# Studies on Fungal Foliar Diseases of Cucumber (*Cucumis sativus* L.) in Kashmir Valley

**Shanaz Yousuf**
**(2009-268-D)**


**Division of Plant Pathology**
**Faculty of Horticulture**

**Sher-e-KashmirUniversity of Agricultural Sciences & Technology of Kashmir**

**2015**

# Studies on Fungal Foliar Diseases of Cucumber (*Cucumis sativus* L.) in Kashmir Valley

**Shanaz Yousuf**
**(2009-268-D)**

## Thesis

Submitted to

**Faculty of Horticulture**

**Sher-e-Kashmir University of Agricultural Sciences &Technology of Kashmir**

**in partial fulfilment of requirement for the award of the degree of**

## Doctor of Philosophy in Plant Pathology

**2015**

*Dedicated*

*to my*

*"Parents"*

**Sher-e-Kashmir**
**University of Agricultural Sciences & Technology of Kashmir**
**Faculty of Horticulture, Division of Plant Pathology**

## Certificate – I

This is to certify that the thesis entitled **"Studies on fungal foliar diseases of cucumber (*Cucumis sativus* L.) in Kashmir valley"** submitted in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Plant Pathology**, to the **Faculty of Horticulture, Sher-e-Kahsmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Shanaz Yousuf (Regd. No. 2009-268-D)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

**(Dr. G.H. Dar)**
Chairman
Advisory Committee

**Endorsed**

**Prof. & Head,**
**Division of Plant Pathology**

**Sher-e-Kashmir**
**University of Agricultural Sciences & Technology of Kashmir**
**Faculty of Horticulture, Division of Plant Pathology**

## Certificate – II

We, the members of the Advisory committee of **Ms. Shanaz Yousuf (Regd. No. 2009-268-D)**, a candidate for the degree of **Doctor of Philosophy in Plant Pathology**, have gone through the manuscript of the thesis entitle **"Studies on fungal foliar diseases of cucumber (*Cucumis sativus* L.) in Kashmir valley"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of degree.

## Advisory Committee

| | |
|---|---|
| **Chairman** | **Dr. G.H. Dar,**<br>Professor-cum-Chief Scientist, Division of Plant Pathology, SKUAST-Kashmir |
| **Members** | **Dr. N. A. Khan,**<br>Associate Professor, Division of Plant Pathology, SKUAST-Kashmir |
| | **Dr. N. A. Qazi,**<br>Professor, Division of Plant Pathology, SKUAST-Kashmir |
| | **Dr. Kounsar Parveen,**<br>Associate Professor, Division of Vegetable Science, SKUAST-Kashmir |
| **Dean's Nominee** | **Dr. H.R. Naik,**<br>Professor and Head, Faculty of Post Harvest Technology,<br>SKUAST-Kashmir |

**Sher-e-Kashmir**
**University of Agricultural Sciences & Technology of Kashmir**
**Faculty of Horticulture, Division of Plant Pathology**

## Certificate – III

This is to certify that the thesis entitled, **"Studies on fungal foliar diseases of cucumber (*Cucumis sativus* L.) in Kashmir valley"**submitted by **Ms. Shanaz Yousuf(Regd. No. 2009-268-D)** to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Plant Pathology**was examined and approved by the Advisory Committee and external examiner on ……..

**Chairman**
**Advisory Committee**

**External Examiner**

**Prof. & Head,**
Division of Plant Pathology

**Dean,**
Faculty of Horticulture,
SKUAST-Kashmir

**Sher-e-Kashmir**
**University of Agricultural Sciences & Technology of Kashmir**
**Faculty of Horticulture, Division of Plant Pathology**

| | | |
|---|---|---|
| Name of the student | : | **Shanaz Yousuf** |
| Registration No. | : | 2009-268-D |
| Major subject | : | Plant Pathology |
| Minor subjects | : | Vegetable Science |
| Major advisor | : | **Dr. G.H. Dar**<br>Professor-cum-Chief Scientist,<br>Division of Plant Pathology,<br>SKUAST-Kashmir |
| Title of the Thesis | : | **"Studies on fungal foliar diseases of cucumber (*Cucumis sativus* L.) in Kashmir valley"** |

# ABSTRACT

The studies were conducted in the year 2011 and 2012 on prominent foliar fungal diseases of cucumber (*Cucumis sativus* L.) prevalent in Kashmir valley. The survey conducted in four major commercial growing districts *viz.,* Baramulla, Srinagar, Bandipora and Budgam revealed downy mildew, anthracnose, Alternaria leaf spot and powdery mildew as the predominant diseases. During 2011 and 2012, the mean disease incidence of downy mildew, anthracnose, Alternaria leaf spot and powdery mildew was 34.0 and 41.3, 34.7 and 47.2, 35.5 and 45.6, and 33.0 and 39.7 per cent, respectively. The mean disease intensity of respective diseases during 2011 and 2012 was 14.1 and 17.6, 16.1 and 20.8, 13.3 and 16.1 and 14.1 and 16.6 per cent. District-wise highest mean incidence of these diseases, except powdery mildew, was observed in Srinagar followed by Baramulla. However, in case of powdery mildew the highest disease incidence was noticed in Baramulla followed by Srinagar. Each disease was identified by its peculiar characteristic symptoms. The pathogens responsible for inciting these diseases were identified as *Pseudoperonospora cubensis* (downy mildew), *Colletotrichum arbiculare* (anthracnose), *Alternaria alternata* (Alternaria leaf spot) and *Sphaerotheca fuliginea* (powdery mildew). These pathogens perpetuated during winters on fallen diseased leaves in the form of oospores in case of downy mildew, acervulli/conidia in case of anthracnose and as conidia in case of Alternaria leaf spot and powdery mildew. The conidial production and their viability in soil decreased with increasing depth of placement of infected leaves.

The crop debris was available only upto 2nd fortnight of April as it perished thereafter due to decomposition. Disease tolerance of varying magnitude was observed under natural conditions in the available cucumber germplasm. Of the twenty cultivars screened for resistance to all these diseases during 2011 and 2012, 'Pusa Sanyug', Hybrid-5 and Priya were found resistant to most of these diseases, 'Hybrid-5' and 'Priya' were tolerant to downy mildew and anthracnose, while 'Green Express' and 'Marketer 76' were resistant to Alternaria leaf spot, and genotype was Marketer-76 to powdery mildew and Alternaria leaf spot resistant. Only one cultivar 'SKAU-2' was highly susceptible to powdery mildew. Evaluation of SAR chemicals at various growth stages indicated that the intensity of each disease was generally higher in year 2012 than in 2011. The INA and BTH were significantly effective against downy mildew in comparison to check; while BABA and INA most effectively reduced anthracnose and Alternaria leaf spot diseases. BTH and $NaHCO_3$ were most effective in minimizing powdery mildew disease. Other chemicals tested were also effective in reducing diseases though not at par. Amongst the various fungitoxicant sets tested, pyraclostrobin + boscalid 38 WG followed by 2nd spray with captan + hexaconazole 75 WP and 3rd spray with metiram + pyraclostrobin 60 WG showed least disease intensity in each disease. Other sets also effectively reduced these diseases while biocontrol agent (*Amplomyces quisqualis*) was only effective against powdery mildew.

**Key words:** Anthracnose, Alternaria leaf spot, Cucumber, Disease management, Downy mildew, Fungitoxicants, Kashmir, Powdery mildew, Varietal screening, SAR chemicals

Signature of Student

Dated: _____

Signature of Major Advisor

Dated: _____

# ACKNOWLEDGEMENT

At the first, I humbly bow in reverence to Almighty for giving me enough courage, patience and success in this venture and His blessings which will always be a beacon to lead me in all my pursuits in future too.

*It gives me a great pleasure to express my sincere gratitude and regards to my esteemed Major Advisor, Dr. G. H. Dar Professor, Division of Plant Pathology, for his efficient and expert guidance, kind inspiration, keen interest, supportive attitude, suggestions which are highly valuable. I humbly thank him for his sincerity which led this uphill task to its successful completion.*

*It is my privilege to place on record my profound gratitude and thanks to my previous advisor, Dr. Shahzad Ahmad Khan Rtd. Associate Professor, Division of Plant Pathology, for his soft and sober attitude, inspiring guidance, Scholastic supervision and kind cooperation in planning and execution of the research work well as in successful completion of the manuscript.*

*I express my heartfelt thanks to the members of my advisory committee – Dr. N.A. Khan, Associate Professor Division of Plant Pathology, Dr. N.A. Qazi, Professorand Head, Division of Plant Pathology, Dr. Kounser Parveen, Associate Professor, Division of Vegetable Science, and Dr. A.R Naik, Professor and Head (Dean PG's Nominee) for their valuable moral support throughout the period of this study.*

*I thankfully acknowledge the cooperation and helping hand extended by my teachers viz. Dr. G.N. Bhat, Dr. M.Y. Ghani, Dr. M.A Beig, Dr. Ali Anwar, Dr. Khursheed Ahmad, Dr. Ashraf Alam Wani, Dr. V. K, Ambardar, Dr. Shaheen Kounsar, Dr. G.H. Mir, Dr. M.D. Shah, Dr. B.A. Paddar, Dr. Farooq Ahmad, Dr. Tariq Ahmad, Dr Zahoor Ahmad, Dr. Mushtaq Ahmad, Dr. F. A. Mohideen, Dr. Najeeb A. Mughal, Dr. Aflaq Ahmad. Dr. Saba Banday, Dr. Sabiya Ashraf, Dr. Sabiya Basher and Dr. Efath Shahnaz.*

*My special thanks from the core of my heart are due to all my friends and colleagues especially Shubana Bhat, Farahanaz, Summuna, Faheem, Waseem Ali, Parveez Ahmad, Hilal, Rayees, Nasreen Fatima, Humaira and Nasreen for their help during my research work.*

*I also extend my heartfelt thanks to laboratory staff and field assistants of division of Vegetable Science and faculty of Vegetable Science especially Dr. Shabir Ahmed,Dr. Pradeep Kumar, Dr. Shahnaz Mufti, Dr. Faisal Nabi, Dr. Jala-lu-din, and Dr. A. R. Malik (Faculty of Forestry)for their moral support and cooperation during the course of this investigation.*

*I am extremely grateful to the staff members of Central Library SKUAST-K for rendering full cooperation and help in the collection of research material.*

*My heartfelt thanks are due to my family and my in-laws for their love, constant*

*inspiration and encouragement. Very special thanks to my husband Dr. Sham Sul- Haq for his Support which acted as a premium to my achievement. Special thanks to my brothers Mr. Muhammmad Amin Bhat and Yasir Bashir and sisters Tahmeena, Nargis and Suraya,for their love and support instead of all odds. My love is due to my darling sons Ibraaheem Ahmad and Haaid Ahmad my neice Deelak, Haadi, Mariya, Utoiba and Anamm nephew Dr.Abid Amin, Asim, Rawhaan and Dawood whom I couldn't give the required time and attention which they deserved.*

*A word of appreciation is due for Mr. Rafiq Ahmad and Mr. Shahid Sultan of M/s Universal Computers, Shalimar for giving a final shape to this manuscript.*

*Last but not least thanks to my all friends and well wishers for their love and support. All those who care for me may not have got a mention, but none shall ever be forgotten.*

*Shanaz Yousuf*

**Place :** Shalimar, Srinagar

**Dated :**

# CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF PLATES

**Chapter – 1**

# INTRODUCTION

Cucumber (*Cucumis sativus* Linn.) belongs to the family *Cucurbitaceae* and is one of the oldest cultivated vegetable originated from Southern Asia (Wehner and Robinson, 1991; Doijode 2001; Renner, 2007). The genus *Cucumis* contains 52 species, of which *C. sativus* is one of the most important commercial crops grown across the climatic regions from tropical to temperate areas (Ghebretinsae *et al*., 2007). Worldwide cucumber is 4$^{th}$ most widely cultivated vegetable crop after tomato, cabbage and onion (Shetty and Wehner, 2002). Cucumber is a creeping vine that bears cylindrical fruits which are mostly used for culinary purpose. Cucumbers are of three main types i.e. slicing, pickling, and burpless. Of these, the market demand for slicing type cucumber has increased tremendously in recent years (Whitaker and Davis, 1962). Since cucumber is a tender crop, therefore it is frost susceptible and suffers much when temperature falls below 15ºC for a longer period (Singh, 1997). Nutritionally the edible portion of cucumber contains 2.7 per cent carbohydrates, 0.4 per cent mineral matter and rest water (Singh *et al*., 2004).

