03
A_2	75.75	105.50	70.75	61.50	72.00	47.75	65.25	71.21
A_3	85.50	108.00	68.50	84.50	82.50	72.25	58.25	79.92
A_4	106.25	103.75	80.25	67.75	88.25	67.50	42.50	79.46
A_5	90.25	114.75	80.00	61.75	62.25	62.50	37.75	72.75
Marginal means of B CD=13.46 (0.05)	84.85	106.75	74.40	70.50	73.70	62.40	51.55	AB CD=30.09 (0.05)

A_1 .. A.sesami
A_2 .. C.gloeosporioides
A_3 .. C.lunata
A_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

Table 13. Effect of fungicides on stem infection in sesamum

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD=0.29 (0.05)
A_1	9.76 (23.69)	8.48 (23.81)	17.91 (25.24)	25.07 (24.45)	19.88 (24.30)	17.93 (24.24)	34.01 (24.67)	17.62 (24.23)
A_2	10.34 (23.92)	15.94 (24.09)	17.30 (24.22)	17.17 (24.21)	22.69 (24.39)	15.35 (24.15)	39.02 (24.78)	18.25 (24.25)
A_3	11.53 (23.98)	9.58 (23.88)	9.68 (23.88)	13.70 (24.08)	8.98 (23.84)	7.55 (23.75)	17.30 (24.22)	10.85 (23.95)
A_4	8.20 (23.79)	6.10 (23.62)	13.39 (24.07)	17.18 (24.21)	6.60 (23.68)	13.42 (24.07)	25.18 (24.46)	11.64 (23.98)
A_5	4.75 (23.50)	2.69 (23.21)	18.73 (24.27)	8.46 (23.81)	17.86 (24.24)	8.35 (23.80)	27.31 (24.51)	10.06 (23.90)
Marginal means of B CD=0.23) (0.05)	8.58 (23.82)	7.22 (23.72)	15.05 (24.13)	15.54 (24.15)	13.92 (24.09)	11.93 (24)	27.92 (25.53)	AB CD=0.52 (0.05)

Figures in parentheses indicate transformed values

A_1 .. *A.sesami*
A_2 .. *C.gloeosporioides*
A_3 .. *C.lunata*
A_4 .. *B.theobromae*
A_5 .. *F.oxysporum* f. sp. *sesami*

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

4.11. Pod infection

The effect of foliar application of different fungicides on the percentage of pod infection was also studied. F.oxysporum f. sp. sesami caused the maximum pod infection of 97.03 per cent (table 14). C.gloeosporioides caused least incidence (37.25 per cent).

In general, Bavistin (500 ppm) caused maximum reduction (24.55 per cent) of all the diseases. There was 99.27 per cent infection in control.

4.12. Percentage of healthy leaves

Among the five species of fungi, maximum reduction in the percentage of healthy leaves was caused by F.oxysporum f. sp. sesami (table 15). C.lunata caused the least reduction. Bavistin at both the concentrations has significantly increased the percentage of healthy leaves over all the other treatments.

4.13. Incidence of powdery mildew

During the experiment period, the powdery mildew incidence could be observed in most of the plots. In order

Table 14. Effect of fungicides on pod infection by various fungi in sesamum (percentage)

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD=2.06 (0.05)
A_1	38.96 (24.78)	13.43 (24.07)	77.06 (25.61)	73.31 (25.51)	67.72 (25.37)	44.96 (24.90)	62.99 (25.27)	53.49 (25.07)
A_2	19.92 (24.3)	28.02 (24.53)	49.24 (24.98)	38.20 (24.76)	46.38 (24.93)	19.79 (24.3)	67.68 (25.37)	37.25 (24.74)
A_3	21.35 (24.35)	22.82 (24.39)	65.02 (25.31)	49.69 (24.99)	20.04 (24.31)	42.23 (24.84)	65.19 (25.31)	39.50 (24.75)
A_4	32.28 (24.63)	19.00 (24.28)	61.02 (25.22)	40.70 (24.81)	44.82 (24.9)	39.79 (24.79)	43.73 (24.87)	39.47 (24.79)
A_5	51.22 (25.02)	46.55 (24.93)	82.50 (25.78)	68.91 (25.4)	49.99 (25.00)	31.57 (24.61)	100.00 (36.46)	97.03 (26.74)
Marginal Means of B CD=2.34 (0.05)	31.71 (24.62	24.55 (24.44)	68.14 (25.38)	54.67 (25.09)	45.04 (24.9)	34.97 (24.69)	99.27 (27.46)	AB CD=5.24 (0.05)

Figures in parentheses indicate transformed values

A_1 .. A.sesami
A_2 .. C.gloeosporioides
A_3 .. C.lunata
A_4 .. P.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

Table 15. Effect of fungicides on the percentage of healthy leaves in sesamum

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD=0.32 (0.05)
A_1	25.43 (3.27	37.95 (3.6)	6.29 (1.99)	6.36 (2.0)	11.29 (2.51)	13.55 (2.68)	11.16 (2.5)	13.26 (2.66)
A_2	38.60 (3.68	34.93 (3.58)	9.70 (2.37)	7.42 (2.13)	26.50 (3.32)	19.13 (3.0)	1.92 (1.07)	14.42 (2.74)
A_3	31.83 (3.49)	40.86 (3.73)	19.90 (3.04)	14.05 (2.71)	25.17 (3.26)	20.75 (3.08)	3.21 (1.44)	18.41 (2.97)
A_4	20.48 (3.07)	46.42 (3.86)	10.31 (2.43)	14.76 (2.76)	15.84 (2.82)	15.16 (2.78)	2.56 (1.88)	15.44 (2.8)
A_5	21.61 (3.12)	19.70 (3.03)	7.90 (2.19)	10.78 (2.47)	8.60 (2.36)	9.33 (2.34)	2.52 (1.26)	9.80 (2.38)
Marginal means of B CD=0.42 (0.05)	26.83 (3.33)	34.64 (3.57)	10.04 (2.40)	10.16 (2.49)	16.03 (2.89)	15.05 (2.78)	4.10 (1.63	AB CD=0.93 (0.05)

