ETIOLOGY AND MANAGEMENT OF POWDERY MILDEW DISEASE OF PUMPKIN (*Cucurbita moschata* Poir)

By

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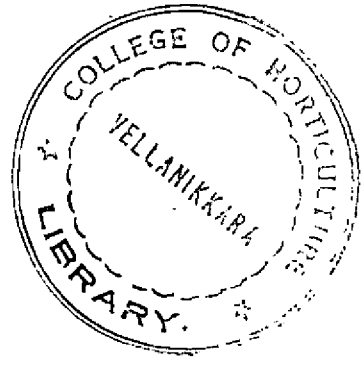

THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Pathology
COLLEGE OF HORTICULTURE
Vellanikkara, Thrissur

1992

DECLARATION

I hereby declare that this thesis entitled "Etiology and Management of Powdery Mildew disease of Pumpkin (Cucurbita moschata Poir)." 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.

Vellanikkara
27-8-1992.

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CERTIFICATE

Certified that this thesis entitled "Etiology and Management of Powdery Mildew disease of Pumpkin (Cucurbita moschata Poir)." is a record of research work done independently by **Kum. VEENA.S.S.** *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

I consider it a previlege to express my heartfelt thanks and indebtedness to Dr. L. Rema Devi, Professor, Department of Plant Pathology and Chairman of my advisory committee.

Let me place on record my thanks for the help I received from Prof. C.K. Ramakrishnan, Professor and Head, Department of Plant Pathology.

I thankfully acknowledge the help I received from Dr. Sally .K. Mathew, Associate Professor, Department of Plant Pathology.

I have deep appreciation for the sincere guidance and critical comments of Dr. T.R. Gopalakrishnan, Associate Professor, Department of Olericulture.

I remember the candid suggestions and constructive criticisms of Prof. P.C. Jose, Professor, Department of Plant Pathology.

My deep sense of gratitude goes to Dr. A.V.R. Kesava Rao, Associate Professor of Agrl.

Meteorology for the keen interest and whole hearted co-operation extended to me throughout the period of this investigation.

I express my sincere gratitude to Dr. M. C. Nair, Professor and Head, Department of Plant Pathology and Dr. C. Gokulapalan, Associate Professor, Department of Plant Pathology, College of Agriculture for their valuable help in the preperation and presentation of this thesis.

I thankfully acknowledge the help I received from Dr. S. Rajan, Professor, Department of Olericulture, Dr. Luckins .C. Babu, Professor, College of Forestry and Dr. Sudhakara, Associate Professor, College of Forestry.

My heartiest thanks to Sri. S. Krishnan, Associate Professor of Agrl. Statistics and Dr. P. Saraswathy, Associate Professor, Department of Agrl. Statistics, College of Agriculture for their timely help in the preperation of this thesis.

My profound gratitude is placed on record to Dr. J. K. Sharma and Sri. C. Mohanan, Scientists, K.F.R.I for their good help and co-operation.

I owe my gratitude to Mrs. T.N. Vilasini, Ph.D. Scholar for her constant encouragement and valuable suggestions.

I am very much grateful to all the members of the staff of the Department of Plant Pathology for the timely assistance rendered to me by each and every one of them.

My friends were of immense help to me especially Miss. Sabitha, R., Miss. Veena Kumari, D., Miss. Safeena, A.N., Miss. Beena, S., Miss Shalini Pillai, P and Mr. Judy, K.G. by giving me physical and moral support for this study.

I am grateful to the Kerala Agricultural University for the Junior Fellowship granted to me. Thanks are also due to Repromen, Thiruvananthapuram for typing the manuscript neatly.

At this juncture I remember with gratitude the blessings of my family members for their encouragement and help which made me possible for the completion of this study.

And last but not the least, I bow my head before God Almighty for showering his choicest blessings.

VEENA .S.S.

Dedicated to
my loving parents

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Introduction

INTRODUCTION

A number of cucurbits are grown all over the world. There are about 90 genera and 750 species in the family cucurbitaceae, of which 10 genera and 25 species are cultivated in different parts of the world. Cucumber, pumpkin, watermelon, bitter gourd, squashes, bottle gourd, ivy gourd, snake gourd, etc. are cultivated in large scale in India.

Powdery mildew of cucurbits is a wide spread disease occuring throughout the world. The disease is destructive especially in dry cool weather conditions. It has a great damaging potential and regularly appears on most of the cucurbits every year and inflicts substantial loss to the growers in tropics and subtropics.

Powdery mildew can be recognised by its characteristic powdery growth of the fungus on the host surface. Three powdery mildew species Erysiphe cichoracearum. D.C., Sphaerotheca fuliginea (Schlecht.) Poll. and Leveillula taurica (Lev.) Arn. infect cucurbits. Great similarities between anamorphs of S. fuliginea and E. cichoracearum and a rarity of teleomorphs compounded the difficulty in establishment of their identity. There is no information on the true

identity of the pathogen causing powdery mildew of cucurbits in Kerala State.

In Kerala, the perithecial stage of the fungus has not been recorded so far (Sharma and Khan, 1991). Whether they overwinter or over summer as perithecia or vegetative mycelium and whether ascopores or conidia initiate primary disease cycle remain to be satisfactorily answered.

S. fuliginea has rather large number of families in its host index. Numerous genera of Compositae, Cucurbitaceae, Scrophulariaceae and Leguminosae are infected by this fungus. Host specificity of S.fuliginea has been reported. Khan et al. (1971) observed that S. fuliginea from pumpkin infected only cucurbits and not the other cultivated vegetables. But this has not been established beyond doubt.

Number of atmospheric factors are claimed to favour cucurbit powdery mildew. Dry atmosphere, moderate temperature, reduced light intensity, fertile soil and succulent plant growth are important in this respect (Yarwood, 1957). A general correlation between the intensity of the disease and rainfall of an area is also found. The disease develops better in shade and

is more severe in fields with closely spaced plants. As the disease is caused by different species of powdery mildew pathogens in different regions, it is likely that variation may exist in the conditions necessary for disease development in an area.

One of the most successful methods for controlling a plant disease is through development of resistant varieties. Even though resistant varieties are available in cucumber, it has not been successful with pumpkin and other commonly cultivated cucurbits. Screening of pumpkin varieties to locate a resistant source is in progress throughout the world.

Chemical control of cucurbit powdery mildew has not been thoroughly investigated as chemical control of many other plant diseases. Some of the chemicals which are effective against powdery mildew are phytotoxic to cucurbits and some others even though effective are not cost effective.

In depth study of powdery mildew of cucurbits has not been undertaken in Kerala. Thus the present investigation is undertaken to study the occurrence of powdery mildew on pumpkin and to establish the identity and survival of the fungus in this region. Attempts have also been made to study the epidemiology and management of the disease.

Review of Literature

REVIEW OF LITERATURE

Symptomatology

The powdery mildew disease initiate as tiny white, round, superficial spots on leaves and stems of cucurbitacious host plants[Sitterly, 1978]. These spots gradually enlarge and become powdery in nature. In due course of time the thick white lesion increase in number and coalesce and eventually may cover the stem and both surfaces of the leaf. Infection on young leaf may result in general chlorosis and eventual death of the leaves. Severely affected leaves become brown and shrivelled. Under favourable conditions, premature defoliation may occur as the fungus cover the leaf surface. Black pin point bodies rarely occur but are conspicuous when they do occur. Roots are not attacked[Sitterly, 1978]. Walker (1952) showed yield reduction in proportion to time and severity of disease development, with fruits often failing to mature and being small and malformed. Ristic (1985) stated that both the upper and lower surface of leaves were attacked by powdery mildew and according to him the pathogen often appeared on leaves or the stem. He failed to get fruit infection even when the leaves were severely infected. Ibrahim et al.(1986) reported that fungus

affects all green parts of the plants gradually causing death. In spring the infection appeared mostly on the lower surface of leaf blades. Under ideal conditions premature defoliation may occur as the fungus covers both the leaf surfaces. The findings of Khan (1989) indicates that the symptoms in powdery mildew of cucurbits appear first on lower surface which gradually spread to the upper surface.

Causal Organism

Studies on identity on cucurbit powdery mildew organism has not been extensive. Most of powdery mildew from the tropics, where the teleomorph rarely, if ever occurs, indicate only that the fungus belongs to the genus Oidium. In India, as early as in 1918 Butler reported the occurrence of Sphaerotheca fuliginea (Schlecht) Poll. and Erysiphe cichoracearum. D.C on cucurbits. Jhooty(1967) claimed that S. fuliginea was responsible for powdery mildew of cucurbits in Punjab. Kapoor (1967) described that S. fuliginea exclusively attacks cucurbits, whereas E. cichoracearum is confined to the members of compositae and other non cucurbitaceous plants. Ballantyne(1975), Sitterly (1978) and Khan (1983) pointed out that there have been three genera and six species of powdery mildew recorded

on the major species of the cucurbitaceae. These include E. cichoracearum, E. communis, E. polygoni, E. polyphaga, Leveillula taurica, and S. fuliginea. The existence of three species, namely E.communis, E. polygoni and E. polyphaga, however, have not been substantiated by later works and according to Khan (1989) they appear to be cases of mistaken identity or taxonomic confusions. The other three species, E. cichoracearum, S. fuliginea and L. taurica infect cucurbits in different parts of the world. In TamilNadu two species of powdery mildew were recorded on cururbits and established their identity as Sphaerotheca fuliginea on cultivated cucurbits and E. cichoracearum on C. grandis. Donenbaeva (1978) reported the occurrence of E. cichoracearum and S. fuliginea in the Alma-ata region. Kontaxis (1979) in California conducted studies on the causal organism of cucurbit powdery mildew and he confirmed it as S. fuliginea. Lebeda (1983) collected powdery mildew samples from 37 localities of Czechoslovakia and those comprised, of two species, E. cichoracearum and S. fuliginea. Bedlan (1986) in Vienna, Molot and Lecoq (1986) from France revealed E. cichoracearum and S. fuliginea as the powdery mildew pathogens of major economic importance. Khan and El-Ammari (1987) presented evidence of the occurrence of E. cichoracearum, L. taurica and S.

fuliginea in Libya making one of the few countries where all three pathogens are present. Cvjetkovic et al. (1988') proved that powdery mildew of cucurbits in Yugoslavia is caused by S. fuliginea and not by E. cichoracearum. Thus the most widely occuring powdery mildew species on cucurbits are apparently S. fuliginea and E. cichoracearum. This generalization was based on reports originating from different countries of the world. Recent reports, however, emphasize the dominance of S. fuliginea over E. cichoracearum.

Identification of the pathogens involved in cucurbit powdery mildew is a matter of fundamental importance. When teleomorphs are present, identification of the pathogen infecting cucurbits is not a problem, but teleomorphs are rarely formed on cucurbits and the pathogen usually appear in their anamorphs. Anamorph of S. fuliginea and E. cichoracearum have great similarities and consequently a great deal of confusion have been surrounding their identity.

Ballantyne (1975) formed certain criteria for identification of powdery mildew fungi in its anaphase.

1. Type of conidiophore: Both Erysiphe and Sphaerotheca

have oidium type of conidiophores with long conidial chains and external mycelium.

2. Presence or absence of well developed fibrosin bodies (as recognized by Clare, 1958). Erysiphe has a granular form and Sphaerotheca has a cylindrical or cone form (Homma, 1937).

3. Mode of conidial germiniation (Zaracovitis, 1965). The germ tube of E. cichoracearum are single with inconspicuous appressoria, while some of the germ tubes from S. fuliginea are forked.

El-Kazzaz (1983) stated that the presence of fibrosin bodies in conidia was diagnostic. The conidia of S. fuliginea ordinarily possess a number of well developed fibrosin bodies. Fibrosin bodies are lacking or not well developed in conidia of E. cichoracearum which forms simple germ tube with thick walled club shaped appressoria. Molot and Lecoq (1986) indentified the species from the shape of spores or appressoria, position of germ tube and presence of fibrosin bodies in conidia. According to Khan (1989) shape of conidia, conidial dimensions, rate of germination, germination in relation to moisture stress etc. are doubtful characters of taxonomic importance and there is much disagreement

about the utility in differentiating S. fuliginea from E. cichoracearum as these characters are influenced by a number of factors including relative humidity, temperature, host and nutrition status. However, in the absence of detectable teleomorphs fibrosin bodies and germ tube characters could be used for postive identification of S. fuliginea and E.cichoracearum. Castanon et al. (1987) reported that the most reliable characteristics for identification of powdery mildew pathogen in its anamorphic stage were the unlobed indistinct appressoria, conspicuous fibrosin bodies and forked conidial germ tubes. This was supplemented by Cvjetkovic et al.(1988).

Teleomorph

Rudenko (1968) believed that both S. fuliginea and E. cichoracearum over winter as perithecia. Price (1970) pointed out that cleistothecia mature on senescent leaves and woody stems towards the end of an epidemic but not all varieties of host necessarily support their production.

Anamorph

Yarwood (1957) stated that powdery mildew can overwinter thorough normal mycelium, dormant mycelium in

buds, dormant haustoria and perithecia. Jhooty (1971) conducted a series of studies in India which indicated that cucurbit powdery mildew overwintered as active mycelium in sheltered situations on a number of volunteer or self grown cucurbits. According to him, cucurbit powdery mildew in Punjab survive in the form of normal mycelium. This view was supported by the findings of Khan (1989). Further he observed that in plains of North India, intense summer created problem for oversummering of the fungi. But as the cucurbits are grown abundantly on hills during summer it is likely that these pathogens survive on the summer crops on hills and blown to the plains when the intense heat and rains are over and cucurbit hosts are available.Recent studies conducted by Sharma and Khan (1991) showed that in Tamilnadu teleomorphs of S.fuliginea were observed on Lagenaria siceraria and on Coccinia grandis and these could help in the over summering of the pathogen.

