VARIETAL SCREENING, HOST RANGE AND CONTROL OF DOWNY MILDEW OF BITTERGOURD (*Momordica charantia* L.) CAUSED BY *Pseudoperonospora cubensis* (BERK. & CURT.) ROSTOW

By

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THESIS

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COLLEGE OF HORTICULTURE

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DECLARATION

I hereby declare that the thesis entitled '**Varietal screening, host range and control of downy mildew of bittergourd (*Momordica charantia* L.) caused by *Pseudoperonospora cubensis* (Berk.& Curt.) Rostow**' 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, fellowship, associateship or other similar title, of any other university or society.

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CERTIFICATE

Certified that the thesis entitled '**Varietal screening, host range and control of downy mildew of bittergourd (*Momordica charantia* L.) caused by *Pseudoperonospora cubensis* (Berk. & Curt.) Rostow**' is a record of research work done independently by **Miss.Mini Simon**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of **Miss.Mini Simon**, a candidate for the degree of **Master of Science in Agriculture** with major in Plant Pathology, agree that the thesis entitled '**Varietal screening, host range and control of downy mildew of bittergourd (*Momordica charantia* L.) casued by *Pseudoperonospora cubensis* (Berk. & Curt.) Rostow**' may be submitted by Miss.Mini Simon in partial fulfilment of the requirement, for the degree.

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INTRODUCTION

Vegetables are rich and comparatively cheaper source of vitamins, proteins, carbohydrates and minerals besides having medicinal values. India produces largest quantity of vegetables next to China. Also, it grows maximum number of vegetable crops due to diversity of agroclimatic conditions. Among the various vegetables, cucurbits are the largest group of summer vegetables grown all over India. All the cucurbit vegetables are fair source of Thiamine and Riboflavin.

Bittergourd (*Momordica charantia* L.) is one of the most popular cucurbitaceous vegetable and it is getting popularity day by day due to large scale cultivation and use. It is widely distributed in India, China, Malaysia and Tropical Africa. Due to its high nutritive value and medicinal properties it is considered as a valuable vegetable. It ranks first among cucurbits in respect of iron and vitamin C content.

Major factor which seriously impede the vegetable production in our country is the problem of pests and diseases. Among the various fungal diseases of cucurbits, downy mildew is one of the important and common disease. This disease was responsible for the loss of two third of late varieties of cucumber in United States and 80 per cent of melons in Austria.

In India, downy mildew was first observed in 1910 on species of *Luffa* and *Trichosanthes*. Heavy damage of bittergourd due to outbreak of downy mildew disease was observed in Assam in 1992 (Phookan and Gogoi, 1995). Downy mildew of cucurbits is caused by *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow. Majority of the cucurbitaceous crops are parasitized by this pathogen.

Although various workers have studied different aspects of downy mildew of curcurbits in other parts of India, this disease has not received any attention in Kerala so far. In the recent past, downy mildew disease has been found to be the major constraint for bittergourd cultivation in Kerala during monsoon season. Investigation was hence carried out on the following aspects of downy mildew:

1. Reactions of different bittergourd varieties/lines to *Pseudoperonospora cubensis*
2. Host range of bittergourd downy mildew pathogen and existence of physiological races of *P. cubensis* infecting bittergourd
3. Effect of certain fungicides and botanicals in reducing downy mildew infection
4. Estimation of crop loss due to downy mildew disease.

Review of Literature

REVIEW OF LITERATURE

The term 'mildew' was employed initially in the United States to denote a group of parasitic fungi with little in common except their appearance as a delicate out growth caused by proliferation and fruitification of mycellium on the surface of the necrotic tissue. The term 'mildew' followed by downy mildew was very quickly adopted in Europe at the time of the introduction of *Plasmopara viticola* (Berk. & Curt.) Berl. from North America. At about the same time, Planchon (1879) suggested calling the disease 'false oidium or mildew'. It was Riley (1886) who first proposed a distinction between the 'downy mildew' produced by certain fungi of the Peronosporaceae.

Shurtleff (1973) reported that though downy mildews of dicotyledonous plants are most serious in temperate zones, the main damage area of the downy mildews on Graminae is clearly in the tropics and subtropics. This can probably be explained by the significant thermophilic reaction on oospore germination. Downy mildew disease was responsible for the loss of two third of late varieties of cucumber in United States and of 80 per cent of melons in Austria.

Downy mildew of cucurbits is widespread in tropical regions all over the world, in some semi-arid regions such as Southern USA, in the Middle East, and in temperate regions of America, Europe, Japan, Australia and South Africa (Palti, 1974).

In India, downy mildew was first observed in 1910 on species of *Luffa* and *Trichosanthes* at Pusa and on melons in Punjab (Butler, 1918). Heavy damage

of bittergourd due to outbreak of downy mildew disease was observed in Assam in 1992 (Phookan and Robin Gogoi, 1995).

2.1 Causal organism

Downy mildew of cucurbits caused by *Pseudoperonospora cubensis* (Berk. & Curt.) Rostow is a common and important disease. This parasite is an interesting example of a fungus, described first on what seems to have been a wild plant, and considered to be of no economic importance, which by its gradual spread to other countries and the damage that it has caused on new hosts has won for itself a position amongst the major enemies of cultivated plants.

It was first described from Cuba in 1868. Nothing more was heard of it until 1889, when a new blight on cucumbers in New Jersey was found to be due to this fungus. This pathogen causing downy mildew occurred every year and caused severe damages during the years of favourable climatic conditions.

Walker (1952) pointed out that the mycelium lived intercellularly in the host with haustoria being intracellular, and sporangiophores which arise in groups through the stomata, are branched and produced sporangia on the tips. He also noticed that sporangia are greyish-purple in mass, ovoid, and have a papilla at the distal end, and they germinate by producing biciliate zoospores, which in turn produce germ tubes that penetrate through the stomata.

Infection commences when free moisture is present on a leaf on which sporangia have alighted (Iwata, 1938). Cohen and Rotem (1969) reported that sporulating potential is highest in chlorotic lesion and negligible on either greenish or necrotic lesions. Pathogen required wet plant surface for conidial infection

(Royle, 1976) and the optimum temperature for sporangial germination was found to be 15-18°C (Kuznetson, 1980). Shetty *et al.* (1982) pointed out that pollen of *Luffa acutangula* has a stimulatory effect on the germination of the downy mildew pathogen. Spraying leaves with a mixture of pollen and sporangial suspension enhanced the development of lesions. Peterson (1986) reported that rainy weather after mid summer favoured *P. cubensis*.

2.2 Epidemiology

Although the downy mildew pathogen [*Pseudoperonospora cubensis* (Berk. & Curt.) Rostow] cannot over winter in areas with temperatures below O°C, it can thrive in both warm and cool temperatures. Humidity is the most important factor in the establishment of this disease and this makes it particularly important in the humid environment encountered in the eastern United States and other parts of the world.

Palti and Chorin (1964) observed that the development of downy mildews in Israel during the rainless summer and autumn months depended on the duration of dew. This was 9-10 h in June-July when nights are short and morning evaporation is rapid, and 12-13 h in September-October with longer nights and slower evaporation. The spread of *P. cubensis* under these conditions was explained by the findings that a proportion of the sporangia released during day time could survive for more than 22 h except at temperatures of 22°C and higher and were consequently able to infect their host during the dew period in the following night (Cohen and Rotem, 1971a; Rotem *et al.*, 1971). Sporulation is reported to be most favoured by darkness, continuous wetness and temperatures between 10 and 25°C (Tarr, 1962).

According to Cohen and Rotem (1971b) downy mildews, are able to sporulate repeatedly for several successive nights on the same lesions.

Sporangia of *P. cubensis* lose much of their capacity to germinate when sprayed on to leaves and allowed to dry immediately (Cohen and Rotem, 1971; Cohen *et al.*, 1974). Thus rainfall, or in some cases sprinkler irrigation, can be considered to be the limiting factor for most downy mildew epidemics based on conidial infection (Palti and Rotem, 1971). Varady and Ducrot (1985), observed that the disease spreads by wind-borne spores, which germinate in the presence of water on mature leaves.

Environmental conditions after the appearance of sporangia were most important in influencing primary infection, followed by conditions, at sporulation and during the ensuing incubation period. These findings enabled exact forecasting of outbreaks in 1987 (Bedlan, 1987). Rainy weather in Sweden in late summer favoured out breaks of *P. cubensis* on cucumbers (Norin, 1987).

Findings of Ullasa and Amin (1988) showed that day temperature of 25-30°C, night temperature of 15-21°C and relative humidity 75 per cent favoured the infection of *Luffa acutangula* by *P. cubensis* and infection caused a decrease in the yield by 61 per cent.

Singh and Singh (1992) stated that hot, dry weather had a significant influence on the spread of *P. cubensis* in muskmelon.

2.3 Host resistance

The use of resistant varieties is a simple, effective and economical means of controlling plant diseases. A search on relevant literature indicated no information about the resistance in bittergourd against *P. cubensis*. However, resistance against *P. cubensis* have been reported in various other cucurbitaceous crops by many workers.

2.3.1 Resistance on cucumber

The Indian cucumber cultivar Bangalore was the basis for the development of resistant cultivars in cucumber in the U.S.A. Later, Chinese Long and PI 197087 have been used. Out of 100 varieties of cucumber screened for downy mildew resistance, only a Chinese variety (Chinese Long), introduced in 1933 was found to be resistant (Roque and Adsuar, 1938, 1939). Using Chinese Long, two resistant lines Puerto Rico 39 and 40, were distributed in 1940. These were used in breeding programmes in South Carolina which led to the development of Ashly, Palmetto and Santee.

Blasquez (1970) screened 18 promising cucumber varieties and found that only Poinsett and Cherokee were resistant to downy mildew caused by *P. cubensis*. According to Cohen (1976) only Poinsett and Chippa were highly resistant and stable under high inoculum load.

Sambandam *et al.* (1979) tested the reaction of 26 *Cucumis* spp. to downy mildew under natural infection and observed that Buduma Types 1, 2 and 3, Phootee, Goomuk, Nakkadosa and Ex-2 were resistant to *P. cubensis*.

Pivovarov (1984) assessed 1048 accessions of cucumber of diverse origin for resistance to downy mildew under artificial and natural infection, only Hatuey I, Sadao Russio, Heiva and TSKhA line 114474 were most resistant and none was immune.

According to Pivovarov and Kudelic (1985), out of 162 lines of cucumber assessed under natural epiphytotic conditions in the Havana area for resistance to *P. cubensis*, no immune varieties were found and highest resistance was shown by Heiva, Sado Rishu and Shumoshizaza with Mid, line 1144-74, F_1 P_{240}-75 and Shimoksuki Aonaga Jibai being relatively resistant.

Krivchenko *et al.* (1986) assessed 1644 accessions of cucumber from 47 countries, under both natural and artificial conditions and observed that Poinsett, Fixle, Carolina, Polaris, Calipso, Green Spear 14, a local Indian variety (Vr.K 1509) and MSU 9410 were resistant to downy mildew disease.

Resistance in many introduced cucumbers was studied over three years in field trials by Neykoy and Dobrev (1988) and they reported Simo si radzu from Japan and Bulgarian cultivars as the least resistant.

Tsyplenkov (1990) tested 13 cucumber and six *Cucurbita* varieties for resistance to *P. cubensis*. Resistance was observed in cucumbers Hatucy, Mig and Wisconsin SR_6 and the *Cucurbita* varieties Obrazets and Kubanskaya. Fairly high resistance to *P. cubensis* was also shown by the cucumbers TSKh A98, Early White Spine and Delikates.

Yurina *et al.* (1990) studied cucumber accessions for resistance to *P. cubensis* in the Non-chernozem zone of European Russia and reported that Hokus, Higanfushinari, Long Green, Shimo Shirazu, Datsy-gua, Syao-tsy-gua, Wisconsin SMR 12, Stono F_1, Breso F_1, Nankinskil, Zelenyl, Summer Prolific, Pioner, Wisconsin. SMR 18, Mid. Natsukodze, Zya-Stet-ga, Beleir F_1 and Autumn Green were most resistant.

Medvedev *et al.* (1991) tested more than 70 released cucumber varieties and hybrids in the Krasnodar area of European Russia for resistance to downy mildew and the varieties like Konkurent, Parad, Dekan, Vadolei, Beregovoi, F_1 Brigadnyi, F_1 Kontaki, F_1 Rodnichok, Avangard 121, Dal'nevostochnyi 6, Dal'nevostochnyi 27, and Mig showed relative resistance. They also tested more than 2500 accessions from 45 countries for resistance against *P. cubensis* and the most resistant lines were Sadaorishu Mid, Autumn, Green, Mestnyi 502786, F_1 Lunzakhuan, F_1 Dzhuntsin 1101 and a local variety from Vietnam.

Marinkovic *et al.* (1992) screened 25 cucumber genotypes of *P. cubensis* under field conditions and observed that lines S-440-S, V-33, MM-76 and pickling hybrids L-PMS, L-78, PMS-78 F_1 and Pannonia F_1 were most resistant. Wessel-Beaver (1993) evaluated 343 accessions of *Cucurbita moschata* for resistance to downy mildew and recorded field resistance in 45 accessions. All resistant accessions were from Central America, mainly Mexico, with exception of two PI from India.

Doruchowski *et al.* (1994) reported that cucumber F_1 hybrids Aladyn, Heron, Edyp, Parys and Cezar developed in 1991 in Poland showed tolerance to downy mildew. Resistance to different cucumber genotypes to *P. cubensis* were

tested by Komnenic *et al.* (1995) and pointed out that the line S-440-S and hybrids Slicer Astrea F, Nastasja F and Regal F were most resistant to downy mildew.

2.3.2 Resistance on melons

The first mildew-resistant muskmelon was introduced by Ivanoff (1944) as Texas Resistant No. I followed by Georgia 47, Rio Sweet, Edisto, Homegarden, Seminole, Florigold, Florisun and Floridew (Walker, 1965). Sambandam *et al.* (1979) observed that the muskmelon cultivars Annamalai, Edisto, Harvest Queen, Early Gold, Planter's Jumbo and Gulf stream were resistant.

Pitrat and Blancard (1988) pointed out that muskmelon breeding line MRI was resistant to all isolates tested, while PII 64323 and PI 414273 possessed moderate resistance which is controlled by different genes from those in the line MRI.

Lebeda (1991) studied six muskmelon lines for resistance to eight isolates of cucurbit downy mildew (*P. cubensis*) originating from cucumbers and found that only line MRI was highly resistant. This line was also resistant to powdery mildew under green house and laboratory conditions.

Response of melon breeding lin e (pickling melon, *Cucumis melo*) to *P. cubensis* was evaluated by Cohen *et al.* (1995) and reported that two lines, P22a and P6a-3 were relatively tolerant to downy mildew. Dhimon *et al.* (1995) evaluated four muskmelon genotypes viz., MR-12, Hara Madhu and Punjab Sunehri and the F_1 hybrid Punjab hybrid for their reaction to downy mildew (*P. cubensis*) and observed that MR-12 showed the least intensity of the disease and gave highest marketable fruit yield.

Pans and More (1995) screened melons for resistance to downy mildews and reported that wild *Cucumis species, C. figarei* exhibited high level of resistance. Phoot or snapmelon (*Cucumis melo* var. *momordica*) was highly resistant and Iroquois was moderately resistant to downy mildew.

2.3.3 Resistance on bottlegourd

Ram and Pandey (1995) screened 57 lines/genotypes of bottlegourd against *P. cubensis* in field conditions and found that PDVRBG-4, PDVRBG-5, PDVRBG-6, PDVRBG-7, PDVRBG-8, PDVRGB-9, PDVRBG-14, PDVRBG-66, IC-144389, IC-92372, IC-92426, IC-92428, IC-92467 and U-10-316 were resistant.

2.4 Host Range

Downy mildew of cucurbits caused by *P. cubensis* (Berk. and Curt.) Rostow is a common and important disease. Many workers reported that *P. cubensis* infecting cucurbits had wide host range. There is no evidence that any wild host is important in the disease cycle of *P. cubensis* eventhough it has been reported from about 40 wild and cultivated species of Cucurbits.

Sydow and Butler (1916) and Butler (1918) reported *P. cubensis* on leaves of *Luffa acutangula, Luffa aegyptica, Trichosanthes dioica* and *T. cucumerina* from Pusa, Bihar. Uppal *et al.* (1935) noted *P. cubensis* on *Trichosanthes dioica*, from Bengal and on *Cucurbita maxima* from Poona.

P. cubensis from melons have been reported by Bouriquet (1951) from Madagascar. Ellis (1951) reported that *P. cubensis* developed slowly on susceptible

cucumber than on melon. Parris (1951) observed downy mildew on water melon near infected melon plots. Ramakrishnan *et al.* (1953) observed *P. cubensis* on *Luffa acutangula, Cucumis sativus, C. melo* and *T. anguina* from Coimbatore. Venkatanarayan and Venkatakrishnaiah (1953) and Rangaswami *et al.* (1970) reported *P. cubensis* on *Citrullus vulgaris* and *Lagenaria vulgaris* from Bangalore and Mysore respectively. Roy (1965) noted this pathogen on leaves of *Cucumis sativus* L., from Madhya Pradesh and Assam.

P. cubensis causes downy mildew on cucurbitaceous vegetables only, chiefly on cultivated species of *Cucumis* (cucumber, melon), *Cucurbita* (squash, marrow, pumpkin) and *Citrullus* (watermelon) and less frequently on approximately 40 wild and cultivated species of 18 other genera like *Benincasa, Lagenaria, Luffa, Momordica, Trichosanthes* (Palti, 1975).

Bains and Jhooty (1976) observed the presence of *P. cubensis* on different cultivated and wild cucurbits. They found that downy mildew was severe on the leaves of muskmelon, longmelon, chibbher (wildmelon), cucumber, sponge-gourd and ridgegourd. They also noticed slight infections of *P. cubensis* on bitter-gourd, pumpkin, vegetable marrow and ashgourd. However it was not observed on the leaves of roundmelon and colocynth. Bains *et al.* (1977) reported *Melothria madraspatana*, as a new host of *P. cubensis*.

Palti and Cohen (1980) published a list of host plants of *P. cubensis* and noticed that *Cucumis sativus* L., *Cucumis melo* L., *Cucurbita spp.* and *Citrullus vulgaris*, were the most important cultivated species attacked.

2.5 Physiological races of *P. cubensis*

The wild and cultivated cucurbits susceptible to the pathogen elsewhere in America (Clinton, 1905), were resistant in Massachusetts (Doran, 1932). The sudden break down of resistance in the cucumber cultivar Palmetto in South Carolina in 1950 supports the evidence for the existence of races of *P. cubensis* (Epps and Barnes, 1952).