Figures in parentheses indicate transformed values

A_1 .. A.sesami
A_2 .. C.gloeosporioides
A_3 .. C.lunata
B_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Bord Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

to know the relationship between the inoculated fungi, the incidence of powdery mildew and applications of fungicides, observations on the incidence/and control of powdery mildew were also recorded. It was noticed that *E.theobromae* inoculated plants showed the maximum incidence of powdery mildew followed by plants inoculated with *F.oxysporum* f.sp.*sesami*, *C.lunata* and *C.gloeosporioides* and plants inoculated with *A.sesami* showed least incidence of powdery mildew (table 16). Bavistin at the higher level (500 ppm) and Bordeaux mixture at the lower level (5000 ppm) tested were significantly superior to Dithane M-45 in reducing the incidence of powdery mildew.

4.14. Residues of Bavistin (Carbendazim)

Residual effect of Bavistin (carbendazim) on sesamum plants was estimated. Residue of the fungicide in sesamum leaves as well as in pods were recorded thrice at an interval of one week after spraying.

The residue of Bavistin as estimated as carbendazim, in sesamum leaves was found to be 0.156 ppm after one week of spraying at 250 ppm which decreased after second and third

Table 16. Effect of fungicides on powdery mildew in sesamum

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A C.D=0.38 (0.05
A_1	0.78	0.46	0.38	0.68	0.71	0.75	1.28	0.72
A_2	0.95	0.66	0.78	1.01	1.75	1.98	1.74	1.27
A_3	2.25	1.86	2.06	1.99	2.30	2.30	2.34	2.16
A_4	2.70	2.48	2.85	2.73	3.12	2.40	1.99	2.61
A_5	2.58	2.59	2.53	2.58	2.55	2.63	1.99	2.49
Marginal means of B CD=0.27 (0.05)	1.85	1.61	1.72	1.80	2.05	2.01	1.87	AB CD=0.61 (0.05)

A_1 .. A.sesami
A_2 .. C.gloeosporioides
A_3 .. C.lunata
A_4 .. P.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

weeks to 0.076 and 0.043 ppm, respectively (table 17). At 500 ppm the residue on leaf samples were 0.216, 0.133 and 0.053 ppm after first, second and third week of spraying respectively.

In sesamum pods, with 250 ppm spray of Bavistin, the residues were 0.086, 0.046 and 0.036 ppm, respectively after first, second and third week of spraying and the values were 0.133, 0.080 and 0.043 with 500 ppm spray.

4.15. Influence of fungicides on quality and yield of oil

4.15.1. Oil quality

Influence of three fungicides, viz., Bavistin, Bordeaux mixture and Dithane M-45 on the quality of sesamum oil was studied.

4.15.1.1. Acid value

Among the three fungicides, Bavistin was found to reduce the acid value at both the concentrations tested while Bordeaux mixture and Dithane M-45 caused an increase in the acid value at both the concentrations (table 18). The acid value of the oil was higher in *B.theobromae* and *F.oxysporum* f. sp. *sesami* inoculated plants compared to other fungi and control.

Table 17. Residue of Carbendazim in sesamum plants

Concentration (ppm)	Carbendazim (ppm)					
	Weeks after spraying					
	1		2		3	
	Leaf	Pod	Leaf	Pod	Leaf	Pod
250	0.156	0.086	0.076	0.046	0.043	0.036
500	0.216	0.133	0.133	0.080	0.053	0.043

Table 18. Influence of fungicides on acid value of sesamum oil

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD = 0.99 (0.05)
A_1	4.15	3.65	4.78	5.05	6.40	5.20	5.63	4.98
A_2	3.80	3.13	5.35	4.33	5.03	4.77	4.70	4.44
A_3	4.25	5.65	5.13	5.38	4.60	3.70	4.05	4.68
A_4	3.60	4.03	7.08	7.63	6.40	7.95	5.03	5.96
A_5	4.55	6.05	6.28	5.43	5.10	5.40	5.60	5.49
Marginal means of B CD = 01.17 (0.05)	4.07	4.50	5.78	5.56	5.51	5.40	5.00	AB CD=2.61 (0.05)

A_1 .. Alternaria sesami
A_2 .. Colletotrichum gloeosporioides
A_3 .. Curvularia lunata
A_4 .. Botryodiplodia theobromae
A_5 .. Fusarium oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

4.15.1.2. Iodine value

All the fungicides were found to reduce the iodine value of sesamum oil (table 19). The iodine value was least (98.7) in the case of Bavistin at 250 ppm. Iodine value with respect to inoculation by each fungus was also determined. Oil from C.lunata inoculated plants showed maximum reduction (88.39).

4.15.1.3. Saponification value

Application of fungicides caused a general increase in the saponification value except in the case of Bavistin at 250 ppm (table 20). Saponification value determined from various treatments showed that A.sesami, C.gloeosporioides, C.lunata and B.theobromae caused an increase in the saponification value, while F.oxysporum f. sp. sesami showed a decrease.

4.15.2. Oil yield

Application of all the three fungicides at both the levels tested significantly increased the oil content compared to untreated control. Among the three fungicides, Bavistin treated plants yielded maximum percentage of oil (55.81 and 55.46) followed by Bordeaux mixture and Dithane M-45 (table 21).