Globally cucumber production is 71.36 million tonnes and is grown on 2.11 million hectare area with yield value of 33.49 tonnes/ha (FAOSTAT, 2013). About 80 per cent world cucumber production occurs in Asia alone with China as a leading producer (Wehner and Maynard, 2003). Cucurbits including cucumber share about 5.6 per cent of the total vegetable produced in India and according to FAO estimate cucurbit crops in India are cultivated on about 4.29 million ha with the productivity of 10.52 t/ha. The cucumber export and import in Jammu and Kashmir is 218.75 and 5.42 thousand tonnes, respectively (Anonymous, 2014). In Kashmir valley cucumber is grown on approximately 640 hectare area (Masoodi, 2003). India exports about 24,096 metric tons cucumber each year and shares 1.49 per cent vegetable export (FAOSTAT, 2006). France, USA, Spain, Netherlands

and Belgium are the major importers of fresh cucumber from India and import 21.0, 14.0, 10.7, 8.5 and 7.0 per cent fresh cucumber from India (Kumar *et al.*, 2008).

The cucumber seeds are often used in Ayurvadic preparations and are good for brain and body development (Shanmugavelu, 1989). Cucumber is beneficial to jaundice patients and prevents constipation due to its cooling effect. Cucumber has both culinary and non-food use. Some cosmetic products, including lotions, perfumes and soaps contain cucumber extracts. The fruits are commonly eaten afresh as salad, pickle or cooked. Cucumber seed oil is used in French cuisine (Robinson and Decker-Walters, 1997). Like many cucurbit crops, cucumber is prone to a number of fungal, bacterial and viral diseases which cause serious economic losses to the crop. Mostly fungal diseases which include downy mildew (*Pseudoperonospora cubensis*); powdery mildew (*Sphaerotheca fuliginea; Erysiphae cichoracearum*); anthracnose (*Colletotrichum orbiculare* syn. *C. lagenarium*), Cercospora leaf spot (*Cercospora citrullina*); Alternaria leaf spot (*Alternaria alternata*); damping off (*Pythium* spp.) Fusarium wilt (*Fusarium oxysporum* f.sp. *cucumerinum*) and Phytophthora crown and root rot (*Phytophthora capsici*) inflict huge economic losses worldwide (Zitter *et al.*, 1998; Saha, 2002). Of these downy mildew, powdery mildew, anthracnose, Alternaria leaf spot, scab, septoria leaf spot and ulocldium leaf spot are most wide spread and economically important destructive diseases all over world (Zitter *et al.*, 1998).

Downy mildew in cucumber is wide spread in tropical, semi-arid and temperate regions (Palti and Cohen, 1980). It manifests as pale green lesions on dorsal sides of leaves giving them a mottle appearance. The spots increase in size, turn yellow and coalesce to cover entire leaf. The ventral side of leaves is covered with light purple mycelium which bears lemon-shaped sporangia. The disease decreases flower set and fruit development by killing foliage (Hashmi, 1994). The causal pathogen *P. cubensis* shows highly distinct host specificity and attacks

above-ground portions mainly the leaves. The formation of zoospores depends on the environmental conditions and occurs only in presence of water but is inhibited at high temperature. As infection progresses, the chlorotic lesions expand and become necrotic (Oerke *et al*., 2006). Low temperatures delay symptom development while still promoting leaf colonization, whereas high temperature causes lesion chlorosis at a faster rate that inhibits pathogenic growth (Cohen, 1977). With disease progression, the leaves die within days following the initial infection (Thomas, 1996). Reduced canopy leads to the cessation of fruit development and more exposure of fruits to sun, thereby causing sun scald and secondary rots; and adversely affects crop yield and fruit quality (Keinath *et al*., 2007). Downy mildew perpetuates as oospore in cucurbits including cucumber.

Another disease powdery mildew inflicts huge economic losses to both field and greenhouse grown cucumber plants (Reuveni *et al*., 2000). The disease, caused by *S. fuliginea,* produces white talcum-like conidia and mycelium on leaf surface, petiole and stem. The floccose circular discrete to coalescing powdery spots of various sizes appear on infected leaves. The spots are mostly hypo-phyllous but in some cases may be epiphyllous (Khan and Sharma, 1995). The premature senescence of infected leaves results in fruit sunburn or premature ripening (Mc Grath, 1996). The perithecia formation occurs due to the interaction of host, parasite and environment. The powdery mildew fungus perpetuates as mycelium and conidia (Saenz and Taylor, 1999).

Anthracnose (*Colletotrichum orbiculare*) is another serious disease which infects all the aerial parts of cucumber plant and manifests as angular to roughly circular reddish brown lesions on leaves. Under humid conditions the lesions become dotted with pinkish masses of conidia. Conidia are mostly produced singly and occasionally in chains at the tip of conidiophores acrogenously (Vashishta, 1999; Saha, 2002). The disease affects foliage, stem and fruit of cucumber, gourd, muskmelon and watermelon (Delahuat and Stevenson, 2004) but rarely occurs on pumpkin and squash (Wasilwa *et al.*, 1993). In severe

attack, anthracnose may reduce crop yield. Such attacks occur mostly in early season when the conditions of enough precipitation and temperature <32°C prevail (Thompson and Jenkins, 1985). The pathogen survives as conidia in plant debris and seeds (Palenchar *et al.*, 2009).

Alternaria leaf spot incited by *Alternaria alternata* appears first on older leaves as small circular necrotic spots, somewhat water-soaked or transparent, which may be surrounded by a yellow halo. The lesions expand to form large brown spots in concentric ring pattern and later coalesce, sometimes causing leaf blight (Watson and Napier, 2009). As the disease progresses, the leaves curl, wither and fall prematurely leading to plant decline (Kucharek, 2000). Alternaria leaf spots increase rapidly in warm humid weather on older leaves and later spread to younger leaves mostly toward the vein tips. Vines may be partly or completely defoliated by harvest time (Babadoost, 1989). *Alternaria* species are mostly saprophytic fungi but some species may acquire pathogenic capacities causing disease over a broad host range (Thomma, 2003). *Alternaria* over-winters as spores in a plant debris (Watt, 2004).

Scab caused by *Cladosporium cucumerinum* affects all the aerial parts of cucumber. Water-soaked spots appear on leaves which eventually turn grey to white and attain 3-4 mm size. The spots ooze a gummy substance. The fungus is seed-borne and also survives in soil on plant debris. The disease spreads by wind under moist conditions. Cool, wet weather, including rain, dew and fog, favour disease development (Watson and Napier, 2009).

Septoria leaf spot, caused by *Septoria cucurbitacearum,* under moist conditions appears as small, dark brown, water-soaked spots which measure 1-2 mm in diameter. Under dry conditions the spots beome circular or occasionally irregular. On older lesions, small black pycnidia embedded in tissue are formed (Watson and Napier, 2009).

Ulocladium leaf spot, incited by *Ulocladium cucurbitae,* appears as reddish

brown spots of 1 to 2 mm diameter on lower leaves near the crown. Under favourable moisture and temperature, the lesions enlarge, become mostly circular to irregular and attain 6-7 mm size. The centers are beige to brown but occasionally white, surrounded by a dark brown ring and a brown halo. No fruiting bodies are formed. The pathogen survives on infected debris in soil as conidia which act as primary inoculum for infections (Zitter, 1987).

The above diseases can be managed through foliar biocidal applications, but for this it is imperative to have the knowledge about the pathogens involved, their etiology, perpetuation and predisposing factors. However, biocidal applications have adverse consequences on human health and ecosystem so there is urgent need to assess the role of less harmful fungicides as well as screen the existing varieties/genotypes so as to formulate safer integrated disease management strategies. Induced systemic resistance (SAR) imparted by some biotic and abiotic inducing agents has been demonstrated in a number of plant-pathogen systems (Sticher *et al*., 1997). The major hallmark of this form of resistance is the ability of plants to defend themselves against broad spectrum pathogens by triggering plant species-specific defense responses without disturbing the environment (Metraux, 2001). SAR chemicals like salicylic acid (SA), 2,6-dicholoroisonicotinic acid (INA), β-amino butyric acid (BABA), benzo-(1,2,3)-thiadiazole-7-carbothioic acid S-methyl ester (BTH), etc., have reportedly been used to induce resistance in several host plants but such approach needs thorough investigation prior to their recommendation for field application (Siegrist *et al*., 2000; Hafez *et al*., 2004). Another approach to minimize diseases with less thrust on biocidal use is to select the plants showing disease resistance/ tolerance against most prevalent diseases among the available germplasm pool (Trigiano *et al*., 2004; Singh and Singh, 2005). Fungal diseases are major production constraint in successful cucumber production in Kashmir valley and appear frequently in field, substantially reducing the crop yield. Therefore, it was thought imperative to conduct systematic study on major cucumber diseases and

explore strategies to combat multiple diseases. Such information under Kashmir temperate conditions is either meager or almost lacking so a comprehensive study was undertaken with the following objectives:

- To ascertain the status of fungal foliar diseases of cucumber in Kashmir;
- To study the symptomatology of diseases;
- To study the perpetuation of associated pathogens;
- To screen the available cucumber germplasm against the diseases; and
- To devise suitable management programme

**Chapter – 2**

# REVIEW OF LITERATURE

Cucumber (*Cucumis sativa*) is grown worldwide but suffers from several production constraints including frequent occurrence of diseases. Mostly huge economic losses to the crop are inflicted by fungal diseases. The present chapter reviews the work done in India and abroad on the important fungal diseases of cucumber:

## 2.1. Status of fungal diseases on cucumber

Cucumber crop is amenable to a number of fungal, bacterial and viral pathogens during growth period leading to a substantial crop loss (Harfoush and Salama, 1992; Reuveni *et al*., 1993; El-Gamal, 2003). The major fungal diseases which inflict heavy economic losses to the crop include downy mildew [*Pseudoperonospora cubensis* (Berk & Curtis)]; powdery mildew [*Sphaerotheca fuliginea* (Schlechtend. Fr:) Pollaci and *Erysiphae cichoracearum* DC]; anthracnose [*Colletotrichum orbiculare* Berk & Mont. Arx (syn. *C. lagenarium* (Pass. Ellis & Halst.)]; Cercospora leaf spot (*Cercospora citrullina* Cooke*)*; Alternaria leaf spot [*Alternaria alternata* (Fr.) Keissler]; damping off (*Pythium* spp.) and Fusarium wilt [(*Fusarium oxysporum* Schlechtend Fr. f.sp. *cucumerinum* (J.H. Owen)], etc. (Saha, 2002).

Berkeley and Curtis first documented downy mildew on cucurbits in 1868 in Cuba and named its causal pathogen *Peronospora cubensis* (Berkeley and Curtis, 1868). Rostovtsev in Russia on the basis of sporangial germination described the pathogen of cucurbit downy mildew as a new genus namely *Pseudoperonospora* (Skalicky, 1961). Later, downy mildew fungus was reported from England and USA in 1889 (Walker, 1969). Although the disease has been studied extensively for more than 100 years, still the area-specific information about this pathogen is lacking (Lebeda, 1990, 1999; Lebeda and Schwinn, 1994). *P. cubensis* is a widely distributed pathogen found in all cucurbit growing areas

worldwide (Lebeda and Cohen, 2011). During the first half of 20th century, it was recorded several times from several countries but in sporadic form (Zacha *et al*., 1985; Lebeda, 1986; Ackermann, 1990). The downy mildew in eastern USA resurged as a major problem on cucumbers when a more virulent form of pathogen caused about 40 per cent loss in cucumber production (Holmes and Ojiambo, 2009; Holmes and Thomas, 2009).