Hughes and Haltern (1952) observed the existence of two separate biological forms of the fungus on cucumber in South Carolina and on watermelon in Georgia.

Iwata (1953) observed three races of the pathogen (*Cucumis* type, *Cucurbita* type and *Benincasa* type) in Japan and none of them was found attacking cultivar *Citrullus vulgaris*.

Bains and Jhooty (1976) observed that *P. cubensis* from muskmelon was not pathogenic to ashgourd and pumpkin, whereas isolates from various cucurbits were pathogenic to muskmelon.

Lebeda (1992) reported that out of 56 accessions belonging to 19 species of *Cucumis*, none was resistant to any of seven isolates of *P. cubensis* isolated from cucumber.

2.6 Disease Management

The downy mildews are included among the most devastating plant diseases. So efforts to control them have been made since the early phase of plant

protection. The effect of plant protection chemicals and botanicals on the control of downy mildew disease is an aspect of practical importance and scientific interest. Effect of fungicides on downy mildew of cucurbits have been reported by many workers.

2.6.1 Cucumber

Copper fungicides have long been used to protect cucurbits from downy mildew (Doran, 1932; Van Haltern, 1933). Cohen (1979) studied the effect of two systemic fungicides on *P. cubensis* of cucumbers. Propyl (3-(dimethylamino)-propyl) carbamate monohydrochloride (SN 66752, Propamocarb) and prothiocarb (SN 41703) exhibited systemic activity against *P. cubensis*. Aqueous solutions of the chemicals applied as soil drenches to potted cucumbers protected them from mildew for 25 days.

Effect of fungicides was tested against *P. cubensis* in cucumber by Angelov (1981) and found that all fungicides tested were strongly inhibitory in the laboratory. However, in the field, only perocin, Anthracol (Propinch) and polymarcin were effective and weekly spraying with 0.4 per cent perocin is recommended. Sumner *et al.* (1981) observed that when an epidemic of downy mildew of cucumber developed on a susceptible cultivar, chlorothalonil and mancozeb were found most effective in lowering infection rate and reducing disease severity.

In Israel, Sumoucha and Cohen (1984) investigated sensitivity of mancozeb to metalaxyl-sensitive and metalaxyl-resistant isolates of *P. cubensis* in cucumber and reported that while mancozeb efficiently controlled downy mildew in

cucumbers inoculated with three metalaxyl sensitive isolates, it failed to do so when the plants were inoculated with five other metalaxyl-tolerant isolates. In a field experiment in Moldova, Romania, Ridomil plus-45 (0.5%) (metalaxyl), Ridomil MZ-72 (0.25%) (metalaxyl), Mikal cu (0.6%) (fosetyl) and Sandofan C (0.25%) (copper oxychloride) gave control to *P. cubensis* on cucumber cultivars (Manole, 1988). Rondomanski and Wozniak (1989) found that chlorothalonil was very effective against *P. cubensis* infecting cucumber.

Chaban *et al.* (1990) obtained most effective control with Arcerid [metalaxyl + Poly karbacin (metiram)], zineb and mixtures of Ridomil (metalaxyl) with Cuprosan (Pyrifenox and copper oxychloride applied four to five days before the appearance of first symptoms. Fan *et al.* (1994) studied the efficacy of systemic and contact fungicide mixture (ND-901, ND-903) in controlling downy mildew of cucumbers and found out that ND-901 and ND-903 gave better control of *P. cubensis* than the standard fosetyl.

Akrobat MC (dimethomorph) and tank mixtures of dimethomorph + Daconil (chlorothalonil), dimethomorph + copper oxychloride and dimethomorph + Poly karbacin (metiram) were tested for the control of *P. cubensis* on cucumber by Golyshin *et al.* (1994) and they noticed that the best control was achieved with Akrobat MC (at 2 kg/ha) and dimethomorph + chlorothalonil (0.36 kg/ha + 1.8 kg/ha).

In the fungicide trials carried out by Merz *et al.* (1995) under field and green house conditions, Aliette (fosetyl A) was found to give good control of downy mildew (*P. cubensis*).

2.6.2 Melons

Schenck and Crall (1963) found maneb alone or maneb + zineb were most effective against downy mildew of muskmelon. Jhooty and Munshi (1975) carried out an experiment to find out the most effective fungicide for the control of downy mildew of melon. Out of nine fungicides, viz., Dithane Z-78, Dikar, Blitox, Blitare, Miltox, Thiride, Dithane M-45 each at 0.5 per cent concentration and Difolatan (0.2%) and Benlate (0.1%) tested, Dithane M-45 gave the maximum disease control with the lowest disease intensity.

Bains and Jhooty (1978) studied the efficacy of four fungitoxicants against *P. cubensis* on muskmelon and observed that the fungitoxicants Dithane M-45 (mancozeb), Dithane Z-78 (zineb), Difolatan (captafol) and Tricap-50 (copper oxychloride) did not eradicate established infection but Dithane M-45 significantly reduced sporulation.

Patel and Patel (1980) studied the effect of systemic and non-systemic fungicides on the control of downy mildew of muskmelon and found that the incidence of *P. cubensis* was most effectively reduced by Daconil 2787 (chlorothalonil) followed by Dithane M-45 (mancozeb).

Effectiveness of some chemicals against downy mildew of muskmelon was tested by Guncu (1986) and observed that the protective systemic mixtures Ridomil MZ-72 (mancozeb + metalaxyl) and Mikal (fosetyl aluminium + folpet) were more effective compared with Dithane M-45.

Brunelli *et al.* (1989) tested 13 fungicides against *P. cubensis* of which chlorothalonil applied before and after symptom appearance gave good control

followed by fosetyl Al. Copper oxychloride, folpet and thiram were found less effective.

Mahrishi and Siradhana (1990) tested metalaxyl and mancozeb mixtures for the control of downy mildew of muskmelon and observed that the best control was given by metalaxyl + mancozeb at 0.05 and 0.1 per cent respectively followed by Daconil (chlorothalonil), Dithane M-45 (mancozeb), Dithane Z-78 (zineb), Difolatan (captafol) 0.2 per cent and Blitox (copper oxychloride) 0.3 per cent. Two sprays of zineb 0.1 per cent with a 30-d interval was as effective as 4 sprays of mancozeb 0.2 per cent at a 7-d interval.

In laboratory, pot culture and field studies, mancozeb at 0.3 per cent provided good control of *P. cubensis* on musk melon when used as a protectant but failed to check established infections when applied 24 hours after inoculation. Formulations of acylalanines, eg. Ridomil MZ (metalaxyl + mancozeb), Galben M-68 (benalaxyl + mancozeb) and fosetyl aluminium showed good protectant and eradicant activity under artificial and natural infection. Acylon, Pulsan and Caltan were similarly effective. Ridomil MZ at 0.25 per cent had the longest persistance (8d) and best eradicant action (Thind *et al.*, 1991).

Khalil *et al.* (1992) tested the efficacy of five fungicides for the control of downy mildew on melon and reported that all the five fungicides gave adequate control, but the most effective treatments were Trimeltox forte (0.2%), Vitigran blue 0.3 per cent (copper oxychloride) and Dithane M-45 0.15 per cent (mancozeb).

2.6.3 Pumpkin

Mullins *et al.* (1993) reported that Bravo (chlorothalonil) + RH 3866

(myclobutunil) applied on a weekly or biweekly schedule, was effective for controlling downy mildew of pumpkin.

2.6.4 Spongegourd

Suhag *et al.* (1988) reported that a combination of seed treatment with Apron 2 g ai/kg seed, followed by two sprays of Ridomil or three sprays of Blitox at 20-day interval is better treatment for the possible management of downy mildew disease of spongegourd.

2.6.5 Effect of botanicals

Although downy mildew can be successfully controlled by fungicidal application, the increased use of these chemicals had led to the development of some resistant races, incidence of phytotoxicity and environmental pollution. In this context, use of plant extracts to control the downy mildew disease is relevant. A search on relevant literature indicated that so far there is no information on the effect of plant extracts on downy mildew disease of cucurbits. However, effects of plant extracts on disease control of other crops have been reported by various workers. Antifungal properties of some plant extracts were studied against *Thanatephorus cucumeris* by Lakshmanan *et al.* (1990) and revealed that aqueous extracts of *Allium sativum, Bougainvillea spectabilis* and *Azadirachta indica* were the most effective in inhibiting mycelial growth and sclerotial germination.

Pradeepa *et al.* (1990) studied the effect of six plant extracts on the growth of oyster mushroom (*Pleurotus ostreatus*) and observed that mycelial growth of *P. ostreatus* on PDA was considerably enhanced by extracts from *Cassia occidentalis, Lantana camara* and *Tithonia diversifolia*. They also noticed that

L. camara extract suppressed the competitive weed moulds *Aspergillus* and *Penicillium*. Singh and Dwivedi (1990) observed fungicidal properties of neem and blue gum against *Sclerotium rolfsii* and found that neem oil was the most effective on the volatile and non-volatile fractions tested against *S. rolfsii*.

Upadhyaya and Gupta (1990) studied the effect of some medicinal plant extracts on the growth of *Curvularia lunata* and reported that the ethanol extracts of garlic was most inhibitory to *C. lunata*, followed by those of *Ocimum sanctum*, *Datura alba* and aqueous extracts were less effective. Fungitoxic properties of flower extracts of some wild plants were tested by Sundrival (1991) and found out that the flower extracts of *Acacia arabica, Cassia fistula, L. camara, Rhododendron arboreum* and *Thevetia peruviana* inhibited spore germination and germ tube growth of *Alternaria solani* under *in-vitro* condition. Conidial germination remained completely inhibited by flower extracts from *L. camera*. Antifungal activity of plant products have also been studied by Mohan and Ramakrishnan (1991) on leaf blight of sorghum caused by *Exserohilum turcicum* and observed that the extracts of *Allium sativum, Lantana camara, Azadirachta indica* were highly inhibitory to spore germination and mycelial growth of the pathogen. Tewari and Nayak (1991) studied the activity of four plant extracts on three fungal pathogens of rice and reported that leaf extracts from *Piper betel* and *O. sanctum* could control *Pyricularia oryzae, Cochliobolus miyabeanus* and *Rhizoctonia solani*.

Patil *et al.* (1992) observed that water extracts of *O. sanctum* inhibited spore germination of *Rhizopus arrhizus* and *Botryodiplodia theobromae* under *in vitro* condition, which checked mycelial growth, reduced protein content and production of pectinolytic and cellulolytic enzymes.

Evaluation of some plant extracts for antifungal properties were investigated by Kazmi *et al.* (1993) and observed that hexane extracts of *A. indica* seed, turmeric and *Valeriana officinalis* rhizomes and seed oil of mustard and *Anethum graveolens* were inhibitory to *Alternaria alternata, Aspergillus flavus, A. fumigatus* and *A. asentii*, the fungi commonly causing spoilage of stored grain. Meena and Mariappan (1993) showed that leaf extracts of *A. indica, Metha arvensis, Aegle marmelos, Catharanthus roseus, L. camara, Pongamia pinnata, Vitex negundo* and *Nerium odorum* and flower extracts of *C. roseus* inhibited mycelial growth and spore germination of the seed borne mycoflora of sorghum such as *Alternaria tenuis, Aspergillus flavus, Curvularia lunata, Fusarium moniliforme* and *Rhizopus stolonifer*. The extracts of neem, *C. roseus* and *L. camara* were more effective than the other plant extracts tested.

Narasimhan *et al.* (1993) observed that neem seed kernel extract (5%) applied as foliar sprays at booting and 10 d later, gave control of *Sarocladium oryzae* under field condition and also increase in yield, compared to that achieved with 0.1 per cent carbendazim. Saruamangala and Dutta (1993) evaluated plant extracts of *A. indica, Calotropis gigantea, C. roseus, Eucalyptus* sp., *Parthenium hysterophorus* and *P. pinnata* against *Cerotelium fici* and *Cercospora moricola* and reported that *A. indica* was the most effective against *C. fici*, inhibiting uredospore germination by 91.2 per cent. Extracts from Eucalyptus and *C. gigantea* inhibited conidial germination of *C. moricola* by 91.5 and 91.3 per cent, respectively.

Treatments of infested banana fruits with aqueous leaf extracts of some medicinal plants (*Calotropis procera, V. negundo, L. camara, A. indica, O. sanctum, Ficus religiosa, Thuja orientalis, Argemone mexicana, Achyranthes*

aspera, Datura fastuosa and *Ricinus communis*) gave good control of the diseases development by *Botryodiplodia theobromae, Fusarium oxysporum, Helminthosporium spiciferum, Curvularia lunata, Aspergillus flavus* and *Trichothecium roseum* (Singh *et al.*, 1993).

Water extracts of leaves of *Vinca rosea, L. camara, O. tenuflorum, Solanum melongena, A. indica, Polyalthia longifolia, Aegle marmelos* and *Datura metel* showed antifungal activity against *Pyricularia oryzae* and *Helminthosporium oryzae* under *in vitro* condition (Ganguly, 1994). He also noticed that extract of *C. roseus* showed maximum inhibition of mycelial growth and spore germination of both fungi, followed by those of *P. longifolia* and *A. indica*.

Mahapatra and Tewari (1994) reported that ethanol and essential oil extracts of *O. sanctum* inhibited growth and multiplication of *Aspergillus niger* and *A. flavus* and increased seed germination of groundnuts.

Sobti *et al.* (1995) conducted a comparative study of fungicidal compounds and plant extracts against three pathogens of *Arachis hypogaea* (*Aspergillus niger, Macrophomina phaseolina* and *Aspergillus flavus*). The extracts of *A. indica, P. longifolia, O. gratissimum* were used in comparison with fungicides thiram and carbendazim and observed that all treatments significantly inhibited mycel ial growth of the fungi, with the fungicides being most effective followed by *P. longifolia.*

Materials and Methods

MATERIALS AND METHODS

Investigations on, host resistance to *Pseudoperonospora cubensis*, various collateral hosts of this pathogen, disease management and yield loss due to the downy mildew disease were conducted in the vegetable plot of Department of Olericulture, Vellanikkara. The soil of the experimental plot was laterite type. The experiments were conducted during the last week of May to first week of November, 1994. The crop received a total of 100.2 mm rainfall which was evenly distributed during actively growing period. The relative humidity ranged from 80-90 per cent. During this period, the minimum temperature ranged from 22-24°C and maximum temperature ranged from 28-32°C. In general, weather conditions were congenial for the natural occurrence of the disease. The variety 'Priya' was used for different studies except for investigation on resistance.

3.1 Screening of bittergourd varieties/lines for resistance against downy mildew disease caused by *Pseudoperonospora cubensis*

Bittergourd varieties/lines obtained from the Department of Olericulture, College of Horticulture, Vellanikkara were screened for their resistance to downy mildew disease during last week of May 1994. Experiment was laid out in Randomized Block Design with three replications. The following varieties/lines were used for the experiment.

Varieties	Source
1. Preethi (MC-84)	KAU, Vellanikkara
2. Priya	KAU, Vellanikkara
3. Pusa Do Mausmi	I.A.R.I.
4. Pusa hybrid	I.A.R.I.
5. Pusa Vishesh	I.A.R.I.
6. BG-6	Rahuri
7. RHRBG-4-1	Rahuri
8. RHRBG-5	Rahuri

3.1.1 Preparation of field

Land was prepared thoroughly and mounds of size 45 cm in diameter and 50 cm in height were taken at a spacing of 2 x 2 m. Well dried farm yard manure and fertilizers were mixed with top soil. Five seeds were sown in each mound. When the seeds germinated, three healthy seedlings were retained per mound and excess seedlings were thinned out. There were four mounds/replication. Plants were trailed on iron frames. Observation on disease incidence and disease intensity were recorded at 45 and 70 days after sowing. Lower most five leaves from each plant were selected, tagged and numbered serially. Disease intensity was assessed using 0-5 scale as mentioned below (Jhooty and Munshi, 1975).

Disease ratings	Percentage of the leaf area infected
0	No infection
1	Below 10
2	11-25
3	26-50
4	51-75
5	Above 75

Based on the percentage of the leaf area infected, disease intensity was calculated using the following formula (Wheeler, 1969).

$$\text{Percentage of Disease Intensity (PDI)} = \frac{\text{Sum of all numerical ratings}}{\text{Total number of leaves assessed}} \times \frac{100}{\text{Maximum disease category}}$$

Percentage of disease incidence was calculated by using the following formula:

$$\text{Percentage of disease incidence} = \frac{\text{No. of plants infected}}{\text{Total no. of plants}} \times 100$$

3.2 Evaluation of bittergourd genotypes of NBPGR, Vellanikkara for resistance against *Pseudoperonospora cubensis*

One hundred and seventy four bittergourd genotypes maintained at NBPGR, Vellanikkara were evaluated for their resistance to downy mildew disease.

The evaluation was conducted during August 1994. Observations on the incidence and intensity of the disease were recorded at 70 days after sowing. Based on the percentage of disease intensity, the genotypes were grouped into five categories as adopted by Rajkumar *et al.* (1995).

Disease Intensity (%)	Category
0	Immune
1-10	Highly Resistant
10.1-25	Moderately Resistant
25.1-50	Moderately susceptible
Above 50	Highly susceptible

3.3 Host range studies

In this study, the common cucurbitaceous vegetables growing in Kerala such as pumpkin (*Cucurbita moschata* Duch ex Poir.), cucumber (*Cucumis sativus* L.), snakegourd (*Trichosanthes anguina* L.), ashgourd (*Benincasa hispida* (Thunb.) Cogn.), bottlegourd (*Lagenaria siceraria* Standl.), ivygourd (*Coccinia cordifolia* L.), watermelon [*Citrullus lanatus* (Thunb.) (Matsumara and Nakai)] were tested in pot culture and field condition to find out the host range of *Pseudoperonospora cubensis* infecting bittergourd (*Momordica charantia* L.).

3.3.1 Field studies

In order to find out the collateral hosts of bittergourd downy mildew fungus under natural condition, the above mentioned cucurbitaceous plants were planted adjacent to the bittergourd field infected with downy mildew disease. Intensity of downy mildew disease on these hosts were recorded.

3.3.2 Pot culture studies

3.3.2.1 Preparation of inoculum

Inoculum used for the study was prepared according to Bains and Jhooty (1976) with slight modification. Infected leaves were collected from the field and brought to the laboratory. Leaves were washed in tap water and dried with blotting paper. Lesions were cut and surface sterilized with 0.1 per cent mercuric chloride for 30 seconds and then washed in repeated changes of sterile distilled water. These bits were plated aseptically in large sterilized petri dishes containing moistened filter paper. Petri dishes were incubated at room temperature 25 $\pm$ 2°C for 12-18 hours for sporulation. These bits were then transferred into conical flasks containing sterile water, shaken thoroughly and incubated in the dark for 2 hours for liberation of zoospores.