Table 19. Influence of fungicides on iodine value of sesamum oil

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD = 14.35 (0.05)
A_1	113.25	109.00	109.25	112.25	106.50	105.25	108.75	109.18
A_2	100.50	97.25	114.25	114.00	105.00	103.75	109.00	106.25
A_3	90.50	97.00	88.75	77.50	82.25	74.25	108.50	88.39
A_4	77.50	111.75	106.50	83.50	119.75	126.25	103.25	104.07
A_5	111.75	100.25	105.75	110.50	106.25	103.75	124.50	108.96
Marginal means of B CD = 14.35 (0.05)	98.7	103.05	104.90	99.55	103.95	102.65	110.80	AB CD = 33.65 (0.05)

A_1 .. Alternaria sesami
A_2 .. Colletotrichum gloeosporioides
A_3 .. Curvularia lunata
A_4 .. Botryodiplodia theobromae
A_5 .. Fusarium oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

Table 20. Influence of fungicides on saponification value of sesamum oil

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD = 12.80 (0.05)
A_1	191.25	196.10	196.25	201.50	198.50	205.75	199.75	198.43
A_2	194.00	200.25	200.25	193.25	189.25	195.50	186.00	194.07
A_3	197.50	197.50	201.75	204.00	214.50	197.00	188.50	200.11
A_4	197.25	196.75	195.50	199.00	201.25	199.50	198.75	198.29
A_5	162.50	175.25	189.25	173.00	164.50	184.75	189.75	177.00
Marginal means of B CD = 12.67 (0.05)	188.50	193.15	196.60	194.15	193.60	196.50	192.55	AB CD=28.32 (0.05)

A_1 .. Alternaria sesami
A_2 .. Colletotrichum gloeosporioides
A_3 .. Curvularia lunata
A_4 .. Botryodiplodia theobromae
A_5 .. Fusarium oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

Table 21. Influence of fungicides on oil yield of sesamum (Percentage)

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	Marginal means of A CD=6.00 (0.05)
A_1	42.50	40.25	33.44	34.18	44.26	34.80	26.63	36.58
A_2	72.39	58.32	49.35	46.25	50.15	66.00	42.38	55.26
A_3	47.67	51.28	51.75	50.67	41.90	32.55	32.36	44.03
A_4	50.47	46.75	41.00	55.63	41.05	58.00	36.13	47.00
A_5	66.05	80.68	46.13	46.55	33.18	32.47	31.85	48.12
Marginal means of B CD=5.26 (0.05)	55.81	55.46	47.35	47.05	42.11	44.77	33.87	AB CD=11.77 (0.05)

A_1 .. A.sesami
A_2 .. C.gloeosporioides
A_3 .. C.lunata
A_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. 250 ppm Bavistin
B_2 .. 500 ppm Bavistin
B_3 .. 5000 ppm Bordeaux mixture
B_4 .. 10000 ppm Bordeaux mixture
B_5 .. 1000 ppm Dithane M-45
B_6 .. 2000 ppm Dithane M-45
B_7 .. Control

Among the fungi inoculated, maximum reduction in oil content was observed in *A.sesami* (36.58) followed by *C.lunata* and *B.theobromae*.

4.16. Varietal screening for resistance against leaf spot diseases

Screening of ten varieties of sesamum against five leaf spot diseases caused by *A.sesami*, *C.gloeosporioides*, *C.lunata*, *B.theobromae* and *F.oxysporum* f. sp. *sesami* was carried out. Observations on the disease index of all the ten varieties of sesamum against the five species of fungi are presented in table 22.

4.16.1. Disease index

The lowest disease index with respect to leaf spot caused by *A.sesami* was in Si.44 (table 22). The varieties Kayamkulam-2, Si.866 and Trivandrum local were on par with Si.44.

In the case of *C.gloeosporioides* the variety North Kerala local No.24 which had the lowest disease index was on par with IC.284 and Timbi-9. With respect to leaf spot

Table 22. Disease index values of different varieties of sesamum in response to infection by the five leaf spot fungi

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	Marginal means of A CD=0.34 (0.05
A_1	4.70	4.38	3.19	3.97	3.17	4.36	4.38	2.85	3.67	3.97	3.86
A_2	6.47	3.73	3.98	3.77	4.26	3.17	3.28	3.63	4.05	2.54	3.88
A_3	3.01	3.00	4.28	4.34	2.52	3.77	4.09	3.60	3.39	3.56	3.56
A_4	3.40	3.09	3.56	4.29	3.04	4.31	4.59	3.76	3.94	3.56	3.75
A_5	3.57	4.34	3.57	4.08	2.76	4.20	3.52	3.24	3.43	3.37	3.61
Marginal means of B CD=0.48 (0.05)	4.23	3.71	3.71	4.09	3.15	3.96	3.97	3.42	3.70	3.40	AB CD=1.07 (0.05)

A_1 .. *Alternaria sesami*
A_2 .. *Colletotrichum gloeosporioides*
A_3 .. *Curvularia lunata*
A_4 .. *Botryodiplodia theobromae*
A_5 .. *Fusarium oxysporum* f.sp.*sesami*

B_1.. Kayamkulam-1
B_2.. B.64
B_3.. Si.866
B_4.. T.13
B_5.. Kayamkulam-2

B_6.. IC.284
B_7.. Timbi.9
B_8.. Si.44
B_9.. Trivandrum local
B_{10}. North Kerala local No.24

caused by C.lunata the lowest disease index was in Kayamkulam-2, which was on par with B.64, Kayamkulam-1, Trivandrum local and North Kerala local No.24.

Lowest disease index value in response to B.theobromae infection was also in Kayamkulam-2. This was on par with B.64, Kayamkulam-1, Si.866, North Kerala local No.24, Si.44 and Trivandrum local.

Kayamkulam-2 showed the least disease index against F.oxysporum f. sp. sesami. Except B.64, T.13 and IC.284 all other varieties were on par with Kayamkulam-2.

4.16.2. Stem infection by the leaf spot fungi

Among the ten varieties lowest percentage of stem infection caused by A.sesami was observed in B.64 (table 23). But all the other varieties were on par with this. Stem infection caused by C.gloeosporioides was lowest in T.13 and Trivandrum local and except Timbi-9 all the other varieties were on par with these two.