In India, downy mildew on cucumber was first reported from Coimbatore (Tamil Nadu) (Ramakrishnan *et al*., 1952). In Kashmir Langoo (2006) described downy mildew as an important disease in cucumber. *P. cubensis* does not produce any systemic infection in host plant (Cohen, 1981). The incubation period, for the disease is reported to be 4-12 days under field conditions, depending upon the prevailing environmental conditions, inoculum load and inherent resistance/ susceptibility of the host (Lebeda and Widrlechner, 2003). The repeated occurrence of heavy infections on cucumbers in the following several decades indicated that *P. cubensis* had acquired epidemic character in Central Europe and in many areas of the world (Holmes *et al*., 2004). Disease index in cucumber crops ranges from strong to very strong severities at harvest time (Lebeda and Urban, 2007).

The other important cucumber disease, anthracnose, is caused by *Colletotrichum lagenarium* [(Pass) Ellis & Halst]. Tode (1790) first reported the genus *Vermicularia* as *Colletotrichum* and the name was introduced by Corda (1831) for *C. lineola* on unidentified host belonging to *Apiaceae* and is now known to comprise of "*Coelomycetes*" with *Glomerella* as teleomorph stage (Sutton, 1992; Shenoy *et al*., 2007; Hyde *et al*., 2009). Sitterly and Keinath (1996) reported that *C. lagenarium* belongs to family *Glomerellaceae* within the phylum Ascomycota and *C. arbiculare* (syn. *C. lagenarium*) is the asexual stage of pathogen while *Glomerella lagenarium,* sexual stage of pathogen, is rarely found in nature (Arx, von 1957). Based on perceived scientific and economic importance, the genus has recently been ranked as 8th most important group of

phytopathogenic fungi in the world (Dean *et al.,* 2012). Stevens (1931) reported *Colletotrichum arbiculare* from USA. Watanabe and Tamura (1952) reported *Glomerella cingulata* var. *arbiculare* from Japan which was later reported from USA by Jenkins and Winstead (1962).

*C. arbiculare* is widely distributed throughout the world and has been reported from several countries in Asia, Africa, USA, Europe and Oceania (Farr *et al*., 1989; CABI, 2014). Anthracnose primarily has tropical and sub-tropical distribution, although there are some high-profile species which affect temperate crops too, and fruit production is especially affected in high-value crops (Dean *et al.,* 2012). Anthracnose is relatively a common disease in humid areas but appears sporadically in dry weather and inflicts significant losses under favourable conditions (Goldberg, 2004). *C. arbiculare* in artificially inoculated water melon caused upto 63 per cent yield losses (CABI, 2014). The disease in cucumber plants, both in greenhouse and field conditions, manifests as roughly circular, brown to reddish lesions on all above-ground tissues including leaves, stems, petioles and fruits (Qi *et al.,* 2013). The pathogen infects plant at any growth stage and whenever enough moisture is present the spores germinate and enter host plant within three days (Ferreira and warren, 1982). *C. arbiculare* is an important anthracnose causing pathogen in vegetable crops especially in family *Cucurbitaceae* infecting more than 40 species worldwide including cucumber, water melon, pumpkin, melon, squash, etc. (Wasilwa *et al*., 1993; Farr and Rossman, 2013; Damm *et al.,* 2013). *Colletotrichum* causes devastating disease of coffee berries in Africa and seriously affects cereals (Lenne, 2002). *C. orbiculare* exhibits a series of changes in fungal morphology, including the formation of a specialized infection structure called ‘appressorium’, for successful infection (Kubo and Takano 2013).

The other important economic disease in cucumber is Alternaria leaf spot. The genus *Alternaria* was established in 1817 with *A. alternata* (originally *A. tenuis*) as a type isolate described by Nees (Groves and Skolko, 1944;

Neergaard, 1945). *A. alternata* (Fr.) Keissler is common saprobe found on many plants including vegetable crops (Lu *et al*., 2000; Grunden *et al*., 2001; Mamgain *et al.*, 2013). *A. alternata* infects almost all cucumbers worldwide and its spores are transported by wind over longer distance through rain under warm and humid (60-80%) conditions (Neeraj and Verma, 2010). Leaf spot disease in cucumber, incited by *Alternaria alternata* f. sp. *cucurbitae,* was recorded for the first time in Crete (Greece) and reportedly appeared as necrotic flecks, surrounded by chlorotic halos, on middle and upper leaves of plants, the flecks enlarged and coalesced to form larger lesions of $\geq$ 2 cm dia. with brown fructifications of pathogen on their surface (Vakalounakis and Malathrakis 1982). Later the disease in cucumber was reported from Australia by Tesoriero (2004). Subramanian (1971) and Ellis (1971, 1976) gave comprehensive account of distinguishing characters of Indian species of *Alternaria* including *A. alternata*. Bains and Singh (1996) reported Alternaria leaf spot caused by *A. alternata* in *Cucumis melo* var. *momordica* (cv. Local) and *Momordica charantia* (cv. Local) from Punjab. Srivastava *et al.* (1964) and Mangala *et al.* (2006) also reported different species of *Alternaria* including *A. alternata* and respective symptoms on a member of families *Cucurbitaceae, Brassicaceae* and *Solanaceae* from different parts of India and found that *Alternaria* affects all the aerial parts of plants. Vakalounakis and Malathrakis (1988) reported that when infection progresses rapidly throughout the crop it results in severe damage within a few days.

Another major disease in cucumber is powdery mildew which is incited by *Sphaerotheca fuliginea* and *Erysiphae cichoracearum.* Yarwood (1978) reviewed the taxonomy of powdery mildew and found 74 genus names applied to powdery mildews till 18$^{th}$ century. Leveille (1851) published details of powdery mildew genera based on chasmothecial appendages and ascus number. Braun (1987) summarized the concepts regarding subfamilies, tribes and genera based on morphological features and distinguished them on the basis whether mycelia were external or internal to the host. *Podosphaera* synonym of *Sphaerotheca* was

placed in tribe *Cystotheceae*. The powdery mildew species (*Erysiphales*) are well-known obligate biotrophic pathogens of many crops and wild plant species and are most diverse in temperate regions of northern hemisphere (Braun, 1987; Braun *et al*., 2002; Bolay, 2005). Powdery mildew caused by *Sphaerotheca fuliginea* syn. *Podosphaera xanthii* is one of the most serious foliar disease attacking cucurbits including cucumber plants worldwide (Harfoush and Salama, 1992; Mosa, 1997; Reuveni *et al*., 1997; Verhaar *et al*., 1997; Palenius *et al.*, 2006). It caused devastation to greenhouse- and field-grown cucurbits in Australia (Letham and Priest, 1989). Khan *et al.* (1972) reported perithecial stage of *S. fuliginea* in Kashmir from the leaves of *Lagenaria leucantha* and *Cucurbita maxima*. It has also been reported to occur on *Bidens bitrenata* (Lour.) In Kashmir valley, Malik *et al.* (1973) and Khan (1976) reported that the perithecial stage of *Erysiphae cichoracearum* was confined to *Coccinia cordifolia* and *Benincasa hispida*, whereas *S. fuliginea* developed on *Luffa cylindrica* in Bihar (Khan 1976). Sohi and Nayar (1969) claimed that perithecial stage of *S. fuliginea* on *Cucurbita moschata* from Himachal Pradesh. Powdery mildew causes substantial reductions in plant growth, premature defoliation and consequently significant reductions in cucurbit yield (McGrath, 1996; McGrath and Thomas, 1996). The most conducive conditions for disease development are 15-25$^{o}$C temperature and > 70 per cent relative humidity during flowering and fruit filling stages (El-Naggar *et al.*, 2012). Powdery mildew affects leaves, stem and fruits of cucumber both in green-house and field (Morsy *et al*., 2009). Yield losses due to the disease are reported to be 10-20 per cent, if no appropriate measures are taken (Eastburn and Ribbing, 1999). A powdery mildew infection causes reduction in plant growth, premature foliage loss and consequent yield loss. The yield loss is proportional to the severity of disease and the length of time the plant is infected (Mossler and Nesheim, 2005).

## 2.2 Disease symptoms

Downy mildews are primarily foliage blights that attack and spread

rapidly in young tender green leaf, twig and fruit tissues (Agrios, 2005). Kucharek (2000) noticed initial symptoms on cucumber leaves as small yellowish areas on upper surface which later became more brilliant coloured with brown colour in centre. Downy mildew is recognized easily by chlorotic lesions on adaxial leaf surface which are restricted by leaf vein so giving them angular appearance (Savory *et al*., 2011). Leaves colonized by *Pseudoperonospora cubensis* undergo changes in temperature and transpiration rates which vary during the course of infection (Lindenthal *et al*., 2005; Oerke *et al*., 2006). Low temperatures delay symptom development while still promoting colonization of leaf tissue. However, higher temperatures cause fast lesion chlorosis that inhibits pathogen growth (Cohen, 1977). A reduced canopy leads to the cessation of fruit development and increases sun exposure so causing sun-scald and secondary rots (Keinath *et al*., 2007). Moreover, crop yield and fruit quality gets affected. Although the disease infects foliage only, a reduction in photosynthetic activity early in plant development results in stunted plant growth and yield reduction in cucumber. Leaf wetness due to dew, irrigation or rainfall leads to the formation of conspicuous water-soaked lesions (Colucci and Holmes, 2010). A temperature between 25 to 30ºC during day and 10 to 15ºC during night allows lesion formation at relative humidity $\geq$90 per cent. Sporulation on lower leaf surface may be the first sign of disease (Rotem *et al*., 1978; Palti and Cohen 1980). As disease progresses, the lesions expand and coalesce; ultimately leading to the death of entire leaf within days following the initial infection (Thomas, 1996).

Anthracnose disease symptoms include limited but sunken necrotic lesions on leaves, stem, flowers, etc. (Agrios, 2005). Severe infection causes deterioration in plant quality and yield. The disease manifests as brown circular lesions which measure upto 1 cm in dia., while lesions on petiole and stem are elliptical, sunken and circular lined with dark fungal stroma bearing masses of pink spores (Sitterly and Keinath, 1996). The lesions on cucumber leaves are less angular than those on water-melon (Egel, 2014). Further, the lesions are typically

irregular and jagged in appearance and the centers of larger older leaf lesions may fall out which give the leaf a “shot-hole” appearance. On leaves, small pale yellow water-soaked circular lesions emerge near the veins which enlarge rapidly, turn tan to dark brown and coalesce resulting in blighting, distortion and death of entire leaves (Delahaut and Stevenson 2004; Smith and Cartwright, 2014; Li, 2014).

The symptoms of Alternaria leaf spot appear in late autumn mainly on middle and upper leaves of plant in the form of necrotic flecks (Vakalounakis and Malathrakis, 1988). Initially small light brown circular spots surrounded by chlorotic halo are formed. The spots enlarge and coalesce to form brown lesions upto 1 cm in dia. which later become dark brown irregular lesions and coalesce to form large necrotic areas ultimately leading to the drying of leaves (Watt, 2004). Besides, severely infected leaves become yellow, senescent, curl and die while no other plant part is affected (Seedbold, 2010).

Powdery mildew infection in cucumber is characterized by the appearance of spots/patches of white to grayish powdery growth on young tissues of leaves and other plant parts (Agrios, 2005; Cosme *et al*., 2012). Typical powdery mildew symptoms depicted as white or off-white fungal growth on plant surface consist of mycelium and conidia (Anonymous, 2007; Fujiwara *et al.*, 2009). Bolay (2005) and Koike *et al*. (2007) found *Sphaerotheca fuliginea* as the pathogen responsible for powdery mildew causing severe foliage loss and yield reduction. Powdery mildew fungi not only cover the leaf surface, petiole and stem by forming white powdery colonies but also reduce yield, limit photosynthetic activity and cause plant senescence and premature fruit ripening (Takamatsu, 2004).