3.3.2.2 Inoculation of bittergourd downy mildew pathogen on other cucurbitaceous hosts

Different cucurbitaceous plants mentioned under 3.3 were raised in pots. The inoculum from bittergourd infected leaves were prepared as mentioned above and 10 ml of the inoculum was sprayed on these hosts using an atomizer 14 days after sowing. The incoulated plants were covered with wetted polythene covers to provide humid condition congenial for disease development. Development of symptoms on these hosts were recorded. Pathogen from these hosts was back inoculated to bittergourd to prove the Koch's postulates.

3.3.3 Studies on physiological races of *Pseudoperonospora cubensis*

All cucurbitaceous hosts mentioned in 3.3 except watermelon were used in this study. Watermelon was not included due to the non-availability of this crop during this season.

Various cucurbitaceous plants were raised in earthen pots of size 20 cm diameter. Downy mildew infected leaves of various cucurbitaceous plants were collected from different fields and the inocula from the different hosts were prepared as mentioned in 3.3.2.1. The different inocula (10 ml) were then cross inoculated on various cucurbitaceous hosts with an atomizer. Inoculated plants were covered with polythene bags to provide proper humidity and kept under natural conditions. Development of symptoms on these hosts was recorded.

3.4 Management of downy mildew of bittergourd

The effectiveness of the selected plant protection chemicals and botanicals were tested against the downy mildew pathogen under *in vitro*, pot culture and field conditions.

3.4.1 Details of the plant protection chemicals used

The following fungicides were used for the experiment.

Sl. No.	Common/Generic name	Trade name	Concentration used
1	Potassium phosphonate	Akomin 40	0.3%
2	Chlorothalonil	Kavach 75 WP	0.2%
3	Mancozeb	Indofil M-45 75 WP	0.2%
4	Copper oxychloride	Fytolan 50 WP	0.3%

3.4.2 Details of the plant extracts used in the experiment

Plant extracts were prepared in distilled water by macerating the plant leaves using pestle and mortar. The extract was filtered through muslin cloth and the required concentration (10%) of the various plant extracts were adjusted by adding more of distilled water. The following plants were used for the study.

Sl. No.	Botanical name	Common name	Malayalam name	Family
1	*Bougainvillea spectabilis* Comm. ex Juss. Mut. Choisy	Bougainvillea	Kadalasupuvu	Nyctaginaceae
2	*Lantana camara* L.	Lantana	Puchedi	Verbenaceae
3	*Azadirachta indica* A. Juss. (nim)	Neem	Aryaveppu	Meliaceae
4	*Ocimum sanctum* L.	Sacred Basil	Thulasi	Labiatae

3.4.2.1 Details of the treatments used in the various disease management studies are as follows

Treatments	Chemical/botanical	Concentrations (%)
T_1	Potassium phosphonate	0.3
T_2	Chlorothalonil	0.2
T_3	Mancozeb	0.2
T_4	Copper oxychloride	0.3
T_5	Bougainvillea leaf extract	10
T_6	Lantana leaf extract	10
T_7	Neem leaf extract	10
T_8	Ocimum leaf extract	10
T_9	Control	

3.5 Evaluation of fungicides and botanicals against *Pseudoperonospora cubensis* in *in vitro* condition

Healthy bittergourd leaves were collected from the field, washed with distilled water and dried using blotting paper. These leaves were then sprayed with required concentrations of fungicides and plant extracts mentioned above. The leaves were then kept under fan for drying up the suspension sprayed and kept in large sterilized petri dishes lines with moistened blotting paper. The fungal inoculum was prepared as mentioned in 3.3.2.1. Approximately 2 ml of the inoculum was sprayed on the treated leaves and kept for observation. Leaves sprayed with sterile water served as control. Disease intensity was recorded daily till the control leaves showed maximum disease rating. Data was subjected to Chi-square analysis.

3.6 Evaluation of fungicides and botanicals against *Pseudoperonospora cubensis* in pot culture studies

Earthen pots of size 20 cm diameter were filled with potting mixture. Seeds of bittergourd were sown in these pots at the rate of five per pot. After germination, three healthy plants were retained in each pot. The seedlings were inoculated with downy mildew pathogen 20 days after sowing. First spraying of the chemicals and botanicls was given with the first appearance of symptom and subsequent three sprayings were given at fortnightly interval. The plants were then kept under natural conditions. Observations on disease intensity were recorded ten days after the last spraying. The experiment was conducted in Completely Randomized Design with three replications.

3.7 Field trial

To find out the effective fungicide/plant extract to reduce the severity of the disease, a field trial was conducted during late May to September 1994.

3.7.1 Details of the field experiment were as follows

Crop	: Bittergourd
Variety	: 'Priya'
Replication	: 3
No. of mounds/replication	: 4
Treatments	: 9

The field was prepared thoroughly and mounds were taken as mentioned in 3.1.1. Crops received the respective cultural and manural practice as recommended by the Package of Practices of Kerala Agricultural University (KAU, 1993). After germination, three healthy plants were retained in each mound and the plants were trailed on iron frame. First spraying of chemicals/botanicals were given with the onset of monsoon and with the appearance of symptom. Subsequent three sprays were given at fortnightly intervals and observations were taken ten days after the last spraying. Disease intensity was scored using the same score chart used in varietal screening. Yield data per plot were also recorded and the cost:benefit ratio worked out.

3.8 Assessment of crop loss in bittergourd due to downy mildew disease

To estimate the crop loss due to downy mildew disease, a field experiment was conducted on susceptible variety 'Priya', during August to

November, 1994. The experiment was conducted in Randomized Block Design with six replications. There were 10 plants per replication. The crop was raised as mentioned in 3.1.1. Two healthy plants were retained in each mound. There were two treatments. In the first treatment, plants were sprayed periodically with 0.2 per cent chlorothalonil which was found to be the most effective fungicide in the disease control experiment. Spraying was started two weeks after sowing, before the symptom expression and subsequent spraying was given at fortnightly intervals. Other set of plants without fungicidal spray served as control. For quantifying the amount of infection in each plot, the percentage of disease incidence and percentage of disease intensity were calculated 70 days after sowing. Each plant was evaluated for its disease reaction by scoring the disease intensity of five lower leaves and the extent of leaf damage at different stages of infection was noted. Yield per plot was also recorded and the cost:benefit ratio worked out. From per cent disease incidence and per cent disease intensity values, coefficient of disease index (CODEX) was then calculated as suggested by Datar and Mayee (1981).

$$\text{CODEX} = \frac{\text{Per cent disease incidence x Per cent disease intensity}}{100}$$

For recording yield loss due to disease, yield of every plot was taken separately, and yield loss was calculated by the following formula:

$$\text{Per cent yield loss} = \frac{\text{Yield in treatment - Yield in control}}{\text{Yield in treatment}} \times 100$$

Yield in treatment = Yield of plots sprayed with 0.2% chlorothalonil

Yield in control = Yield of plots without fungicidal spray

Statistical analysis

Data relating to different experiment were analysed statistically followed the method of Panse and Sukhatme (1978).

Results

RESULTS

4.1 Screening of bittergourd varieties/lines to downy mildew disease caused by *Pseudoperonospora cubensis*

The varieties obtained from the Department of Olericulture were screened for resistance/tolerance against downy mildew pathogen during rainy season. Data on the degree of susceptibility of the evaluated varieties are given in Table 1. The lowest disease intensity was observed in variety Preethi (4.88%) and highest intensity was recorded in RHRBG-4-1 (41.77%) and there was significant difference between varieties tested at 45 days after sowing. Whereas, at 70 days after sowing, disease intensity increased tremendously ranging from 13 to 33 per cent in different varieties. But the increase was negligible in RHRBG 4-1. Lowest and highest disease intensity were observed in Preethi (36.88%) and RHRBG-5 (49.77%) respectively during this period.

Statistical analysis revealed no significant difference among varieties at 70 days after sowing. However, Preethi and Priya showed minimum infection as compared to other varieties. As per the classification of Rajkumar *et al.* (1995) all varieties were moderately susceptible.

4.2 Evaluation of bittergourd genotypes of NBPGR, Vellanikkara for resistance against *Pseudoperonospora cubensis*

Reactions of bittergourd genotypes maintained at NBPGR were recorded and furnished in Table 2. The result showed a greater extent of variation (10.66-62.66%) among the bittergourd genotypes to downy mildew infection under natural

Table 1. Screening of bittergourd varieties for resistance against *Pseudoperonospora cubensis*

Varieties	Disease intensity								Category
	45 days after sowing				70 days after sowing				
	R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean	
Priya	18.66	0	12.00	10.22 (2.87)	36.00	46.66	40.00	40.88	MS
Preethi	14.66	0	0	4.88 (1.77)	52.00	29.33	29.33	36.88	MS
Pusa Do Mousmi	45.33	28.00	17.33	30.22 (5.44)	44.00	46.66	49.33	46.66	MS
Pusa hybrid	50.66	30.66	0	27.10 (4.48)	44.00	24.00	54.66	40.88	MS
Pusa Vishesh	44.00	0	0	14.66 (2.70)	58.66	33.33	52.00	47.99	MS
BG 6	49.33	30.66	22.66	34.21 (5.82)	38.66	40.00	46.66	41.77	MS
RHRBG 4-1	64.00	61.33	0	41.77 (5.31)	50.66	25.33	50.66	42.21	MS
RHRBG 5	28.00	34.66	12.00	24.88 (4.94)	29.33	57.33	62.66	49.77	MS
CD at 5%				3.09				NS	

Figures in paranthesis are square root transformed values
MS - Moderately susceptible
NS - Not significant

Table 2. Evaluation of bittergourd genotypes of NBPGR, Vellanikkara for resistance against *Pseudoperonospora cubensis*

Sl.No.	Genotypes No.	Disease intensity (%)	Category
1	2	3	4
1	CON 1	49.33	M.S
2	2 W	44.00	M.S
3	6 G	24.00	M.R
4	7 B	57.33	H.S
5	10 G	54.66	H.S
6	12 G	45.33	M.S
7	12 glths	48.00	M.S
8	12 B	54.66	H.S
9	13 W	49.33	M.S
10	14 W	54.66	H.S
11	27 A(B)/	50.66	H.S
12	27 A	62.66	H.S
13	26 G	40.00	M.S
14	25 G	50.66	H.S
15	22 W	46.66	M.S
16	20 G	38.66	M.S
17	19 G	42.66	M.S
18	17 B	41.33	M.S
19	16 C	52.00	H.S
20	CON 2	58.66	H.S
21	15 W	38.66	M.S

Contd.

Table 2. Continued

1	2	3	4
22	28 G	41.33	M.S
23	28 A	46.66	M.S
24	28 B	38.66	M.S
25	30 G	38.66	M.S
26	CON 3	41.33	M.S
27	34 A_2/	49.33	M.S
28	35 G	52.00	H.S
29	36 G	56.00	H.S
30	37 A	44.00	M.S
31	39 W	52.00	H.S
32	42 G	42.66	M.S
33	67 A	44.00	M.S
34	63 G	32.00	M.S
35	61 G	42.66	M.S
36	55 G	44.00	M.S
37	CON 4	50.66	H.S
38	54 G	41.33	M.S
39	50 G/	29.33	M.S
40	50 G	45.33	M.S
41	45 G	48.00	M.S
42	43 G	42.66	M.S
43	67 W/	40.00	M.S

Contd.

Table 2. Continued

1	2	3	4
44	71 G	44.00	M.S
45	72 A	52.00	H.S
46	74 G	37.33	M.S
47	75 B/	56.00	H.S
48	CON 5	37.33	M.S
49	76 AWM/	53.33	H.S
50	78 B	34.66	M.S
51	80 B	37.33	M.S
52	83 G	44.00	M.S
53	116 B	50.66	H.S
54	108 G	50.66	H.S
55	CON 6	48.00	M.S
56	108 W	45.33	M.S
57	104 G	57.33	H.S
58	103 A	42.66	M.S
59	91 W	45.33	M.S
60	91 G	46.66	M.S
61	90 G	48.00	M.S
62	86 W	40.00	M.S
63	85 W	50.66	H.S
64	116 C	46.66	M.S
65	125 W	50.66	H.S

Contd.

Table 2. Continued

1	2	3	4
66	12 G	56.00	H.S
67	128 G	44.00	M.S
68	139 W	50.66	H.S
69	141 G	49.33	M.S
70	145 W	53.33	H.S
71	147 W	53.33	H.S
72	148 W	54.66	H.S
73	159 WM	53.33	H.S
74	152 WM	48.00	M.S
75	CON 7	50.66	H.S
76	183 G	40.00	M.S
77	182 G	40.00	M.S
78	179 W	48.00	M.S
79	177 G	45.33	M.S
80	175 G	34.66	M.S
81	169 G	34.66	M.S
82	167 BG/	37.33	M.S
83	167 BW/	32.00	M.S
84	CON 8	24.00	M.R
85	163 W	44.00	M.S
86	162 W/	29.33	M.S
87	186 AG/	36.00	M.S

Contd.

Table 2. Continued

1	2	3	4
88	188 G	38.66	M.S
89	195 B	41.33	M.S
90	CON G	56.00	H.S
91	196 G	53.33	H.S
92	197 G	40.00	M.S
93	198 G	49.33	M.S
94	199 W	52.00	H.S
95	199 G/	41.33	M.S
96	199 A/	49.33	M.S
97	202 G	34.66	M.S
98	222 G	42.66	M.S
99	221 AW/	42.66	M.S
100	219 G	56.00	H.S
101	213 G	36.00	M.S
102	214 G	41.33	M.S
103	203 G	16.00	M.R
104	224 AG	44.00	M.S
105	224 AG/	32.00	M.S
106	225 L	40.00	M.S
107	225 W/	26.66	M.S
108	231 G	28.00	M.S
109	234 G	32.00	M.S

Contd.

Table 2. Continued

1	2	3	4
110	234 W	41.33	M.S
111	238 G	29.33	M.S
112	CON 12	41.33	M.S
113	261 G	26.66	M.S
114	251 W	36.00	M.S
115	CON B	14.66	M.R
116	250 B/	28.00	M.S
117	266 G	37.33	M.S
118	268 G	17.33	M.R
119	270 G	26.66	M.S
120	271 G	22.66	M.R
121	CON 14	18.66	M.R
122	276 A	22.66	M.R
123	285 G	20.00	M.R
124	290 G	24.00	M.R
125	293 G	10.66	M.R
126	298 G	17.33	M.R
127	340 G	36.00	M.S
128	337 W	32.00	M.S
129	336 W/	25.33	M.S
130	CON 15	13.33	M.R
131	336 G/	26.66	M.S

Contd.

Table 2. Continued

1	2	3	4
132	333 G	30.66	M.S
133	332 W	28.00	M.S
134	331 G	16.00	M.R
135	CON 16	16.00	M.R
136	345 W	21.33	M.R
137	350 G	21.33	M.R
138	352 G	44.00	M.S
139	358 W	34.66	M.S
140	CON 17	16.00	M.R
141	361 G	33.33	M.S
142	362 W	26.66	M.S
143	369 W	30.66	M.S
144	366 W	32.00	M.S
145	364 G	29.33	M.S
146	363 G	26.66	M.S
147	378 W	25.33	M.S
148	387 W	22.66	M.R
149	386 W	28.00	M.S
150	385 G	33.33	M.S
151	380 W	30.66	M.S
152	379 G	30.66	M.S
153	388 G	37.33	M.S

Contd.

Table 2. Continued

1	2	3	4
154	390 G	33.33	M.S
155	393 W	32.00	M.S
156	397 H/	30.66	M.S
157	397 W/	33.33	M.S
158	397 G/	32.00	M.S
159	202 Gm	32.00	M.S
160	CON 21	25.33	M.S
161	21 WL	21.33	M.R
162	CON 22	21.33	M.R
163	26 Gr.S	16.00	M.R
164	26 Gr L	14.66	M.R
165	50 Gr M	21.33	M.R
166	71 Gr L	21.33	M.R
167	78 ^{W}Gr	22.66	M.R
168	245 Gr	21.33	M.R
169	182 WM	12.00	M.R
170	85 Gr L	18.66	M.R
171	78 BGr	21.33	M.R
172	255 ^{W}M	26.66	M.S
173	255 Gr M	22.66	M.R
174	CON 24	21.33	M.R

I - Immune
H.R - Highly Resistant
M.R - Moderately Resistant
M.S - Moderately Susceptible
H.S - Highly Susceptible

condition. Lowest disease intensity (10.66%) was observed in 293 G and maximum intensity (62.66%) was observed in 27 A. Based on disease intensity rating, all genotypes were grouped into 5 categories as mentioned in 3.2 and they are as follows:

Immune	Nil
Highly Resistant	Nil
Moderately Resistant	6 G, CON 8, 203 G, CON B, 268 G, 271 G, CON 14, 276 A, 285 G, 290 G. 293 G, 298 G, CON 15, 331 G, CON 16, 345 W, 350 G, CON 17, 387 W, 21 WL, CON 22, 26 Gr.S, 26 Gr.L., 50 Gr.M, 71 Gr.L, 78 Gr, 245 Gr, 182 WM, 85 GrL, 78 BGr, 255 GrM, CON 24
Moderately susceptible	CON 1, 2W, 12 G, 12 G lths, 13 W, 26 G, 22 W, 20 G, 19 G, 17 B, 15 W, 28 G, 28 A, 28 B, 30 G, CON 3, 34 A_2, 37 A, 42 G, 67 A, 63 G, 61 G, 55 G, 54 G, 50 G/, 50 G, 45 G, 43 G, 67 W/, 71 G, 74 G, CON 5, 78 B, 80 B, 83 G, CON 6, 108 W, 103 A, 91 W, 91 G, 90 G, 86 W, 116 C, 128 G, 141 G, 152 WM, 183 G, 182 G, 179 W, 177 G, 175 G, 169 G, 167 BG/, 167 BW/, 163 W, 162 W/, 186 AG/, 188 G, 195 B, 197 G, 162 W/ 186 AG/188 G, 195 B, 197 G, 198 G, 199 G/, 1991 A/, 202 G, 222 G, 221 AW/, 213 G, 214 G, 224 AG/224 AG/, 225 L, 225 W/, 231 G, 234 G, 234 W, 238 G, CON 12, 261 G, 251 W, 250 B/, 266 G, 270 G, 340 G, 337 W, 336 W/, 336 G/, 333 G/, 832 W, 352 G, 358 W, 361 G,

362 W, 369 W, 366 W, 364 G, 363 G, 378 W, 386 W, 385 G, 380 W, 379 G, 388 G, 390 G, 393 W, 397 H/, 397 W/, 397 G/, 202 GM, CON 21, 255 WM

Highly susceptible — 7 B, 10 G, 12 B, 12 W, 27 A(B)/, 27 A, 25 G, 16 C, CON 2, 35 G, 36 G, 39 W, CON 4, 72 A, 75 B/, 76 A WM/, 116 B, 198 G, 104 G, 85 W, 125 W, 12 G, 139 W, 145 W, 148 W, 159 WM, CON 7, CON G, 196 G, 199 W, 219 G

Out of 174 genotypes collected, not even a single genotype has been found 'Immune' or 'Highly Resistant' and there were 32 'Moderately Resistant' lines, 110 'Moderately Susceptible' lines and 32 'Highly susceptible' lines.