Spore germination

The pattern of germination of powdery mildew spores vary according to the genera and species. Conidia of powdery milew can be considered to be germinated when the length of the germ tube exceeded the breadth of the spore (Manners and Hossain, 1963). The mode of

germination of conidia, morphology of germ tube and development of appressoria are important factors in determining the identity of the pathogen when teleomorph are not observed. The spores when make a contact with the host surface under conditions of reduced light intensity, a temperature of 22° to 31°C and absence of moisture, germination commences within two hours. The first germ tube is usually short, forming a convoluted appressorium (Sitterly, 1978). But the findings of Khan (1989) showed that the conidia of S.fuliginea when germinate, a number of them form forked germ tubes and do not produce appressoria. In contrast conidia of E cichoracearum form simple germ tubes with thick walled club shaped appressoria.

Hashioka (1937) reported conidia of cucurbit powdery mildew germinate from 22° to 31°C with a peak at 28°C. According to Jhooty (1970) conidia of S.macularis, S.fuliginea and E.cichoracearum do not germinate satisfactorily on glass slides under conditions of moisture stress, however, these conidia germinate much better on host and host leaves. He also found that germination of E.polygoni conidia followed a diurnal cycle, where as this phenomenon was absent in S macularis, S fuliginea, E cichoracearum and E graminis.

Conidia of S. pannosa germinated over a wide

temperature range (Weinhold, 1961). Slight germination occured at 4°C. Optimum temperature was from 21°-27°C and no germination occurred above this. At controlled relative humidity ranging from 43 to 100 per cent, germination of spores on glass slide was less than 1% where as 9.5 to 12.3% of spores on the upper surface of peach leaf germinated. He further observed that on peach leaves, under conditions conducive to condensation 25% germination occurred. He failed to observe any stimulatory effect of sugars and aminoacids on germination of the spores. Ragazzi (1981) reported germination of conidia of S. pannosa was best at 20°C on rose extract agar.

Quinn and Powell (1982) stated that under controlled temperature, relative humidity and light, the conidia of Oidium begoniae germinated on glass slide at 23° to 25°C in the range of 4 to 32%. At 28°C or more reduction of the germination occured. Lakra (1990) studied effect of wetting periods on germination of E.polygoni conidia from pea in vitro and reported that conidia were unable to survive being submerged continuously for five hours or more at 21± 1°C and germination was prevented by submergence for two hours. While the susceptibility of host tissue is important, the growth of the fungus in this tissue is considerably

influenced by temperature, relative humidity and presence of free water. Although optimum relative humidity for germination of S.fuliginea is 95%, free water is detrimental (Hashioka, 1937). Levykh (1940) found that tobaco powdery mildew pathogen on dry slide germinated best at 60 to 100% relative humidity. Manners and Hossain (1963) revealed that the optimum relative humidity for germination of E. graminis is 100 per cent. Grainger (1947) observed no germination below 85% relative humidity. Schnathorst (1965) conducted a detailed study on the influence of relative humidity on conidial germination and found that conidia of S.pannosa could give maximum germination at 75 to 99% relative humidity and E.polygoni germinated throughout a wide range of moisture stress from 0 to 99% relative humidity. Drandarevski (1969), observed high percentage of germination of conidia of powdery mildew organism from sugar beet occured at 100% relative humidity but even at 40% air humidity more than 70% of the conidia germinated. Quinn and Powell (1982) pointed out that under controlled temperature, light intensity and decreased relative humidity only slight decrease in conidial germination of Oidium begoniae occurs.

The water content of powdery mildew spores can be almost 75% of the fresh weight (Somers and Horsfall,

1966) It is probable that water required for germination is provided internally (Yarwood, 1957) and has been suggested that lipid in the cell wall form a barrier which limits water loss (Johnson et al., 1976). However, water content depends on the humidity conditions under which spores are produced (Somers and Horsfall, 1966) and this probably explains why these produced at high relative humidities germinate better than those produced at low relative humidity (Prabhu et al., 1963). Formation of appressoria is delayed by both darkness and high light intensity (Aust, 1974). Long periods of continuous darkness or very low light intensity may prevent or very much reduced disease development (Pratt, 1944). In contrast, exposure to darkness immediately after inoculation was found to stimulate infection (Sempio, 1939).

Epidemiology

Epidemiology is a branch of ecology concerned with coexisting populations of plant parasites and their hosts in natural and agricultural ecosystems. Cucurbit powdery mildew is generally favoured by dry atmospheric and soil conditions, moderate temperatures, reduced light intensity, fertile soil and succulent plant growth (Yarwood, 1957).

Tolerance of cucurbit mildew to heat is usually lower than that of the host. Walker (1952) noted cucurbit powdery mildew was able to thrive in hot climates because vines shade the ground and mycelium develops on the under side of the leaves. Yarwood et al.(1954) reported that most powdery mildews infect plants within a temperature range of 11° to 28°C., with an average of about 21°C. The relative importance of cucurbit powdery mildew was correlated with rainfall in those areas and powdery mildew for example, may be very severe in summer in arid portion of California in Western United States, but not important in Eastern portion of states where abundant rainfall normally occurs (Sitterly, 1978). In tropics cucurbit powdery mildew was severe on crop grown on hill sides and shallow valleys having dry cool conditions. In both the hottest and the wettest portion of the tropics, there was least damage from powdery mildew except for areas where a prolonged dry season occured. After the beginning of rainy season the disease disappeared (Wellman, 1972). Singh (1985) pointed out that germination and growth of the fungus occurs best at 22° to 27°C. The fungus occured in epidemic form only when there was more than average rainfall. Disease development can occur at 20° to 30°C with optimum at 25°C under conditions of 100% relative humidity for at

least 18 hours. Abiko and Kishi (1979) indicated that high humidity was most conducive to conidial germination of S. fuliginea. At later stages of infection low humidity was more favourable. Molot and Lecoq (1986) reported that sporulation of E. cichoracearum was favoured by dry conditions while more humidity and good plant nutrition appeared to favour development of S. fuliginea.

Singh (1985) reported E. polygoni on pea can grow at any temperature form 16° to 28°C, but conidial germination was best at 20° to 24°C. A fairly dry soil and heavy application of nitrogenous fertilizers increased the disease incidence.

Light can influence the development of many diseases. Light intensity affects the survival of inoculum, pre penetration processes, entrance of some pathogens, length of incubation period, abundance of sporulation and sometimes the type of pathogenic effect. Powdery mildews often develop better under shaded conditions. Walker (1952) conducted the experiment in cucurbit powdery mildew and reported that it developed better in shade than in full light, thus more severe in close plant spacings and under a high carbohydrate level with its subsequent luxuriant growth.

Apart from the temperature and light there are several other factors which are also known to influence powdery mildew incidence. Many studies revealed resistance to infection by powdery mildew organism with age of leaf. Mence and Hildebrand (1966) showed it was associated with increasing thickness of the cuticle and epidermal wall. In grape vine leaves may be attacked at any age of time (Bulit and Lafon, 1978). Angelov and Pethova (1979) reported that the response of cucurbit to powdery mildew pathogen varied at different stages of plants growth. Maximum susceptibility was at the cotyledon stage. Ferriere and Molot (1988) stated that cotyledon of cucurbits to be very susceptible to the pathogen. While the first leaf was relatively resistant, susceptibility increased upto 4 to 5th leaf and decreased.

Disease Management

Resistant Varieties

One of the most successful procedures for controlling a plant disease is through the development of resistant varieties.

Akram and Khan (1977) conducted varietal screening of some cultivated cucurbits to S. fuliginea. They

tested 13 varieties of Cucumis sativus, two of Cucurbita maxima, eight of C. moschata, two of C. pepo, four of Luffa acutangula, five of L. cylindrica 11 of Momordica charantia and 11 of Trichosanthes anguina. All the cultivars of Cucumis sativus proved to be highly susceptible in glass house as well as in the field. Both the varieties of Cucurbita moschata proved to be highly resistant out of the eight varieties of C. moschata, Chal Kumra and Early White Bush were susceptible; Bright red susceptible; Red large, White Bush, Caserta, Zucchini and Zucchini improved were moderately resistant in glass house and in field all of them were highly susceptible. The reason they suggested for this was that the field was exposed to inoculum repeatedly under different sets of conditions. They repeated the same experiment using Benincasa hispida, Citrullus vulgaris, Cucumis melo and Lagenaria leucantha. All the five varieties of B. hispida proved to be moderately resistant in field and glass house conditions. Out of the five varieties of Citrullus vulgaris three were susceptible and two were highly resistant in glass house. In the field even susceptible became resistant. All the varieties of Cucumis melo became infected to a varying degree. Kabitarani and Bhagirath (1991) conducted a study to find out resistance of 12 Cucurbita moschata germplasm

collected from different parts of N.E. India under field conditions. None of the germplasms were immune to S. fuliginea. Some varieties showed high degree of resistance while others were highly susceptible.

Chemical Control

Practical control of powdery mildew disease of cucurbits with the present state of knowledge seems to be difficult. Chemical control of cucurbit powdery mildew has not been as thoroughly investigated as has chemical control of many other plant diseases. Powdery mildew of cucurbits are sensitive to the action of fungicide at all stages of life cycle except for perithecial stage.

Sulphur

Sulphur exerts its fungicidal action at the surface of the leaves, stems, flowers or fruits to which it is applied. It is re-distributed over such surface to a limited extent by vaporization and also by the action of rain and dew. Because powdery mildews grow mainly on the plant surface, applied sulphur can come into direct contact with existing mycelium and suppress its growth and sporulation. Powdery mildew fungus is vulnerable to the action of sulphur through most of its life cycle

except for the perithecial stage (Yarwood, 1957). Cucumbers are somewhat sensitive to sulphur, gourds, pumkins, squashes and watermelon are sulphur tolerant. The principle objection to the use of sulphur is its phytotoxic action. Jain and Srivastava (1977) showed the best control of E. cichoracearum by Sultaf, Thiovit (wettable sulphur) and Elosal (elemental sulphur). Donenbaeva (1978) recommended 0.1 to 0.2% colloidal sulphur against cucumber powdery mildew. Behad (1979) and Charifi-Tehrani (1984) observed the effectiveness of wettable Sulphur against powdery mildew. Singh and Yadav (1985) showed powdery mildew of bottlegourd was controlled by application of Sevisulf at an interval of 15 days. According to Ratnam et al. (1985) eventhough powdery mildew disease of bottlegourd could be reduced by spraying sulphur, it is not recommended as it showed phytotoxicity. Suhag and Mehta (1982) and Bhatia and Thakur (1989) used sulphur for controlling powdery mildew in bottlegourd, muskmelon and pumkin and they concluded it was very effective.

Carbendazim

Carbendazim is a benzimidazole derivative. [2-(Methoxy-carbamoyl) benzimidazole] is effective aginst ascomycetes and fungi imperfecti which are considered to be difficult control. Carbendazim is

translocated within the plant and has both prophylactic and curative actions.

Delp and Klopping (1968) reported that Bavistin act as protectant and curative agent and gave control over a wide range of fungal pathogens including powdery mildew. And he observed that it was translocated in the transpiration stream of plants. Suhag and Mehta (1982) could control powdery mildew of cucurbits by the application of 0.1% Bavistin. Ratnam et al. (1985) compared 10 fungicides against powdery mildew of Lagenaria siceraria. Bavistin gave good control with more yield. Same results were obtained by Mathur and Daftari, (1985). Bhatia and Thakur, (1989) also evaluated the efficiency of Bavistin to control powdery mildew of cucurbits and it was found effective.

Srivastava (1982) in pea, Nawaz and Narayanaswamy (1983) in blackgram and greengram, Samy (1984) in blackgram, Verma and Gupta (1984), Shrestha (1985), Chauhan et al. (1986), Ray (1987) in pea tested Bavistin against powdery mildew and all of them could control powdery mildew by Bavistin application. Narain (1990) carried out field experiments in Bhuvaneswar and found powdery mildew of Vigna radiata contorlled by Bavistin application.

Edathil et al. (1988) reported that carbendazim controlled Oidium heveae infection in rubber more effectively on young trees.

Tridemorph

Tridemorph (2,6 - dimethyl - 4- tridecyl morpholine) is highly effective against phytopathogenic fungi including Erysiphe. It controls powdery mildew of wheat, cucurbits, peas, roses, rubber and tobacco. Tridemorph is absorbed through leaves and translocated in the xylem tissue, providing a systemic protection. The exact mode of action of the compound is not known. Pommer et al. (1969) reported that Tridemorph was highly effective against powdery mildew. Suhag and Mehta (1982) found best control of S. fuliginea on bottlegourd, summersquash and pumpkin with tridemorph. Tehrani (1984; 1987) noted two application of Tridemorph could control powdery mildew of cucumber.

Srivastava (1982); Bhatia and Thakur (1988) proved Tridemorph performed very effectively against E. polygoni in pea. Mishra and Ashok Krishna (1990) investigated the effect of Tridemorph on development of mildew epidemics on pea in India. Calixin reduced

conidial germination, and reduced conidial yield. Mehta et al. (1990) obtained highest yield in cumin plants sprayed with 0.04% Tridemorph against E. polygoni. Russell and Mukhopadhyay (1981) concluded Tridemorph was very effective against E. betae. Edathil et al. (1988) reported Tridemorph controlled O. heveae infection more effectively on mature rubber trees.

Hexaconazole

It is a triazole fungicide with Butyl 2-4 dichloro phenyl triazole ethanol as the active ingredient. Hexaconazole is an inhibitor of ergosterol biosynthesis of fungi. It is effective against many basidiomycetes, ascomycetes, especially powdery mildew of grape vine.

Shephard et al. (1986) presented the specturm of activity and important properties of Hexaconazole. Field experiments conducted by him demonstrated its excellent performance against powdery mildew disease of grape vine. Heaney et al. (1986) showed excellent protectant, curative and translaminar activity of Hexaconazole against grape vine powdery mildew.