Table 23. Percentage of stem infection caused by the five leaf spot fungi in different varieties of sesamum

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	Marginal means of A CD=0.41 (0.05)
A_1	2.87	1.79	2.57	2.46	2.58	2.15	2.90	3.09	2.95	1.91	2.53
A_2	3.40	2.83	3.41	2.33	2.68	3.40	3.69	3.35	2.33	2.71	3.02
A_3	2.32	4.54	3.18	2.96	4.58	5.54	2.39	4.13	5.47	5.09	4.02
A_4	2.67	3.58	2.91	2.75	4.49	3.41	2.58	3.22	2.97	2.22	3.09
A_5	3.58	3.06	3.23	2.67	2.69	2.74	5.09	3.65	4.20	3.79	8.47
Marginal means of B CD=0.59 (0.05)	2.97	3.16	3.10	2.64	3.40	3.45	3.32	3.49	3.58	3.15	AB CD=1.31 (0.05)

A_1 .. A.sesami
A_2 .. C.gloeosporioides
A_3 .. C.lunata
A_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. Kayamkulam-1
B_2 .. B.64
B_3 .. Si.866
B_4 .. T.13
B_5 .. Kayamkulam-2
B_6 .. IC.284
B_7 .. Timbi.9
B_8 .. Si.44
B_9 .. Trivandrum local
B_{10} .. North Kerala local No.24

Stem infection caused by C.lunata was the lowest in Kayamkulam-1 and it was on par with Timbi-9, T.13 and Si.866. Highest infection was in IC.284. Lowest percentage of stem infection caused by B.theobromae was in North Kerala local No.24. The varieties Timbi-9, Kayamkulam-1, T.13 and Si.866 were on par with this.

Variety T.13 showed the lowest percentage of stem infection with respect to F.oxysporum f. sp. sesami. This was on par with all the other varieties except Timbi-9 and Trivandrum local.

4.16.3. Pod infection by the leaf spot fungi

Pod infection caused by A.sesami was least in Kayamkulam-2 which was on par with Trivandrum local and Si.44 (table 24). C.gloeosporioides also caused least incidence of pod infection in Kayamkulam-2 and it was on par with Trivandrum local and North Kerala local No.24. C.lunata infection on sesamum pods was also lowest in Kayamkulam-2 which was on par with Si.866.

Table 24. Percentage of pod infection caused by the five leaf spot fungi in different varieties of sesamum

Fungi	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	Marginal means of A CD=0.32 (0.05)
A_1	4.79	4.43	4.03	4.08	2.91	4.45	4.51	3.70	3.64	4.22	4.08
A_2	4.61	4.19	4.48	4.38	2.54	4.20	4.18	3.99	3.16	3.26	3.90
A_3	4.82	3.97	3.70	5.08	2.73	5.30	4.64	5.12	4.20	4.21	4.34
A_4	5.41	4.81	4.29	4.17	3.49	4.95	3.74	4.34	3.68	3.29	4.21
A_5	4.58	4.92	4.07	3.83	3.36	3.38	4.57	4.22	3.49	2.70	4.01
Marginal means of B CD=0.46 (0.05)	4.78	4.47	4.32	4.31	3.00	4.45	4.33	4.27	3.64	3.54	AB CD=1.02 (0.05)

A_1 .. A.sesami
A_2 .. C.gloeosporides
A_3 .. C.lunata
A_4 .. B.theobromae
A_5 .. F.oxysporum f. sp. sesami

B_1 .. Kayamkulam-1
B_2 .. B.64
B_3 .. Si.866
B_4 .. T.13
B_5 .. Kayamkulam-2
B_6 .. IC.284
B_7 .. Timbi.9
B_8 .. Si.44
B_9 .. Trivandrum local
B_{10} .. North Kerala local No.24

B.theobromae infection on pods was lowest in North Kerala local No.24. Kayamkulam-2, Trivandrum local and Timbi-9 were on par with North Kerala local No.24. Pod infection by F.oxysporum f. sp. sesami was also lowest in North Kerala local No.24 which was on par with Kayamkulam-2, IC.284 and Trivandrum local. With respect to pod infection caused by the five species of leaf spot fungi Kayamkulam-2 with 3.00 per cent infection was superior to all the other varieties tested.

Among the ten varieties screened against the five leaf spot fungi, the varieties Si.866, Kayamkulam-2, Si.44, Trivandrum local and North Kerala local No.24 were found more resistant/tolerant than the other varieties, as they showed resistance as assessed by considering the lowest value and C.D. of the three characters studied, viz., disease index, percentage of stem infection and percentage of pod infection (table 25).

Table 25. Varieties of sesamum with low disease index, stem infection and pod infection

Fungi	Disease index	Stem infection	Pod infection
1. *A.sesami*	B_3, B_5, B_8, B_9	B_1, B_2, B_3, B_4, B_5, B_6 B_7, B_8, B_9, B_{10}	B_5, B_8, B_9
2. *C.gloeosporioides*	B_6, B_7, B_{10}	B_1, B_2, B_3, B_4, B_5, B_6 B_7, B_8, B_9, B_{10}	B_5, B_9, B_{10}
3. *C.lunata*	B_1, B_2, B_3, B_5, B_8, B_9, B_{10}	B_1, B_3, B_4, B_7	B_3, B_5
4. *B.theobromae*	B_1, B_2, B_3, B_5, B_8, B_9, B_{10}	B_1, B_3, B_4, B_6, B_7, B_8, B_9, B_{10}	B_3, B_4, B_5, B_7, B_9, B_{10}
5. *F.oxysporum* f. sp. *sesami*	B_1, B_3, B_5, B_7, B_8, B_9, B_{10}	B_1, B_2, B_3, B_4, B_5, B_6, B_8, B_{10}	B_5, B_6, B_9, B_{10}