## 2.3 Morphology of pathogens

The mycelium of *Pseudoperonospora cubensis* on cucumber leaves appears branched, hyaline and coenocytic with oval to elliptical papillate

sporangia which measure 26.05 × 18.14 µm in size and are borne on the tips of dichotomously branched acute-angled sporangiophores (Sharma *et al.*, 2003). Sporangia of similar age are present at the ends of sterigma (Voglmayr, 2003; Choi *et al*., 2005). Sporangia germinate directly by germ tubes (Lange *et al*., 1989). The morphology of sporangiophore can vary with temperature and sporangia dimensions are influenced by the cucurbit host (Iwata, 1941; Waterhouse and Brothers, 1981).

The conidia formed in acervuli are the infective structures of *Colletotrichum arbiculare*. The acervuli are erumpent and appear pink-coloured slimy mass on infected tissue which are often surrounded by heavily melanized black sterile hair-like structures called 'setae' that are only visible under microscope (Crouch and Beirn, 2009). Conidia are oval or pill-shaped, clear and have no cross walls (Zitter *et al*., 1998). Shen *et al*. (2001) reported that the conidia of *C. arbiculare* are straight to slightly curved with obtuse ends and measure 13.1±1.6 × 5.4±0.7 µm in size. However, Baxter *et al.* (1983) found the average conidial size 16.9-20.2 × 4.2-4.4 µm, depending upon the substrate on which the cultures were raised. Arx von (1957) found the size of *C. arbiculare* conidia as 11-19 × 4-6 µm while Sutton (1992) has reported the conidia size as 4.5-6.0 µm.

The mycelium of *Alternaria alternata* on PDA is hyaline, septate and branched with obclavate to obpyriform or ellipsoidal conidiophores of 3-6 µm width, bearing conidia having short conical beak and arranged in long chain in acropetal fashion (Wagh *et al*., 2013). The conidia are pale brown to golden brown, 22-32 µm long and 13-18 µm wide at broadest point with 3 to 8 transverse septa and 1 to 2 longitudinal septa. Ellis and Holiday (1970) and Sankar *et al.* (2012) reported that the fungal colonies of *A. alternata* are initially white but later become olivaceous and turn brown with age. Also, the conidiophores are short, simple or branched, golden brown in colour, 15 µm long and 2-6 µm in thickness.

*Sphaerotheca fuliginea* has superficial and uninucleate mycelium; erect conidiophore, 4-7 septate, 80-146 mm long, foot cell cylindrical followed by 1-4 barrel-shaped cells, conidia borne in chains (4-7), oblate or ovoid, containing irregular shaped fibrosin bodies, 21-37 x 15-23 mm, L/B ratio 1.28-2.27 (range) (Pawar *et al.*, 2009). Shishkoff (1999) found a very useful morphological feature for taxonomic purposes in *S. fuliginea* complex i.e. the conidia germinate either from their apical and basal part or from side wall while germ tubes are simple or forked. Hirata (1955) stated that the conidial germ tubes of *S. fuliginea* have a shape which characterizes the species i.e. it is forked, simple and curved. Conidia are in chains, ellipsoid to ovoid, 24-28(-38) x (12-)14-17(-20) µm in size with well-developed fibrosin bodies (Letham and Priest, 1989). Conidia are formed on conidiophores which arise from vegetative hyphae, besides conidia are arranged in basipetal order (Oichi *et al.*, 2006). Khan and Khan (1970) observed perithecia stage of *S. fuliginea* on several varieties of cucumber under glasshouse conditions in Aligarh (Uttar Pradesh). However, Grand (1987) observed perithecia of *S. fuliginea* only on the underside of leaves of *Cucumis melo, Cucurbita maxima, C. pepo* and *Lagenaria siceraria* in North Carolina. Janke (1977) reported that *E. cichoracearum* and *S. fuliginea* were identified by conidial characteristics and no cleistothecia were seen.

## 2.4 Perpetuation of diseases

In downy mildew, oospores have been observed in both temperate and tropical regions including Japan, Austria, Russia, China, Italy, Isreal, Iran and India (D'Ercole, 1975; Bains *et al*., 1977; Mahrisi and Siradhana, 1984; Singh and Sokhi, 1989; Bedlan, 1989; Zaker and Ommati, 1991; Cohen *et al*., 2003). The rare occurrence of thick-walled resting structures such as oospores limit the survival of *P. cubensis* in absence of a living host and currently it is unknown whether oospores play any role in disease cycle. Sporangial survival during transport is limited to a maximum of 16 days after dispersal (Cohen and Rotem, 1971) depending upon temperature, relative humidity and solar radiation

(Thomas, 1996; Kanetis *et al*., 2009). Because of obligate biotrophic nature of *P. cubensis* the survival of mycelium in dead leaves is impossible (Lebeda, 1990). *P. cubensis* survives the winter on protected cultures of cucurbit plants in green-houses (Day and Hausbeck, 2009). In areas with conducive climate for the disease, the perennial mycelia overwinters on some other host species of genus *Cucumis,* even under field conditions as proved in India and southern USA (Palti and Cohen, 1980; Holmes *et al.*, 2004). Fungus survives on cucumber seeds and infected crop residues (Palenchar *et al*., 2012).

The conidia of *Colletotrichum lagenarium* overwinters in plant debris, soil and on seed upto 2 years (Delahaut and Stevenson, 2004). The conidia of *C. arbiculare* survive in infected plant residues of cucumber or infected volunteer plants and also on seed of infected fruits. *C. sublineola* was capable of surviving on crop debris for 18 months (Casela and Frederiksen, 1993) and *C. graminicola* for 20 months (Naylor and Leonard, 1977). Corn kernels stored at 4°C may harbour *C. graminicola* for more than 3 years (Warren, 1977), while *C. sublineola* survives in sorghum seed at room temperature upto 2.5 years (Mishra and Siradhana, 1957). *C. falcatum* is frequently spread through use of infected canes or seed in propagation as dormant infections in sugarcane nodes (Singh, 2008). Survival in soil is heavily dependent on environmental conditions, temperature and other soil microflora. When ample debris is present the fungal material may effectively overwinter for lengthy periods and serve as a source of primary inoculum for the following season (Crouch and Beirn, 2009).

The propagules of *Alternaria alternata* survive on infested crop debris upto two years (Schwartz and Gent, 2007). Crop residues infected with pathogen produce sufficient primary inoculum in the following season (Murthy *et al.*, 2003). Lucas (1975) reported that the fungus persisted as mycelium in dead tissues for several months and probably was the principal source of inoculum for subsequent lesion development. Weed hosts are the other sources for primary inoculum in many Alternaria-related diseases through which over-seasoning

occurs (Rotem, 1994). *A. alternata* survives better on infected crop at ground level rather than in buried plant debris (Murthy *et al.*, 2003).

The means of subsistence of *E. cichoracearum* and *S. fuliginea* between successive crops is not clear; and in many areas cleistothecia are considered as the main mode of perenation (Mehrotra, 1980). Further, it is assumed that these fungi survive as conidia on wild hosts which are later blown by wind to the cultivated areas. The initial source of cucurbit powdery mildew infection is difficult to determine due to the fact that conidia are readily airborne and travel longer distances. The disease spreads almost exclusively via conidia (Maia, 2012). Possible sources of infection include cucurbit crops grown earlier in the season, inoculum from greenhouse-grown cucurbits, ascospores stored in chasmothecia on crop debris (McGrath, 1997) and also the alternate hosts (Takamatsu *et al.*, 2009; Troisi *et al.*, 2010; Pawar and Patil, 2011).

## 2.5 Germplasm screening

The cucurbit cultivars do not possess the character of complete resistance and only allow for a limited level of pathogen sporulation (Lebeda, 1999). Recent achievements in cucumber genome mapping and sequencing has provided new opportunities for breeding research and development of elite cucumber cultivars with new traits as well as resistance to diseases (Huang *et al*., 2009; Ren *et al*., 2013). Wehner and Shetty (1997) examined downy mildew resistance in U.S. germplasm collection of cucumbers including cultivars, breeding lines and land-races. Several races of *Pseudoperonospora cubensis* have been reported in differential test studies (Inaba *et al.*, 1986; Angelov *et al*., 2000; Shetty *et al*., 2002). Six pathotypes of *P. cubensis* have been identified on the basis of their compatibility with specific host genera (Cohen *et al*., 2003). Angelov (1994) reported that resistance in genotype ‘PI 197088’ was due to two recessive genes and ‘Poinsett’ resistance was due to one recessive gene. Staub *et al*. (1989) reported 47 plant accessions having high resistance of which 23 accessions were resistant to downy mildew and one or more other cucumber

diseases. Call and Wehner (2010) noted a change in the rank of resistant and moderate cultigens from screening studies before and after a change in pathogen population. Further 'Cultigens' highly resistant in 1988 and 1989 were only moderately resistant in 2005 onwards. Recently, *Cucumis sativus hystrix* introgression lines have been developed which exhibit resistance to downy mildew (Zhou *et al*., 2008).

In cucumber yield reduction is reportedly proportional to the cultivar susceptibility; and several anthracnose resistant cultivars have been developed (Sitterly, 1973). Single and oligogenic resistance to anthracnose has been reported (Busch and Walker, 1958; Abul-Hayja *et al.,* 1978). Linde *et al*. (1990) reported that at least five effective factors controlled the resistance of cucumber to anthracnose 'race 2' in cross of resistance 'AR 79-95' with susceptible 'Model'. Barnes and Epps (1952) introduced four plant introductions (PI 175111, PI 175120, PI 179676 and PI 183445) as carrier of *ar* gene for anthracnose resistance. Barnes (1961) reported that genotype 'Pixie' had multigenic resistance and was moderately resistant. The breeding lines 'GY3' and 'GY14' have been used as anthracnose resistant checks in greenhouse screening tests in which 'GY3' has been considered as one of the most resistant 'Cultigens' and 'GY14' moderately resistant (Wyszogrodzka *et al*., 1987).

The classification of cultivars according to degree of susceptibility to a pathogenic toxin is directly correlated to the actual degree of susceptibility to the live pathogen in plants grown outside (Tabira *et al*., 1989). Saito and Takeda (1984) reported that susceptibility to Alternaria disease is controlled by a single dominant gene, and susceptible cultivars are heterozygous while resistant cultivars are homozygous. An *in vitro* assay system using chemically-synthesized AM-toxin I of *A. alternata* is successful in screening resistant mutants, and the degree of resistance to disease was assayed by the number of necrotic lesions induced by applying various concentrations of AM-toxin I to leaf discs of $1^{st}$, $3^{rd}$ and $5^{th}$ leaves from shoot apex of plants (Suzuki and Saito, 2010).

Akram and Khan (1978) in glasshouse studies detected resistance to *Sphaerotheca fuliginea* in some cultivars of squash and *Momordica charantia*. Pitrate *et al.* (1988) during screening for resistance of muskmelon against downy mildew found breeding line 'MR1' resistant to all the isolates tested, while lines 'PI164323' and 'PI 414723' possessed moderate resistance. Intermediate resistance to *S. fuliginea* was maintained in backcross $F_1$ without the aid of selfing and reappeared in $F_2$ after last backcross and segregates were found uniformly highly resistant (Munger, 1988). The response of 12 cucurbitaceous species to 5 Indian *S. fuliginea* isolates revealed *Benincosa hispida*, *Cucurbita maxima* var. *maxima* and *C. ficifolia* resistant to all the isolates (Akram and Khan, 1985). Love and Rhodes (1991) identified two types of inheritance for resistance of *Citrullus* anthracnose in 3 resistant lines and observed that the resistance was controlled largely by a single dominant gene which was modified by minor genes. Several promising hybrids resistant to downy mildew have been produced by selection method (Medvedeva and Medvedev, 1983). Three weeks after planting of cucumber, anthracnose on $2^{nd}$ leaf of cucumber variety 'Straight Eight', inoculated with *Colletrotrichum arbiculare,* was significantly less severe on the plants grown in compost-amended mixes than in peat mix (Zhang *et al*., 1996). Zhang (2005a) observed inheritance of powdery mildew resistance in cultivar Q to be controlled by a single recessive gene. Morishita *et al*. (2003) reported that the powdery mildew resistance in 'PI 197088-5' was because of two gene pairs, a recessive gene and an incompletely dominant gene. Sakata *et al*. (2006) found susceptibility to powdery mildew in $F_7$ RIL individuals in a continuous distribution from susceptible to resistant suggesting that powdery mildew resistance was controlled by quantitative trait loci. The availability of molecular genetic markers is limited, especially in those linked to important horticultural traits and the linkage maps are relatively unsaturated so have constrained cucumber improvement (Serquen *et al*., 1997; Horejsi *et al*., 1999; Bradeen *et al*., 2001; Fazio *et al*., 2003).