4.3 Host range studies

4.3.1 Field studies

In order to find out the collateral host of bittergourd downy mildew pathogen, a host range study was conducted on different cucurbitaceous plants under field condition. Observations on disease intensity are presented in Table 3.

The study revealed that all cucurbitaceous hosts tested were infected with bittergourd downy mildew pathogen and the symptoms first appeared in bottle gourd and in pumpkin. When all the host plants were taken into consideration, the disease intensity varied significantly at 30 days after sowing (Table 4). The intensity was highest in bottlegourd (42.66%) followed by pumpkin (41.33%). But when the intensity of disease was taken into consideration, there was no significant difference among ivygourd, snakegourd, water melon, ashgourd and cucumber.

Table 3. Effect of bittergourd downy mildew pathogen on other cucurbitaceous host

Sl. No.	Host plants	Disease intensity (%)	
		30 DAS	45 DAS
1	Ivygourd	16.00	21.33
2	Snakegourd	21.33	25.33
3	Watermelon	26.66	32.00
4	Ashgourd	28.00	36.00
5	Cucumber	32.00	40.00
6	Pumpkin	41.33	50.66
7	Bottlegourd	42.66	49.33

DAS - Days after sowing

Table 4. Chi-square evaluation of host range of the fungus on selected cucurbitaceous crops 30 days after sowing

Host range	T_1	T_2	T_3	T_4	T_5	T_6	T_7
T_1	-	0.76	2.66	3.92	6.25	13.89**	19.47**
T_2	-	-	0.59	0.98	2.16	7.45	11.22**
T_3	-	-	-	0.033	0.53	4.11	6.52
T_4	-	-	-	-	0.27	2.77	4.24
T_5	-	-	-	-	-	1.19	1.75
T_6	-	-	-	-	-	-	0.02
T_7	-	-	-	-	-	-	-

T_1 - Ivygourd

T_2 - Snakegourd

T_3 - Watermelon

T_4 - Ashgourd

T_5 - Cucumber

T_6 - Pumpkin

T_7 - Bottlegourd

** Significantly different at 1% level

Table 5. Chi-square evaluation of host range of the fungus on selected cucurbitaceous crop 45 days after sowing

Host range	T_1	T_2	T_3	T_4	T_5	T_6	T_7
T_1	-	0.34	2.22	4.53	7.52	11.42**	16.13**
T_2	-	-	0.78	1.86	3.52	9.09*	12.56**
T_3	-	-	-	0.12	0.89	4.87	6.43
T_4	-	-	-	-	0.21	2.72	3.47
T_5	-	-	-	-	-	1.25	1.45
T_6	-	-	-	-	-	-	0.02
T_7	-	-	-	-	-	-	-

T_1 - Ivygourd T_5 - Cucumber

T_2 - Snakegourd T_6 - Pumpkin

T_3 - Watermelon T_7 - Bottlegourd

T_4 - Ashgourd

** Significantly different at 1% level
* Significantly different at 5% level

After 45 days of sowing, similar results were obtained as in the case of 30 days after sowing except that the disease intensity of pumpkin differed significantly from that of watermelon, ashgourd and cucumber (Table 5). The disease intensity of bottlegourd and pumpkin were 49.33 per cent and 50.66 per cent respectively. Nearly 10 per cent increase in disease intensity was noticed at 45 days after sowing as compared to the first observation.

4.3.2 Pot culture studies

In order to find out the host range of bittergourd downy mildew pathogen under controlled condition, cucurbitaceous plants were artificially inoculated with *Pseudoperonospora cubensis* isolated from bittergourd. From the experiment, it was observed that all cucurbitaceous hosts tested were susceptible to bittergourd downy mildew pathogen. Symptom appeared five days after inoculation in pumpkin and bottlegourd, whereas, in cucumber and ivygourd symptoms appeared 9-10 days after inoculation. Back inoculation of the pathogen to the original host produced typical downy mildew symptom showing that all these cucurbits are the collateral hosts of bittergourd downy mildew pathogen.

4.3.2.1 Symptomatology of downy mildew disease on various cucurbitaceous crops

Symptoms of cucurbit downy mildew varied depending upon the host and the prevailing weather conditions.

Bittergourd

Symptom first appeared on the lower surface of the leaves as water soaked lesions, near margin and the corresponding upper surface showed chlorotic

Plate I. Downy mildew symptom on bittergourd

A. Initial water soaked lesions on the lower surface of the leaves

B. Mosaic pattern

C. Yellowing and necrosis of the leaves

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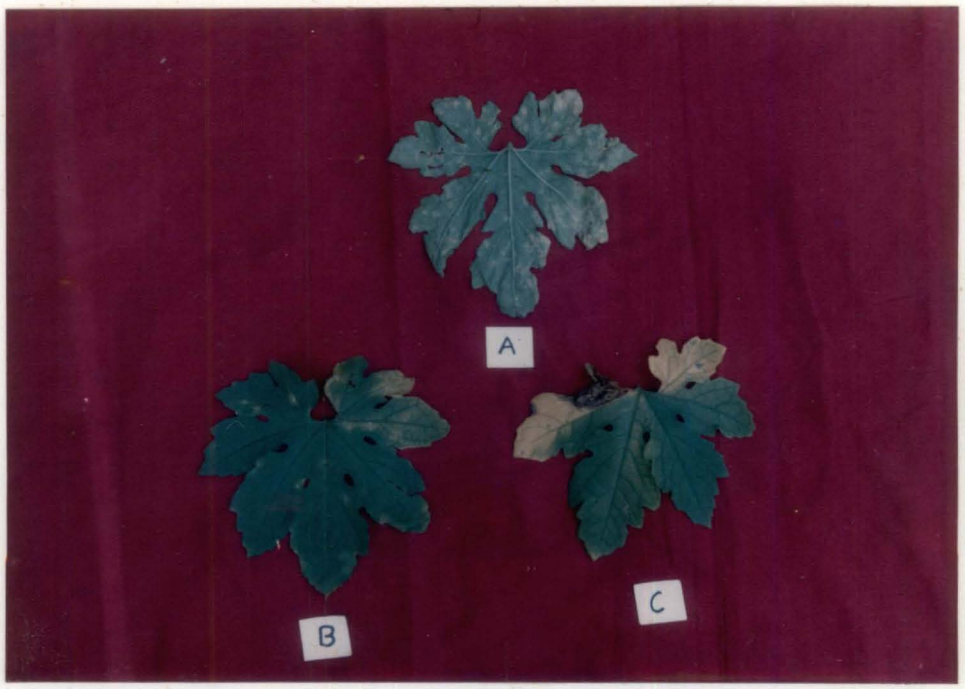

Plate II. Downy mildew symptom on pumpkin

(1)

A. Initial water soaked lesion on the lower surface of the leaves

B. Severe chlorosis and necrosis of the leaves

(2)

A. Chlorotic spots on the upper surface

B. Typical mosaic pattern

C. Yellowing and necrosis

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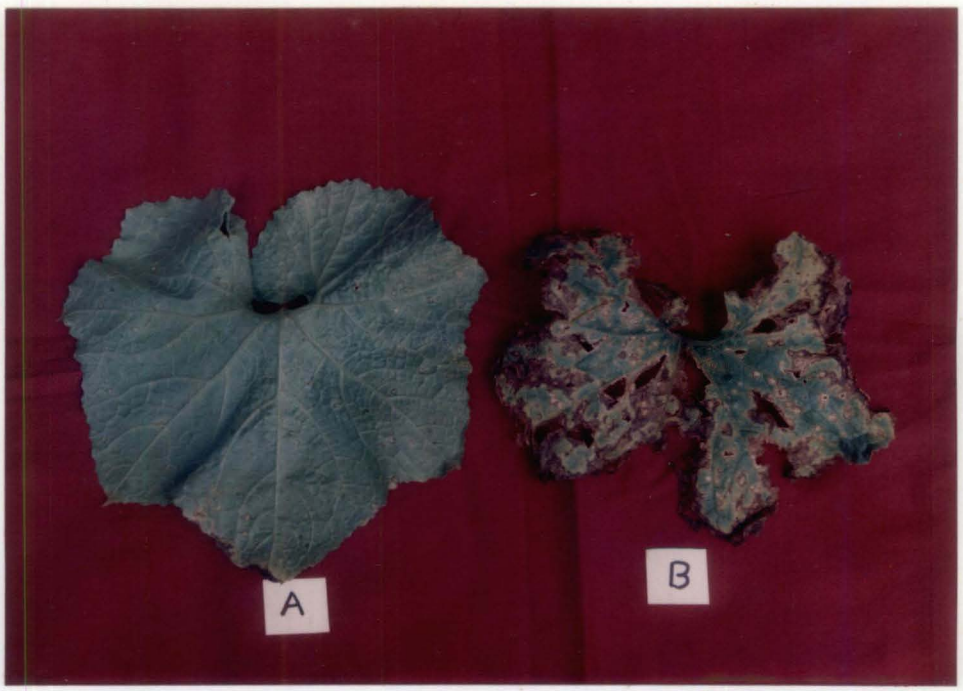


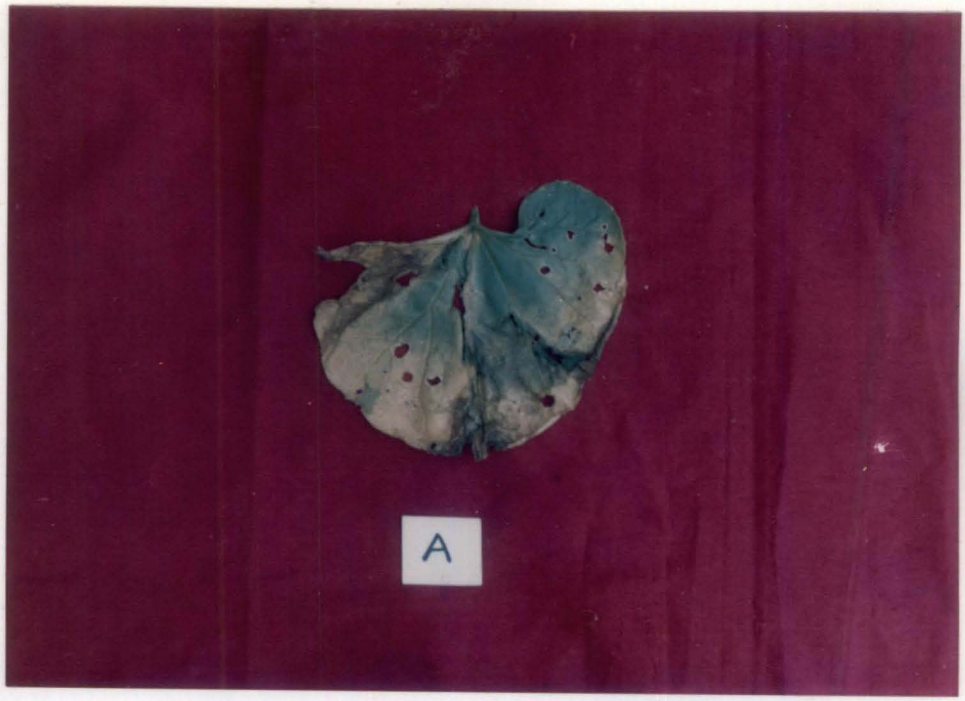
Plate III. Downy mildew symptom on cucumber

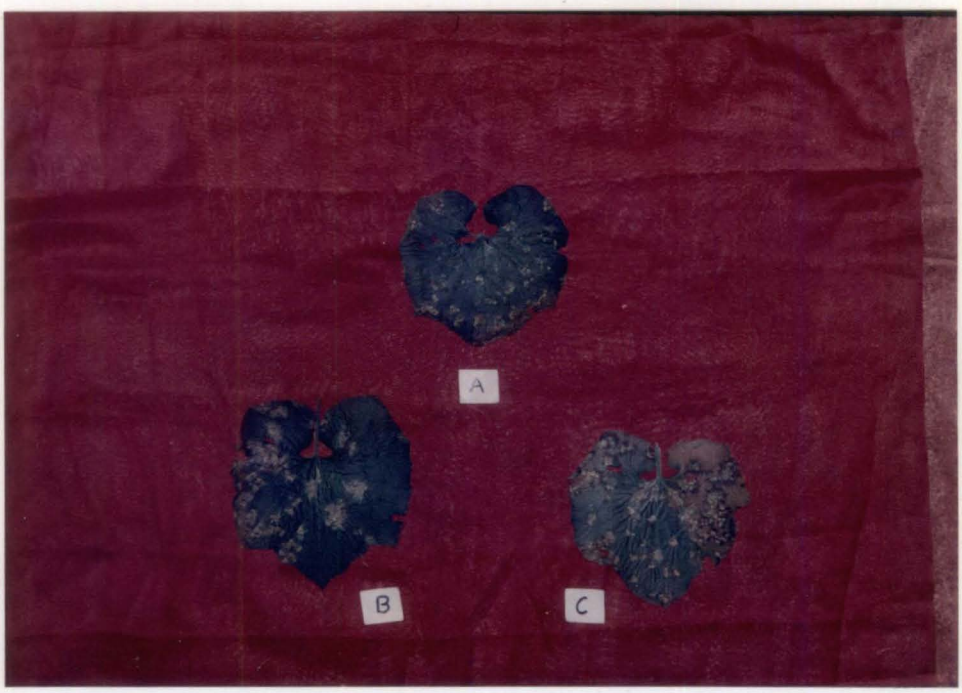
A. Yellowing and rotting of the leaves

Plate IV. Downy mildew symptom on snakegourd

A & B. Papery white necrotic patches on the leaves

C. Chlorosis and severe necrosis of the leaves


A


A
B
C

spots which resembled those of mosaic pattern. The spots were confined between the veins and veinlets giving some angular appearance. The spots were yellow to orange yellow on the abaxial surface of the older leaves which turned purplish during humid weather conditions and finally the entire leaf turned yellow. Necrosis of the severely affected leaves started from the margins and the entire leaf dried up later (Plate I).

Pumpkin

Water soaked lesions first appeared on the lower surface of the leaves mainly at the margins. On the corresponding upper surface, chlorotic spots appeared which resembled typical mosaic pattern. Chlorotic areas were separated by islands of darker green areas. The spots were often restricted by the veins on the upper surface. As the disease advanced, the chlorotic spots enlarged fast and spread along the veins. The affected yellow areas turn brown and necrosis of the leaves started from margin and dried up (Plate II).

Cucumber

Water soaked lesions first appeared on the lower surface of the leaves near the margins. Corresponding upper surface showed angular chlorotic areas limited by veins. As the disease progressed yellowing of the leaves started from the margin and the affected areas later dried up and at humid conditions leaves rotted from the margins and defoliated (Plate III).

Snakegourd

Symptom first appeared on the lower surface as large irregular water soaked lesions at margins as well as on leaf lamina. Corresponding upper surface

Plate V. Downy mildew symptom on ashgourd

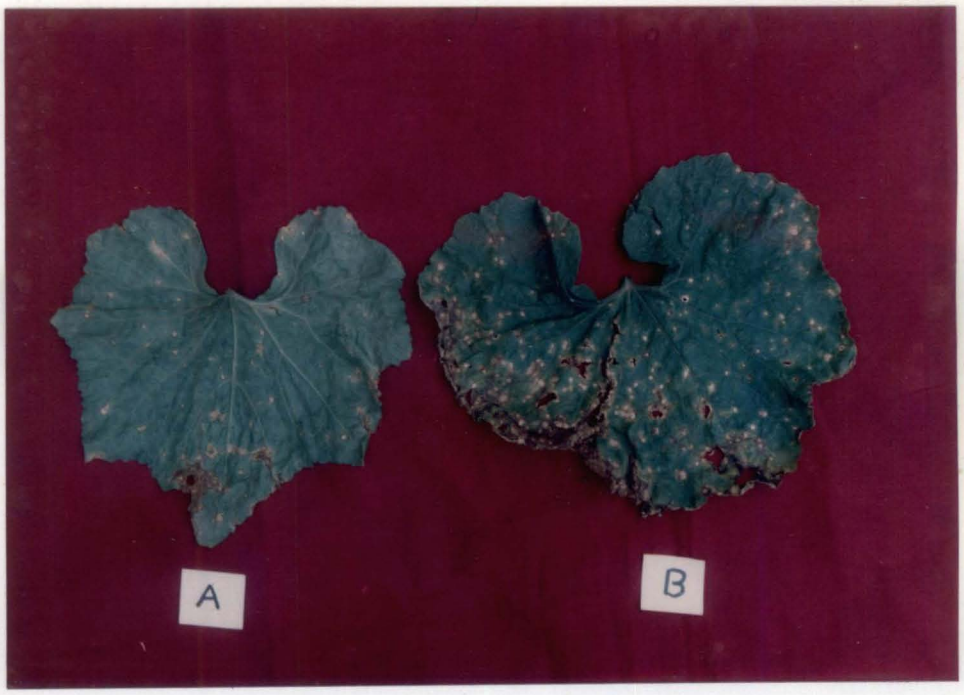
A. Chlorotic spots

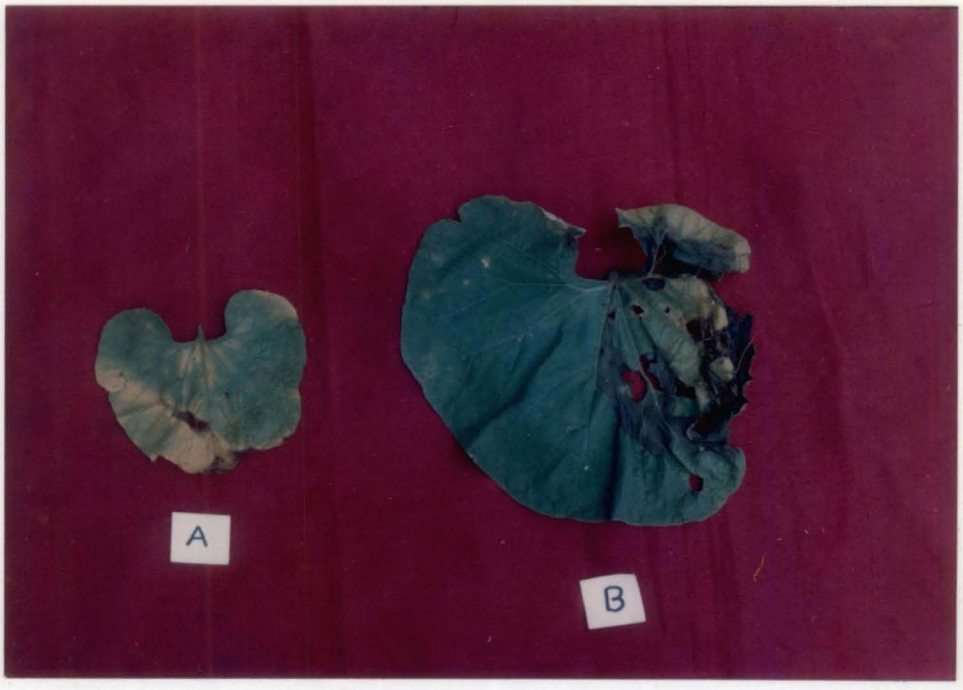
B. Chlorotic spots with shot hole symptoms and necrosis

Plate VI. Downy mildew symptom on bottlegourd

A. Chlorosis and shot hole symptoms

B. Chlorosis and rotting symptom


A
B


A
B

showed large irregular chlorotic patches restricted by veins. These chlorotic areas become necrotic, papery white and affected portion fall off showing large shot hole symptom. As the disease advanced, the leaves became chlorotic green with large severe necrotic patches and then dried up (Plate IV).