B_1 .. Kayamkulam-1
B_2 .. B.64
B_3 .. Si.866
B_4 .. T.13
B_5 .. Kayamkulam-2
B_6 .. IC.284
B_7 .. Timbi-9
B_8 .. Si.44
B_9 .. Trivandrum local
B_{10} .. North Kerala local No.24

DISCUSSION

5. DISCUSSION

Sesamum plants are affected by a number of diseases including those caused by fungi. During the survey conducted in the present study, twelve fungal diseases affecting the crop have been observed from different sesamum growing areas of Kerala and the causal fungi were isolated, described and identified. They were mildew/leaf spots/blights caused by Acrosporium acanthospermi (Chidd.) Subram., Alternaria sesami (Kaw.) Mohanty and Behera, Botryodiplodia theobromae Pat., Cercospora apii Fres., Colletotrichum gloeosporioides (Penz) Penz.& Sacc., Corynespora cassiicola (Berk & Curti) Wei., Curvularia lunata (Wakker) Boedijn, Helminthosporium sesami Miyake and Pestalotia sp. and leaf spot and wilting caused by Fusarium oxysporum f. sp. sesami. Schl., brown leaf spot/stem rot by Phytophthora parasitica Dastur and root/stem/collar rot by Rhizoctonia bataticola (Taub.) Butl.

Among these 12 diseases, those caused by A.sesami, C.gloeosporioides, B.theobromae, C.lunata and F.oxysporum f.sp.sesami were found to inflict considerable damage to the crop.

It was found that among the fungal disease, the incidence of leaf spots caused by Cercospora apii and Corynespora cassiicola occurred in all sesamum growing areas of Kerala during both the seasons of the year. The leaf spots caused by A.sesami and B.theobromae occurred in different localities of Trivandrum, Quilon and Alleppey Districts, but A.sesami caused infection during August-December season while B.theobromae caused infection during December-April. By and large, all the 12 diseases were prevalent in sesamum growing areas of Trivandrum and Alleppey Districts and many of them occurred during both the seasons of the year. All the fungal pathogens caused leaf spot/blight except F.oxysporum f.sp. sesami which caused also yellowing and wilting and R.batatiocola which caused collar rot.

The 12 pathogens can be grouped into four categories based on the stage of the crop at which maximum infection occurs. Diseases caused by F.oxysporum f. sp. sesami, P.parasitica and R.batatiocola are more prevalent at seedling stage while B.theobromae and Pestalotia sp. are more severe at branching stage. Infection by A.sesami is usually seen at the flowering stage. The remaining six species of fungi caused infection generally at the pod formation/maturity stage of the crop.

Studies on the effect of the five important diseases on germination percentage of seeds of sesamum from infected pods showed that the lowest germination percentage was in seeds from pods infected with A.sesami. The seed-borne nature of A.sesami was reported by Gobelez (1960) and Leppik and Sowell (1964). Singh et al. (1980) recorded the seed-borne nature of A.sesami in sesamum from India also and found that in severely infected seeds the fungus invades all the tissues including the embryo.

The seed-borne fungi were studied using blotter method and agar plate method and it was found that the latter was better. Rhizopus nigricans, Mucor haemalis, Aspergillus niger, A.flavus, Penicillium chrysogenum and Alternaria sesami were the predominant seed-borne fungi. Many of the fungi obtained from the seeds of sesamum during the present study were also reported by Mathur and Kabeere (1975) and Kumar et al. (1984) as seed-borne fungi of sesamum. In the present study, the presence of fungal flora in different varieties of sesamum has also been investigated and it was found that Kayamkulam-1, T.C.30, No.42 and Assam local were, in general, harboured more number of fungal propagules.

Studies conducted on mode of entry of the five important fungi revealed that the time taken for entry of the fungi differed considerably. Spores of all the fungal pathogens were found to germinate within 6-24 h. All of them, except F.oxysporum f. sp. sesami formed appressoria. Direct penetration through the cuticle occurred in A.sesami and C.gloeosporioides and in B.theobromae direct penetration as well as stomatal entry could be observed. C.lunata and F.oxysporum f. sp. sesami entered the leaf tissue through the stomata. Direct cuticular penetration of leaves of Populus tremuloides (Marks et al.,1975) and clove, nutmeg and cinnamon (Karunakaran, 1981) by C.gloeosporioides has already been reported. Direct entry of fungal pathogens through the cuticle is usually found by forming appressoria. Eventhough the entry of both C.lunata and F.oxysporum f. sp. sesami was found to be through stomata, appressorium formation is also seen in C.lunata. This indicates that some mechanical force also may be involved in the process of penetration by C.lunata. The formation of appressoria in C.lunata may also indicate the ability of the pathogen for direct penetration through the cuticle which occurred at least in few instances.

Histopathological studies showed that, eventhough all these diseases resulted in leaf spot symptoms, there are differences in the type of tissues which suffered serious damage by these infections. Even in the case of infections by A.sesami and C.lunata which invaded mainly the epidermal cells, the infected cells became enlarged only in the case of infection by C.lunata. C.gloeosporioides and B.theobromae attacked sub epidermal layers of cells, but infection by B.theobromae caused the disintegration of the epidermal cells also near the cork layers. Vascular discoloration was found only in the case of infection by F.oxysporum f. sp. sesami. Infection by this fungus caused wilting symptoms also which probably is a consequence of the damage caused to the vascular tissues. Watanabe (1939) while studying the histological changes in sweet potatoes as a result of invasion by F.oxysporum observed tylosis and vascular discoloration in in advance of the invading mycelium of the fungus. In the present study the changes caused by the infection at different intervals of time have not been investigated and hence it is not possible to arrive at a conclusion as to whether the vascular discoloration appeared in advance or after the hyphae have reached the tissues.