## 2.6 Management of fungal diseases through fungitoxicants and SAR chemicals

Chemical control of downy mildew has been followed since many decades through use of contact fungicides; copper formulations at early times and dithiocarbamates more recently (Palti and Cohen, 1980). The application of appropriate control measures prior to downy mildew infection has previously been reported (Zhao *et al*., 2007; Ojiambo *et al.,* 2009. Urban and Lebeda (2006) have summarized the list of fully systemic, partial systemic and non-systemic fungicides effective against *Pseudoperonospora cubensis* and some oomycetous fungi and reported that copper fungicides and dithiocarmates prevent zoospore release. Portz *et al.* (2008) reported that 50-1,000 µg/ml allicin reduced the severity of cucumber downy mildew caused by *P. cubensis* by approximately 50-100 per cent. Gaikward and Karkeli (1994) reported that the application of two sprays of Ridomil MZ-72 (metalaxyl) reduced disease intensity of cucumber downy mildew and sprays of folpet, Bordeaux mixture and Aliet (fosetyl) + mancozeb were also effective. Treatment with azoxystrobin and metalaxyl inhibited sporulation, on already existing downy mildew lesions, by 85 and 84 per cent, respectively (Wong and Wilcox, 2001). Downy mildew in cucurbits was successfully controlled by chlorothalonil @ 2.4 lbs/ha (Jones, 1978; Timchenko, 1979). Ridomil was most effective when applied @ 0.1 per cent 3-4 times at fortnightly interval and the yield was enhanced by 36.4 to 79.3 per cent as compared to untreated control (Boyadzhiev *et al*., 1983). Yadav and Patil (2008) found a positive significant correlation of downy mildew incidence with maximum temperature and morning humidity but a negative correlation with minimum temperature in all the sowing dates of cucumber.

Several fungitoxic chemicals like chlorothalonil, pyraclostrobin, azoxystrobin, copper, mancozeb, etc. have been used to control cucumber anthracnose in Florida (USA) (Palenchar *et al.,* 2009). Taqat 75 WP, a combination of captan 70 per cent (contact) and hexaconazole 5 per cent (systemic), successfully controlled foliar fungal diseases in various field crops,

including cucurbits (Adinarayana *et al.*, 2013). The most effective fungicides for the control of anthracnose known are chlorothalonil, copper sprays, propiconazole (protective fungicides) and thiophanate-methyl (systemic fungicide). Proper timing of application is critical for all fungicides (Crump, 2009). Tasiwal *et al.* (2009) reported that among the various systemic fungicides tested, carbendazim completely inhibited the growth of *Colletotrichum gloeosporioides* at all three concentrations tested (0.05, 0.10 and 0.15%). Propiconazole successfully inhibited mycelial growth at 0.15 per cent followed by hexaconazole (94.3%) at 0.15 per cent, triadiamefon (92.1%) at 0.15 per cent (Biradar, 2002). Carbendazim and triademefon were found effective in inhibiting the growth of *C. gloeosporioides* (Kumbhar and Chaudhary, 1979; Tomy, 1997). Carbendazim and benomyl (benzimidazole group fungicides) interfere in energy production and cell wall synthesis of pathogen (Nene and Thapliyal, 1982). They also reported the effectiveness of triazole which inhibit sterol biosynthesis pathway in fungi. Carbendazim induced nuclear instability by disturbing the mitosis and meiosis, and of the five non-systemic fungicides tested against *C. gloeosporioides*, only captan at 0.15 per cent was highly effective in inhibiting its growth by 100 per cent, which was followed by mancozeb (88.61%) at 0.15 per cent (Davidse, 1986).

Mancozeb has been reported to be a promising fungicide for controlling *Alternaria alternata,* the causal pathogen of mango black spot (Mohsan *et al*., 1985), chrysanthemum leaf blight (Kumar *et al.*, 2011) and tomato blight (Kumar *et al*., 2012). Sahu *et al.* (2013) reported that mancozeb reduced the incidence of *A. alternata* causing early blight in tomato by 40.4 per cent and increased fruit yield by 40.7 per cent. Among the systemic fungicides thiophanate methyl and among the non-systemic fungicides, iprodione and mancozeb were most effective against *A. alternata* under *in vitro* conditions (Prasad and Naik, 2003). Singh and Singh (2006) evaluated seven fungicides *viz.,* chlorothalonil, copper oxychloride, azoxystrobin, propineb, copper hydroxide, mancozeb (each at 2500, 2000, 1000,

500 and 250 ppm) and hexaconazole (at 1000, 500, 200, 100 and 50 ppm) against *A. alternata*, the causal pathogen of tomato blight. All the fungicides significantly reduced radial growth of the fungus. However, hexaconazole most effectively caused 100 per cent inhibition. The best control of Alternaria leaf spot disease of bottle gourd has been achieved by spraying Indofil M-45 at recommended dose of 0.2 per cent, followed by Chlorothalonil, Ridomil, Indofil Z-78 and Copper oxychloride (Katiyar *et al*., 2001). Indofil M-45, Indofil Z-78, Vitavax and Kavach under *in vitro* conditions effectively reduced the mycelial growth of *A. alternata*, followed by bavistin, benlate and thiram (Singh and Rai, 2003). Sidlauskiene *et al.* (2003) found Amistar (azoxystrobin) very effective in reducing the Alternaria leaf spot disease incidence by 88-93 per cent in cucumber, cabbage and tomato; whereas Euparen + Bion (tolylfluanid + acibenzolar-S-methyl) increased biological efficiency (Verma and Verma, 2010). The effectiveness of mancozeb in controlling early blight, caused by *Alternaria* spp., was reaffirmed by Singh and Thind (2001).

Successful biological control of powdery mildew in cucumber and other vegetable crops has been achieved under greenhouse and field conditions using fungal and bacterial antagonists (Kiss *et al.*, 2004; Hegazi and El-Kot, 2008; Moyer and Peres, 2008). Due to their unique mode of action, these antagonists show no cross-resistance with other chemical classes such as strobilurins so are excellent candidates for managing disease caused by *A. alternata* (Avenot *et al*., 2008, 2009). Under *in vitro* conditions, sporulation occurred at 8-24ºC and relative humidity of 91.5 per cent and mature spores were observed only after 14-24 hour (Humpherson and Phelps, 1989). A minimum of 9-18 hour moisture in the form of rain, dew or humidity is essential for *A. alternata* infection (Chupp and Sherf, 1960). Further, continuous moisture for >24 hours practically guarantees infection.

The disease control in powdery mildew is generally achieved through use of fungicides like strobilurins, benzimidazoles, demethylation inhibitors

(DMIs), b-methoxyacrylates and sulfur (Keinath and DuBose, 2004; Reuveni *et al.*, 2006). Tripathi *et al.* (1995) found Karathane (dinocap), wettable sulphur, Calixin (tridemorph), Bavistin (carbendazim) and Seve-surf (sulphur) effective in controlling powdery mildew disease; however, Karathane proved superior. Control of *S. fuliginea* in cucumber has mainly been achieved by fungicidal treatment; however, the fungal population has potential to develop tolerance against previously used fungicides (De Waard *et al*., 1993). YuanYuan *et al*. (2008) observed that the crude extract of *Euphorbia humifusa* at 30 mg/ml concentration under *in vitro* conditions depicted protective effect against cucumber powdery mildew fungus to the extent of 67.45 per cent. The most active compounds were in water phase, not in organic solvent phases.

The fungitoxicants though effective in combating powdery mildew disease, yet there is increasing concern about their adverse impact on environment, worker safety and the appearance of fungicide resistance in target populations (Mueller *et al*., 2003). This has focused the attention of researchers to find safe alternative fungicides. *Ampelomyces quisqualis* was first described as a hyperparasite of powdery mildew in 1870 by De Bary and in 1930 by Emmons. Yarwood (1932) first attempted to use *A. quisqualis* spore suspension as biocontrol against powdery mildew of red clover incited by *Erysiphae polygoni*. Jarvis and Slingsby (1977) by using *A. quisqualis* successfully controlled powdery mildew, caused by *S. fuliginea*, in cucumber under greenhouse conditions. *A. quisqualis* attacks the mycelium and spores of powdery mildew fungus and also inhibits spore germination (Schalau, 2010). *A. quisqualis* is found worldwide and infects several genera of powdery mildew fungus but does not usually control powdery mildew at natural concentrations (Kiss, 1998).

Hongmin *et al.* (2009) established bioassay method for the screening of fungicides and reported that chrysophanol effectively reduced cucumber powdery mildew. As an obligate parasite, *S. fuliginea* does not grow and reproduce on synthetic medium and it is difficult to adopt high-throughput screening methods

(Zhang, 2005b). Lange *et al.* (1989) during screening observed that vesicular content underwent dynamic changes during zoosporogenesis and contents became finely striated as was typical of these vesicles when zoospore were observed.

There is increasing concern about the ill consequences of synthetic fungicide-use on human health and surrounding ecosystem (Schirra *et al*. 2000; Kirrane *et al*., 2005). Therefore, it is imperative to find alternatives to synthetic fungicides. Certain chemicals like salicylic acid (SA), 2,6-dicholoroisonicotinic acid (INA), potassium salts, β-amino butyric acid (BABA) and benzo-(1,2,3)-thiadiazole-7-carbothioic acid S-methyl ester (BTH) reportedly induce systemic acquired resistance (SAR) in plants against some plant pathogens (Reuveni *et al*., 2000; Oostendorp *et al*., 2001). The broad-spectrum activity of BTH compounds reportedly protect several plant species against a number of bacterial, fungal and viral diseases suggesting indirect mode of action via activation of plant defense mechanisms (Godard *et al*., 1999; Buonaurio *et al*., 2002). The non-protein amino acid BABA induces resistance against many diseases in various crops including *P. cubensis* in cucumber and has no direct effect on pathogen rather it activates host defense (Ovadia *et al*., 2000; Cohen, 2002; Walz and Simon, 2008). Cucumber seedlings grown in compost under greenhouse conditions show less disease severity which is attributed to SAR-associated gene expression in plants (Zhang *et al*., 1996).

Huang *et al*. (2000) reported that pre-flowering foliar spray of plant activator acibenzolar-S-methyl (ASM) @ 50 mg/L a.i. combined with a fruit dip in guazatine @ 500 mg/L a.i. at harvest substantially decreased anthracnose disease in stored melons. Biotic inducers of systemic resistance in cucurbit family include locally infecting fungal pathogens (Caruso and Kuc, 1979; Martin *et al*., 1991). Lin and Ishii (2009) reported that systemic acquired resistance to *C. orbiculare* was induced in young cucumber plants within 3 hours of ASM use onto the 1$^{st}$ leaves. Foliar application of phosphate salts induced systemic resistance in cucumber (Gottstein and Kuc, 1989; Descalzo *et al*., 1990;

Mucharromah and Kuc, 1991). A local application of di-potassium hydrogen phosphate ($K_2HPO_4$) has been found effective in inducing a high level of systemic protection in cucumber plants against anthracnose caused by *C. lagenarium* (Orober, 2002).