Ashgourd

Symptom first appeared as water soaked lesions on lower surface and corresponding upper surface showed small pale yellow spots often restricted by veins. Lesions were restricted in size and did not coalesce rapidly. The centre of these spots became necrotic, ash coloured and fell off showing small shot hole symptom. Distinct blackish rings were noticed near the outer margins of the lesions. As the disease advanced, the infected areas turned yellow and the leaves started drying up from the margins (Plate V).

Bottlegourd

Water soaked areas on the lower surface of the leaves appeared first. The corresponding upper surface showed chlorotic patches. Centre of the patches became necrotic and fell off leaving shot hole symptoms. As the disease advanced, affected leaves turned yellow and dried up. In humid conditions, the affected yellow leaves became rotted (Plate VI).

Ivygourd

Water soaked dot like spots on the lower surface and chlorotic dot with necrotic centre on the corresponding upper surface were noticed. Later, water soaked spots enlarged and formed white patches on the lower surface.

Plate VII. Downy mildew symptom on ivygourd

A. White patches on the lower surface

B. Rotting symptom

C. Rotting and drying up of the leaf

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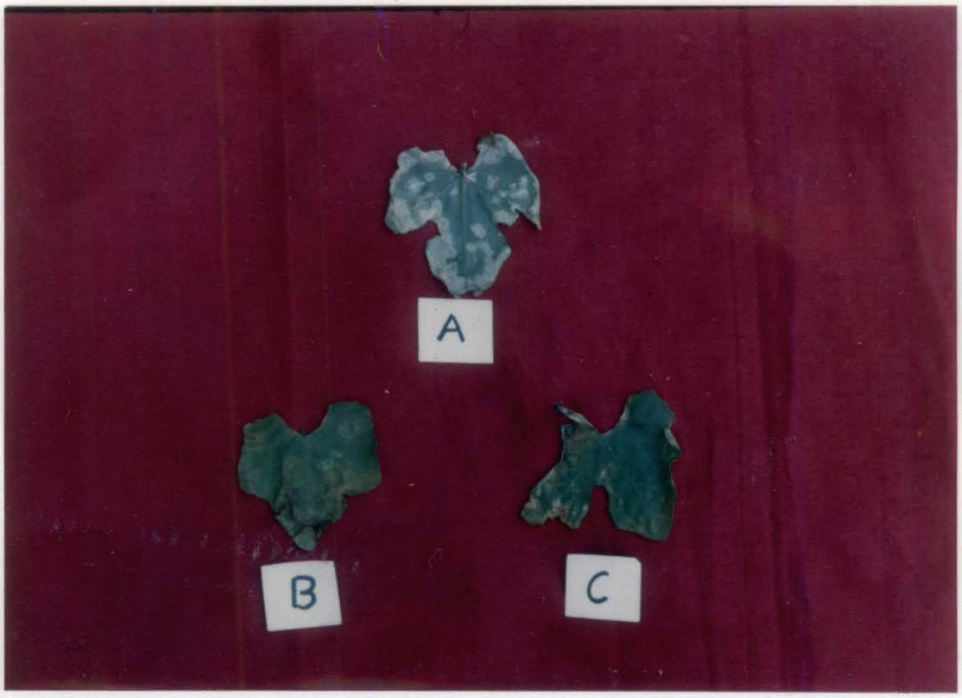

Correspondingly, yellow patches on the upper surface also increased and leaves became chlorotic green and later dried up and under humid conditions leaves rotted from the margin (Plate VII).

Watermelon

Water soaked lesions appeared on the lower surface of the leaves and the corresponding upper surface showed small irregular yellow lesions, and vein delimitation was not clear. These lesions enlarged in size, coalesce rapidly and covered large areas of the leaves. The affected leaves showed chlorotic areas with islands of darker green areas and started drying up from the margin.

4.3.3 Studies on physiological races of *Pseudoperonospora cubensis*

To study the existence of races of *P. cubensis* infecting bittergourd, isolates of the pathogen from bittergourd and other cucurbitaceous hosts were cross inoculated and the symptoms produced on these hosts were recorded. It was found that on cross inoculation, *P. cubensis* from different cucurbitaceous hosts produced the original downy mildew symptoms of the respective hosts. Based on the odour, shape, size and necrosis of lesions, downy mildew symptoms were classified into 4 categories.

Category I

Water soaked lesions on the lower surface and mosaic pattern on the corresponding upper surface, spots angular and restricted by veins, yellowing of the leaves and development of necrosis from the margin and later drying up of leaves. Symptoms produced by *P. cubensis* on bittergourd, pumpkin, cucumber and bottlegourd come under this category.

Category II

Water soaked lesions on the lower surface. Corresponding upper surface showed large irregular chlorotic patches limited by veins which later became papery white necrotic lesions. Affected leaves became chlorotic green with large severe necrotic patches and later dry up. Symptoms produced on snakegourd come under this category.

Category III

Water soaked lesions on the lower surface. On the corresponding upper surface with small pale yellow spots restricted by veins. Spots numerous, restricted in size, and remain isolated. Centre of the spots become necrotic and fall off showing small shot hole symptom with yellow halo around the necrotic spots. As the disease advances, necrosis of the leaves develop from the margin and dry up. Symptoms produced on ashgourd came under this category.

Category IV

Water soaked dot like spots on the lower surface and chlorotic dot with necrotic centre on corresponding upper surface were noticed. Later, water soaked spots enlarged and formed white patches and the corresponding yellow patches enlarged and leaves became chlorotic green and dry up. Symptoms produced on ivygourd came under this category.

4.4 Management of downy mildew of bittergourd

In order to find out the effectiveness of various plant protection chemicals and botanicals in reducing downy mildew infection, experiments were conducted in *in vitro*, pot culture and field conditions.

4.5 *In vitro* evaluation of fungicides and botanicals against *Pseudoperonospora cubensis*

Four fungicides such as potassium phosphonate (0.3%), chlorothalonil (0.2%), mancozeb (0.2%), copper oxychloride (0.3%) and plant extracts of *Bougainvillea spectabilis, Lantana camara, Azadirachta indica* and *Ocimum sanctum* each at 10 per cent concentration were screened for their inhibitory effect on the growth of *Pseudoperonospora cubensis*. The data on per cent disease intensity is presented in Table 6. It was found that chlorothalonil recorded minimum disease intensity of 10 per cent against 76 per cent in control. Among the botanicals, minimum intensity was observed in case of ocimum. On statistical analysis using Chi-square method it was indicated that there is no significant difference in the effect of chlorothalonil when compared with that of potassium phosphonate and copper oxychloride, but it differed significantly when compared with mancozeb, other botanicals and control. Potassium phosphonate did not differ significantly from copper oxychloride and mancozeb whereas significant differences were observed with respect to the effect of botanicals and control. In general, all treatments differed significantly in their effects from control.

Table 6. *In vitro* evaluation of fungicides and botanicals against *Pseudoperonospora cubensis*

Treatments	Average disease intensity (%)
Potassium phosphate (0.3%)	12
Chlorothalonil (0.2%)	10
Mancozeb (0.2%)	22
Copper oxychloride (0.3%)	18
Bougainvillea leaf extract (10%)	35
Lantana leaf extract (10%)	30
Neem leaf extract (10%)	34
Ocimum leaf extract (10%)	28
Control	76

4.6 Evaluation of fungicides and botanicals against *Pseudoperonospora cubensis* under pot culture studies

The apt recommendation of a fungicide for control of a disease could be effectively done only if the effects of the fungicides tested in a phased manner. In consonance with the above mentioned objective, the effect of fungicides and plant extracts to check the severity of the disease were tested by pot culture studies. The results are presented in Table 7. Analysis of variance revealed that all treatments differed significantly in their effect from control but the plant protection chemicals were found to be superior to plant extract. No significant difference was noticed among the four fungicides tested. However, the plants which received chlorothalonil spray showed better protection from downy mildew. All botanicals were found to be equally effective in reducing downy mildew infection but lowest disease intensity was noticed in ocimum extract.

The per cent reduction of disease intensity over control showed no significant difference among treatments. Chlorothalonil spray gave 69.24 per cent reduction of disease while plant extract spray inhibited the disease by 35.38 to 47.7 per cent. The extent of reduction in other fungicides over control ranged from 66.1 per cent (potassium phosphonate) to 56.9 per cent (mancozeb). Among the botanicals, 47.7 per cent reduction over control was obtained in case of plants sprayed with ocimum extract and the lowest reduction over control was obtained in case of bougainvillea. In a clear justification of results already obtained in *in vitro* studies, ranking of treatments revealed that chlorothalonil was best followed by potassium phosphonate and copper oxychloride.

Table 7. Effect of different treatments on downy mildew disease in pot culture studies

Treatments	Mean disease intensity (%)	Per cent disease control over check
Potassium phosphonate (0.3%)	14.67	66.14
Chlorothalonil (0.2%)	13.33	69.24
Mancozeb (0.2%)	18.67	56.91
Copper oxychloride (0.3%)	16.00	63.07
Bougainvillea leaf extract (10%)	28.00	35.38
Lantana leaf extract (10%)	24.00	44.61
Neem leaf extract (10%)	26.66	38.47
Ocimum leaf extract (10%)	22.66	47.70
Control	43.33	-
CD at 5%	10.76	NS

NS - Not significant

4.7 Field trial

The effect of different treatments on severity of downy mildew and on yield was studied under field condition. The experimental findings are presented in Table 8 and 9. From the Table 8, it is evident that all treatments were significantly superior over control in reducing the per cent disease intensity recorded 10 days after fourth spraying. Application of all fungicides and botanicals were found to be effective in reducing downy mildew infection. However, minimum disease intensity (24.53%) was observed in plots sprayed with chlorothalonil and the extent of control observed in plants sprayed with copper oxychloride and potassium phosphonate were also similar to that noticed with chlorothalonil spray. Among the botanicals, lowest disease intensity (28.27%) was observed in plants sprayed with ocimum leaf extract. Under field condition no significant difference was noticed among the treatments with respect to per cent reduction in the intensity of disease over control. However, maximum disease control (59.47%) was obtained in chlorothalonil treated plots and among the botanicals, ocimum extract gave maximum (53.3%) reduction of disease.

Comparison on the effect of fungicides and botanicals on downy mildew under *in vitro*, pot culture and field conditions are given in Fig.1. In all three experiments minimum disease intensity was observed in T_2 (application of 0.2% chlorothalonil). In all cases, treatments were found to be superior than control for maintaining the disease intensity at lower level. However, fungicides were found to be better than botanicals in *in vitro* and pot culture studies. In case of fungicides, disease intensity was very low under *in vitro* and pot culture conditions compared to field studies. Whereas, in case of botanicals, disease intensity was minimum under

Table 8. Effect of fungicides and botanicles against *Pseudoperonospora cubensis* under field condition

Treatments	Mean disease intensity (%)	Per cent disease control over check
Potassium phosphonate (0.3%)	25.87	57.26
Chlorothalonil (0.2%)	24.53	59.47
Mancozeb (0.2%)	26.13	56.83
Copper oxychloride (0.3%)	25.60	57.71
Bougainvillea leaf extract (10%)	30.67	49.33
Lantana leaf extract (10%)	28.53	52.87
Neem leaf extract (10%)	29.87	50.65
Ocimum leaf extract (10%)	28.27	53.30
Control	60.53	-
CD at 5%	7.12	NS

NS - Not significant

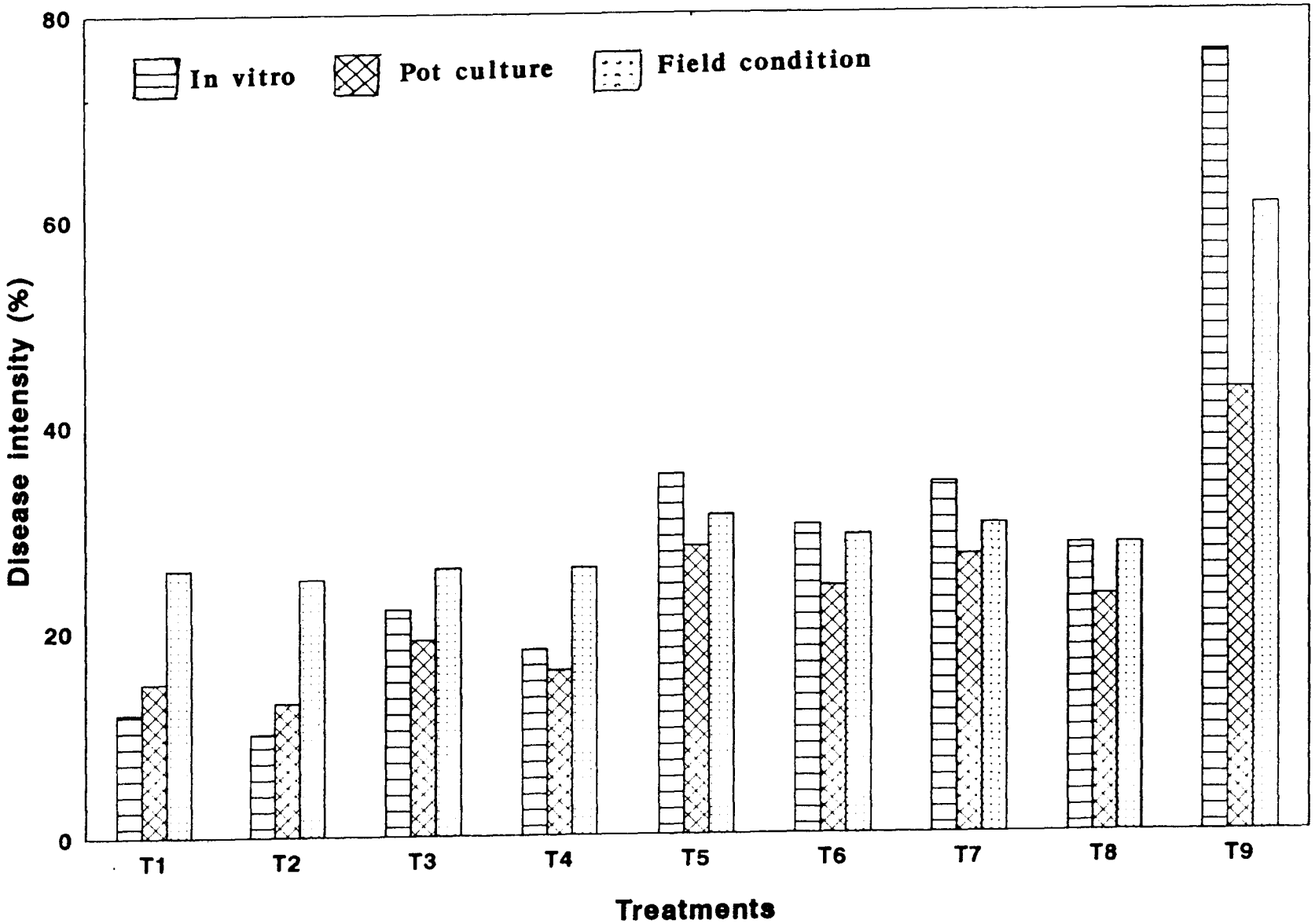

Fig.1 Effect of fungicides and botanicals on downy mildew disease of bittergourd

Table 9. Effect of different reatments on yield of bittergourd

Treatments	Yield in kg/plot			Total kg/plot	Average kg/plot	Per cent increase in yield over control
	R_1	R_2	R_3			
T_1	2.94	3.01	4.13	10.08	3.36	177.69
T_2	3.03	5.44	5.43	13.90	4.63	282.64
T_3	3.21	2.46	2.67	8.34	2.78	129.75
T_4	2.47	3.04	3.25	8.76	2.92	141.32
T_5	1.14	0.83	2.16	4.13	1.38	13.78
T_6	1.38	3.38	3.45	8.21	2.74	126.17
T_7	2.08	2.14	2.55	6.77	2.26	86.50
T_8	3.66	2.55	1.83	8.04	2.68	121.49
T_9	1.68	1.30	0.75	3.63	1.21	-
CD at 5%					1.37	118.725

field condition as compared to *in vitro* condition and same observation was noticed in case of control plot also.

The data on yield presented in Table 9 showed that highest yield (4.63 kg/plot) was recorded from plots treated with chlorothalonil which was statistically superior over other treatments and control, but was on par with potassium phosphonate treatment (3.36 kg/plot). When the control was not taken into consideration, the bougainvillea treatment was found to be the least effective as it yielded only 1.38 kg/plot.

Regarding the per cent increase in yield over control, significant difference was noticed with fungicides and plant extracts. Chlorothalonil was found to be most effective which gave 282.64 per cent increase in yield over control but was on par with potassium phosphonate. Other two fungicides differed significantly from this chemical. Among the plant extracts, plants sprayed with bougainvillea leaf extract gave only 13.78 per cent increase in yield over control.