Toxin production capacity of the five common fungal pathogens of sesamum was tested on different media and found that media have considerable influence on the production of toxins. Richards' medium was the best for maximum toxin production by A.sesami and C.gloeosporioides. Czapek (Dox), potato dextrose and host extract dextrose media were found to be the best for toxin production by C.lunata, B.theobromae and F.oxysporum f. sp. sesami, respectively. The production of toxin by C.gloeosporioides in Richards' medium has been reported by Sharma and Sharma (1969) and Karunakaran (1981).

The process of toxin production may naturally be influenced by the nutrients uhilized by the fungus during its growth and so the different types of media may cause changes in the amount/nature of the toxins. But more detailed study on the effect of different nutrients has to be conducted to identify the effects of individual nutrient elements on toxin production by different fungal pathogens. Such detailed investigations may throw light on the mechanisms involved in the differential susceptibility/resistance of different varieties/crops to the same species of pathogen. The information emanating out of these studies may help in the resistance breeding programmes also.

Both exo toxins as well as endo toxins were produced by all the five important fungal pathogens tested in the present study. Increased production of endo toxin in C.capsici was reported by Nair and Ramakrishnan (1973). A similar trend was seen in the present study also with respect to C.gloeosporioides and A.sesami. But in the case of B.theobromae, C.lunata and F.oxysporum f. sp. sesami, it was found that more of exo toxin was produced than endo toxin. The reaction of different varieties of sesamum in response to the application of fungal toxins is an indication of their resistance/susceptibility which could be successfully utilized in the large scale screening programmes as is being done in the case of many other crop plants. While conducting studies on the effect of toxins produced by Cylindorcladium quinqueseptatum on clove plants Sulochana (1980) observed that as the incubation period of toxin on the plant increases, there was a proportionate increase in length of lesion. Similar were the observations recorded in the present study also with all the five fungi tested. The culture filtrates of the five important fungal pathogens of sesamum were found to inhibit the germination of the spores of fungi. Culture filtrates of A.sesami and C.gloeosporioides were found to cause maximum inhibition of germination of spores of C.gloeosporioides. The inhibition of

germination of spores of C.gloeosporioides by the culture filtrate of C.gloeosporioides itself has been reported by Sharma and Sharma (1969). Maximum inhibition of spore germination of C.lunata was observed in the culture filtrates of B.theobromae and F.oxysporum f. sp. sesami. Culture filtrates of B.theobromae and C.lunata were naturally found to cause maximum inhibition of germination of the spores of each other. The inhibitory action of the toxins produced by fungal pathogens on the germination of spores of fungi vis a vis the incidence of fungal diseases in sesamum needs detailed investigation.

Survival of the five leaf spot fungi varied from 3 to 11 months. The shortest period of survival was observed for A.sesami and longest for F.oxysporum f. sp. sesami, both in plant debris as well as in infested soil. Duration of survival of the other three fungal pathogens was in between these. Results of the investigations carried out with C.falcatum by Chona and Nariani (1952) were more or less similar to those of the present study with C.gloeosporioides.
F.oxysporum f. sp. sesami is a predominantly soil-borne plant pathogen whose survival in soil is known to extend for several months even under very much unfavourable environmental conditions.

In the present study F.oxysporum f. sp. sesami was found to survive in the soil up to 11 months. The comparatively long duration of survival of F.oxysporum f. sp. sesami can be explained as due to its very high competitive saprophytic ability. Survival period of all the fungal pathogens, except F.oxysporum f. sp. sesami, is at the maximum for a period of seven months only, which means that there exists a gap of two to three months time before the next crop. But the diseases caused by these pathogens occur during every year. This indicates the importance of collateral hosts in the perennation of the pathogens. Information on this aspect is lacking at present. Detailed investigations on these lines may help to evolve satisfactory control measures to these diseases.

Among the six fungicides tested in vitro against the five fungal pathogens, Bavistin was found to be the most effective fungicide. Bordeaux mixture at 10,000 ppm also caused complete inhibition of A.sesami, C.gloeosporioides and and F.oxysporum f. sp. sesami. Dithane M-45 also at higher concentrations was very effective in completely inhibiting the growth of all the fungi except F.oxysporum f. sp. sesami. Captafol, Fytolan and Hinosan showed varying effects against the test fungi. Eventhough there are reports stating that

Bavistin is not effective against A.sesami and C.lunata (Kumar and Singh, 1984) in the present study it was found very effective against these fungi also. Patil (1980) reported control of Alternaria alternata by seed treatment with Bavistin. Similarly, Kolobkov and Sidorov (1976) got good control of Alternaria sp. on barley by seed treatment.

Three fungicides, viz., Bavistin, Bordeaux mixture and Dithane M-45 at two concentrations each were tested against the five leaf spot diseases in a field experiment and it was found that Bavistin at 250 and 500 ppm was every effective against all the five leaf spot diseases in the field also and this fungicide was better than the other two which were also effective. The effectiveness of Bordeaux mixture and Dithane Z-78 in controlling Alternaria blight of sesamum is well documented (Samuel et al., 1971). Mathur and Jhamaria (1975) reported that Bavistin was effective in protecting safflower seedlings from foliar diseases caused by Fusarium pisi and Alternaria carthami. In the present study Bavistin was found to be very effective against all the five leaf spot diseases including those caused by A.sesami and C.lunata. This may probably due to the fact that apart from fungicidal properties benzimidazoles have cytokinin like and phytoalexin inducing properties on plants (Skene, 1972; Thomas, 1974). This might have improved general vigour and resistance of the plants

thereby indirectly contributing to the better yield and reduced incidence of the diseases.