Water Spraying

The relative importance of cucurbit powdery mildew in different region is correlated with rainfall in those

areas. Yarwood (1936) observed an improvement in mycelial growth when mildewed plants where protected from rain and young colonies grew abnormally when sprayed with water and he reported that it was possible to obtain complete control of mildew by water spraying. Rotem and Cohen (1966) pointed out that overhead irrigation has reduced the severity of Leveillula taurica on tomato and Ruppel et al. (1975) reported the same result in sugar beet. It has been reported by Khan (1989) that reinfall inhibits powdery mildew development, however, according to Butt (1978) rain fall is not always harmful eventhough free water of rainfall causes poor hyphal growth and impacting rain drops damage conidiophores. Showers can stimulate powdery mildew by raising atmospheric humidity. Wastie (1972) distinguished between these two opposing effects of rain in his study of rubber powdery mildew. Rain for one to two days at the start of defoliation was important for triggering an epidemic, which developed rapidly when the following weather was fine with occasional short showers. If there was frequent rain after initial trigger, the epidemic was unlikely to be severe.

Atomospheric moisture stress is a major factor which controls not only the severity of powdery mildew but also the distribution. Chorin and Palti (1962)

classified powdery mildew disease in Israel into three groups. Species like S. fuliginea on cucurbits, U necator on vines and L. taurica on artichokes are largely independent of humidity. E graminis on cereals and E. cichoracearum on tobacco prefered low moisture stress while species like Oidium on potato preferred high moisture stress.

Materials and Methods

MATERIALS AND METHODS

Symptomatology

Detailed symptomatology of the disease was studied by inoculating pumpkin plants of different age groups and with varying degrees of resistance. A leaf was considered infected when the inoculated leaf showed the characteristic symptoms and produced conidia identical with those of the inoculum, and the control leaves remained healthy. The conidia produced as result of artificial inoculation were transferred to healthy leaves of the original host to complete the cycle. The artificial inoculation studies was conducted using pumpkin seedlings. The plants used for the study were grown in 9" polythene bag. The healthy leaves of varying age viz cotyledonary stage, one day old, five day old, ten day old, fifteen day old and twenty day old were subjected to artificial inoculation by two different methods.

1. Naturally diseased leaves collected from the field were brought near the healthy plants and it was blown using a blower so that the conidia from the infected leaves were carried to the healthy leaves.

2. The pieces of infected leaves were pinned to the

upper and lower surface of healthy leaves. The diseased leaf bits were removed one day after inoculation. The leaves were inoculated in the morning and were kept in sheltered place till the symptoms appeared. Three lines viz. P30, P79 and P86 representing resistant, susceptible and moderately resistant group of lines were utilised for this study. Seeds of the lines were sown in 9" polythene bags and inoculated at cotyledonary stage and kept for constant observation for infection and symptom development for 30 days. The experiment was conducted during summer months (March - April) of the year.

Disease intensity

Wherever the intensity of this disease was assessed it was done following an arbitrarily devised score chart following zero to nine scale as detailed below.

Five leaves from each plant were randomly selected and the disease was scored using the score chart given below.

0 - No symptoms of powdery mildew on leaves.

1 - Small powdery mildew specks covering < 10% leaf area.

3 - powdery mildew lesions small upto 5 mm in size covering 1-10% leaf area.

5 - Powdery lesions covering 11-25% of leaf area.

7 - Powdery mildew lesions coalesce to form big patches covering 26-50% of leaf area.

9 - Big powdery patches covering 51% or more of leaf area.

Host range

In order to find out the host range of pumpkin powdery mildew fungi, it was inoculated on common cucurbitaceous plants viz. snake gourd, bitter gourd, bottle gourd, cucumber, ash gourd, ivy gourd and water melon and also on rubber, mango, Scoparia dulcis, Euphorbia hirta and Stachytarpheita indica. Powdery mildew spores collected from naturally infected pumpkin plants were used for inoculating the plants. Except for mango and rubber seedlings of the plants were raised in polythene bags. In the case of rubber and mango detached healthy branches were planted in pots and the leaves were inoculated.

The powdery mildew spores collected from different host plants were also used to inoculate

pumpkin seedling at cotyledonary stage one, five, ten, fifteen and twenty day old leaf stages. Inoculated plants were kept in a shaded place for further observations.

Morphology of the causal organism

Free hand sections of pumpkin infected by powdery mildew were taken and mounted on microscope slide under dry conditions and observed for detailed morphological characters of conidiophore and conidia. Their measurements were also taken following standard techniques (Mc Cain, 1988) and camera lucida drawing were also made. In order to have a comparative account of the morphological characters powdery mildew organisms from few other cucurbitaceous and other crops were also studied following the same technique. Microphotographs were also takes in an Olympus photomicrograph attachment. The conidia were also subjected to detailed observations for any fibrosin bodies described by Zolf (1887).

Dried debris of pumpkin, old infected vines, etc., were constantly observed for teleomorph of the organism.

Spore germination studies

Spores of the powdery mildew organism was collected from freshly infected Cucurbita moschata seedlings grown under field conditions. Germination of the spores were studied by keeping the spores under various conditons of incubation at different temperature. The following treatments were used.

1. Dry spore was dusted on a dry slide and kept inside a dry petridish.

2. Spores were mixed with water and kept on a slide, inside a dry petridish. The spore load of water was adjusted in such a way that there were 20-30 spores under the low power field of the microscope.

3. The dry spores were dusted on a dry glass slide and this slide was kept on two bits of glass tube in a dry petridish, a droplet of water was kept below the slide without water touching the spores.

4. Dry spores were dusted on dry slide kept inside a humidity chamber. The humidity chamber was prepared by lining the inside of the petridish with moist filter papers.

Germination of the spores was studied by incubating the dishes at room temperature and also at 10°, 20°, 25° and 30°C in a B.O.D. incubator. The germination count was taken at 24, 48 and 72 hour of incubation. A conidium was considered to have germinated, when the length of the germ tube exceeded the breadth of the spores.

Varietal screening

The experiments on varietal screening and fungicidal trial were conducted in the plots of the Department of Olericulture, College of Horticulture, Vellanikkara. This area is located at an altitude of 23m above MSL and is between 10° 32" N and 76° 10°E longitude.

During August - November, 1990 a preliminary screening of 57 lines of pumpkin was conducted. The seeds of these lines supplied by the Department of Olericulture, College of Horticulture, were cultivated as per the Package of Practice Recommendations (1989). There were 3 pits/line. Observations were made at an interval of one week starting from 69 days after planting. The details of the pumpkin lines are given in Table 1.

Table 1

Details of pumkin lines utilized for varietal screening

Sl. No.	Line	Source/Place of collection
1.	P1	Pattancherry, Palakkad
2.	P2	Kavallur, Kannur
3.	P3	Jorhat, Assam
4.	P4	Mudikode, Thrissur
5.	P5	Jorhat, Assam
6.	P6	Valiyakunnu local
7.	P7	Mudikode, Thrissur
8.	P8	I.I.H.R, Bangalore
9.	P9	Chevaranpalam, Thrissur
10.	P11	Assam
11.	P12	Pattambi
12.	P13	Muthalamada, Palakkad
13.	P15	Muvattupuzha local
14.	P16	Peringatuthodu, Irimbilium
15.	P17	Cheruthurithi local
16.	P18	S.K.V.A.S.T, Shalimar, Srinagar
17.	P19	Trithala, Palakkad
18.	P20	Irimbilium local
19.	P21	Irimbilium local
20.	P22	Kizhakkancherry, Palakkad
21.	P24	Jorhat, Assam

Sl. No.	Lines	Source/Place of collection
22.	P25	Ambalavayal local
23.	P29	Godavari
24.	P30	Palai, Kottayam
25.	P31	Puthur, Thrissur
26.	P32	Kollamkodu, Palakkad
27.	P33	Panayur local
28.	P35	CO-2, T.N.A.U
29.	P36	Kuzhalmannam, Palakkad
30.	P38	Irimbilium
31.	P39	Puramannur local
32.	P40	Local, Assam
33.	P42	Chittoor, Palakkad
34.	P45	From CM-14
35.	46	From CM-14, Dept. of Olericulture
36.	47	Pollachi
37.	49	Pollachi-Mannuthy
38.	55	Sel 124 from I.A.R.I.
39.	57	Arka Chandan, I.I.H.R., Bangalore
40.	58	Pollachi-Mannuthy
41.	60	Arka Suryamughi, I.I.H.R., Bangalore
42.	65	M.P.K.V., Rahuri
43.	66	M.P.K.V., Rahuri
44.	67	M.P.K.V., Rahuri
45.	68	M.P.K.V. Rahuri
46.	P69	M.P.K.V., Rahuri
47.	P70	M.P.K.V., Rahuri

Sl. No.	Line	Source/Place of collection
48.	P71	N.B.P.G.R., New Delhi
49.	P76	N.B.P.G.R., New Delhi
50.	P79	N.B.P.G.R., New Delhi
51.	P81	Sikkim
52.	P82	Pilicode, local
53.	P83	Mannuthy-Pollachi
54.	P84	Sikkim
55.	P86	Sikkim
56.	P87	Pilicode, local
57.	Ambili	College of Horticulture, Vellanikkara

Fifty seven lines screened during 1990 was grouped into three based on the disease severity. The first group comprised of plants having a disease index of 15 and below. Second group contained plants having disease index of 15-28 and third group above 28. From the 57 lines, 28 lines namely

P46, P13, P71, P66, P79, P9, P12
P1, P8, P7, P36, P31, P3, P20
P67, P11, P30, P22, P33, P24, P86
P35, P83, P5, P21, P17, P32, and Ambili were selected for further studies during 1991-92.

The 1991-92 trials were conducted during November - March season. The seeds were sown on November fifth. There were three plants for each line.

Intensity of powdery mildew infection was scored using the same score chart given above. The first observation was taken on 22.12.91, when the plants were 47 days old. The plants were scored at an interval of seven days till the harvest. All the plants were sprayed once with Carbaryl 0.2% on 1-2-92 to control leaf miner infection and with Dithane M-45, 0.2% on 11-12-92 to control Alternaria leaf spot disease.

Epidemiology

For epidemiological studies the pumpkin variety Ambili, a popular variety of the locality, was selected. The plants were raised in an isolated area away from the main pumpkin field. Plants were grown in five different pits following the normal cultivation practices. In order to get a continuous crop of pumpkin throughout the year, the crop was planted during the four different seasons as per the details given below.

Serial Number	Date of sowing	Date of final harvest
1	28.3.91	16.7.91
2	2.7.91	28.10.91
3	2.10.91	1.2.92
4	5.1.92	6.5.92

The disease intensity of the plants was scored at weekly intervals. The temperature and relative humidity were recorded by installing a thermohygropgraph at a height of about 30 cm above the soil level in between the plants. The daily rainfall and sunshine hours of the location during the period of observation was collected from the Agrometeorology Department of College Horticulture. Disease intensity was scored according to the score chart (already

described) at weekely intervals. The data were analysed using path analysis technique.

Control of the disease

a. Bioassay

The effectiveness of the chemicals used in the field study to control powdery mildew was also tested under laboratory conditions. The germination of the conidia under different concentrations of the chemical were studied. The concentrations tried were 2000, 1000, 500, 250, 125 and 62.5 ppm of Tridemorph, Hexaconazale and Carbendazim, 4000, 2000, 1000, 500, 250 and 125 ppm of wettable Sulphur and 20000, 10000, 5000, 2500, 1250 and ppm of sodium thiosulphate. The prepared solutions were uniformly sprayed using an atomizer on a glass slide and the slide was allowed to dry overnight, free from dust. In the control, distilled water was used in place of fungicidal solutions. Next morning, fresh harvest of conidia from young lesions of powdery mildew on leaves of pumpkin were shed on dried surface of treated slide by gently tapping the leaves above the slide, there by getting more or less homogenous distribution of conidia. The slides were then kept in humidity chamber and incubated at 25°C in a B.O.D. incubator. The germination count was taken after 24, 48 and 72 hours.

b.Field trial

To study the effectiveness of different plant protection chemicals and also spraying of water on powdery mildew incidence, a field experiment was conducted during November - March season of 1991-92. The details of the experiment were as follows.

Crop - Pumpkin

Line - P46

Date of sowing - November 6th 1991.

Design - R.B.D.

Replication - 4

Treatment - 7

Active ingredient	Common name	Trade name	Concentration (in per cent spray solution
2-(Methoxy-carbamoyl) benzimidazole	Carbendazim	Bavistin	0.1
2,6-dimethyl-4 -tridecyl morpholine	Tridemorph	Calixin	0.1
Butyl 2-4 dicholoro phenyl triazole ethanol	Hexaconazole	Contaf	0.1
Sulphur	Wettable sulphur	Sulfex	0.2
Sodium thiosulphate	Sodium thiosulphate	Sodium thiosulphate	1
Water spray			
Control (No spray)			

The plants were grown following package of practice of recommendations of Kerala Agricultural University. The first spray was given on 28.1.92, two days before the spraying the intensity of the diseases was scored using the score chart used for varietal screening.

To avoid drifting of fungicidal spray, the plants were caged in a polythene cage of height 120cm while spraying. The disease intensity was estimated at weekly interval. Second spray was given on 25.2.92 ie 28 days after first spray and disease intensity was scored after seven days. The crop was harvested on 18.3.92.

The plants were sprayed once with 0.2% carbaryl on 1.2.92. to control leaf miner.

RESULTS

Symptomatology

The powdery mildew disease on pumpkin developed as tiny, white, round or irregular superficial fungal growth on leaves and stems. The lesions increased in number and coalesced and eventually covered the stem and both surfaces of the leaves. Infection on young leaves resulted in general chlorosis and death of the vines. The severely affected leaves turned brown, shrivelled and in few cases resulted in premature defoliation. Roots and fruits were not seen infected.