4.7.1 Cost : benefit ratio for management of downy mildew disease of bittergourd

Cost : benefit ratio of the spraying operation is given in Table 10. The maximum yield was obtained by spraying chlorothalonil (5358.79 kg/ha) and minimum was recorded in bougainvillea extract (1597.22 kg/ha). The total additional expenditure for control of downy mildew with various treatments ranged from Rs.5907/- to Rs.12465/-. Since all the cultural operations except plant protection measures were common in all treatments, only the additional expenditure incurred is taken into account while calculating cost : benefit ratio. The highest cost : benefit ratio of 1:1.91 was observed with chlorothalonil spray followed by copper oxychloride (1:1.48).

Table 10. Cost : benefit ratio for the management of downy mildew disease of bittergourd

Treatments	Yield kg/ha	Net returns Rs.6/kg	Cost of sparying (Rs.)	C : B ratio
Potassium phosphonate (0.3%)	3888.89	23333.34	10844.87	1:1.38
Chlorothalonil (0.2%)	5358.79	32152.74	12465.27	1:1.91
Mancozeb (0.2%)	3217.59	19305.54	7527.00	1:1.45
Copper oxychloride (0.3%)	3379.63	20277.78	8020.83	1:1.48
Bougainvillea leaf extract (10%)	1597.22	9583.32	5906.63	1:0.2
Lantana leaf extract (10%)	3171.30	19027.80	5906.63	1:1.80
Neem leaf extract (10%)	2615.74	15694.44	5906.63	1:1.23
Ocimum leaf extract (10%)	3101.85	18611.10	5906.63	1:1.73
Control	1400.46	8402.76	-	-

Among the botanicals, the cost : benefit ratio was higher (1:1.8) for lantana leaf extract treatment, whereas the cost : benefit ratio was only 1:0.2 in case of bougainvillea treatment.

4.8 Assessment of crop loss in bittergourd due to downy mildew disease

To estimate the crop loss due to downy mildew disease, a field experiment was conducted with six replications. Two sets of plants were raised. One set was sprayed periodically with the most effective fungicide and other set without spray served as the control. Observations on disease intensity and yield are presented in Table 11. The result showed significant difference between treated and untreated plots in case of disease intensity and yield. The mean disease intensity was found to be 35.77 per cent when treated with fungicide whereas it was 60.22 per cent in the control plot. In case of yield also, plots sprayed with fungicide gave higher yield of 4.07 kg, whereas control plot recorded only 2.21 kg.

4.8.1 Extent of leaf damage due to downy mildew disease in bittergourd

The extent of leaf damage due to downy mildew disease in treated and control plots are presented in Table 12 and Fig. 2. Hundred leaves were scored in each treatment. It was observed that during the first appearance of the disease, 62 leaves were disease free in treated plot and 10 leaves showed 25 per cent infection, whereas in control plot only 51 leaves were disease free and 16 leaves showed 25 per cent infection. All leaves were infected in both plots ten days after symptom appearance, but the extent of damage varied in treated and untreated plots. In treated plots 45 leaves showed 10 per cent infection and only 5 leaves showed 50 per cent infection. While in control plots, 10 per cent infection was noticed only in 5 leaves

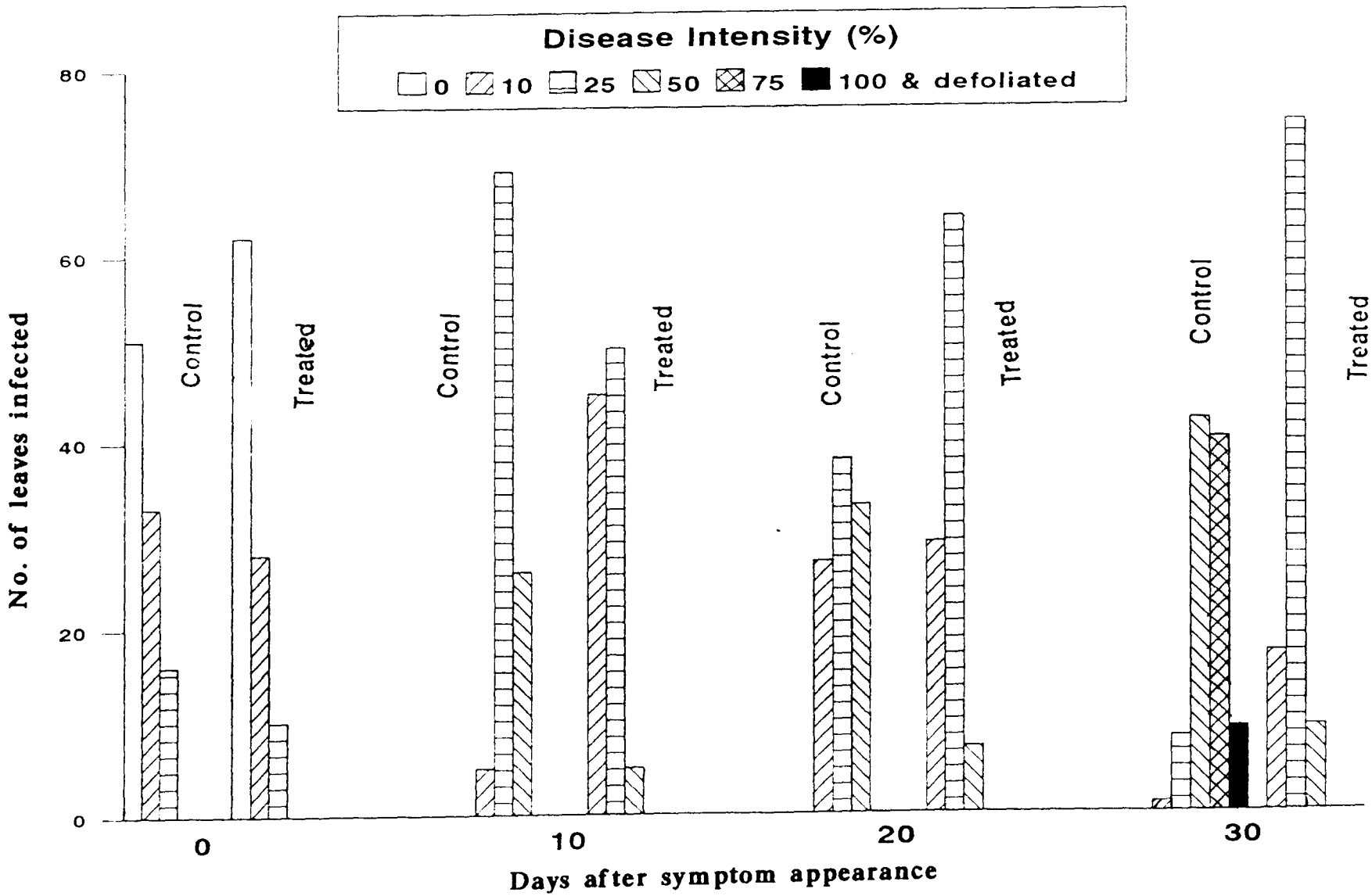

Fig.2 EXTENT OF LEAF DAMAGE DUE TO DOWNY MILDEW DISEASE IN BITTERGOURD

Table 11. Assessment of crop loss in bittergourd due to downy mildew disease

Replications	Disease intensity (%)		Yield/plot (kg)	
	Sprayed with fungicide	Control	Sprayed with fungicide	Control
R_1	30.66	48.00	3.81	2.10
R_2	34.66	70.66	4.90	1.90
R_3	38.66	73.33	5.29	2.03
R_4	34.66	46.66	3.50	3.03
R_5	37.33	49.33	3.80	2.98
R_6	38.66	73.33	5.13	1.20
Mean	35.77	60.22	4.07	2.21
t value	4.339**		8.0544**	

** $P < 0.01$

Table 12. Extent of leaf damage due to downy mildew disease in bittergourd

Observations	Treatment	Disease intensity (%)					
		0%	10%	25%	50%	75%	100% and defoliated
0 DASA	Treated	62	28	10	0	0	0
	Control	51	33	16	0	0	0
10 DASA	Treated	0	45	50	5	0	0
	Control	0	5	69	26	0	0
20 DASA	Treated	0	29	64	7	0	0
	Control	0	28	39	33	0	0
30 DASA	Treated	0	17	74	9	0	0
	Control	0	1	8	42	40	9

DASA - Days after symptom appearance

and 26 leaves showed 50 per cent infection. In both plots, maximum number of leaves showed 25 per cent infection. In case of 20 days after symptom appearance, the extent of leaf damage was only 50 per cent in both treated and control plots. In treated plot, only 7 leaves showed 50 percentage of infection as against 33 leaves in control. Whereas 30 days after symptom appearance, 100 per cent infection was noticed in control plot with 9 leaves showing full infection and defoliation whereas 40 leaves showed 75 percentage of infection. However, only 50 per cent infection was noticed in 9 leaves and maximum number of leaves showed 25 per cent infection in treated plot.

4.8.2 Effect of fungicidal spraying on co-efficient of disease index and yield of bittergourd

Coefficient of disease index and yield loss was calculated according to the formula given in material and methods (3.8) and the values are given in Table 13. From the Table 13, it is observed that co-efficient of disease index decreased significantly as compared to control plot. Highest CODEX of 60.22 was registered in the non-treated plots while lowest CODEX (35.77) was obtained in the plots sprayed with chlorothalonil. Similarly a yield loss of 45.7 per cent was recorded as against the yield of 4710.6 kg/ha in treated plot. From the overall, it was found that severe outbreak of disease (60.22) could cause a loss of 45.7 per cent in yield under natural condition. Yield loss decreases as the severity of the disease reduces.

4.9.3 Cost : benefit ratio

The cost : benefit ratio for the management of downy mildew diseases of bittergourd is furnished in Table 14. As the cultural operation were common in both treatments, only the expenditure incurred for spraying operation is taken into

Table 13. Effect of fungicidal spraying on CODEX and yield of bittergourd

Treatments	Mean coefficient disease index	Mean yield kg/ha	Yield loss (%)
Sprayed with fungicide	35.77	4710.6	45.70
Control	60.22	2557.87	-
t value	4.339**	8.054**	

** P < 0.01

Table 14. Cost : benefit ratio by spraying with chlorothalonil fungicide

Treatment	Yield/ha (kg)	Net returns (Rs.6/kg)	Cost of spraying (%)	C:B ratio
Sprayed with fungicide	4711	28263.84	9452	1:1.37
Control	2558	15347.22	-	

account while calculating cost benefit ratio and it was observed that in the plot sprayed with fungicides gave an yield of 4701 kg/ha as compared to control plot (2558 kg/ha). The treated plot also yielded a net returns of Rs.28,264/- with a cost benefit ratio of 1:1.37.

4.10 Percentage of disease incidence

Percentage of disease incidence was calculated in all experiments using the formula given in materials and methods (3.1.1). It was observed that, all plants were found to be infected with downy mildew disease. So cent per cent disease incidence was recorded in all experiments.

Discussion

DISCUSSION

Bittergourd is one of the major Cucurbitaceous vegetable crops grown on a commercial scale in India. The production of this crop is greatly reduced due to various diseases and downy mildew is one of the most serious problems. The downy mildew disease of cucurbits was first observed in India during 1910 on *Luffa* and *Trichosanthes* species. It was reported to be common in Northern India where it becomes serious during later part of the rainy season. Ramakrishnan *et al.* (1952), Rangaswami *et al.* (1970) reported the occurrence of downy mildew of cucurbits in Tamil Nadu and Mysore. Bains and Jhooty (1976) first observed downy mildew in bittergourd. Phookan and Gogoi (1995) reported severe occurrence of downy mildew disease of bittergourd in Assam and adjoining states of North East India. A search on literature revealed no information of downy mildew disease of cucurbits in Kerala. In the recent years, downy mildew has been found to be a serious problem for bittergourd cultivation in different parts of Kerala during monsoon period. In view of this, the present study was undertaken to provide useful informations mainly regarding the disease management.

The most effective, simplest and economic way of controlling a disease is the use of resistant varieties. An attempt was made to screen the bittergourd varieties/lines obtained from Department of Olericulture, College of Horticulture, Vellanikkara, for host resistance against *Pseudoperonospora cubensis*. Among the bittergourd varieties/lines tested, none was resistant to downy mildew. Eventhough, the varieties Preethi, Priya and Pusa Vishesh showed low infection at 45 days after

sowing, there was no significant difference among the varieties at 70 days after sowing. The percentage of disease intensity of varieties ranged from 36.88 to 49.77 and all the varieties under the study were found to be moderately susceptible. However, the lowest mean disease intensity was recorded on Preethi. Eventhough the disease intensity varied among the varieties, the disease incidence was cent per cent as none of the varieties was disease-free.

A comparison between disease intensity on 45th and 70th day has revealed that, the varieties resistant at early stage of plant growth were susceptible to disease at later stage. A variety may show resistant type of reaction when the conditions for infection are not conducive, the inoculum load is not sufficient, the races of the pathogen present are not pathogenic or due to the nutrient status of the soil in which the crops are cultivated (Yarwood, 1978; Khan, 1989). A variety could be called as resistant only if it shows the resistant characters consistently under different sets of environmental conditions and under uniform inoculum pressure. It is also observed that increase in the disease intensity from 45th to 70th day ranged from 13 to 33 per cent. Exception to this may be the line RHRBG 4-1 which showed almost uniform resistant reaction in both 45 and 70 days after sowing.

Screening of large number of genotypes of a crop with considerable genetic diversity is a method for locating resistant types against disease which could be further utilized for the development of resistant varieties with desirable characters. With this idea, a large number of genotypes of bittergourd maintained at regional station of NBPGR, Vellanikkara were scored for host resistance against downy mildew under field condition during August 1994. The result showed that, out of 174 genotypes evaluated, none was found to be immune or highly resistant,

32 genotypes were moderately resistant, 110 genotypes were moderately susceptible and 32 genotypes were found to be highly susceptible to the disease. Lowest disease intensity was recorded in genotype 293 G and maximum was observed in 27 A, which is in accordance with the reports of Van der Plank (1968) who reported that the differential responses of genotypes in the case of disease resistance may be due to the differential interaction of pathogens with the genotypes, they affected. No informations is available on the varietal reactions of bittergourd against *P. cubensis*. However, varietal resistance of other cucurbits to *P. cubensis* has been studied by various workers. Cucumber varieties such as Chinese Long, Ashley, Palmetto, Poinsett etc. [Roque and Adsuar (1938, 1939); Blasquez (1970); Krivehenko *et al.* (1986)]. Muskmelon lines such as PI 124111, Seminole, Georgia 47, Kalisto, Homegarden, Gulf stream, Planter's Jumbo etc. [Cohen *et al.* (1995); Walker (1965); Sambandam *et al.* (1979)] and few bottle gourd lines of PDVR were found to be resistant to downy mildew disease (Ram and Pandey, 1995).

The next aspect of investigation was to find out the host range of *P. cubensis* infecting bittergourd. Collateral hosts play an important role in the perpetuation of the pathogens. Therefore, commonly known cucurbitaceous crops of Kerala such as pumpkin, cucumber, snakegourd, bottlegourd, ashgourd, ivygourd and water melon were tested to know whether *P. cubensis* causing downy mildew of bittergourd could infect these hosts and it was observed that all crops tested in this study took infection under natural and artificial conditions indicating that all these cucurbits are collateral hosts of *P. cubensis* infecting bittergourd. These findings confirmed the earlier investigation of Bains and Jhooty (1976) who observed infectivity of *P. cubensis* of muskmelon on cucumber, bottlegourd, bittergourd, snakegourd, spongegourd and ridgegourd. Palti and Cohen (1980) observed infection

of *P. cubensis* on watermelon. *P. cubensis* which has been reported to parasitize various cucurbits in India was recorded on ivygourd during the present investigation. Infectivity of *P. cubensis* on ivygourd observed in the present study is an additional useful information on the collateral hosts of this pathogen.

The existence of different races of *P. cubensis* infecting bittergourd was studied by isolating the pathogen from bittergourd and other cucurbitaceous hosts and conducting cross inoculations. On cross inoculations, it was observed that *P. cubensis* from bittergourd was pathogenic to all cucurbits tested and conversely, isolates from other cucurbits were pathogenic to bittergourd also. On inoculation of *P. cubensis* from different cucurbitaceous hosts produced the original downy mildew symptoms of the respective hosts. The symptoms were found to be host specific. On comparison of symptomatology, the symptoms on bittergourd were similar to those on pumpkin, cucumber, bottlegourd and watermelon. But the vein delimitation was not clear in watermelon, whereas on snakegourd, the pathogen produced large irregular papery white necrotic patches limited by veins. The lesions produced by *P. cubensis* on ivygourd were very small and dot like in the beginning and later enlarged. White patches were seen on the lower surface. On ashgourd, the lesions were numerous, restricted in size and remained isolated. A distinct blackish ring was noticed near the outer margin of the lesions. Bains and Jhooty (1976) also observed a distinct blackish ring near the outer margins of the lesions in case of downy mildew of muskmelon. Iwata (1942) observed that cucumber and squash are attacked by distinct biological races of *P. cubensis*. Bains and Jhooty (1976) reported that downy mildew organisms from muskmelon did not infect ashgourd and pumpkin while the reverse was possible indicating the presence of pathological specialization in *P. cubensis*. In the present investigation, downy mildew pathogen from

bittergourd could cause infection on all cucurbits tested, and the isolates of the organism from these hosts were also pathogenic to bittergourd. The disease symptoms on bittergourd were similar to those on pumpkin, cucumber, bottlegourd and water melon but differ from those on snakegourd, ashgourd and ivygourd. This result may indicate the existence of physiological specialisation of *P. cubensis*.

Present studies on varietal reaction to downy mildew revealed that most of the bittergourd varieties of Kerala are susceptible to the disease. So the control of the disease by chemicals or botanicals was found to be the another alternative method. Plant disease control aims at prevention or reduction in the incidence or severity of the disease. Among the various methods of plant disease control, use of chemicals offer comparatively more effectiveness and quick action in prevention or reduction of disease. As downy mildew of bittergourd is very serious during rainy season use of chemicals offer better control of the disease. Although the earlier reports revealed successful control of downy mildew by fungicidal application, the increased use of these chemicals had led to the occurrence of resistant races of the pathogen, phytotoxicity and causes environmental pollution. In this context, use of plant extracts to control the disease is relevant. So in the present investigation, an attempt was made to find out the effect of certain selected plant extracts to inhibit *P. cubensis* along with certain fungicides, which are reported to be effective against this disease. Fungicides such as potassium phosphonate (0.3%), chlorothalonil (0.2%), mancozeb (0.2%), copper oxychloride (0.3%) and leaf extracts of *Bougainvillea spectabilis, Lantana camara, Azadirachta indica, Ocimum sanctum* each at 10 per cent concentration were tested under *in vitro*, pot culture and field conditions, to find out the most effective fungicide and plant extract in reducing the downy mildew infection of bittergourd. It is a well established fact that downy mildew pathogens

are obligate parasites and cannot be cultured on artificial media. Therefore, *in vitro* study to find out the effectiveness of four fungicides and four leaf extracts were carried out on detached bittergourd leaves. It was found that none of the chemicals/plant extracts completely checked the lesion development. However, all chemicals were found to be significantly superior to botanicals. Among the chemicals, chlorothalonil (0.2%) recorded minimum infection which was on par with potassium phosphonate (0.3%) and copper oxychloride (0.3%). Mancozeb (0.2%) recorded the least effect. All botanicals significantly reduced infection compared to control. Among the botanicals, ocimum leaf extract was found to be more effective in inhibiting *P. cubensis* and bougainvillea extract exhibited low efficacy. There are no reports of testing fungicides on detached leaves against downy mildew pathogen (*P. cubensis*). Screening fungicide on detached leaves in the laboratory is easy and can be done in a short time at much less cost when compared with large scale field experiments.