Eventhough sesamum crop is affected by a number of diseases, precise assessments have not yet been made on the losses caused by most of the diseases. In the present study yield loss was also estimated from the field experiment on the fungicidal control of the five leaf spot diseases of sesamum. The trend in the yield loss estimated on 1000 seed weight basis as well as on par plot yield basis was the same, i.e., maximum reduction was caused by A.sesami and least reduction by C.lunata and C.gloeosporioides was also found to be as destructive as A.sesami. Bavistin spray was found to give high yield when compared with Bordeaux mixture and Dithane M-45. Siddaramaiah et al. (1981) reported that A.sesami caused significant reduction in the weight of sesamum seeds. The difference in the yield from Bavistin sprayed and unsprayed plots inoculated with A.sesami was about 30 per cent. The additional expenditure increased in this plant protection operation will be far less than the economic gain achieved by the increased yield.

The maximum stem infection of sesamum plants was caused by C.gloeosporioides followed by A.sesami.

F.oxysporum f. sp. sesami caused the least percentage of stem infection while it was responsible for maximum pod infection. A.sesami was next to F.oxysporum f. sp. sesami in causing pod infection. Maximum reduction in the percentage of healthy leaves was caused by F.oxysporum f. sp. sesami and the least reduction in this case also was by C.lunata. The incidence of powdery mildew was maximum in plants inoculated with B.theobromae and it was least in plants inoculated with A.sesami. This indicates that eventhough the yield reduction caused by B.theobromae was comparatively not very serious, infection by this fungus may cause more incidence of powdery mildew which will in turn cause serious damage to the crop. In general, Bavistin at 250 ppm as well as 500 ppm was very effective in controlling all these fungal diseases, except powdery mildew. In the case of powdery mildew none of the fungicides tested could control the disease in an effective manner.

Since Bavistin was found to be the most effective fungicide for the control of all the fungal diseases investigated in the present study, its residues were also estimated. The residues of Bavistin as estimated as carbendazim, after spraying Bavistin even at the higher dose of 500 ppm were below the maximum residue limit for oil seeds (Parmer, et al., 1988) in pods after second week of spraying

The influence of fungicidal sprays on the quality of sesamum oil as indicated by the changes in the acid value, iodine value and saponification value was also assessed. Acid value of an oil is a measure of the free fatty acid content in the oil and so a reduced acid value indicates an improvement in the quality of oil. Bavistin was found to reduce the acid value, while Bordeaux mixture and Dithane M-45 caused an increase. Iodine value is a measure of the amount of unsaturated fatty acids and therefore an increase in this value is a desirable quality of an oil. The iodine values of oil from the sesamum plants sprayed with all the three fungicides in the present study were less than that of the control, but the reduction was not significant in the case of any treatment. Saponification value is an indication of low molecular weight fatty acids and hence a reduced saponification value is a measure of better quality of oil. In the present study the saponification value was the least in the case of Bavistin 250 ppm, while all the other treatments caused an increase in this value eventhough these changes were not statistically significant.

Oil yield of sesamum was also found to be influenced by application of the fungicides. Bavistin at 250 and 500 ppm caused significant increase in the yield of oil. Therefore, considering the aspects of disease control, fungicide residues, oil quality, yield, etc., Bavistin at 250 ppm can be regarded, in general, as a very effective fungicide for the control of the five important leaf spot diseases subjected to investigations in the present study.

Among the ten sesamum varieties screened for resistance against the five leaf spot fungi, five varieties were found to be resistant/tolerant to different fungi. These were Si-44, Si-866, Kayamkulam-2, Trivandrum local and North Kerala local No.24.

SUMMARY

6. SUMMARY

A survey was conducted to study the occurrence of various fungal diseases affecting sesamum crop in Kerala. Twelve fungal diseases affecting the crop in Kerala were described.

1. Powdery mildew caused by *Acrosporium acanthospermi* (Chidd.) Subram.
2. Leaf spot/leaf blight caused by *Alternaria sesami* (Kaw.)Mohanty and Behera
3. Leaf spot caused by *Botryodiplodia theobromae* Pat.
4. Leaf spot caused by *Cercospora apii* Fres.
5. Leaf spot caused by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.
6. Leaf spot caused by *Corynespora cassiicola* (Berk and Curti.)Wei.
7. Leaf spot caused by *Curvularia lunata* (Wakker) Boedijn
8. Leaf spot/wilt caused by *Fusarium oxysporum* f. sp. *sesami* Schl.
9. Leaf spot/blight caused by *Helminthosporium sesami* Miyake
10. Leaf spot caused by *Pestalotia* sp.
11. Stem rot/root rot/leaf blight caused by *Phytophthora parasitica* var. *sesami* Dastur.
12. Collar rot/stem rot caused by *Rhizoctonia bataticola* (Taub.) Butl.

The leaf spot diseases caused by *B.theobromae* and *Pestalotia* sp. are first records.

Detailed studies on five important diseases caused by A.sesami, C.gloeosporioides, C.lunata, B.theobromae and F.oxysporum f. sp. sesami were carried out since they are found serious in all the sesamum growing areas in Kerala.

Germination of sesamum seeds from diseased plants was found to be reduced considerably and maximum inhibition (57.76 per cent) was observed in seeds from pods infected with A.sesami. The common seed-borne fungi from sesamum seeds were Rhizopus nigricans, Aspergillus flavus, A.niger and Mucor haemalis.

Entry of Alternaria sesami, C.gloeosporioides and B.theobromae was observed to be by direct penetration while stomatal entry was noticed in C.lunata and F.oxysporum f.sp.sesami.

Histopathological studies of sesamum leaves infected by the five species of fungi showed that invasion of the fungi caused various types of alterations of the host tissues depending upon the organisms.

Rechards' medium was the best for toxin production by A.sesami and C.gloeosporioides. Czapek (Dox) and potato dextrose media were found equally suitable for the toxin

production by C.lunata. Potato dextrose and host leaf extract dextrose media were most suitable for the production of toxic metabolites by B.theobromae and F.oxysporum f. sp. sesami respectively.