MacLennan *et al.* (1963) evaluated various butyric acid derivatives against apple scab pathogen and found 2-aminobutyric acid active against disease. Functional analogs of salicylic acid like INA and BTH activate resistance mechanism downstream of SA (Friedrich *et al.,* 1996). ASM has proved effective in controlling several diseases caused by virulent pathogens in a number of plants (Louws *et al.,* 2001; Romero *et al*., 2001). Brock *et al*. (1994) applied 2,6-dichloroisonicotinic acid to the cotyledon of cotton and found next emerging leaves less susceptible to infection by *Alternaria macrospora* than those of control. Further, the treatment applied to cotyledon had neither any visible effect on plant development nor any direct effect on the fungus *in vitro* suggesting that resistance was induced systematically in cotton plants. Bishnoi and Payyavula (2003) evaluated two plant activators *viz.,* Messenger® (a.i. harpin protein) and Actigard$^{TM}$ (a.i. BTH) on 3 tomato cultivars (Mountain Pride, Floralina and Florida-47) and 2 canola (*Brassica napus* L.) cultivars (Flint and 188-20B) and found that Messenger® and Actigard$^{TM}$ decreased the severity of early leaf blight in tomato (caused by *A. solani*) by 8 to 12 per cent and increased fruit yield by 10 to 13 per cent in comparison to control; however, in canola activators showed non-significant effect on crop maturity and severity of black leg (*Leptosphaeria maculans*) disease. Similar observations have been reported by Inbar *et al*. (1998) and Pervaiz *et al.* (2002) who found the application of Actigard$^{TM}$ effective in lowering the disease severity.

Reuveni *et al.* (2000) observed that phosphate containing nutrient solutions at 5, 20 and 40 ppm concentration, applied through a hydroponics system, induced systemic resistance against *S. fuliginea* in young cucumber plants with 53-91 per cent reduction in conidia/ infected leaf area and 72.3 per cent

reduction in fungal sporulation. An acidic peroxidase isozyme has been identified as a molecular marker of SAR in plants (Albert *et al*., 1987). The spray of 2.0 per cent baking soda and oil solution as SAR-inducers proved most effective in combating powdery mildew in cucumbers (Williams *et al*., 1993). Conti *et al.* (1996) observed that salicylic acid in *C. sativus* reduced the intensity of infection by *S. fuliginea* and enhanced the expression of systemic resistance in cucumber to the pathogen. The exemption of sodium- and potassium-bicarbonates from residue tolerance facilitated the development and release of commercial bicarbonate products for horticultural use (Otten and Paul, 1997). SAR to *C. arbiculare* and *S. fuliginea* was induced in young cucumber plants of ASM application onto the 1$^{st}$ leaves (Lin *et al.,* 2009). $NaHCO_3$ (2%) and $KHCO_3$ (2%) were very effective against *S. fuliginea* (Ziv and Zitter, 1992).

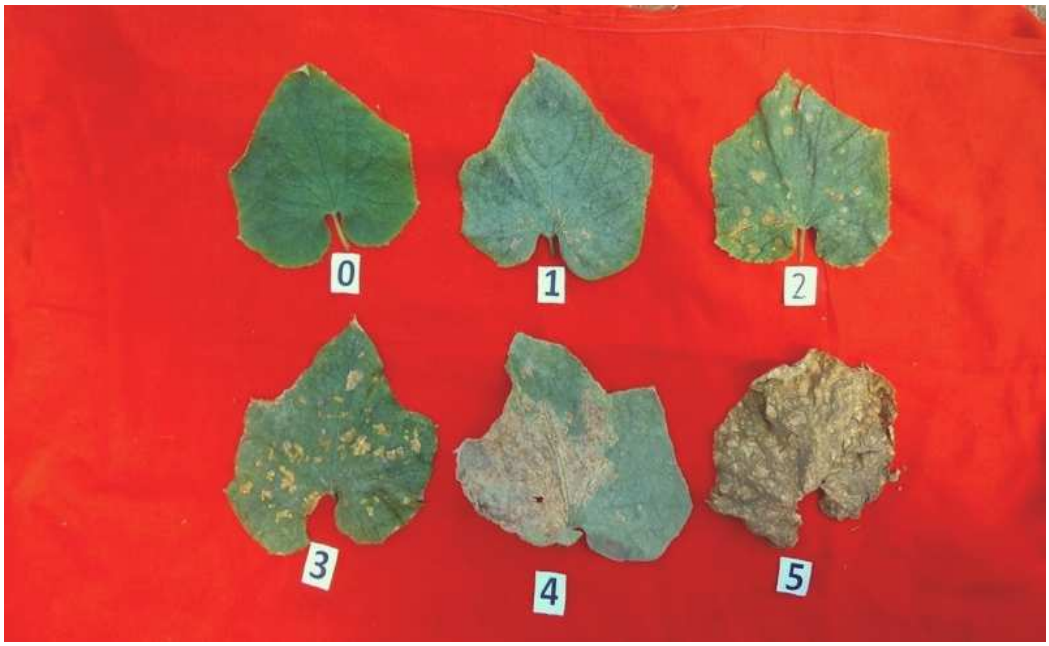



**Plate 1:Scale (0-5) for the assessment of disease intensity of downy mildew**

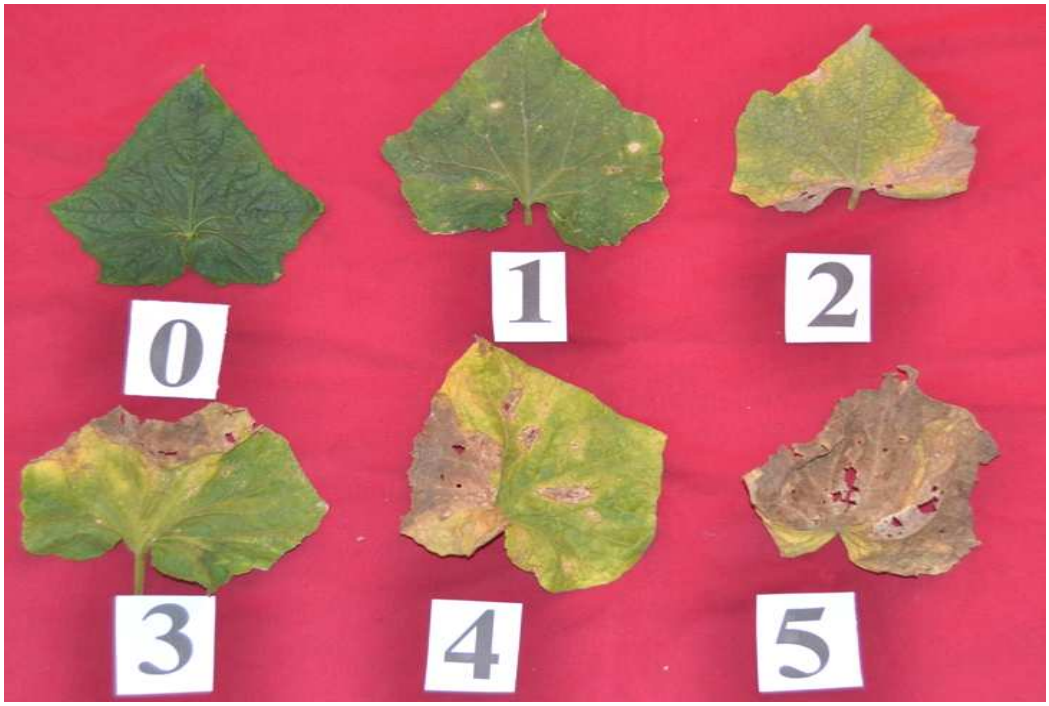



**Plate 2: Scale (0-5) for assessment of disease intensity of anthracnose**

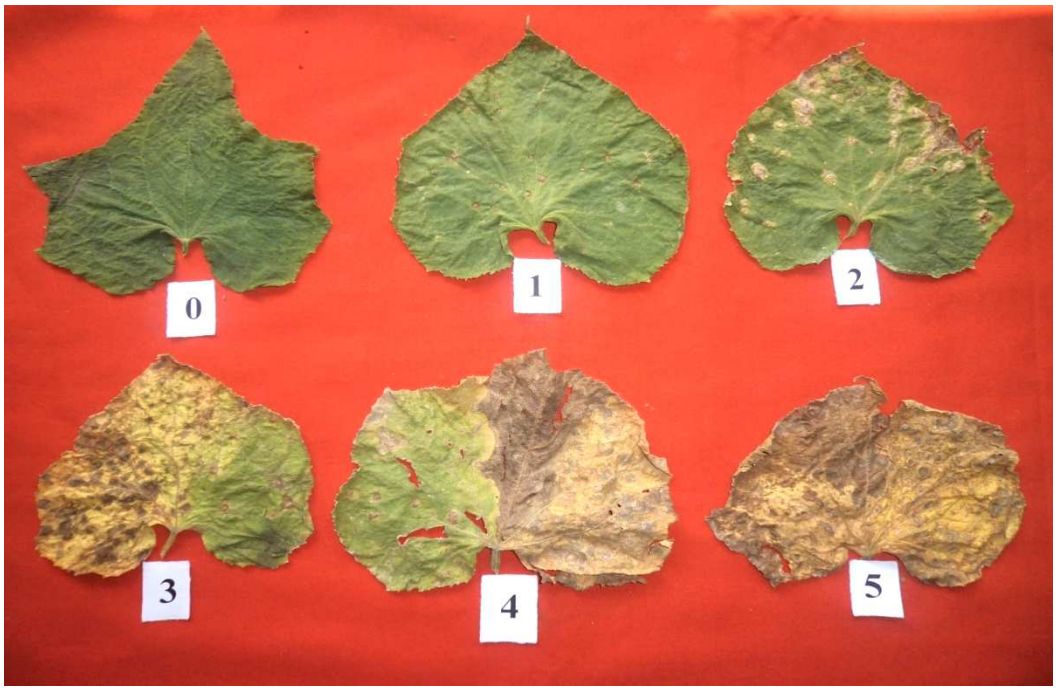



**Plate 3: Scale (0-5) for assessment of disease intensity of Alternaria leaf spot**

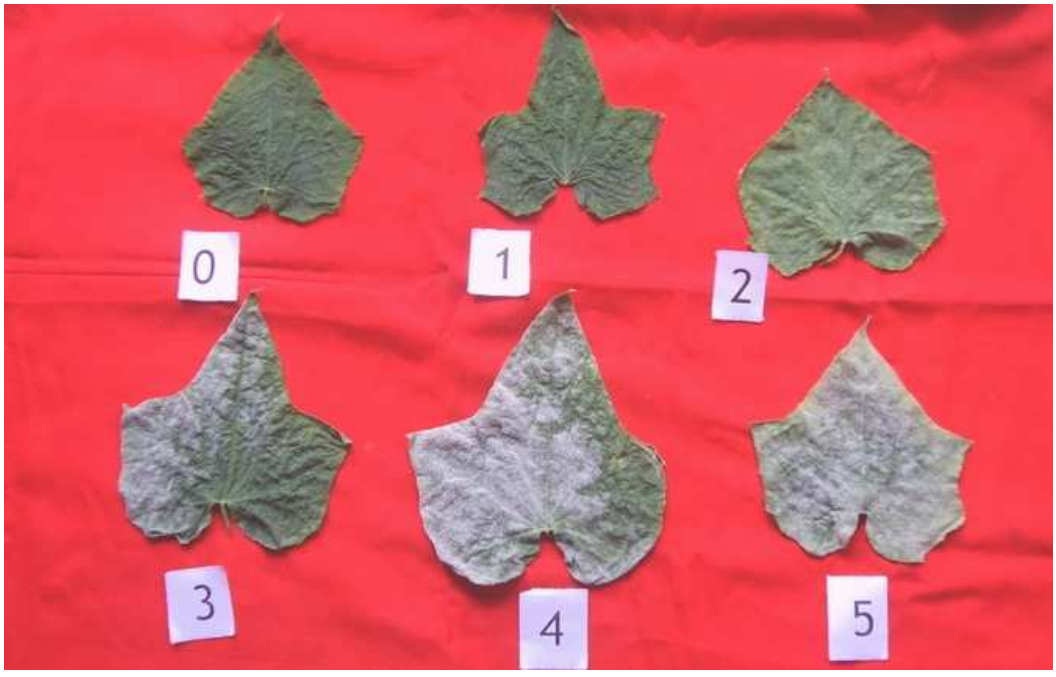



**Plate 4: Scale (0-5) for assessment of disease intensity of powdery mildew**

**Chapter – 3**

# MATERIALS AND METHODS

The present study was conducted during the years 2011 and 2012 in the Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar (J&K). The materials used and the methodology adopted in achieving the set objectives of the study are described as under:

## 3.1 Disease survey

A field survey for the assessment of major foliar diseases of cucumber was conducted in four districts of Kashmir valley *viz.*, Srinagar, Budgam, Bandipora and Baramulla in the months of July and August (peak periods of diseases) in the years 2011 and 2012. Five locations from each selected district were selected. The sites selected in district Baramulla were: i) Sopore, ii) Baramulla, iii) Pattan, iv) Janwara and v) Seelu. The sites selected in district Srinagar were: i) Kawoosa, ii) Dal, iii) Shalimar, iv) Shadipora and v) Harwan while the sites chosen in district Bandipora were: i) Patushai, ii) Nadihal, iii) Kemah, iv) Aloosa and v) Ongam. The sites selected from district Budgam were: i) Batpora, ii) Sheikhpora, iii) Gangbug, iv) Kremshora and v) Narkara. From each location three vegetable fields were chosen and in each fields ten random plants and from each plant twenty five leaves were assessed to record disease incidence and intensity. Separate leaves were examined for each disease. The intensity was recorded on the same leaves used for recording the incidence. The matereological data with respect to temperature, rainfall and relative humidity for the years 2011 and 2012 (from May to July) was collected from the Division of Agronomy, SKUAST-Kashmir, Shalimar.