Based on the result of *in vitro* experiment, effectiveness of fungicides and botanicals was studied under natural conditions by pot culture and field trials. In pot culture studies also similar type of result was obtained as in *in vitro* studies. Chlorothalonil treatment gave maximum disease control of 69.24 per cent over check, whereas, ocimum leaf extract gave only 47.70 per cent disease control indicating superiority of fungicides over botanicals. It was also observed that in pot culture studies, botanicals showed more reduction in disease intensity as compared to *in vitro* studies.

An optimal recommendation of a fungicide for control of downy mildew could be brought forth only when applying under field conditions. The natural

environment will be definitely a limitating factor. A fungicide which is more effective even in such adverse conditions may be termed stable. With this view, effects of different fungicides as well as plant extracts were tested under natural field conditions. In the field experiment, all treatments were significantly superior over control in reducing disease intensity, recorded 10 days after fourth spray. Applications of fungicides and botanicals were found to be equally effective in reducing downy mildew infection under field conditions. However, in this experiment also, maximum disease control (59.47%) was obtained in chlorothalonil treatment and no significant difference could be noticed with potassium phosphonate and copper oxychloride treatments. Mancozeb is found to be the least effective. Among the botanicals, maximum reduction of disease over control (53.3%) was obtained with ocimum leaf extract and bougainvillea leaf extract gave minimum control. Thus the result of the field trial supported the findings obtained in *in vitro* and pot culture studies.

Eventhough the disease intensity found varied with different treatments, the disease incidence was cent per cent in all treatments as none of the plants was found to be disease free.

Any treatment used in disease management will be effective when it reduces the infection and at the same time gives maximum yield also. In the present study, maximum yield of bittergourd was recorded from the plot which was sprayed with chlorothalonil followed by potassium phosphonate. The maximum reduction in the disease intensity was also observed in these plots. This may be well explained from the fact that increase in yield is obtained corresponding to decrease in disease intensity. Maximum cost:benefit ratio was obtained from chlorothalonil treated

plots. However, potassium phosphonate gave less cost : benefit ratio compared to copper oxychloride and mancozeb.

There were discrepancies among the cost : benefit ratio and the actual yield increase and disease control by various treatments. This is obviously due to the cost of different fungicides. Comparative evaluation on the performance of fungicides and botanicals under *in vitro*, pot culture and field studies revealed that fungicides are superior to plant extracts in reducing the downy mildew intensity in bittergourd. However, plant extract treatments were significantly better than control. Among the four selected fungicides and plant extracts tested in all the three experiments, chlorothalonil was the most effective fungicide and ocimum was the most effective plant extract as these recorded maximum disease control over check.

Maximum yield and highest cost : benefit ratio was also obtained in chlorothalonil treatment. Therefore, on the basis of the results of the present investigations it can be concluded that chlorothalonil is more effective than other fungicides in the control of downy mildew.

In reviewing the effect of application of fungicides in toto showed the drift in intensity when the study is gradually shifted from the *in vitro* set up to pot culture and field set up. In the *in vitro* studies, chlorothalonil brought down the disease to 10 per cent whereas the percentage of intensity of disease was 13.33 per cent in case of pot culture and it was nearly double the figure (24.53%) in field condition. Positively, the change from micro environment to macro environment is evident. For better results, the weather parameters and forecasts should also be taken into consideration before the application of fungicides. A comparative study of Table 7 and 8 bring forth the fact that the disease spreads faster in an open field conditions

which is revealed by the figures of the untreated set up, ie., 43.33 per cent in pot culture and 60.53 per cent in field conditions. The fungicidal treatments showed better control in *in vitro* and pot culture than in field studies because the leaves must have received adequate amount of fungicides compared to field condition.

In case of botanicals, similar disease intensity was observed in pot culture and field conditions. This may be due to the effect of sun light which helps in activation and further interconversion of the extract. In case of botanicals, by the action of sunlight, enzymes released helps in the conversion of phenols to quinones which are more toxic than phenols against the pathogen. Disease intensity was found to be less in pot culture studies as compared to field experiment because the leaves must have received more quantity of botanicals than field condition.

No work has been reported so far in disease management of downy mildew in bittergourd. However, the effect of fungicides like chlorothalonil, mancozeb and copper oxychloride in controlling downy mildew of other cucurbits has been reported by many workers. Effectiveness of chlorothalonil against *P. cubensis* infecting cucumber was observed by Ullasa and Amin (1988), Brunelli *et al.* (1989) and Randomanski and Waznicle (1989). Schenck and Crall (1963) found maneb alone or maneb + zineb were most effective against downy mildew disease of muskmelon. Jhooty and Munshi (1975) and Bains and Jhooty (1978) reported that Dithane M-45 gave maximum disease control among the different fungicides tested against *P. cubensis* on melons. Effectiveness of chlorothalonil and mancozeb in controlling downy mildew of muskmelon and cucumber was observed by Patel and Patel (1980) and Sumner *et al.* (1981), respectively. However in the present study mancozeb gave the minimum control of downy mildew of bittergourd among the

four fungicides tested. Manole (1988) and Chaban *et al.* (1990) obtained effective control of downy mildew of cucurbits with copper oxychloride. The experimental results regarding the efficacy of copper oxychloride in controlling downy mildew infection in the present investigation confirm the observations made by the above workers. However, Brunelli *et al.* (1989) found copper oxychloride to be less effective. Mahrishi and Siradhana (1990) obtained best control of downy mildew of muskmelon with metalaxyl + mancozeb mixture followed by chlorothalonil 0.1 per cent, Dithane M-45 0.2 per cent and copper oxychloride 0.3 per cent. In the present study, potassium phosphonate treatment gave effective control next to chlorothalonil. On perusal of literature, it was observed that there is no report on the effect of potassium phosphonate against downy mildew of cucurbits. However, the effectiveness of potassium phosphonate in controlling another Oomycetes fungus, *Phytophthora palmivora* on cocoa was noticed by Anderson and Guest (1990) and Edwin Prem (1995). Hence the fungicides chlorothalonil, potassium phosphonate and copper oxychloride found promising in checking the severity of downy mildew of bittergourd could be utilised for better management of the disease.

The loss due to disease can be lessened by greater use of agrochemicals but the costs associated with their use are prohibitive in many countries and in those where they are acceptable, the benefits have to be considered against the background of potential risk to man, animals and the environment. Fortunately, there are many reports on effective control of many pathogen by using botanicals especially bougainvillea, neem, ocimum and lantana extracts. In the present study, all leaf extracts tested were found to be effective in reducing downy mildew infection. Of these ocimum leaf extract gave maximum disease control. Lakshmanan *et al.* (1990) observed inhibition in the mycelial growth and sclerocial germination of

Thanatephorus cucumeris with aqueous extracts of *Allium sativum, Bougainvillea spectabilis* and *Azadirachta indica*. Mohan and Ramakrishnan (1991) studied antifungal activity of certain plant products and observed that extracts of *Allium sativum, Lantana camara, A. indica* were highly inhibitory to the spore germination and sclerotial growth of *Exserohilum turcicum* causing leaf blight of sorghum. Tewari and Mandakini (1991) showed effectiveness of leaf extracts of *Piper betel, Ocimum sanctum* against *Pyricularia oryzae, Cochlibolus miyabeanus* and *Rhizoctonia solani* on rice. Ganguly (1994) reported that water extracts of *Vinca rosea, L. camara, O. tenuiforum, Solanum melongena, A. indica, Polyalthia longifolia, Aegle marmelos* and *Datura metel* showed antifungal activity against *Pyricularia oryza* and *Helminthosporium oryzae* in *in vitro* condition. Thus these reports supported the findings obtained in present study regarding the effectiveness of botanicals against downy mildew pathogen.

The next point of consideration was to find out the crop loss due to downy mildew disease. Crop loss was assessed by estimating the percentage of leaf damage and loss in yield due to disease in chlorothalonil (0.2%) treated and untreated plots. The study showed significant differences between treated and control plots in case of disease severity and yield. The disease intensity was found to be 35.77 per cent in treated plot where it was 60.22 per cent in the control plot. Eventhough there was significant difference in the disease severity of treated and untreated plot, all plants in both treatments were infected with downy mildew indicating cent per cent disease incidence. The extent of leaf damage in both plots increased as the disease advanced. During the first appearance of the disease, 62 leaves were free of disease in treated plot while 30 days after symptom appearance, none of the leaves was found to be disease free and the extent of damage raised to 50

per cent. But only nine leaves showed this maximum infection. Whereas, in untreated plots, even though 51 leaves were disease free during the first appearance of disease, the extent of leaf damage increased tremendously with increase in days after symptoms appearance. Cent per cent infection and defoliation were observed in few leaves after 30 days of symptom appearance and about 40 leaves showed 75 per cent infection. From the CODEX value and yield loss estimated, highest CODEX of 60.22 per cent was registered in the untreated plot while the lowest CODEX (35.77%) was observed in chlorothalonil treated plot. Similarly, a yield loss of 45.7 per cent was recorded as against the yield of 4710.6 kg/ha in treated plot. In general, it was found that yield loss decreases as the severity of the disease reduces. Datar and Mayee (1981) and Kamlesh Mathur and Bhatnagar (1995) also observed similar type of results during their studies on disease loss in tomato by early blight and grey leaf spot, respectively.

Summing up the discussion so far, it may be concluded that the present studies have enriched our knowledge in various aspects of downy mildew of bitter-gourd especially disease management aspects. There are still many lacunae in our knowledge particularly the area of epidemiology to attain the desired level.

Summary

SUMMARY

Bittergourd (*Momordica charantia* L.) is one of the most popular cucurbitaceous vegetables cultivated throughout India. The damages caused by the attack of pests and diseases are the major constraints for the bittergourd cultivation in Kerala. Downy mildew disease caused by *Pseudoperonospora cubensis* is one of the most serious diseases observed in Kerala. Hence the present investigations were carried out to enter into certain aspects of downy mildew disease with particular emphasis on host resistance, host range of the pathogen and disease management.

Bittergourd varieties obtained from Department of Olericulture, College of Horticulture, Vellanikkara were screened for host resistance against *P. cubensis*. Among the varieties/lines tested, none of them was resistant to downy mildew disease. The varieties viz. Preethi, Priya and Pusa Vishesh showed lowest infection and all the varieties/lines tested under study were moderately susceptible.

Out of 174 genotypes of bittergourd maintained at NBPGR, Vellanikkara screened against downy mildew, none was immune or highly resistant. However, lowest disease intensity was recorded in genotype 293 G and maximum in 27 A.

Host range studies revealed that all commonly cultivated cucurbitaceous vegetables of Kerala are collateral hosts of *P. cubensis* infecting bittergourd. Cross inoculation studies showed that *P. cubensis* from bittergourd was pathogenic to all cucurbits tested and conversely isolates from other cucurbits were pathogenic to bittergourd also. On inoculation, *P. cubensis* from different cucurbitaceous hosts produced the original downy mildew symptoms of the respective hosts. Disease

symptoms in bittergourd were similar to those on pumpkin, cucumber, bottlegourd and watermelon, but differ from those on snakegourd, ashgourd and ivygourd indicating the existance of physiological races of *P. cubensis*.

In order to find out the effectiveness of various plant protection chemicals and botanicals in reducing downy mildew infection experiments were conducted under *in vitro*, pot culture and field conditions. Four fungicides such as potassium phosphonate (0.3%), chlorothalonil (0.2%), mancozeb (0.2%), copper oxychloride (0.3%) and four leaf extract of *Bougainvillea spectabilis, Lantana camara, Azadirachta indica* and *Ocimum sanctum* each at 10 per cent concentration were tested for their inhibitory effect on the growth of *P. cubensis*.

In *in vitro* studies, chlorothalonil recorded minimum disease intensity of 10 per cent against 76 per cent in control. Among the botanicals, minimum intensity was recorded in case of ocimum leaf extract. There was no significant difference in the effect of chlorothalonil from those of potassium phosphonate and copper oxychloride, but it differed significantly from mancozeb, other botanicals and control. Pot culture studies also showed that plant protection chemicals were superior to plant extracts and no significant difference was not noticed among the four fungicides tested. Eventhough all plant extracts were also found to be equally effective, the lowest disease intensity was noticed in plants sprayed with ocimum leaf extract.

From field studies also, chlorothalonil was found to be most effective as it gave maximum per cent disease control over check, followed by copper oxychloride and potassium phosphonate. Mancozeb was found to be the least effective. Among the botanicals, ocimum leaf extract was found to be superior in

reducing the disease. Maximum yield was recorded from the plots which were sprayed chlorothalonil followed by potassium phosphonate. Highest cost benefit ratio of (1:1.91) was also obtained from chlorothalonil treated plots. However, potassium phosphonate gave lowest cost benefit ratio compared to copper oxychloride and mancozeb. Consolidating the findings of *in vitro*, pot culture and field studies, fungicides and botanicals were effective in reducing the intensity of downy mildew infection in bittergourd. However, fungicides were superior to plant extract. Chlorothalonil was more effective as it gave maximum control of disease with maximum yield and highest cost benefit ratio. Among the botanicals, ocimum leaf extract gave maximum reduction of disease.

In crop loss assessment, significant difference was noticed between treated and untreated plots for disease intensity and yield. Percentage of leaf infection varied in treated and untreated plots and the extent of damage increased as the disease advanced. The highest CODEX of 60.22 per cent caused loss of 45.7 per cent in yield under natural condition.

References

REFERENCES

Anderson, R.D. and Guest, D.I. 1990. The control of black pod, canker and seedling blight of cocoa caused by *Phytophthora palmivora* with potassium phosphonate. *Aust. Pl. Pathol.* **19**:127-129

Angelov, D. 1981. The use of chemicals in the control of downy mildew of cucumber. *Rostitelna Zashchita*. **29**(11):31-35

Bains, S.S. and Jhooty, J.S. 1976. Host range and possibility of pathological races in *Pseudoperonospora cubensis* - cause of downy mildew of mush melon. *Indian Phytopath*. **29**:214-215

Bains, S.S. and Jhooty, J.S. 1978. Mode of efficacy of four fungitoxicants against *Pseudoperonospora cubensis* on musk melon. *Indian Phytopath*. **31**(3):339-342

Bains, S.S., Soki, S.S. and Jhooty, J.S. 1977. *Melothria madraspatana* a new host of *Pseudoperonospora cubensis*. *Indian J. Mycol. Pl. Pathol.* **7**:86

Bedlan, G. 1987. Studies for optimizing the dates of treatments against *Pseudoperonospora cubensis* (Berk. et Curt.) Rost. in cucumbers in Austria. *Pflanzenschutzberichte*. **48**(3):1-11

Blasquez, C.H. 1970. Varietal resistance to three cucumber foliar diseases in S.W. Florida. *Plant Dis. Rep.* . **54**(1):52-55

* Bouriquet, G. 1951. *Les maladies des plantes et la vegetation a Madagascor. Rev. Bot. appl* **31**:213-226

Brunelli, A., Davi, R., Finelli, F. and Emiliani, G. 1989. Control trials against cucurbit downy mildew (*Pseudoperonospora cubensis* (Berk. and Curt.) Rostow) on melon. *Difesadelle Piante*. **12**(1-2):265-273

Butler, E.J. 1918. Fungi and diseases in plants. Thacker Spink & Co., Calcutta, VI, p.547

*Chaban, V.V., Kitsno, L.V. and Nedobytkyn, V.A. 1990. Testing fungicides against downy mildew on cucumber. *Zashchi[illegible] Raste[illegible]* 9:27-28

Clinton, G.P. 1905. Downy mildew, or blight, Peronoplasmopara cubensis (B. & C.) Clint. *Conn. (State) Agrl. Exp. Stn., Ann. Rept. for 1904*, **28**:329-362

Cohen, R.,Schreiber, S. and Nerson, H. 1995. Response of melofon breeding lines to powdery mildew, downy mildew, *Fusarium* wilt and sudden wilt. *Plant Disease*. **79**(6):616-619

Cohen, Y. 1976. Quantitation of resistance of cucumbers and cantaloups to *Pseudoperonospora cubensis*. *Phytoparasitica*. **4**(1):25-31

Cohen, Y. 1979. A new systemic fungicide against the downy mildew disease of cucumbers. *Phytopathology*. **69**(5):433-436

Cohen, Y., Perl, M. and Roten, J. 1971. The effect of darkness and moisture on sporulation of *Pseudoperonospora cubensis* in Cucumbers. *Phytopathology*. **61**(5):594-595

Cohen, Y., Perl, M., Rotem, J.,Eyal, H. and Cohen, J. 1974. Ultrastructural and physiological changes in sporangia of *Pseudoperonospora cubensis* and *Phytophthora infestans* exposed to water stress. *Can. J. Bot.* **52**(3):447-450

Cohen, Y. and Rotem, J. 1969. The effect of lesion development, air temperature and duration of moist periods on sporulation of *Pseudoperonospora cubensis* in Cucumbers. *Israel J. Bot.* **18**(3):135-140

Cohen, Y. and Rotem, J. 1971a. Dispersal and viability of sporangia of *Pseudoperonospora cubensis*. *Trans. Br. Mycol. Soc.* **57**(1):67-74

Cohen, Y. and Rotem, J. 1971b. Rate of lesion development in relation to sporulating potential of *Pseudoperonospora cubensis* in Cucumbers. *Phytopathology*. **61**(3):265-268

Datar, V.V. and Mayee, C.D. 1981. Assessment of losses in tomato yields due to early blight. *Indian Phytopath.* **34**:191-195

Dhimon, J.S., Lal, T. and Bajaj, K.L. 1995. Evaluation of musk melon (*Cucumis melo* L.) genotypes for multiple disease resistance, yield and quality characteristics. *Trop. Agric.* **72**(1):58-62