The exo and endo toxin production capacity varied with different species of the organisms. In A.sesami, C.gloeosporioides and B.theobromae endo toxin production was more than that of exo toxin whereas, in C.lunata and F.oxysporum f. sp. sesami the exo toxin production was higher.

The culture filtrates of A.sesami and C.gloeosporioides caused maximum inhibition of spore germination of C.gloeosporioides while in C.lunata culture filtrates of B.theobromae and F.oxysporum f. sp. sesami caused maximum inhibition of spore germination.

A.sesami could survive up to three months and C.gloeosporioides and C.lunata for four months and B.theobromae and F.oxysporum f. sp. sesami up to eleven months.

In vitro evaluation of fungicides revealed that, in general, Bavistin, Bordeaux mixture and Dithane M-45 were superior to all the other fungicides tested in inhibiting the growth of the five species of leaf spot fungi.

Field evaluation of the above three fungicides showed that Bavistin was the best and could give satisfactory control of all the five fungal diseases.

Maximum percentage of stem infection was caused by C.gloeosporioides while F.oxysporum f. sp. sesami caused maximum pod infection. The incidence of powdery mildew was found maximum in plants infected with B.theobromae.

Residue analysis of sesamum leaves and pods sprayed with Bavistin was carried out and it was found that the residue levels of carbendazim were well below the maximum residue level fixed.

Acid value, iodine value and saponification value of sesamum oil from fungicide treated plants were estimated. Bavistin alone caused a reduction in the acid value while iodine value was reduced by all the fungicides. Application of fungicides resulted in a general increase in saponification value.

Application of fungicides significantly influenced the oil yield of sesamum. Bavistin at both the concentrations tested (250 and 500 ppm) increased the yield considerably.

Hence, Bavistin can be considered as an effective fungicide in checking the important leaf spot diseases of sesamum.

Among the ten varieties screened against the five leaf spot fungi, Si.866, Kayamkulam-2, Si.44, Trivandrum local and North Kerala local No.24 were found resistant/ tolerant than the other varieties as they showed positive responses of disease resistance to the three characters studied, viz., disease index, percentage of stem infection and pod infection.

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* - Originals not seen

APPENDIX

APPENDIX I

I. Solid medium

Czapek (Dox) agar

$Mg\ SO_4\ 7\ H_2O$	.. 0.50 g
$K\ H_2\ PO_4$	.. 1.00 g
Kcl	.. 0.50 g
$Fe\ SO_4$	.. 0.01 g
$Na\ NO_3$	.. 2.00 g
Sucrose	.. 30.00 g
Agar agar	.. 20.00 g
Distilled water	.. 1000.00 ml
pH	.. 6.5

II. Liquid media

Host leaf extract medium

Sesamum leaves	.. 200.00 g
Distilled water	.. 1000.00 ml

Host leaf extract dextrose medium

Sesamum leaves	.. 200.00 g
Dextrose	.. 20.00 g
Distilled water	.. 1000.00 ml
pH	

Richards' medium

$K\ NO_3$	.. 10.00 g
KH_2PO_4	.. 5.00 g
$MgSO_4 \cdot 7H_2O$	.. 2.50 g
$FeCl_2$	.. 0.02 g
Sucrose	.. 50.00 g
Distilled water	.. 1000.00 ml
pH	.. 6.6 - 7.2

Czapek (Dox)medium

$Mg\ SO_4 \cdot 7H_2O$	..	0.50 g
$KH_2\ PO_4$	..	1.00 g
KCl	..	0.50 g
$Fe\ SO_4$	..	0.01 g
$Na\ NO_3$	..	2.00 g
Sucrose	..	30.00 g
Distilled water	..	1000.00 ml
pH	..	6.5

Potato dextrose medium

Pealed and sliced potato	..	200.00 g
Dextrose	..	20.00 g
Distilled water	..	1000.00 ml
pH	..	6.0 - 6.5

FUNGAL DISEASES OF SESAMUM IN KERALA

By
K. K. SULOCHANA M.Sc. (Ag.)

ABSTRACT OF THE THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE
DOCTOR OF PHILOSOPHY
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT PATHOLOGY
COLLEGE OF AGRICULTURE
VELLAYANI - TRIVANDRUM

1989

ABSTRACT

Only limited information is currently available on the fungal diseases of sesamum in Kerala. During the course of the present study 12 fungal diseases could be identified and among these, leaf spots caused by Botryodiplodia theobromae and Pestalotia sp. are new records.

Investigations were carried out to find out the losses caused by the major fungal pathogens, viz., Alternaria sesami, Colletotrichum gloeosporioides, Curvularia lunata, Botryodiploida theobromae and Fusarium oxysporum f. sp. sesami. Loss estimation studies conducted revealed that all the above fungi reduced the yield considerably.

Rhizopus nigricans, Aspergillus flavus, A.niger and Mucor haemalis were the common fungi found associated with sesamum seeds.

Mode of entry, histopathology and toxin studies were conducted with the five major fungal pathogens. These varied with different organisms.

Survival ability of the five species of fungi ranged from three months in A.sesami to eleven months in B.theobromae and F.oxysporum f. sp. sesami.

In vitro evaluation of fungicides, in general, revealed that, Bavistin, Bordeaux mixture and Dithane M-45 were superior to the other fungicides tested, and in the field experiment Bavistin was found to be the best.

The residue levels of carbendazim on Bavistin sprayed sesamum leaves and pods were below the maximum residue level fixed.

Application of fungicides caused alterations in the acid value, iodine value and saponification value of sesamum oil.

Bavistin was found to be the most efficient as well as economical fungicide in controlling the leaf spot diseases of sesamum.

Varietal screening trials showed Si.866, Kayamkulam-2, Si.44, Trivandrum local and North Kerala local No.24 as resistant/tolerant varieties against the five species of fungi.