The age, genetic make up and the cropping season showed a profound influence on the time taken to develop the disease symptoms (Table 2). Cotyledons were the most susceptible part of the plant to infection. During December to January, cotyledonary stage took three days to develop symptoms, while during the summer months, March to April visible symptoms on cotyledons were developed only after four days. One day old, ten day old and 20 day old leaves developed symptoms four days after inoculation during December to January while it took five to six days during March to April. Five and fifteen day old leaves required five days during winter months and six days during summer months to produce

Table 2

Symptomatology of powdery mildew on pumpkin

Days after inoculation (in days)	Types of symptom development on		
	Resistant line (P30)	Moderately resistant line (P86)	Susceptible line (P79)
5	-	-	Minute specks
7	-	Minute specks	Powdery growth grade 1
9	-	Powdery growth grade 1	Grade 3
10	Minute specks	Grade 3	Grade 5 with chlorosis
12	Grade 1	Chlorosis	Chlorosis extended
13	Grade 1	Grade 5	Grade 7 drying from the tip
14	Grade 3	Grade 5 Chlorosis	Grade 7 most of the portion became chlorotic
16	Grade 3	Grade 5 drying from the tip	Drying increased
18	Grade 3	Grade 5 more drying	Drying 75 per cent area
20	Grade 3	Chlorosis and drying extended	Drying
22	Grade 3	Drying	Drying
24	Grade 3	Drying	Dried
25	Grade 3	Drying	Dried
26	Grade 3	Dried	Dried

visible symptoms.

During cooler periods of the year, the powdery growth of the fungus was more pronounced on the upper surface of the leaves while in summer months the powdery growth was comparatively more on the lower surface. During this period the disease could easily be identified by the appearance of chlorotic patches seen on the upper surface. Based on the field study the plants were grouped into resistant, moderately resistant and susceptible types. The symptoms of powdery mildew on the one day old leaf of the susceptible line P79 were developed five days after inoculation while it took seven days in the line P86 (moderately resistant). The resistant line P30 took ten days to develop symptom. In susceptible variety chlorotic patches with powdery growth was seen nine days after inoculation and drying of the leaves was observed by 12th day and by 17th day nearly 75% of the lamina portion developed drying.

In moderately resistant line of pumpkin initial symptoms appeared after seven days of inoculation on one day old leaves. The development of chlorotic patches was observed only after eleven days and it took 26 days to cause drying up of the leaves. The resistant lines of pumpkin took ten days to develop powdery specks on the

leaves, which failed to spread. The chlorotic patches seen in susceptible and moderately resistant groups were not pronounced in this type. In most of the cases further development of the symptoms was not noticed.

Host range

The cross inoculation studies using the conidia collected from powdery mildew of pumpkin with cucurbitaceous plants, namely, bittergourd, snakegourd, bottlegourd, ash gourd, coccinia (ivy gourd) and watermelon, cowpea and weed plants commonly seen in this tract, (Scoparia dulcis, Euphorbia hirta, Stachytarpheita indica) and perennial trees like mango and rubber were conducted. Except bittergourd and ivygourd none of the other cultivated plants and weeds took up infection from powdery mildew spores collected from infected pumpkin.

In bittergourd maximum infection was obtained when the cotyledons were inoculated with the spores. Cotyledons took up infection after five days of inoculation while one day, 10 day and 15 day old leaves were seen infected after six days. The spores collected from infected bittergourd could infect pumpkin on cross inoculation.

Cross inoculation studies were also successful with coccinia. The leaves of different age group got infected with spores from pumpkin within a period of five to seven days. The spores collected from this could reinfect pumpkin.

Morphology of the causal organism

Perithecia of the powdery mildew fungus was not observed on pumpkin as well as on the other cucurbitaceous and non cucurbitaceous host plants studied.

Conidia

The conidia of the fungus were circular to ovoid in shape. The length and breadth of the conidia are given in Table 3. The length of the conidia ranged from 29.4 to 35.2 µm and breadth 14.2 to 18.6 µm. The conidia from pumpkin were 34.2 x 18.6 µm in size being the biggest and that from bitter gourd were the smallest with a measurement of 30 x 16.2 µm.

Fibrosin body

Inclusions resembling fibrosin bodies were seen in few conidia obtained from cucurbitaceous crops especially in pumpkin. The per cent occurrence of

Table 3

Measurements of conidia (in μm) of powdery mildew organism from common host plants (average of 50 measurements)

Name of the host plant	Length	Breadth
Pumpkin	34.2	18.6
Bitter gourd	30.0	16.2
Ivy gourd (coccinia)	32.6	15.5
Cowpea	34.8	15.8
Euphorbia hirta	35.2	16.2
Scoparia dulcis	29.4	14.4
Zinnia	32.8	17.6
Vicoa indica	32.2	16.2
Rubber	34.6	16.0

fibrosin bodies in conidia from pumpkin ranged from 70 to 90. In rare cases fibrosin like bodies were also observed in conidia of noncucurbitaceous crops (Plate 1).

Spore germination

On germination, conidia from cultivated cucurbits produced simple and forked germ tubes from the side walls of the conidia (Fig. 1). The percentage of forking of germinating conidia was less than 20. The germinating conidia did not develop appressoria. Germination of spores commenced with in 24 hour.

The spores were dusted on dried glass slides and incubated at 10°c, 20°c, 25°c and 30°c in humid chambers kept inside a B.O.D incubator (Table 4). Maximum germination was obtained in 72 hours. After 72 hour there was no further increase in the germination percentage at any of the temperatures tested. During the first 24 hours no spores germinated at 10°C. Percentage of spores germinated at this temperature after 48 and 72 hours of incubation was very low. Comparatively high germination was observed after 24 hour at 20°C. During this period germination percentage observed at 25°C was less than that oberved at 30°C.

Plate 1

Conidia of Sphaerotheca fuliginea with fibrosin body

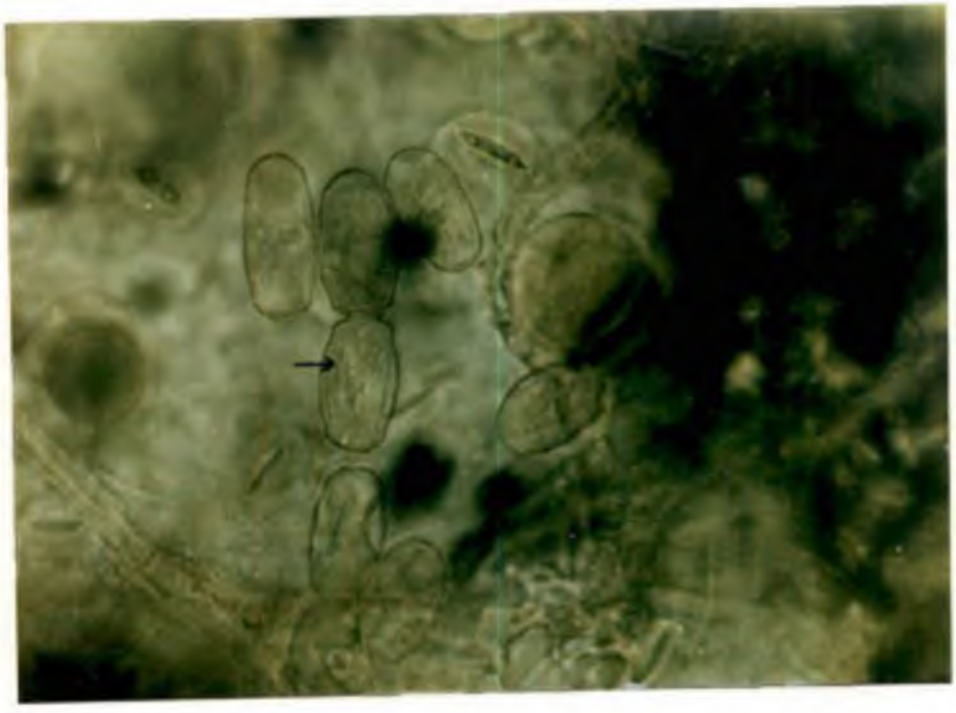
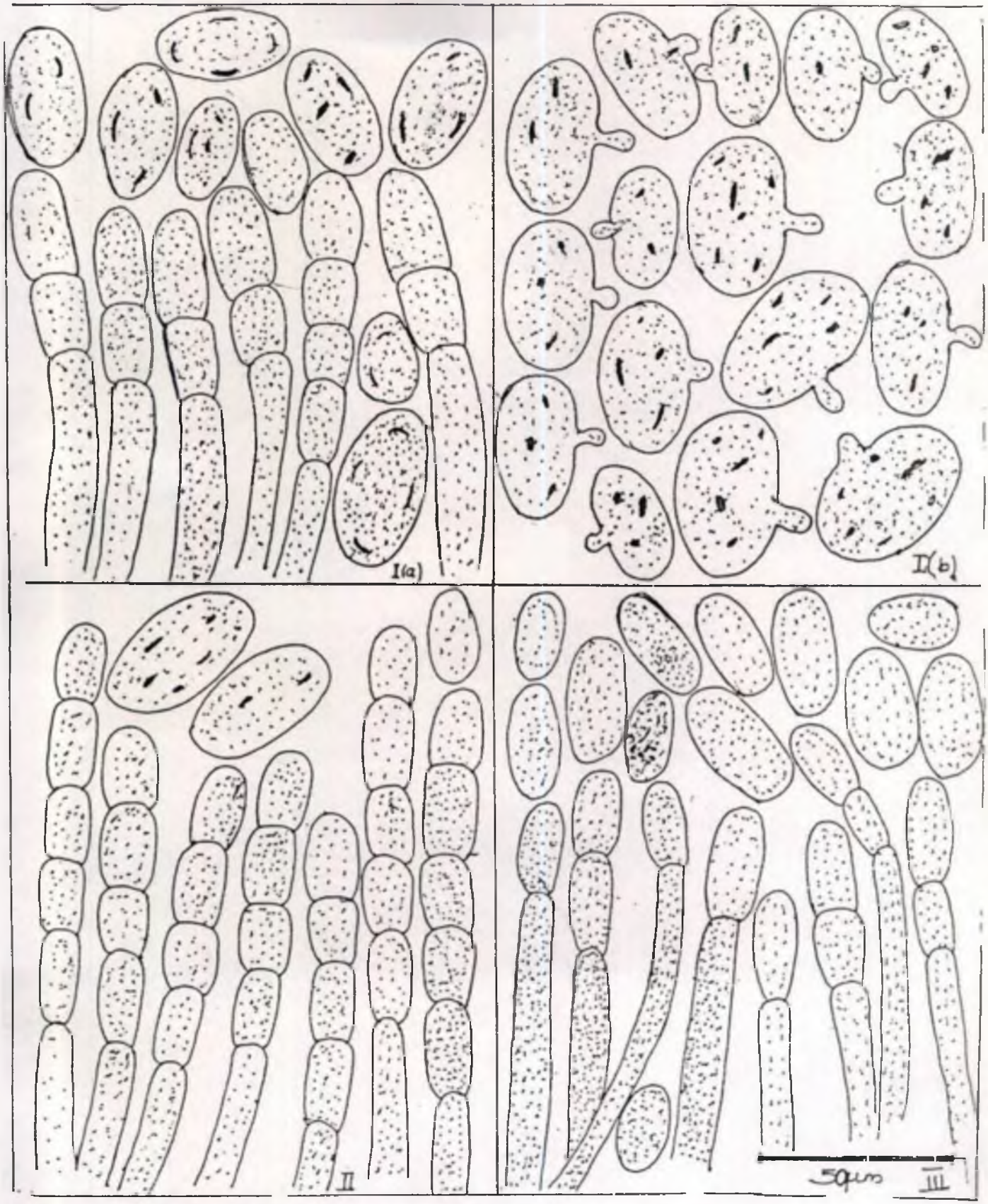


Fig. I

Conidia and conidiophore of powdery mildew fungus



I (a) Pumpkin I (b) Germinated conidia of pumpkin
II Bitter gourd III Rubber.

Table 4

Influence of temperature on germination of conidia of powdery mildew of pumpkin (percentage germination)

Temperature (in degree celsius)	Hours of incubation		
	24	48	72
10	0	1.8	1.9
20	8.64	13.9	21.0
25	1.96	13.5	25.4
30	2.30	5.3	7.34

Highest germination of 25.4 per cent was observed when the spores were incubated at 25°c for 72hours. When incubated at 20°C even though there was an increased rate of germination (8.64 %) compared to other temperatures, the increased rate was not observed at the end of 72 hour where germination at this particular temperature was less than that observed when incubated at 25°C (2.3%). At the end of 48 hour the germination of conidia incubated at 20° and 25°C did not vary considerably and it was higher than that observed at 30°C.

Moisture

In conidial germination, the spores were kept under four different conditions (Table 5). In general the percentage germination of spores in all the treatments was less than 26 per cent.

The powdery mildew spores did not germinate when it was submerged in water and incubated under different temperatures. Highest germination of 25.4 per cent was observed when the spores were kept in a humid chamber and incubated for 72 hour. This was followed by the

Table 5

Germination of conidia of powdery mildew organism at varying degrees of relative humidity (percentage germination)

Sl.No.	Methods of incubation	Temperature											
		10°C			20°C			25°C			30°C		
		Hours of incubation											
		24	48	72	24	48	72	24	48	72	24	48	72
1	Spores mixed with water	0	0	0	0	0	0	0	0	0	0	0	0
2	Spores on dry slides in dry petridish	0	4.2	4.0	0	1.9	10.7	0	8	14.2	0	7.4	8.3
3	Spores on dry slides in humid chamber	0	1.8	1.9	8.6	13.9	21.0	1.96	13.5	25.4	2.3	5.3	7.3
4	Spores on dry slides above glass rod (water drop at the centre of petridish)	2.04	2.0	1.9	5.8	9.43	17.6	3.7	10.3	22.2	0	6.5	5.7

method in which the spore slides were kept over a drop of water and incubated for 72 hour (22.2%). No germination was noted at the end of 24 hours when spores dusted on dry slides were kept in a dry petridish and incubated at different temperatures.