* Doran, W.L. 1932. *Bull. Mass. Agr. Exp. Stn.* 283, p.22

Doruchowski, R.W., Rondomanski, W. and Lakowska-Ryk, E. 1994. Tolerance of the new Polish cucumber F_1 hybrids of downy mildew (*Pseudoperonospora cubensis* Berk. & Curt.) and limitation or elimination of chemical disease control. *Acta Horticulturae*. **371**:129-133

Edwin Prem, E. 1995. Etiology and control of seedling blight of cocoa. M.Sc.(Ag.) Thesis, Kerala Agricultural University, p.105

Ellis, D.E. 1951. Noteworthy diseases of cucurbits in North Carolina in 1949 and 1950. *Plant Dis. Repr.* **35**:91-93

Epps, W.M. and Barnes, W.C. 1952. The increased susceptibility of the Palmetto Cucumber to downy mildew in South Carolina. *Plant Dis. Repr.* **36**(1):14-15

Fan, Z.X. 1994. Study on efficacy of systemic and contact fungicide mixture (ND-901, ND-903) controlling downy mildew of plastic green house cucumbers. *Journal of Jilin Agric. Univ.* **16**(1):34-40

Ganguly, L.K. 1994. Fungitoxic effect of certain plant extracts against rice blast and brown spot pathogen. *Environ. and Ecol.* **12**(3):731-733

Golyshin, N.M., Maslova, A.A. and Goncharova, T.F. 1994. Fungicides against peronosporose. *Zasch. Raste.* **73**(11):18

Guncu, M. 1986. Effectiveness of some chemicals against to downy mildew (*Pseudorperonospora cubensis* (Berk. & Curt.) Rostow. on musk melon. *J. Turkish Phytopath.* **15**(2):83-87

* Haltern, V.F. 1933. Georgia Exp. Stn. Bull. p.175

Hughes, M.B. and Haltern, V.F. 1952. Two biological forms of *Pseudoperonospora cubensis. Plant Dis. Repr.* **36**:365-367

Ivanoff, S.S. 1944. Resistance of cantaloupes to downy mildew and the melon aphid. *J. Hered.* **35**:35-39

Iwata, Y. 1938. Studies on the penetration phenomena in *Pseudoperonospora cubensis* Berk. and Curt. *Ann. Phytopath. Soc. Japan.* **8**(2):125-144

Iwata, Y. 1942. Specialisation in *Pseudoperonospora cubensis* (Berk. & Curt.) Rostow. *Ann. Phytopathol. Soc. Japan.* **11**:101-103, 172-185

* Iwata, Y. 1953. *Bull. Fac. Agric. Mie Univ. Japan.* **6**:32-36

Jhooty, J.S. and Munshi, G.D. 1975. Control of Downy Mildew of Muskmelon with fungicides. *Indian J. Mycol. and Pl. Pathol.* **5**:105-106

Kamlesh Mathur and Bhatnagar, G.C. 1995. A study on yield losses due to leaf spot and foliage blight of tomato. *Veg. Sci.*. **22**(1):68-70

KAU. 1993. *The Package of Practices Recommendations*. Kerala Agricultural University, Trichur.

Kazmi, A.R., Niaz, L. and Jilani, G. 1993. Evaluation of some plant extracts for antifungal properties. *Pak. J. Phytopath.* **5**:93-97

Khalil, M.R., Khan, N.U., Younas, M., Shab, N.H. and Hassan, G. 1992. Control of downy mildew (*Pseudoperonospora cubensis* (Berk. & Curt.) Rostow) of melon (*Cucumis melo*) with different fungicide. *Pak. J. Phytopath.* **4**:1-2

Khan, M.W. 1989. Powdery mildew of cucurbits - A three pathogen disease. *Int. J. Trop. Pl. Dis.* **7**:123

* Komnenic, M., Obradavic, A. and Stankovic, C. 1995. Resistance of different cucumber genotypes to *Pseudoperonospora cubensis*, causal agent of downy mildew. *Zatita Bilja.* **46**(1):69-74

* Krivchenko, V.I., Medvedeva, N.I. and Medvedev, A.Y. 1986. Disease resistance of accessions from the cucumber collection. *Sbornik Nauchnykh Trudov po Prikladnoi Botunike, Genetike i Selektsii*. **102**(19):65-72

* Kuznetson, N.N. 1980. The effect of temperature and moisture on the pathogen of downy mildew. *Zasch[illegible] Raste[illegible]* **11**:35

Lakshmanan, P., Mohan, S. and Jayarajan, R. 1990. Antifungal properties of some plant extracts against *Thanatephorus* cucumeris, the causal agent of collar rot disease of *Phaseolus aureus*. *Madras Agric. J.* **77**:1-4

Lebeda, A. 1991. Resistance in muskmelons to Czechoslovak isolates of *Pseudoperonospora cubensis* from cucumbers. *Scientia Horticulture* **45**:225-260

Lebeda, A. 1992. Screening of wild *Cucumis* species against downy mildew isolates from cucumbers. *Phytoparasitica* **20**(3):203-210

Mahapatra, T.K. and Tewari, S.N. 1994. *Ocimum sanctum* L. leaf extract toxicity against collar rot (*Aspergillus niger*) and yellow root (*A. flavus*) diseases of groundnut. *Allelopathy Journal*. **1**(2):114-117

Mahrishi, R.P. and Siradhana, B.S. 1990. Metalaxyl and mancozeb mixtures - fungicide for the control of downy mildew of musk melon. *Summa Phytopathologica* **16**(2):174-177

* Manole, N. 1988. Control of cucumber pathogens in Moldova. *Cercetari Agronomice in Moldova*. **21**(4):69-74

* Marinkovic, N., Obradovic, A., Mijatovic, M., Stankovic, L. and Milic, B. 1992. Reaction of some cucumber genotypes to infection caused by *Pseudoperonospora cubensis* Rost. *Zastita Bilja*. **42**(1):55-58

* Medvedev, A.V., Medvedeva, N.I. and Yakimenko, L.N. 1991. Sources of resistance to downy mildew. *Kartofel i Ovoshchi*. **6**:16

Meena, S.S. and Mariappan, V. 1993. Effect of plant products on seed borne mycoflora of sorghum. *Madras Agric. J.* **80**(7):383-387

* Merz, F., Schrameyer, K. and Sell, P. 1995. Establishment of a standard treatment against downy mildew in cucumber. *Gemiise* **31**(7):438-439

Mohan, S. and Ramakrishnan, G. 1991. Antifungal activity of various plant extracts/products on *Exerohilum turcicum* (Pass.) Leonard. *Madras Agric. J.* **78**:57-59

Mullins, C.A., Straw, R.A., Bost, S.C., Onks, D.O., Pitt, W.D. and JR. 1993. Pumpkin cultivar and fungicide trials. *Tennesse Farm and Home Science.* **168**:29-34

Narasimhan, V., Sridhar, V.V. and Kareem, A.A. 1993. Efficacy of botanicals in managing sheath rot (ShR) of rice. *International Rice Research Notes.* **18**(3):33

Neykov, S. and Dobrev, D. 1988. Introduced cucumber cultivars relatively resistant to *Pseudoperonospora cubensis* in Bulgaria. *Acta Horticulturae* **221**:115-119

Norin, I. 1987. Plant Protection year 1986 - horticulture. *Vaxtskyddsnotiser.* **51**(2):38-40

Palti, J. 1974. The significance of pronounced divergences in the distribution of *Pseudoperonospora cubensis* on its crop hosts *Phytoparasitica.* 2(2):109-115

Palti, J. 1975. Peronosporales. CMI Descriptions of Pathogenic Fungi and Bacteria. Set 36. No.457, Commonwealth Mycological Institute, Kew, Surrey, England.

* Palti, J. and Chorin, M. 1964. *Phytopathol. Mediterr.* 3:50-56

Palti, J. and Cohen, Y. 1980. Downy mildew of cucurbits (*P. cubensis*) : the fungus and its hosts, distribution, epidemiology and control. *Phytoparasitica.* **8**(2):109-147

* Palti, J. and Rotem, J. 1971. *Z. Pfl. Krankh.* **78**:495-501

Pan, R.S. and More, T.A. 1995. Multiple disease resistance in melon (*Cucumis melo* L.). Paper presented in National Symposium on Recent Developments in Vegetable Improvement, 2-5 February at Raipur. p. 24-25

Panse, V.G. and Sukhatme, P.V. 1978. *Statistical Methods for Agricultural Workers.* 3rd edn. ICAR, New Delhi.

Parris, G.K. 1951. Downy mildew resistant strains of water melon from the Dominican Republic, West Indies. *Plant Dis. Rep.* 35:399-401

Patel, J.G. and Patel, A.J. 1980. Efficacy of systemic and non-systemic fungicides on the control of downy mildew of mus k melon. *Indian J. Mycol. Pl. Pathol.* 10(1):87

Patil, R.K., Sharma, A. and Pathak, V.N. 1992. Inhibition of polyamine biosynthesis in *Botryodiplodia theobromae* Pat. and *Rhizopus arrhizus* Fisher by *Ocimum sanctum* leaf extract. *Indian J. Mycol. Pl. Pathol.* 22(2):201-202

*Pettersson, M.L. 1986. Plant protection year 1985-horticulture. *Vaxtskyddsnotiser.* 50(1):13-16

Phookan, A.K. and Gogoi, R. 1995. Occurrence of Downy Mildew on Bittergourd in Assam. *Indian J. Mycol. Pl. Pathol.* 25(3):331

* Pitrat, M. and Blancard, D. 1988. Some aspects of resistance of musk melon to downy mildew. *Avignon Montfavet.* p.57-62

* Pivovarov, V.F. 1984. Breeding cucumber for disease resistance using different ecological conditions. *Selektsiya i Semenovadstvo* 10:20-22

* Pivovarov, V.F. and Kudelich, V.S. 1985. Using the VIR collection in breeding cucumber for downy mildew resistance in the republic of Cuba. *Genetike i Selektsii* 92:97-102

* Planchon, J. 1879. *Cr. Acad. Sci. Paris.* 89:697

Pradeepa, A., Sivakadadcham, B. and Amarasiri, S.L. 1990. Effect of six plant (*Pleurotus ostreatus*) and some associated common weed moulds. *Trop. Agric.* **146**:93-103

Rajkumar., G, Kalloo and Pandey, P.K. 1995. Resistance in cowpea to *Pseudocercospora*. Paper presented in National Symposium on Recent Developments in Vegetable Improvement. 2-5 February at Raipur. p.23

Ramakrishanan, T.S., Srinivasan, K.V. and Sundaram, N.V. 1953. Additions to fungi of Madras XIII. *Proc. Ind. Acad. Sci.* **36B**:85-95

Ram, D. and Pandey, P.K. 1995. Varietal resistance of bottle gourd to downy mildew (*Pseudoperonospora cubensis*). Paper presented in National Symposium on Recent Developments in Vegetable Improvement. 2-5 February at Raipur. p.26

Rangaswami, G., Seshadri, V.S. and Lucy Channamma, K.A. 1970. Fungi of South India. University of Agricultural Sciences, Bangalore, p.193

* Riley, C.V. 1886. *Rural New Yorker*. **45**:72-87

Rondomanski, W. and Woozniak, J. 1989. Distribution and chemical control of downy mildew on cucumber. *Biluletyn Wazzywniczy*. **2**:145-149

* Roque, A. and Adsuar, J. 1938. *Ann. Rept. Puerto Rico Agric. Expt. Sta.* 1937-1938, p.45-46

* Roque, A. and Adsuar, J. 1939. *Ann. Rept. Puerto Rico Agric. Expt. Sta.* 1938-1939, p.61-62

* Rotem, J., Palti, J. and Lomas, J. 1971. *Final Rep. Res. Agric. Res. Organ.*, Volcani Center, Bet Dugan, Israel, p.229

Roy, A.K. 1965. Additions to the fungal flora of Assam-I. *Indian Phytopath.* **18**:327-334

Royle, D.J. 1976. Downy mildews and weather. *Ann. Appl. Biol.* **84**:227-278

* Sambandam, C.N., Parthasarathy, V.S. and Anthony Raj, S. 1979. Reaction of certain forms of *Cucumis* spp. to downy mildew. Auara. 7:149-150

Samoucha, Y. and Cohen, Y. 1984. Differential sensitivity to mancozeb of metalaxyl-sensitive and metalaxyl-resistant isolates of *Pseudoperonospora cubensis*. *Phytopathology*. **74**(12):1437-1439

Sarvamangala, H.S. and Datta, R.K. 1993. Evaluation of plant extracts for the control of fungal diseases of mulberry. *Indian Phytopath*. **46**(4):398-401

Schenck, N.C. and Crall, J.M. 1963. Fungicidal control of watermelon foliage diseases. *Proc. Fla. St. Hort. Soc.* 75th annual meeting. p.225-228

Shetty, A., Shetty, H.S. and Safeeulla, K.M. 1982. Effect of ridge gourd pollen on goospore germination of *Pseudoperonospora cubensis* and its significance in epidemiology. Proceedings of the Indian Academy of Sciences, Plant Sciences. **91**(5):427-431

Shurtlett, M.G. 1973. *Ann. Phytopath. Soc.* p.64

Singh, H.N.P., Prasad, M.M. and Sinha, K.K. 1993. Efficacy of leaf extracts of some medicinal plants against disease development in banana. *Letters Appl. Microbiol.* **17**(6):269-271

Singh, P.P. and Singh, R. 1992. Disease severity gradient of downy mildew of musk melon from a source point of infection. *Plant Dis. Res.* 7(2):197-203

Singh, R.K. and Dwivedi, R.S. 1990. Fungicidal properties of neem and blue gum against *Sclerotium rolfsii* Sacc. a foot rot pathogen of barley. *Acta Botanica Indiae*. **18**(2):260-262

Sobti, A.K., Sharma, O.P. and Bhargava, A.K. 1995. A comparative study of fungicidal compounds and plant extracts against three pathogens of *Arachis hypogaea*. *Indian Phytopath* **48**(2):191-193

Suhag, L.S., Maheshwari, S.K. and Duhan, J.C. 1988. Chemical control of *Pseudoperonospora cubensis* causing downy mildew on sponge gourd (*Luffa cylindrica*). *Indian J. Agric. Sci.* **58**:462-464

Sumner, D.R., Phatak, S.C., Smittle, D., Johnson, A.W. and Glaze, N.C. 1981. Control of cucumber foliar diseases, fruit rot and nematode by chemicals applied through over head sprinkler irrigation. *Plant Disease.* **65**(5):401

Sundrival, R.C. 1991. Fungitoxic properties of flower extracts of some wild plants of Garhwal Himalaya. *Advances in Plant Science.* **4**(2):230-234

Sydow, H. and Butler, E.J. 1916. Fungi Indiae Orientalist Pars V. *Ann. Mycol.* **14**:177-220

* Tarr, S.A.J. 1962. *Diseases of Sorghum, Sudan grass and Broom corn.* p.380

Tewari, S.N. and Nayak, M. 1991. Activity of four plant leaf extracts against three fungal pathogens of rice. *Trop. Agric.* **68**(4):373-375

Thind, T.S., Singh, P.P., Sokhi, S.S. and Grewal, R.K. 1991. Application timing and choice of fungicides for the control of downy mildew of musk melon. *Plant Dis. Res.* **6**(1):49-53

* Tsyplenkov, A.E. 1990. Trial of cucurbitaceous crops in Cuba. *Kartofel i Ovoshchi.* **3**:26

Ullasa, B.A. and Amin, K.S. 1988. Ridge gourd downy mildew epidemics in relation to fungicidal sprays and yield loss. *Mysore J. Agric. Sci.* **22**:62-67

Upadhyaya, M.L. and Gupta, R.C. 1990. Effect of extracts of some medicinal plants on the growth *Curvularia lunata. Indian J. Mycol. and Pl. Pathol.* **20**(2):144-145

Uppal, B.N., Patel, M.K. and Kamat, M.N. 1935. The fungi of Bombay VIII: 1-56

Vanderplank, J.E. 1968. *Disease Resistance in Plants.* Academic Press, New York, 7-53

* Varady, C. and Ducrot, V. 1985. Downy mildew of cucumber. *Revue Suisse de Viticulture.* **17**(2):103-106

Venkatanarayanan, S.V. and Venkatakrishniah, N.S. 1953. New hosts of the downy mildew of cucurbits in India. *Curr. Sci.* **22**:183-184

Walker, J.C. 1952. Diseases of Vegetable Crops. McGraw-Hill Book Company, Inc.

Walker, J.C. 1965. Disease resistance in the vegetative crops. III. *Bot. Rev.* **31**:331-380

* Wessel-Beaver, L. 1993. Powdery and downy mildew resistance in *Cucurbita moschata* accessions. Report - *Cucurbit genetic cooperative*. University of Puerto Rico.

Wheeler, B.E.J. 1969. An introduction of Plant Disease. John Wiley & Sons Ltd., London. p.301

Yarwood, C.E. 1978. History and Taxonomy of Powdery Mildews. *The Powdery Mildew*. (Ed. D.M.Spencer). Academic Press, London, p.1-32

* Yurina, O.V., Anikina and Yurina, T.P. 1990. Search for resistant forms. *Kartofel i Ovoschchi*. **3**:25-26

* Originals not seen

VARIETAL SCREENING, HOST RANGE AND CONTROL OF DOWNY MILDEW OF BITTERGOURD (*Momordica charantia* L.) CAUSED BY *Pseudoperonospora cubensis* (BERK. & CURT.) ROSTOW

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ABSTRACT

A study was conducted at the College of Horticulture, Vellanikkara, during 1993-95, on varietal screening, host range and control of downy mildew of bittergourd [*Pseudoperonospora cubensis* (Berk. & Curt.) Rostow]. Varieties obtained from the Department of Olericulture were screened for disease resistance and it was found that all the varieties tested were moderately susceptible to the disease. A preliminary screening of 174 genotypes of bittergourd available at NBPGR was conducted during August 1994 and all the genotypes were found to be infected. Only 32 genotypes were moderately resistant to the disease.

Host range studies revealed that *P. cubensis* from bittergourd can infect other cucurbitaceous crops, such as bottlegourd, pumpkin, cucumber, snakegourd, ashgourd, watermelon and ivygourd. Four fungicides and four plant extracts were tested in *in vitro*, pot culture and field conditions to find out their effectiveness in reducing downy mildew infection. Among the fungicides, chlorothalonil (0.2%) was found to be the most effective as it gave maximum disease control, maximum yield and highest cost : benefit ratio. Among the botanicals, ocimum leaf extract (10%) gave maximum reduction of the disease. In crop loss assessment, it was found that the highest CODEX of 60.22 per cent could cause an yield loss of 45.7 per cent under natural condition.