### 3.1.1 Disease incidence

The disease incidence for each disease of cucumber was recorded by

counting the total number of leaves and the number of infected leaves. The per cent disease incidence for each disease was calculated as per formula adopted by Kalloo *et al.* (1997):

$$\text{Per cent disease incidence} = \frac{\text{Number of infected leaves}}{\text{Total number of leaves examined}} \times 100$$

### 3.1.2 Disease intensity

The per cent disease intensity for each disease was recorded by visual observation using 0-5 scale adopted by Singh *et al.* (1996). Five disease categories were made on the basis of per cent leaf area diseased as per following key:

| Disease rating scale | Leaf area affected (%) |
|---|---|
| 0 | No disease |
| 1 | 1-10 |
| 2 | 11-25 |
| 3 | 26-50 |
| 4 | 51-75 |
| 5 | ≥76 |

The per cent disease intensity (PDI) was calculated as per the formula:

$$\text{Per cent disease intensity (PDI)} = \frac{\sum (n \times v)}{N \times S} \times 100$$

Where,

∑ = Summation
n = Number of leaves in each category
v = Numerical value of each category
N = Number of leaves examined, and
S = Maximum numerical value

### 3.2 Symptomatological studies

Detailed symptomatological study for each disease was conducted on cucumber cultivar 'Japanese Long Green' on randomly selected plants in experimental field in the Division of Vegetable Sciences, SKUAST-Kashmir, Shalimar. The plants were kept unsprayed throughout the growing season to study the symptoms of above diseases under natural epiphytotic conditions. First observation was taken no sooner the disease(s) appeared. The symptom development with respect to the size, shape and colour of lesion on leaves was recorded at weekly interval for each disease; however in case of mildews it was recorded at three days interval.

### 3.3 Isolation of pathogens

Non-obligate pathogens were isolated from infected leaves by tissue segment method, purified by single spore technique (Johnston and Booth, 1983) and maintained on oat meal culture medium and PDA medium, respectively. These pathogens were sub-cultured at regular intervals. Obligate pathogens were maintained on their host.

### 3.4 Morphological characterization of pathogens

The morphological characteristics of causal organisms were studied on host in case of obligate pathogens; while the morphological characters of non-obligate pathogens were studied both on host and in culture. Semi-permanent slides were prepared from the infected host tissues as well as in culture, and stained with cotton blue and lactophenol. These slides were examined for various morphological characters under microscope at 40x.

#### 3.4.1 In culture

The non-obligate pathogens were grown either on PDA or oatmeal agar, at their optimum temperature for the specific pathogens (25 or 28°C). The colony characters were studied along with the shape, size, colour, septation, etc. of

mycelium and conidia after 7 days incubation. For fructifications the cultures were incubated at 28 $^{o}$C upto 21 days and fructification, if any, noted.

### 3.4.2 On host

Infected leaves with specific spot initials were kept in humid chambers at room temperature (22±3°C) and observations regarding fungal growth noticed after 3 days. The swollen diseased spots and fruiting structures on leaves were observed under stereo-microscope and observations regarding shape, colour and size noted. The acervuli, if any, were studied with respect to size, shape, colour and septation of their setae and conidia. Fresh leaves infected with mildew were examined under stereoscopic microscope and observations regarding shape, colour and size recorded. The mycelium, sporangia and conidia were studied with respect to septation, size, shape and colour. For observation of zoospores, if any, fresh diseased leaves from the field were taken to the laboratory early in the morning to observe the release of zoospore from zoosporangium.

## 3.5 Perpetuation

The survival of pathogens in fallen diseased leaves of susceptible cucumber cultivar 'Japanese Long Green' was studied during the year 2011 and 2012 in Vegatable Science field at SKUAST-Kashmir, Shalimar, Srinagar (J&K).

### 3.5.1 Survival in over-wintered diseased leaves

Fallen diseased leaves of almost similar size were collected during mid week of October in both the years 2011 and 2012. The leaves were kept in mesh nylon bags. Each bag contained equal number of leaves i.e. twenty five leaves per bag. The total number of bags was six. The bags were divided into two sets. One set of was kept on soil surface (3 bags) and the other was buried in soil at 5 cm depth in the research field of Division of Plant Pathology. The same procedure was followed for all diseases. These sets were made separately for each disease. The fallen diseased leaves in mesh nylon bags were removed at fortnightly interval beginning from the 1$^{st}$ week of March onwards till ending June and

examined in laboratory for the presence and viability of conidia, sporangiospores and oospores.

### 3.5.2 Estimation of oospore production

The presence of oospores in fallen diseased leaves was estimated as per the method of Ronzon-Tran and Clerjeau (1988). Twenty five leaf discs of 1 $cm^2$ dia. bearing downy mildew symptoms were randomly selected and powdered in a pestle and mortar. The powder was soaked in 30 ml sterile distilled water and strained through a double layer cheese cloth. Twenty ml of this suspension was centrifuged at 6000 rpm for 15 minutes and 15 ml supernatant drawn with the help of a pipette. The pellet was re-suspended in 5 ml sterilized water and the number of oospores estimated as mean of 10 haemocytometer readings/replication. The presence of oospore production was computed on the basis of number/unit leaf area.

### 3.5.3 Viability of oospore

The viability of oospores in overwintered diseased leaves was assessed by oospore germination method (Panchbhai *et al.,* 1991). The sample used for the estimation of oospore production was also used for observing viability. The previous sterilized water was drained off from the sample and oospores were suspended in 5 ml 2.5 per cent sodium hypochlorite (NaOCl) solution which was then incubated at 18°C for 24 hours. After incubation, NaOCl was drained off and oospore re-suspended in 5 ml distilled sterilized water. Two drops of 50 µl from each processed sample were placed on a glass slide and incubated in moist chamber at 20±1°C for over night. After incubation, one drop of lactophenol was added to each drop and semi-permanent slides prepared by placing a cover slip over each drop. The number of germinated oospores in each drop, seen under microscope at 40x, were recorded.

### 3.5.4 Estimation of conidia production

Conidia production in fallen diseased leaves was estimated as per the

method of Murthy *et al.* (2003) with slight modification. The leaf samples with a spotted area of 10 to 15 mm were used to estimate conidial production. Twenty leaf discs having spots were taken and powered in a pestle and mortar. The powder was soaked in 30 ml distilled sterile water and strained through double layered cheese cloth. Fifteen mililitre of this suspension was centrifugated at 6000 rpm for 15 minutes. After centrifugation, 10 ml sterilized water was drawn off with a pipette. The pellet was re-suspended in 5 ml sterilized water and the number of conidia estimated as mean of 10 haemocytometer readings/replications. The conidia production was computed on the basis of number/unit leaf area. For viability, spore suspension was suspended in sterilized water and the number of germinated conidia was estimated as mean of 10 haemocytometer readings/replication.

### 3.6 Screening of germplasm for disease resistance

Twenty cucumber genotypes were evaluated against all the major diseases for resistance under natural epiphytotic conditions in the year 2011. The genotypes were procured from the Division of Vegetable Science, Shalimar. The genotypes screened were Priya, Japanese Long Green, S-5(m), Poinsette, Pusa Sanyug, Sweet Delight, Green Express, 10/cucu Hybrid-4, SKAU-2, CH-20, Hybrid-5, Swarna Ageta, AAUC-1, Hermophrodite, S-7, Local, Marketer-76, Khera-90, S-6(m) and SKAU-3. The genotypes were grown in plastic pots of 30 cm diameter. Five seeds/pot were sown in the 1$^{st}$ week of April and only two seedlings/ pot were maintained. One pot represented one replication. Each genotype was replicated three times. Five leaves were assessed for disease severity per pot. The expriment was laid as randomazid block design. The well sterilized loamy soil was used in pot. Plants were grown without any chemical treatment throughout study period. The plants were assessed for occurrence of all above diseases at peak period of each disease. This experiment was again repeated in the year 2012. The cultivars were arbitrarily categorized into five different reaction categories on the basis of per cent disease intensity (Singh *et al.*, 1996). This categorization, opted for all the four diseases, was as under:

**Disease reaction categories based on per cent disease intensity**

| Reaction category | Leaf area affected (%) |
|---|---|
| Immune | 0 |
| Tolerant | 1-10 |
| Moderately tolerant | 11-25 |
| Moderately susceptible | 26-50 |
| Susceptible | 51-75 |
| Highly susceptible | 76-100 |

**Ranking of cultivars on the basis of their performance**

| Category | Rank |
|---|---|
| Immune | 0 |
| Tolerant | 1 |
| Moderately tolerant | 2 |
| Moderately susceptible | 3 |
| Susceptible | 4 |
| Highly susceptible | 5 |

## 3.7 Management of diseases

### 3.7.1 Management through SAR chemicals

Five systemic acquired resistance (SAR) chemicals were evaluated for their efficacy under controlled conditions of disease development during the year 2011 and 2012.

| S. No. | Common/trade name | Chemical name | Source |
|---|---|---|---|
| 1 | Bion | 2,6-dicholoroisonicotinic acid (INA) | Sigma-Aldrich (India) |
| 2 | Actigard | benzothiadazol S-methyl ester (BTH) | Syngenta (Canada) |
| 3 | Gamma (FH) | β-aminobutyric acid (BABA) | Alibaba (America) |
| 4 | Baking Soda/ cooking soda | Sodium bicarbonate ($NaHCO_3$) | Hi-Media (India) |
| 5 | Aerated salt | Potassium bicarbonate ($KHCO_3$) | Hi-Media (India) |

The evaluation of SAR chemicals was carried out on cucumber cultivar 'Japanese Long Green' in a polyhouse at 27±1$^{o}$C. Seeds were sown in pots of 30 cm dia. in the 1$^{st}$ week of April. The concentration of each SAR chemical tested was BTH @ 100 ppm, BABA @ 1000 ppm, INA @ 1000 ppm, $NaHCO_3$ @ 100 ppm and $KHCO_3$ @ 100 ppm. A check was also maintained where plants were sprayed with water. The experiment was laid in a completely randomized design with each treatment replicated three times. A single plant represented one replication. The plants were categorized into four groups on the bases of spray schedule *viz.*, i) SAR treatment on cotyledon stage (single spray), ii) SAR treatment at cotyledon stage and a single spray of same chemical 15 days later (two sprays), iii) no treatment at cotyledon stage but two sprays of SAR at 15 day intervals, and iv) no treatment at cotyledon stage but two sprays of SAR at 30 day intervals. In each group check plants (water sprayed) were also maintained. In first group, spray of each test SAR compound was given at cotyledon stage (3-4 leaf stage) on each single plant followed by inoculum spray 24 hour later. The

disease intensity was recorded after 30 days. In second group, the spray of each test SAR compound was given at cotyledon stage on each single plant followed by inoculum spray 24 hour later and repeating the spray of test SAR chemical 15 days after cotyledon treatment. The disease intensity in this case was recorded 15 days after each spray. In third group, the first spray of test SAR chemical was given to each single plant 15 days after cotyledon stage followed by inoculum spray 24 hour later and repeating the same chemical spary 15 days after first spray. The disease intensity in this case was recorded 15 days after each spray. In last group, the first spray of each test SAR chemical was given to each single plant 30 days after cotyledon stage followed by inoculum spray 24 hour later and repeating the same chemical spray 30 days after first spray. After each spray inoculum spray was given to test plants. Spore suspension of each pathogen responsible for diseases was made on the basis of spore count in haemocytometer. The spore count of $10^3$ sporangia/ml for downy mildew pathogen and $10^5$ conidia/ml for other pathogens was prepared. The plants were sprayed with the help of an automizer. The intensity of each disease was observed after 30 days of in 1st category; while in 2nd and 3rd category disease intensity was observed two times at 15 day intervals. In 4th category the disease intensity was observed two times but at 30 day intervalss as per the method described above in 3.1.2.