Screening for disease resistance

During August - November, 1990 57 lines of pumpkin were screened to study the resistance/susceptibility of the lines against powdery mildew infection (Table 6). During the first observation (69 days after sowing) 32 lines showed symptoms of powdery mildew. The highest disease index of 46.6 was observed on the line P46, which is a selection from the type CM-14, collected from Vellanikkara. During the second week of Novemner (76 days after sowing) except 10 lines all the others were seen infected and the maximum disease index was again noted on the line P46. During this period four other lines (P33, P79, P11 and P13) also showed a disease index of more than 40. During the third week of November, when the plants were about to be harvested, all the lines were found infected and the disease index ranged from 2.2 to 60. The least disease index was noticed in line P25 (collected from Ambalavayal). P24 (Jorhat, Assam) and P58 (Pollachi, T.N). The

Table 6

Reactions of different lines of pumpkin to powdery mildew infection
(Disease index at weekly interval)

Lines	Days after sowing			Category
	69	76	83	
P20	-	6.6	33.3	S
P32	-	4.4	11.1	R
P21	-	4.4	8.8	R
P8	-	4.4	6.6	R
P33	15.5	44.4	48.8	S
P83	2.2	6.6	6.6	R
P69	2.2	15.5	15.5	M.R
P79	22.2	44.4	60.0	S
P31	22.2	37.7	37.7	S
P11	13.3	40.0	48.8	S
P1	-	11.1	15.5	M.R
P9	4.4	28.8	35.5	S
P13	11.1	48.8	51.1	S
P86	2.2	2.2	8.8	R
P87	2.2	2.2	13.3	R
P82	-	-	4.4	R
P25	-	-	2.2	R
P42	-	-	4.4	R
P84	2.2	2.2	8.8	R
P40	4.4	4.4	8.8	R

Contd..2

Lines	69	76	83	Category
P15	11.1	15.5	15.5	M.R
P57	2.2	13.3	17.7	M.R
P46	46.6	51.1	55.5	S
P22	4.4	8.8	13.3	R
P71	2.2	22.2	20.8	M.R
P76	4.4	22.2	26.6	M.R
P30	2.2	6.6	13.3	R
P24	-	-	2.2	R
P47	6.6	35.5	42.2	S
P81	4.4	4.4	8.8	R
P16	17.7	28.8	26.6	M.R
P4	4.4	8.8	15.8	M.R
P66	4.4	17.7	24.4	M.R
P35	2.2	15.5	17.7	M.R
P19	2.2	8.8	15.5	M.R
P58	-	-	2.2	R
P67	-	-	4.4	R
P70	-	2.2	6.6	R
P29	-	2.2	6.6	R
P65	2.2	13.3	20.0	M.R
P3	-	-	6.6	R
P17	2.2	13.3	20.0	M.R
P18	2.2	20.0	31.1	S
P5	-	15.5	20.0	M.R
P45	-	-	11.1	R

Contd..3

Lines	69	76	83	Category
P6	22.2	26.6	26.6	M.R
P36	15.5	22.2	26.6	M.R
P60	-	4.4	15.5	M.R
P12	-	2.2	8.8	R
P39	-	4.4	11.1	R
P49	-	2.2	15.5	M.R
P7	-	13.3	20.0	M.R
P38	-	-	8.8	R
P2	-	2.2	13.3	R
P55	-	2.2	22.2	M.R
P65	-	-	13.3	R
CO-1	-	2.2	28.8	S

R - Resistant line

M.R - Moderately resistant line

S - Susceptible line

highest disease index was on P79 (N.B.P.G.R. New Delhi). Based on the disease index ratings all the lines were grouped into three. Lines with disease index of 15 and below were considerd as 'resistant' and those with disease index of 15 to 28 was grouped as 'moderately resistant' and those with disease index above 28 as 'susceptible'. There were 26 resistant, 20 moderately resistant and 11 susceptible lines. Out of 26 resistant lines 10 lines developed disease only late in the season (83 days after sowing).

Of the 57 lines screened during August - Novermber, 1990 season, 28 lines were selected for further screening during November 1991 to March 1992. These consisted of nine susceptible, nine moderately resistant and 10 resistant lines. The intensity of disease was calculated at weekly interval (Table 7). The Kruskal Walli's one way analysis of the data on disease index of different lines of pumpkin showed that there was significant difference in the disease intensity among the lines.

The powdery mildew infection was not noticed in any of the lines upto 47 days after planting. When the disease index was taken 54 days after planting, four lines (P71, P9, P7, P1) were found infected with a

Table 7

Intensity of powdery mildew disease in pumpkin-varietal reaction during different periods of summer season

Lines	Days after sowing											
	47	54	61	68	75	82	89	96	103	110	117	124
P46	-	-	-	-	-	15.5	44.4	46.6	38.8	33.3	40.5	41.6
P13	-	-	18.5	20.0	20.0	61.0	62.2	66.7	68.2	66.7	70.3	73.0
P71	-	15.6	20.7	28.9	33.3	33.3	36.3	43.0	40.7	44.4	44.4	47.4
P66	-	-	-	1.5	4.4	5.9	6.7	7.4	9.6	17.0	20.0	21.5
P79	-	-	-	11.1	19.3	34.0	76.3	70.4	72.6	71.9	83.7	87.4
P9	-	5.2	2.2	1.5	7.4	7.4	10.4	13.3	14.8	17.7	19.2	28.1
P12	-	-	0.74	2.9	5.9	6.6	10.4	12.6	27.4	32.6	45.1	43.7
P1	-	8.9	10.4	11.9	40.0	57.8	51.1	67.4	66.6	70.4	80.7	79.3
P18	-	-	13.3	22.9	37.0	56.2	60.0	57.8	57.8	57.8	65.9	57.0
P7	-	6.7	6.7	6.7	6.7	6.7	6.7	6.7	7.4	9.6	10.4	11.9
P36	-	-	-	0.74	2.2	5.2	20.0	13.3	19.3	22.2	22.9	24.4
P31	-	-	-	-	5.9	20.0	20.7	24.4	36.3	36.3	40.7	48.2
P3	-	-	-	-	-	-	-	2.2	10.4	14.0	20.0	22.2

Contd..2

Lines	Days after sowing											
	47	54	61	68	75	82	89	96	103	110	117	124
P20	-	-	-	-	3.7	8.2	28.2	22.9	26.7	27.4	24.4	24.4
P67	-	-	-	-	9.6	20.7	34.0	26.5	21.5	22.9	34.8	43.7
P11	-	-	-	-	-	-	13.3	14.8	12.6	19.3	20.7	26.7
P30	-	-	-	-	-	-	-	0.74	0.74	1.48	1.48	2.2
P24	-	-	-	-	-	6.7	2.9	5.9	12.6	3.7	20.0	22.9
P86	-	-	-	-	6.7	20.7	40.0	60.0	62.9	64.4	80.0	75.5
P35	-	-	-	-	-	4.4	4.4	4.4	6.7	11.1	25.9	31.1
P83	-	-	-	-	-	-	1.5	1.5	2.2	5.9	22.9	25.9
P5	-	-	-	-	-	34.8	61.5	73.3	68.9	71.9	71.9	76.3
P21	-	-	-	-	-	-	-	-	49.6	51.1	57.0	54.0
P17	-	-	-	2.2	7.4	12.6	28.9	28.9	39.3	39.5	51.9	54.8
P32	-	-	-	-	0.74	0.74	2.96	32.6	35.5	33.3	35.6	27.4
Ambili	-	-	-	-	-	0.74	7.4	6.7	7.4	8.9	12.6	17.7
P22	-	-	-	-	-	-	7.4	6.7	14.0	14.0	24.4	22.9
P33	-	-	-	-	-	-	8.9	9.6	9.6	15.6	16.3	17.7

disease index ranging from 6.7 to 15.6. None of the resistant lines developed disease during this period. Till the end of 68 days, eventhough 11 lines were found infected all these lines were from moderately resistant and susceptible group. On the 75th day of sowing, 16 lines got infected and the disease index ranged from 0.74 (P32) to 33.3 (P71). Three lines belong to the group resistant viz.,P 32, P 67 and P 86 were also found infected . All the lines except P21 were found infected on 96th day of sowing. At this stage P79 and P5 had more than 70% infection. All the lines were found infected when the plants were 103 days old. Least infection of 0.74 was observed on line P30. This line eventhough got infected on 89th day of sowing did not show any increase in the intensity till 103 days. Just before harvest (124th day) the maximum disease intensity was observed on the line P79 (87.4) and the minimum on P30 (2.2). Five lines (P1, P5, P13, P79 and P86) had more than 70% infection at this stage.

Epidemiology

Climatic factors like temperature (maximum and minimum), relative humidity (morning and evening), sunshine hours and rainfall during the cropping period were recorded from the area where the pumpkin was continuously cultivated to correlate the climatic factors on disease development and its severity.

First crop

The first crop was free from the powdery mildew infections (Table 8). The crop was sown on 28.3.91 and was finally harvested on 16.7.91 (110 days). During this period there was rain in all except in two weeks. Total number of days of continuous dry spell was only 14, between 28.4.91 to 11.5.91 during this crop. The total number of rainy days during this period was 46 and the average weekly rainfall ranged from 0 to 42 mm. The average weekly maximum temperature ranged from 28°c to 37°c and the minimum from 22.8 to 26.1°c. Maximum relative humidity which was recorded in early morning ranged from 78.5 to 93.6 while that of evening was between 50.4 to 85.7. The average sunshine hour was above 8.5 during the first 5 weeks and between five and eight for the next five weeks while it ranged from 0.3 to 3.7 during the last four weeks.

Second crop

Second crop was planted on 2.7.91 and harvested on 28.10.91 (118 days). The second crop overlapped the first crop during last 15 days thus there was a continuity of crop in the field. Measurable rain was

Climatic factors and intensity of powdery mildew incidence in the first crop (28.3.91 - 16.7.91)

Days after Sowing	Disease index	Temperature °C			Humidity %			Sunshine hours	Average rainfall (mm)No.of rainy days/week	Dry spell days
		Maximum	Minimum	Average	Morning	Evening	Average			
7	-	37	25	31	78.5	50.5	64.5	9.9	0	-
14	-	35.5	23.8	29.7	81.3	50.6	66.0	8.8	3.3/2	4
21	-	35.9	25.4	30.7	85.1	54.7	70.0	8.4	3.5/2	3
28	-	35.4	24.8	30.1	87.4	55.7	71.6	8.9	3.9/2	1
35	-	34.7	24.1	29.4	86.9	52.4	69.7	9.2	1.3/1	5
42	-	34.7	26.1	30.4	85.6	55.2	70.4	6.1	-	14
49	-	35.9	26.1	31.0	84.1	53.9	69.0	7.4	0.4/2	1
56	-	36.3	25.5	30.9	82.0	51.8	67.0	7.5	0.9/1	5
63	-	34.6	25.4	30.0	87.8	50.4	69.1	7.9	5.0/4	1
70	-	32.7	23.6	28.2	90.3	68.5	79.4	5.6	30.6/4	0
77	-	28.8	24.3	26.6	93.4	85.7	89.6	0.89	42.0/7	0
84	-	30.4	23.5	26.9	93.4	71.5	82.5	3.7	36.0/7	0
91	-	29.7	23.5	26.6	93.6	82.6	88.1	3.5	14.4/7	0
98	-	28.0	22.8	25.5	92.3	78.3	85.3	0.3	30.0/7	0
105	-	29.0	22.9	26.0	94.1	80.1	87.1	2.8	31.7/7	0
112	-	28.9	23.5	26.2	93.7	76.9	85.3	2.2	18.6/7	0

recorded during fifteen out of seventeen weeks with a total of 80 out of 118 days of the crop (Table 9). The maximum continuous dry spell during this period was for fourteen days (30.8.91 to 14.9.91). During the initial eight weeks of the crop the maximum weekly average temperature was below 30°C while it was between 30 and 32 during the rest of the period. The fluctuation in the minimum temperature was only 2.5 (2i. 8 - 24.3) except for two weeks ie. between 4.9.91 to 13.9.91. The morning relative humidity was above 90% while the evening humidity was between 66 and 83% in all the weeks except from 4.9.91 to 27.9.91 when it was between 59 and 65 percent. The sunshine hour during 2nd crop was less than 7 hours during the entire period except from 3.9.91 to 13.9.91 when it ranged from 7.1 to 8.9 hours. The crop was free from disease upto 63 days of sowing. Disease was first observed on 3.9.91 when a disase index of 2.6 was recorded. The intensity of disease increased slightly during next week to 8.4 but again reduced to 2.6 during the subsequent week and disease disappeared from 29.9.91 onwards and reappeared on 5.10.91 and this continued till the harvest. The maximum disease intensity recorded was 12.4 which was recorded a week before harvest.

Third crop

The third crop was sown on 2.10.91 and harvested on

Table 9

Climatic factors and intensity of powdery mildew incidence in second crop (2.7.91 - 28.10.91)

Days after sowing	Disease index	Temperature °C			Humidity %			Sunshine hours	Average rainfall (mm) No.of rainy days/week	Dry spell days
		Maximum	Minimum	Average	Morning	Evening	Average			
0	-	28.0	22.8	24.5	92.3	78.3	85.3	0.3	30/7	0
7	-	29.0	22.9	26.0	94.1	80.1	87.1	2.8	31.7/7	0
14	-	28.9	23.5	26.2	93.7	76.9	85.3	2.2	18.6/7	0
21	-	29.7	22.5	26.1	94.4	77.0	85.7	3.0	21.9/7	0
28	-	29.2	22.5	25.9	92.8	81.6	87.2	3.1	54.3/7	0
35	-	28.9	23.5	26.1	94.2	83.2	88.7	1.5	3.98/7	0
42	-	29.0	23.0	26.0	94.7	80.0	87.4	2.3	15.4/6	0
49	-	28.1	21.8	24.9	24.7	79.4	87.0	1.8	30.2/6	0
56	-	29.2	22.5	25.8	95.7	78.9	87.2	4.2	8.7/7	0
63	2.6	30.6	23.4	26.9	93.2	66.0	79.6	7.1	0.6/2	0
68	8.4	31.54	23.2	27.4	58.8	59.0	73.9	8.9	-	9
73	2.6	31.8	24.3	88.03	89.00	62.4	75.7	8.3	-	14
80	-	31.4	23.1	27.3	92.9	61.6	77.3	6.2	0.97/3	3
87	-	31.5	23.2	27.4	91.0	65.1	78.0	6.5	7.8/7	0
96	8.8	31.6	24.1	27.8	91.4	76.8	84.0	4.3	1.46/4	1
101	11.5	30.6	23.6	27.7	90.2	78.0	84.1	4.04	11.7/4	0
106	12.4	30.8	22.4	26.6	93.6	69.6	81.6	5.5	3.08/2	1
113	9.7	32.2	23.0	26.9	94.9	77.4	75.4	5.7	8.2/4	1

1.2.92 (123 days). Third crop overlapped the second crop during the last 20 days. Measurable rainfall was recorded only during the first nine weeks of the crop (Table 10). Then till the end of the crop there was no rain except on 16.12.91 (0.2mm). Thus there was a continuous dry spell of 47 days. The variation in the maximum weekly temperature was only 3.2°C (30 to 33.2°C) while that of minimum temperature was 4.2 (19.9 to 24.1°C) and the average weekly temperature 1.6 (26.2° to 27.8°C). The average weekly relative humidity during this period could be identified into three groups. During the first group relative humidity was between 75 and 85 (5.10.91 to 17.11.91). In the second group, the average relative humidity ranged from 60 to 70 (24.11.91 to 4.1.92) and in the third group was between 47 and 55 (11.1.92 to 1.2.92). The powdery mildew was first observed on the 20th day after planting and it gradually increased till the harvest. The disease index ranged from one to eight during the first five weeks and 10 to 32 during the next seven weeks and 34 to 52 from the next four weeks. The highest disease index of 52 was recorded on the day of final harvest.

Fourth crop

Fourth crop was planted on 5.1.92 and harvested on 6.5.92 (122 days). Third crop overlapped fourth one for

Table 10

Climatic factors and intensity of powdery mildew incidence in Third crop (2.10.91 - 1-2-92)

Days after sowing	Disease index	Temperature °C Maximum	Minimum	Average	Humidity % Morning	Evening	Average	Sunshine hours	Average rainfall (mm) No.of rainy days/week	Dry spell days
3	-	31.6	24.1	27.8	91.4	76.8	84.0	4.3	1.46/4	1
8	-	30.6	23.6	27.1	90.2	78.0	80.1	4.04	11.7/4	0
13	-	30.8	22.4	26.6	93.6	69.6	81.6	5.5	3.8/2	1
20	1.3	32.2	23.0	26.9	94.9	77.4	75.4	5.7	8.2/4	1
27	4.0	30.6	23.2	26.8	89.8	73.5	80.7	4.3	6.6/5	0
34	7.1	30.0	23.0	26.5	93.3	74.9	84.9	3.7	13.5/4	4
41	4.0	32.2	22.4	27.3	26.7	61.2	75.5	6.7	19.2/5	0
48	5.7	31.4	22.8	27.1	82.2	66.4	79.9	5.5	4.4/3	1
55	10.2	31.1	24.0	27.6	76.9	60.2	68.4	7.2	4.5/2	5
61	12.8	31.8	22.3	27.0	72.0	57.2	69.7	8.5	-	11
68	15.5	31.5	21.3	26.3	71.7	49.9	63.3	9.7	-	18
75	17.3	30.8	21.9	26.3	87.4	49.3	60.7	8.8	0.02/7	25
82	23.1	31.5	23.8	27.7	87.0	52.8	62.3	7.7	-	5
89	32.4	33.2	20.4	26.8	70.7	41.1	64.3	8.3	-	12
96	32.0	32.7	21.9	27.3	69.5	48.7	67.8	8.2	-	19
103	34.2	32.4	19.9	26.2	64.6	31.7	51.2	8.3	-	26
110	38.6	31.9	21.4	26.7	67.4	41.2	55.3	9.5	-	33
117	47.6	33.2	20.8	27.0	87.6	30.7	47.6	9.5	-	40
124	52.0	33.0	20.3	26.7	91.9	35.2	51.3	9.4	-	47

a period of 27 days. There was no rainfall for the first 16 weeks while measureable rain was recorded during the last two weeks (Table 11). The average maximum temperature ranged from 30° to 37.6°C. The average minimum weekly temperature during this period could be grouped into two ie is from the first week till 11th and from 12th to 18th week. During these periods the temperature ranged from 19° to 23°C and from 23.5° to 24.8°C respectively. The average weekly temperature could also be grouped in to two. In the first group temperature ranged from 26.2° to 29.5°C and in the second group, ranged from 30° to 30.6°C. The relative humidity during this period ranged from 47.6 to 70.3. During most of the days, average low relative humidtiy was between 30 to 50%, while the higher side it ranged from 64.6 to 91.9 per cent. The maximum sunshine hours during the year was observed during this period and the average weekly sunshine hours ranged from 8.17 to 9.7 hours.

Climatological data collected over a period of one year (1991 April to 1992 April) from the pumpkin field were analysed using path analysis technique (Table 12). Climatological parameters like temperature relative humidity, rainfall, sunshine hours were correlated with disease index. The direct effect of minimum

Table 11

Climatic factors and intensity of powdery mildew incidence in Fourth crop (5.1.92 - 6.5.92)

Days after sowing	Disease index	Temperature °C			Humidity %			Sunshine hours	Average rainfall (mm) No. of rainy days/week	Dry spell days
		Maximum	Minimum	Average	Morning	Evening	Average			
0	0	32.7	21.9	27.3	69.5	48.7	67.8	8.2	-	26
6	0	32.4	19.9	26.2	64.6	31.7	51.2	8.3	-	33
13	0	31.9	21.4	26.7	67.4	41.2	55.3	9.5	-	40
20	4	33.2	20.8	27.0	87.6	30.7	47.6	9.5	-	47
27	17.7	33.0	20.3	26.7	91.9	35.2	51.3	9.4	-	54
34	28.8	34.0	21.5	27.8	90.4	48.1	67.9	9.4	-	61
41	49.3	34.9	22.5	28.7	77.0	43.3	67.6	8.8	-	68
48	51.1	33.6	21.3	27.4	90.4	50.1	70.3	9.15	-	75
55	58.6	35.6	22.0	28.8	77.0	31.1	54.0	9.6	-	82
62	59.5	37.1	22.1	29.6	90.4	37.8	64.1	9.3	-	89
69	50.6	36.9	22.3	29.5	81.6	30.2	55.9	9.2	-	96
76	51.1	36.2	22.7	29.5	78.0	36.1	57.0	8.9	-	103
83	44.4	37.6	23.5	30.5	84.1	40.7	62.4	8.17	-	110
90	45.7	36.7	24.1	30.4	82.3	40.8	61.6	9.7	-	117
97	43.5	35.4	24.5	29.9	83.6	49.4	66.5	8.6	-	1
104	41.7	36.6	24.5	31.5	81.5	47.9	64.6	9.17	-	0
111	43.1	36.6	24.7	30.6	76.8	50.4	63.6	8.3	-	6
118	49.3	35.7	24.4	30.0	81.8	51.8	66.8	N.R	6.3/2	
125	45.7	35.6	24.8	30.2	80.6	55.7	68.2	N.R	0.7/1	

Table 12

Effect of climatological parameters on disease development

(Path analysis)

I

X_1	X_2	X_3	X_4	X_5	Total correlation
0.1944	-0.1933	0.0957	-0.0111	-0.3627	-0.2769
0.0898	-0.4184	-0.3985	-0.3696	0.1801	-0.9166
-0.0350	-0.3138	-0.5314	-0.4480	0.5286	-0.7997
0.0027	-0.1944	-0.2994	-0.7957	0.5485	-0.7380
0.1006	0.1075	0.4008	0.6227	-0.7008	+0.5308
		Residue = 0.1738727 = 17%			
II					
3.5585	0.6460	2.9735	3.2344	-9.8382	+0.5741
1.7465	1.3162	-1.9819	1.1680	-2.1682	+0.0806
-1.6123	0.3975	-6.5626	-4.1513	11.4439	+0.4849
-2.2870	-0.3055	-5.4135	-5.0325	12.5742	-0.4643
2.6884	0.2191	5.7672	4.8594	-13.0222	+0.5120
		Residue -13.33. not estimable			
III					
1.8468	0.0258	-0.5025	0.5138	-1.2198	+0.6641
-0.0467	-1.0193	0.4624	-0.3448	0.5412	-0.4072
-1.0639	-0.5404	0.8722	-0.7119	1.1866	-0.2575
-0.9973	-0.3694	0.6527	-0.9514	1.5524	-0.1130
1.3598	0.3330	-0.6247	0.8916	-1.6566	+0.3103
		Residue -0.022 not estimable			

I - First occurrence of the disease.

II - At 20 days old.

III - At 63 days old.

X_1 - Maximum temperature

X_2 - Minimum temperature

X_3 - Relative humidity

X_4 - Rainfall

X_5 - Sunshine hours

temperature, humidity and rainfall on the disease were negative and their correlation with the disease index was also negative. While the direct effect of maximum temperature on disease index (0.1944) was positive, its correlation with disease index was negative. The negative correlation of maximum temperature with disease index was (-0.2769) is mainly the resultant of its indirect effect via sunshine hours (-0.3627).

The correlation between minimum temperature and disease index was significant (-0.9166). About 46% of the correlation was attributed to its negative direct effect via relative humidity and rainfall (-0.3985, -0.3696) by about 84% and positive effect via maximum temperature and by about 20% via sun shine hours.

Sixty six per cent of the correlation of relative humidity with disease index (-0.7997) was attributed to its direct effect (-0.5314). The negative indirect effect with minimum temperature and rainfall (-0.3138 and -0.4480) and positive indirect effect via sunshine hours (0.5286) resulted mainly in the observed correlation. The direct effect of rainfall on disease index (-0.7955) was slightly more than that of its correlation with disease index (-0.7380). The reduction in this correlation is attributed partially to the

positive indirect effect via sunshine hours and the indirect effect via minimum temperature and relative humidity (-0.1944 and -0.2993). The direct effect of sunshine hours on disease index was high and negative (-0.7008) and its correlation was positive (+0.5308). The indirect effect of sunshine hours via others were positive, resulting a positve correlation this is mainly because of the indirect effect via rainfall and relative humidity.

Both direct effect of maximum temperature and also the indrect effect via maximum temperature were positive except with relative humidity which is comparatively small. The direct effect of minimum temperature and indirect effect via minimum temperature were also negative, here also with the exception of its indirect effect via sunshine hours. The indirect effect of maximum temperature and sunshine hours via relative humidity was positive while with others negative.

Sunshine hours has positive indirect correlations with minimum temperature, relative humidity and rainfall. Eighty three per cent of the variation in disease score is attributed to the factors, maximum temperature, minimum temperature, relative humidity, rainfall and sunshine hours as evident from the residual

factor 0.17 or 17 per cent.

The direct and indirect effects of climatological parameters on disease score exhibited different nature on 20th and 63rd day of the crop in comparison with disease development at initial stages. The correlation of these parameters with disease score was less in magnitude. However to describe the differential response of these parameters on disease score, path analysis was performed and presented in Table 12.

The results of 20th day and 63rd day are presented in Table 12. All the direct effects and indirect effects were high. The residual factors were not estimable.

Control of the disease

a. Bioassay

The conidia of powdery mildew organism failed to germinate at 250 ppm and above in fungicides, Carbendazim, Tridemorph and Hexaconazole (Table 13). Complete inhibition of germination was observed only above 500ppm in Sulphur while the minimum concentration required to inhibit spore germination using sodium

thiosulphate was above 2500 ppm. The per cent germination of conidia in four fungicides and sodium thiosulphate at the lowest concentration were tried and the results are given in table 13. Conidia of the fungus germinated in 24 hours after incubation at 25°C in control. But only 3.7% of the conidia germinated during this time. Even after 72 hours in control only 25% of the conidia germinated. At 250 ppm none of the conidia germinated in Carbendazim at the end of 24 hours. But at 125 and 62.5 ppm it showed slight germination (2.7%). When the incubation was extended to 72 hours even 250 ppm concentration of Carbendazim brought about 1% germination and while at the same period, germination was 64% at 62.5 ppm. Almost a similar trend was observed in the case of Hexaconazole and Tridemorph treatments. However, at the end of 24 hours both these fungicides supported some germination. Compared to other fungicides wettable Sulphur was less effective. Even at a concentration of 500ppm, 3% germination was noticed 24 hours after incubation. The ability of sodium thiosulphate in inhibiting conidial germination was very poor. Sodium thiosulphate was less fungitoxic compared to other chemicals tested. After 24 hours of incubation 2.6% of the spores germinated at a concentration of 2500ppm and at a concentration of 625 ppm 11.25% of the fungal spores germinated within 72 hours.

Table 13

In vitro effect of antifungal compounds on germination of conidia of powdery mildew organism on pumpkin

Antifungal compound	Concentration (ppm)	Percentage germination after 24 hr.	48 hr.	72 hr.
	250	0	1.05	1.06
Carbendazim	125	2.08	3.19	3.39
	62.5	2.7	4.4	6.4
	250	2.7	3.06	2.83
Tridemorph	125	2.08	3.09	5.97
	62.5	2.7	7.0	9.0
	250	2.6	2.9	4.1
Hexaconazole	125	3.96	3.9	5.3
	62.5	8.42	9.18	7.5
Sodium -	2500	2.6	3.5	3.4
thiosulphate	1250	3.8	4.9	5.2
	625	8.57	9.09	11.25
	500	3.03	2.98	3.6
Wettable Sulphur	250	2.17	5.0	4.9
	125	4.76	7.9	9.0
Control		3.7	13.5	25.4

b. Field trials

In general, powdery mildew of pumpkin was seen reduced by application of all the fungicides, sodium thiosulphate and water spray (Table 14). All the treatments were found to be better than control in inhibiting powdery mildew infection. The disease severity was least in Carbendazim sprayed plants. The extent of control observed in plants sprayed with sodium thiosulphate, wettable Sulphur and Tridemorph were equal to that noticed with Carbendazim spray. The fungicide Hexaconazole eventhough better than water spray was inferior to other chemicals in inhibiting powdery mildew. The plants which received water spray was significantly better than the control.

The percentage reduction in the intensity of the disease over the control was 94.2 per cent, while water spray inhibited the disease by 48.4 per cent (Table 15). The extent of reduction in other treatments over the control ranged from 77.8% (Tridemorph) to 86.9% (sodium thiosulphate). Even after two weeks the effect of fungicidal spraying was evident. The disease index during this period was the least in plots which received Tridemorph but this was not significantly superior over the other treatments except water spray which was on par

Table 14

Effect of antifungal compounds on the disease intensity of powdery mildew of pumpkin

Treatments	Before spraying	One week after spraying	Two weeks after spraying	Three weeks after spraying	Second spraying	One week after second spraying
Carbendazim	21.1	2.7	5.0	8.3	11.6	7.2
Tridemorph	29.6	10.3	3.7	15.5	15.5	12.5
Hexaconazole	50	21.6	6.6	13.3	22.2	15.5
Sodium-thiosulphate	20.5	6.1	2.7	16.1	18.8	8.8
Wettable sulphur	19.4	7.7	10	13.8	13.8	6.6
Water spraying	42.2	23.8	21.6	26.6	32.2	21.6
Control	44.4	46.6	38.8	33.3	40.5	41.6
CD (5%)		1.3355	1.4296	2.4731		0.9702

Table 15

Effect of antifungal compounds on the powdery mildew of pumpkin (Per cent reduction over the control)

Treatments	One week after spraying	Two weeks after spraying	Three weeks after spraying	Second spraying	One week after second spraying
Carbendazim	94.2	87.1	75	71.3	82.6
Tridemorph	77.8	90.4	53.4	61.7	69.9
Hexaconazole	53.6	82.9	60.0	45.1	62.7
Sodium - thiosulphate	86.9	93.0	51.6	53.5	78.8
Wettable sulphur	83.4	74.2	58.5	65.9	84.1
Water spray	48.9	44.3	20.0	20.4	48.0

with control. The percentage reduction of powdery mildew over the control during this period ranged from 44.3 (water spray) to 90.4 (Tridemorph).

The inhibition of powdery mildew as a result of chemical spray was not very effective when the disease indices were compared three weeks after spray. During this period Carbendazim was significantly better than all other treatments and which gave 75% reduction over the control.

The second spray was given 28 days after the first spray. This was necessitated because there was an increase in the disease index compared to that observed during the previous week. The variation in different treatments observed during this period was almost similar to that noticed after the first spray. When the disease index was recorded one week after the second spray, all the treatments were found to inhibit powdery mildew significantly. The least infection (6.6) was observed in plants sprayed with wettable Sulphur, but it did not differ significantly from Carbendazim and sodium thiosulphate spray. The plants which received water spray was found to be as effective as Hexaconazole. The per cent inhibition of powdery mildew one week after the second spray ranged from 48.5 % in control to 84.3% in wettable Sulphur.

Cost benefit ratio

The cost benefit ratio of the spraying operation is given in Table 16. The maximum yield increase was obtained by spraying Tridemorph (5.8t) followed by wettable Sulphur (4.8t) and minimum in Hexaconazole (4.2t). The yield increase obtained by water spray was even better than Carbendazim treatment. The total additional expenditure for powdery mildew control with various treatments ranged from Rs. 500 (water spray) to Rs. 1059 (Tridemorph). Since all the cultural operations except plant protection measures were common in all the treatments while calculating cost benefit ratio only the additional expenditure is taken into account. Best cost benefit ratio of 1:6 was observed with water spray followed by Tridemorph 1:5.15. The cost benefit ratio was only 1:2.5 in case of Hexaconazole and carbendazim treatments.

Table 16

Cost benefit ratio for management of powdery mildew disease of pumpkin

Name of the chemical	Yield/ha (t)	Netreturns Rs. 2/Kg	cost of spraying (Rs)	C:B ratio
Carbendazim (0.1%)	4.35	8700	985	1:2.53
Tridemorph (0.1%)	5.83	11660	1059	1:5.15
Hexaconazole (0.1%)	4.2	8400	880	1:2.5
Sodium - thiosulphate (1%)	4.3	8600	800	1:3
Wettable sulphur (0.2%)	4.8	9600	600	1:5.6
Water spray	4.6	9200	500	1:6
Control	3.1	6200		

Discussion

DISCUSSION

Powdery mildew diseases are generally diagonised by the presence and details of the morphology of the causal agent (signs), rarely by the host response (symptoms). This is mainly because powdery mildew generally causes symptoms other than slow decline and drying up of affected plant parts and decrease in productivity of hosts (Yarwood, 1978). Detailed study of the symptomatology of pumpkin powery mildew in the present study is in agreement to Yarwood's general statement. The fungal structure can be seen ramified all through the aerial foliar parts of the affected plant and under severe infection it resulted in host response like drying, defoliation, etc.

Sphaerotheca fuliginea found on Cucurbita moschata was found to infect only Momordica charantia and Coccinia spp. on artificial inoculation. The spores produced from naturally infected M. charantia and Coccinia spp. could infect pumpkin also. The fungus failed to produce symptom even on the other cucurbitaceous and also on non cucurbitaceous plants. Thus the study clearly indicated that S. fuliginea found on C. moschata is different from that found on other cucurbitaceous crops. Eventhough it is in accordance

with the findings of Akram et al. (1975) is in variance with those reported by Nour (1959); Alcorn (1969); Munjal and Kapoor (1973).

Identity of the pathogen involved in cucurbit powdery mildew is a subject of controversy. When teleomorphs are present, identification of the pathogen is not a problem, but teleomorphs are not observed under Kerala conditions and the pathogen usually appear as anamorphs. The anamorphs of Sphaerotheca fuliginea and Erysiphe cichoracearum, two powdery mildew causing fungi on cucurbits reported from different parts of the world have several similarities and it is difficult to differentiate them in their anamorph statge. However, some of the features of conidia could be utilized to differentiate S.fuliginea and E. cichoracearum. Prominent among them are presence or absence of fibrosin bodies, mode of germination of conidia, morphology of germ tube and development of appressoria. The conidia collected from pumpkin during the present investigation had structures resembling fibrosin bodies (Plate 1) and some of the conidia were found to produce forked germ tubes. Invariably none of the conidia produced appressoria. The size and shape of conidia collected from various crops and weeds, affected with powdery mildew disease did not show marked variations. Thus the

only characters for differentiating powdery mildew pathogen observed on pumpkin from those present in other related crop plants were the presence of fibrosin bodies in the conidia, germination of conidia, forked germ tube and absence of appressoria. According to Khan (1989) the conidia of S.fuliginea had fibrosin bodies and many of them germinated by the production of forked germ tube and it failed to produce appressoria. Thus based on the present study it is safe to conclude that likely in Kerala, Sphaerotheca fuliginea is the principal causal organism of pumpkin powdery mildew. However, in view of the reported occurrence of two species of powdery mildew pathogens namely S. fuliginea and E. cichoracearum on pumpkin, in the neighbouring state of Tamil Nadu (Sharma and Khan, 1991) the existence of E.cichoracearum cannot be completely ruled out. Hence further extensive studies on cucurbit powdery mildew are required to find out the possible presence of other powdery mildew pathogens in Kerala.

The mode of perpetuation and survial of powdery mildew of Cucurbita moschata is perplexing. In the present study perithecia were not found on host plants. The possibility of the fungus tiding over non crop season in a pure crop of pumpkin as mycelium or as conidia, is excluded as C. moschata is an annual crop

and there are several months in an year without the crop been cultivated and the inability of mycelium and the conidia of S. fuliginea to survive for a long period of time in the absense of host plant (Khan, 1989). In Kerala sometimes neglected crops of pumpkin are seen growing in the field and harbour the fungus. S. fuliginea attacking pumpkin has also been found on Coccinia which is perennial crop. Coccinia which is usually trailed on to big trees or roof tops harbour the inoculum throughout the year and when the pumpkin crop is in the field and when the conditions are favourable, it results in powdery mildew disease of pumpkin. Thus in Kerala eventhough the teleomorph of the fungus is not seen it can survive and perennate as anamorphic forms on perennial cucurbitaceous crops. The role of weed plants in harbouring the pathogen during new crop season needs further investigation.

Powdery mildew fungi are unique: they thrive under dry conditions and the conidia of most species do not require free water for germination. Yarwood (1950) suggested that this is possible by their relatively large water content. This concept of self sufficient conidium is also supported by large volume of vacuoles in which water appears to be stored (Mitchell and Mc Keen, 1970) and the gelatinous sheath which makes the

cell walls impervious (Mc Keen et al., 1967). In the present study conidia failed to germinate in presence of liquid water at different temperatures. This observation is in accordance with the findings of Zaracovitis (1965); and Peries (1962). They observed that immersion in water for as brief a period as three minutes can kill fifty per cent of the conidia.

In the results of the present study maximum spore germination was observed when the spores were kept under humid chamber and when the spore dusted slides were kept over a drop of water. The relative humidity inside a humid chamber was about 100 per cent. The optimum humidity required for germination of E. cichoracearum was 100 % (Manners and Hossain, 1963) and it was more than 95 percent for S. fuliginea (Hashioka, 1937).

Maximum germination of conidia of S. fuliginea was at 25°C, followed by 20°C. This finding is in agreement with that of Hashioka (1937) who observed that cucurbit powdery mildew germinated best at a temperature range of 22° to 31°C. Reduction in germination percentage was observed at 10°C and 30°C when the spores were incubated at very high relative humidity. In experiments carried out at high relative humidity, Longree (1939) found the minimum, optimum and maximum

temperature for germination of S. pannosa to be 3° to 5°C, 21°C and 33°C respectively.

The conidia on germination failed to produce appressoria on glass slides or on leaf surface. Sharma and Khan (1991) also did not observe development of appressoria in germinating conidia collected from cucurbits.

During August - November 1990 season 57 lines of pumpkin were screened for the resistance. Based on this they were classified into three groups: resistant, moderately resistant and susceptible. All the lines were suscepible, but there was difference in intensity and the age at which the plant became susceptible. The highest disease index was noticed on line P46 and least on line P25. Based on this preliminary screening another experiemnt was conducted using 28 lines consisting of nine susceptible, 9 moderative resistant and 10 resistant lines. There was significant difference in the disease intensity among the lines during the season also. The line P11 and P33 were highly susceptible to powdery mildew disease during 1990 season but it showed resistance when planted during 1991 - 92 season. Similarly P86 and P21 which were resistant showed susceptible type symptoms during the same period.

P7 which was moderately resistant during 1990, became resistant in the next year. P1, P5 and P17 were moderately resistant in first season became susceptible in the second season.

P30 which was resistant in 1990 season continued to be resistant in the 1991-92 season also. Thus among 57 lines screened only line which showed consistency in resistant reaction to powdery mildew disease was P30. This line is a local selection from Kottayam. P13, was susceptible during both seasons. Thus it is clear that except some lines, majority of others did not have the stability in character regarding the resistance to powdery mildew. A susceptible variety may show resistant type of reaction when the conditions for infection are not suitable or when the inoculum load is not sufficient or if the races of the pathogen present are not the one which is pathogenic or due to the nutrient status of the soil in which the crops are cultivated (Yarwood, 1978; Khan,1989). These type of apparent resistance of a susceptible variety are not always genetically controlled but the external environmental conditions make a susceptible variety resistant. A variety could be called as resistant only if they show the resistant characters consistently under different sets of

environmental conditions and under uniform inoculum pressure. Thus in the present study in most of the lines the resistance was not governed by genetic make up of the plants. Exceptions to this may be variety P30 which showed uniform resistant reaction in both the seasons. This line should be cultivated under different agroclimatic condition of the state under heavy inoculum pressure to confirm its resistant nature.

A number of atmospheric factors are found to favour cucurbit powdery mildew. In order to find out the effect of different atmospheric factors on disease development, pumpkin crop was grown continuously for a period of one year. During this period four crops of pumpkin were raised. The pattern of disease development varied in different seasons. First crop was free of disease. During second crop season disease occurred after 63 days of planting and in the third and fourth crop season disease was evident even during the initial stages.

In general, correlation between the intensity of disease and rainfall of the area was found. As the number of rainy days per cropping season increased, incidence and intensity of the disease decreased. During the first cropping season which extended for 112 days,

60 days received rain. This might have been one of the reasons for not observing powdery mildew disease during that season. The indirect influence of the rainfall on disease development is clear during the second cropping season also. There was continuous rain during the first 56 days of crop growth and during this period disease was not noticed. Then there was a dry spell for a period of 14 days and during this period there was mild infection. Subsequently intermittent rains during the next three weeks resulted in the disappearance of the disease. From 96 days onwards till the harvest, the intensity of rainfall was mild and there was a few days of dry spell which again accelerated the disease development. For a disease to develop, there should be suceptible host, virulent pathogen and favourable climatic conditions. In the present context, the fact that the crop is susceptible is clear because it got infected from 63 days after planting to 73 days and from 96 days till the harvest. The fact that the pumpkin plants are susceptible to the disease from the cotyledonary stage onwards has been proved in the experiments on inoculation studies. The fact that the plant got infected shows that virulent inoculum is available to cause infection. So one of the reasons for the crops not getting infected upto 56 days and from 73 days to 96 day is due to unfavorable climatic conditions especially rain. The injurious effect of rain on powdery

mildew have been demonstrated by Perera and Wheeler (1975). Rain mechanically removes or injure mycelium and spores and it favours the common parasites of the fungus present on the phyllosphere microflora to develop (Yarwood, 1936).

Rainfall is not always inhibitory. In rare cases, it can indirectly favour powdery mildew infection causing a cooling of the environment by reducing the light intensity and by favouring the growth and inherent susceptibility of the host (Butt, 1978). This positive role of mild rainfall might have helped in the development of mildew infection during early cropping periods of the third crop. In the fourth crop there was a continuous dry spell from the day of planting onwards and the maximum disease intensity was oberved during this cropping season. These findings clearly indicate the significant negative role of rainfall on the disease development.

The influence of other weather parameters like temperature, relative humidity and sunshine hours were not as significant as that of rainfall. In order to find out the role of these weather prameters path analysis was carried out at three different stages of the crop namely 20 day old, 63 day old and during the

first occurrence of the disease. When path analysis was conducted on disease development of plants after 20th and 63rd day of planting, the correlation of these parameters with disease score was less in magnitude, because all the direct effect and indirect effect were high and the residual factors were not estimable. So it may be concluded that disease score is influenced by climatological parameters mainly before the onset of the disease.

The path analysis conducted during the initial stages/before the occurrence of the disease, the direct effect of maximum temperature on disease index was positive, its correlation with disease being negative. The negative correlation has resulted from its indirect effect via sunshine hours. The correlation between minimum temperature and disease index was significant and was through the negative direct effect via relative humidity and rainfall and positive effect via maximum temperature and sunshine hours. According to Schrodter (1963) "not the mean temperature, maximum or minimum temperature but the frequency of favourable and unfavourable temperature are decisive for disease development. The mean values of meterological data are only mathematical fiction without real relation to the development of fungi." The temperature influences

development of the pathogen via different ways like sunshine hours, relative humidity, etc. The correlation between the sunshine hours and disease development is negative which is through the direct effect of temparature. Dry weather is commonly hot weather and inhibitory effect of hot dry weather might be attributed to the dryness rather than more correctly to high temperature. Dry weather is also bright weather and slow development of mildew in this environment might be attributed to the dryness rather than more correctly to high light intensity (Yarwood et al., 1954). Longer exposure of a leaf to sunshine causes several factors unfavourable to the development of the pathogen. According to Toma (1974) germination of powdery mildew spore is checked in bright sunlight and favoured by diffused light.

The effect of relative humidity on the disease development is directly negative and its effect is also expressed through the negative effects of rainfall. The negative effect of rainfall is clear. Thus the path analysis studies indicated that the climatological parameters could be correlated with the disease development only during the early stages of the crop or at the time of initial disease development while it has no correlation during the later stages of crop

especially when the crop is already infected.

All the antifungal compounds including water spray gave significantly better control immediately after the spray. During the second week after spraying also a similar trend was oberved. But during this time the plants sprayed with water did not check the disease development compared to control. Three weeks after spraying only Carbendazim treated plots showed a better inhibition than the control. All other treatments are on par with the check.

The effectiveness of Carbendazim (Delp and Klopping, 1968; Suhag and Mehta, 1982; Ratnam et al., 1985; Mathur and Deftari, 1985; Bhatia and Thakur, 1989), Tridemorph (Pommer et al., 1969; Suhag and Mehta, 1982; Tehrani, 1984; 1987), wettable Sulphur (Yarwood, 1957; Sitterly, 1978; Gasanov, 1978; Donenbaeva, 1978; Behad, 1979; Tehrani, 1984; Ratnam et al., 1985; Bhatia and Thakur, 1989) and Hexaconazole (Shephard et al., 1986; Heaney et al., 1986) have been well documented. A second spray was necessitated as the incidence of the disease showed an increase. The lowest incidence of the disease at the time of second spraying was on Carbendazim sprayed plots, However, nonsystemic wettable Sulphur, was also as effective as carbendazim. Water spray showed a sudden reduction immediately after the first

spray, but there was no further reduction during subsequent periods. After second spray also water spray suddenly reduced the disease intensity. This shows that the water spray is effective only as a temporary measure. The inhibitory effect of water on spore germination has been documented by Perera and Wheeler (1975) and Zara covities (1965).

Traditionaly sulphur fungicides are generally used for the control of powdery mildew diseases eventhough some of the cucurbits are sensitive to sulphur. Pumpkin in the present study was not sensitive to sulphur fungicides.

Maximum yield of pumpkin was recorded from the plots which were sprayed with Tridemorph followed by wettable sulphur. The maximum reduction in the disease intensity was in Carbendazim sprayed plots. Tridemorph, however, gave less cost benefit ratio compared to water spray and sulphur application. The cost benefit ratio was lowest in Hexaconazole and Carbendazim sprayed plots. There were discrepencies among the cost benefit ratio and the actual yield increase and disease control by various fungicides. This obviously is due to the cost of different fungicides. The tridemorph spray was almost 5.5 times costlier than that of Sulphur. While difference between water spray and sulphur were 100 times.

In the present investigation the incidence of the disease was noted late in the season and hence the application of fungicides during the early stages of the crop was not necessary. Further it is clear from control study that the disease reducing ability of the water spray was less compared to the fungicide spray.

Hence, eventhough cost benefit ratio was the best in water spray, its effects on crop which received powdery mildew infection during the early stages of the growth needs to be studied before it could be recommended to farmers.

Summary

SUMMARY

The powdery mildew of pumpkin caused by Sphaerotheca fuliginea is an important disease of pumpkin in Kerala. The present investigation was taken up to study the detailed symptomatology, screening the lines available to disease resistance, influence of various climatic factors on disease development and to derive an effective method to control the disease.

Detailed symptomatology of the disease was studied by inoculating the pathogen. The disease developed as tiny white round or irregular superficial growth on stems and leaves. The lesions increased in size, coalesced and covered both surfaces of the leaves and stem. The severely affected leaves turned brown, shrivelled and in few cases resulted in defoliation. The time taken for getting infection varied in resistant, moderately resistant and susceptible plants.

From the cross inocultaion studies it was clear that the causal organism of pumpkin powdery mildew cannot infect noncucurbitaceous crops and weeds. Even in cucurbits it could infect only bittergourd and coccinia. The powdery mildew seen in bittergourd and coccinia could reinfect pumpkin plants. The pathogen

was observed only in its anamorph, teleomorph was not observed. The conidia of the pathogen had ovoid or circular shape. Conidial size varies from 30 to 34.2 x 15.4 to 18.6 micro meter. The conidia from different host plants did not show variation in their shape and size. Fibrosin bodies, the characteristic feature of S. fuliginea was observed only from the spores collected from powdery mildew of pumpkin, bittergourd and coccinia. The conidia collected from pumpkin germinated occasionally by producing forked germ tubes without formation of appressoria. Hence the causal organism of powdery mildew of pumpkin was identified as S. fuliginea.

Spore germination was influenced by temperature and moisture. The maximum germination of the pathogen was at 25°c followed by 20°c, but germination was very poor in 10°c and 30°c. The spore germination was affected by the contact of water. When the spores were submerged in water they failed to germinate.

During 1990 August - November season, 57 lines of pumpkin were screened to get resistant lines. All the lines screened were susceptible, but their age at which they became susceptible and the intensity of the disease varied. Based on the disease intensity 26 lines were

grouped as resistant, 20 as moderately resistant and 11 as susceptible. During Novermber-February 1991 season 28 selected lines were again screened to confirm their susceptibility/resistant reaction to the disease. During second season also none of the lines were immune. Many lines showed difference in their response to the disease during both the season, while P30 showed resistant reaction during both the season.

Climatic factors like temperature, relative humidity, rainfall and sunshine hours was found to influence the disease development. Out of four crops raised for the study, the first crop was free of disease, because of the continous heavy rain. To find out the correlation between the climatic factors and disease, pathanalysis was conducted. It showed that climatic factors predisposed host to disease development. But during the later stages of the crop, influence of climatic factors was not marked.

Bioassay studies were conducted to find the effectiveness of various antifungal compounds in arresting spore germination. Carbendazim could arrest spore germination by about 94.2 percent.

Field experiment was conducted using the line P46 to find out the efficacy of five antifungal compounds and water spray in reducing the disease. The disease intensity were scored at weekly interval. At the end of one week after the first spraying carbendazim recorded the maximum disease reduction of 94.2%, while water spray even though better than the control was the least (48.9) effective. The observations taken 2 weeks after the first spray showed that the water spray couldn't arrest the pathogen significantly. Sulphur recorded the maximum reduction of the disease after the second spray. Among the treatments carbendazim was the best in reducing the disease intesity. Maximum yield was obtained from the plots sprayed with tridemorph. Cost benefit ratio was worked out and it showed that the most economic treatment was water spray (1:6) followed by sulfex (1:5.6) and the least were carbendazim and hexaconazole (1:2.5) treatments.

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Appendices

Appendix I.

Correlation matric of climatological parameters corresponding to the first occurrence of disease*

0.4620	-0.1801	0.0139	0.5175	-0.2769
0.7499	0.4546	-0.2570	-0.9166	
0.5632	-0.7542	-0.7997		
-0.7827	-0.7380			
0.5308				

This matrix corresponds to table 12 (I)

Appendix II

Analysis of co variance (Table 14)
Effect of antifungal compounds on the disease intensity of powdery mildew of pumplkin

ANCOVA I (One week after spraying)

Source	DF	SSX	SSY	SSXY
Replication	3	11.40082	6.07721	7.810242
Treatments	6	23.51203	61.56281	29.80365
Error (Un.adj.)	18	64.38336	23.98477	26.78742

F (reg) = 14.7566

ANOVA TABLE OF y (Adjusted for x)

Source	DF	S S	MSS	F
Replication	3	1.427587	0.4758622	0.630567**
Treatments	6	36.2721	6.04534	8.00423 **
Error	17	12.83957	0.755268	

CD (5%) = 1.3355 **SE = 0.4345**

$F_{6,17}$ = 8.0042 **Ranking** $\underline{T_7, T_6, T_3, \overline{T_2, T_5, T_4, T_1}}$

ANCOVA II (Two weeks after spraying)

Source	DF	SSX	SSY	SSXY
Replication	3	11.40082	4.209107	6.857819
Treatments	6	23.51203	47.93991	10.22958
Error (Un adj.)	18	64.38336	15.78769	8.31308

F (reg) = 1.240107

ANOVA Table of y (Adjusted for x)

Source	DF	SS	MSS	F
Replication	3	2.245484	0.748494	0.8647636 **
Treatments	6	45.10147	7.516912	8.684569 **
Error	17	14.71432	0.8655481	

CD (5%) 1.4296 **SE = 0.4651**

$F_{6;17}$ **= 8.6845** **Ranking** $\overline{T_7, T_6}, T_5, T_1, T_3, T_4, T_2$

ANCOVA III (Three weeks after spraying)

Source	DF	SSX	SSY	SSXY
Replication	3	11.40082	22.57575	13.51666
Treatments	6	23.51203	22.698	10.24622
Error (Un adj.)	18	64.383336	53.70563	24.95667

F (reg) = 3.734928

ANOVA Table of y (Adjusted for x)

Source	DF	SS	MSS	F	
Replication	3	12.71786	4.239286	1.636734	**
Treatments	6	18.27278	3.045464	1.175807	**
Error	17	44.03178	2.590105		

CD (5%) = 2.4731 **SE = 0.8046**

$F_{6,17}$ = 1.175807 **Ranking** $\underline{T_7 \cdot T_6, T_4, T_5, T_3, T_2}, T_1$

ANCOVA IV (One week after second spraying)

Source	DF	SSX	SSY	SSXY
Replication	3	8.567382	2.340332	3.087158
Treatments	6	31.23413	45.95175	36.15924
Error (Un adj.)	18	39.99371	19.14734	22.61377

F (reg) = 34.17384

ANOVA Table of y (Adjusted for x)

Source	DF	SS	MSS	F	
Replication	3	1.524707	0.5082356	1.358328	**
Treatments	6	10.34231	1.707052	4.562326	**
Error	17	6.36076	0.3741627		

CD (5%) = 0.9702 **SE = 0.30584**

$F_{6,17}$ = 4.5623 **Ranking = $T_7, \overline{T_6, T_3}, T_2, T_4, T_1, T_5$**

ETIOLOGY AND MANAGEMENT OF POWDERY MILDEW DISEASE OF PUMPKIN (*Cucurbita moschata* Poir.)

By

VEENA, S. S.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

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1992

ABSTRACT

The present investigation was undertaken to correctly identify the causal organism of pumpkin powdery mildew disease in Kerala and to find out the environmental factors responsible for the occurrence of infection. Attempts were also made to screen different pumpkin lines to identify resistant ones to powdery mildew. The efficacy of different antifungal compounds against the disease were also tried.

The study was conducted during 1990 -92 at College of Horticulture, Vellanikkara. Detailed symptomatology of the disease was worked out. The time taken for getting infection varied in resistant, moderately resistant and susceptible plants. The fungus causing powdery mildew disease of pumpkin in Kerala was identified as Sphaerotheca fuliginea (Schlecht) Poll. Teleomorphic stage of the pathogen was not observed.

From the cross inoculation studies it was clear that S. fuliginea from pumpkin cannot infect non-cucurbitaceous crops and weeds. Even in cucurbits it could infect only bittergourd and ivy gourd.

The optimum temperature for germination of S. fuliginea was at 25°C followed by 20°C. The spores germinated at very high relative humidity while it was inhibited in water.

Preliminary screening of 57 lines of pumpkin was conducted during 1990 season and 28 lines were selected from this for further studies. All the lines were found infected in both the seasons. But the degree of susceptibility and the age at which they became susceptible were varied. Only the line P_{30} showed consistency in resistant reaction.

Climatic factors like temperature, relative humidity, rainfall and sunshine hours were recorded for an year and was correlated with the disease severity. Incidence of the disease was indirectly correlated with rainfall. However, the influence of climatic factors were more pronounced during the initial stages of the crop. Laboratory and field experiments were conducted to find out the efficacy of five antifungal compounds and water on S. fuliginea. All the chemicals and water inhibited spore germination at varying concentrations. Effect of those chemicals and water were also tried under field conditions on line P. 46. At the end of

one week after spraying Carbendazim recorded maximum disease reduction. Disease at the time of harvest was least in Sulfex treated plants. Even water spray could reduce the disease considerably. Maximum yield was recorded from plants sprayed with Calixin. The best cost effective method to check powdery mildew infection of pumpkin was by spraying water.