### 3.7.2 Management through fungitoxicants

The experiments on evaluation of various fungitoxicants (Appendix-III) were conducted in the experimental field of Division of Vegetable Science, Shalimar, for two years during 2011 and 2012. Susceptible cucumber cultivar 'Japanese Long Green' was used. Each treatment comprized of three fungicides either all the three systemic or combination of systemic and non-systemic and/or biocontrol agent (either present or absent in treatment combination). All the fungicides and bioagent were procured from the Fungicide Laboratory, Division of Plant Pathology. The treatments comprized of i) first spray of mancozeb 75 WP @ (0.3%) followed by captan 50 WP @ (0.3%) and dinocap 48 EC @ (0.3%), ii)

first spray of cymoxanil 50 WP @ (0.3%) followed by tridemorph 50 WP @ (0.3%) and difenconazole 25 EC @ (0.05%) iii) first spary of cholorothalonil 75 WP @ (0.3%) followed by metalaxyl Mz 72 @ (0.25%) and tebeconazole 25 EC @ (0.05%), iv) pyraclostrobin + boscalid 38 WG @ (0.2%) followed by captan + hexaconazole 75 WP @ (0.3%) and metiram + pyraclostrobin 60 WG @ (0.2%), v) three sprays of bioagent [*Ampelomyces quisqualis*] @ (0.01%) at 20 days interval, vi) first spray of tridemorph 50 WP @ (0.3%) followed by two sprays of bioagent @ (0.01%) at 20 days interval, and vii) first spray of dinocap 48 EC @ (0.3%), followed by tridemorph 50 WP @ (0.3%) and bioagent @ (0.01%). Two seeds in each poly bag (1.75 cm dia.) were sown in the 3$^{rd}$ week of March. In 3$^{rd}$ week of April the seedlings were transplanted to field at 30 x 25 cm plant spacing. All agronomic practices, except protective measures, were followed as per the package and practice of SKUAST-Kashmir. First fungitoxicant spray was done on 15$^{th}$ June and remaining sprays were carried out at 20 days interval. The fungitoxicants were evaluated as foliar sprays under field conditions for their efficacy in controlling the diseases. Two plants represented each replication. The experiment was laid in a randomized block design with 3 replications/treatment. Check plants were sprayed with water. In case of bioagent the spore suspension of $5x10^9$ conidia/ml was used for spray. Disease intensity was assessed as discussed above in 3.1.2.

### 3.8 Statistical analysis

The data of various experiments were subjected to statistical analysis using computer software *OP-Stat* developed by O.P.Shoeran, CCSHAU, Hisar, India. The data was subjected to square root transformation and arc sine transformation wherever required. The data was analyzed by analysis of variance and critical difference estimated as per Gomez and Gomez (1984).

**Chapter – 4**

# EXPERIMENTAL FINDINGS

The findings of present study on the status of foliar fungal diseases of cucumber, their symptomatology, morphology, perpetuation, screening of available germplasm and disease management through SAR and fungitoxicants are presented as under:

## 4.1 Status of major fungal diseases of cucumber in Kashmir

The survey was conducted in four districts of Kashmir valley during the years 2011 and 2012 to assess the status of major foliar diseases of cucumber. The various foliar diseases noticed during the survey were downy mildew, anthracnose, Alternaria leaf spot, powdery mildew, Septoria leaf spot, Ulocladium leaf spot and scab. However, the first four diseases were most frequently encountered in all the surveyed districts/sites, while Septoria leaf spot, Ulocladium leaf spot and scab were occasionally noticed. So the information on major diseases is only reported here with respect to their intensity and incidence in the surveyed areas.

### 4.1.1 Downy mildew

The downy mildew disease incidence on cucumber leaves, irrespective of the years, varied from 16.0 to 69.3 per cent. The disease incidence was higher in the year 2012 (41.3%) than in 2011 (34.0%) [Table 1]. The mean disease incidence over the years varied from 20.6 to 63.6 per cent. In 2011, the highest disease incidence was noticed at Janwara (69.3%) and lowest at Kremshore (16.0%). However, in 2012, the highest disease incidence was seen at Dal (67.3%) and lowest at Sheikhpora (22.0%). Amongst the various districts surveyed, the highest mean disease incidence of 51.5 per cent was recorded in Srinagar closely followed by Baramulla (49.1%) (Fig 1a). Least mean disease incidence of 23.5 per cent was recorded in district Budgam. The disease intensity on cucumber leaves, irrespective of years, varied from 8.2 to 36.2 per cent with higher intensity in 2012 (17.6%) than in 2011 (14.1%) [Table 1]. The mean disease intensity over the years varied from 9.5 to 32.6 per cent. In 2011, the highest disease intensity

**Table 1: Incidence and intensity of downy mildew (*Pseudoperonospora cubensis*) on cucumber leaves at various locations of Kashmir during the years 2011 and 2012**

| District | Location | Disease incidence (%) | | | Disease intensity (%) | | |
|---|---|---|---|---|---|---|---|
| | | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| Baramulla | Sopore | 28.0 | 31.0 | 29.5 | 11.0 | 13.2 | 12.1 |
| | Baramulla | 52.0 | 63.3 | 57.6 | 28.0 | 30.0 | 29.0 |
| | Pattan | 45.3 | 50.0 | 47.6 | 23.6 | 27.9 | 25.7 |
| | Janwara | 69.3 | 57.3 | 63.3 | 29.3 | 32.9 | 31.1 |
| | Seelu | 44.0 | 51.3 | 47.6 | 22.5 | 26.6 | 25.0 |
| **Mean** | | **47.7** | **50.6** | **49.1** | **22.8** | **26.0** | **24.5** |
| Srinagar | Kawoosa | 38.0 | 44.0 | 41.0 | 18.1 | 17.6 | 17.8 |
| | Dal | 60.0 | 67.3 | 63.6 | 29.0 | 36.2 | 32.6 |
| | Shalimar | 54.0 | 64.0 | 59.0 | 23.6 | 28.9 | 26.2 |
| | Shadipora | 35.3 | 42.0 | 38.6 | 15.6 | 16.5 | 16.0 |
| | Harwan | 47.3 | 63.3 | 55.3 | 23.3 | 28.2 | 25.7 |
| **Mean** | | **46.9** | **56.1** | **51.5** | **21.9** | **25.4** | **23.6** |
| Bandipora | Patushai | 27.3 | 32.0 | 29.6 | 10.0 | 9.9 | 9.9 |
| | Nadihal | 26.0 | 34.6 | 30.3 | 11.1 | 12.0 | 11.5 |
| | Kemah | 18.0 | 23.3 | 20.6 | 8.9 | 10.2 | 9.5 |
| | Aloosa | 20.0 | 30.0 | 25.0 | 8.8 | 11.4 | 10.1 |
| | Ongam | 19.3 | 29.3 | 24.3 | 9.7 | 12.4 | 11.0 |
| **Mean** | | **22.1** | **29.8** | **25.9** | **9.7** | **11.1** | **10.4** |
| Budgam | Batpora | 18.0 | 30.0 | 24.0 | 10.1 | 15.3 | 12.7 |
| | Sheikhpora | 19.3 | 22.0 | 20.6 | 9.0 | 11.2 | 10.1 |
| | Gangbug | 20.0 | 29.3 | 24.6 | 8.2 | 11.3 | 9.7 |
| | Kremshore | 16.0 | 25.3 | 20.6 | 8.7 | 12.7 | 10.7 |
| | Narkara | 23.3 | 32.0 | 27.6 | 13.1 | 18.3 | 15.7 |
| **Mean** | | **19.3** | **27.7** | **23.5** | **9.8** | **13.7** | **11.7** |
| **Overall mean** | | **34.0** | **41.3** | **37.5** | **14.1** | **17.6** | **15.8** |

was observed at Janwara (29.3%) and lowest at Gangbug (8.2%). However, in year 2012 the highest disease intensity was at Dal (36.2%) and lowest at Patushai (9.9%). District-wise highest mean disease intensity was in Baramulla (24.5%), closely followed by Srinagar (23.6%) [Fig. 1b]. Least mean disease intensity of 10.4 per cent was noticed in Bandipora.

### 4.1.2 Anthracnose

The anthracnose disease incidence on cucumber leaves, irrespective of years, varied from 14.6 to 76.6 per cent with disease incidence higher in the year 2012 (47.2%) than in 2011 (34.7%) [Table 2]. The mean disease incidence over the years varied from 19.6 to 63.3 per cent. In 2011, the highest disease incidence was at Pattan (62.6%) and lowest at Kremshore (14.6%). However, in 2012, the highest disease incidence was recorded at Shalimar (76.6%) and lowest at Narkara (18.6%). Amongst the various districts surveyed the highest mean disease incidence of 57.5 per cent was observed in Srinagar closely followed by Baramulla (51.8%) [Fig. 1a]. Least mean disease incidence of 24.4 per cent was observed in the district Budgam. The disease intensity on cucumber leaves, irrespective of years, varied from 6.0 to 35.4 per cent with disease intensity higher in 2012 (20.8%) than in 2011 (16.1%) [Table 2]. The mean disease intensity over the years varied from 8.9 to 29.1 per cent. In the year 2011 highest disease intensity was observed at Pattan (29.7%) and lowest at Gangbug (6.0%). However, in 2012, the highest disease intensity was at Shalimar (35.4%) and lowest at Narkara (8.1%). District-wise the highest mean disease intensity was in Baramulla (26.0%) closely followed by Srinagar (25.5%) (Fig 1b). Least mean disease intensity of 11.2 per cent was recorded in Budgam.

**Table 2: Incidence and intensity of anthracnose (*Colletotrichum arbiculare*) on cucumber leaves at various locations of Kashmir during the years 2011 and 2012**

| District | Location | Disease incidence (%) | | | Disease intensity (%) | | |
|---|---|---|---|---|---|---|---|
| | | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| Baramulla | Sopore | 49.3 | 53.3 | 41.6 | 22.6 | 25.6 | 24.1 |
| | Baramulla | 54.0 | 61.3 | 51.6 | 27.6 | 27.0 | 27.3 |
| | Pattan | 62.6 | 68.0 | 53.6 | 29.7 | 28.0 | 28.8 |
| | Janwara | 48.6 | 64.6 | 60.3 | 22.5 | 25.3 | 23.9 |
| | Seelu | 49.3 | 58.0 | 52.0 | 22.6 | 29.4 | 26.0 |
| **Mean** | | **52.7** | **61.0** | **51.8** | **25.0** | **27.0** | **26.0** |
| Srinagar | Kawoosa | 45.3 | 63.3 | 54.5 | 21.4 | 29.0 | 25.2 |
| | Dal | 46.0 | 67.3 | 56.6 | 21.6 | 27.3 | 24.4 |
| | Shalimar | 50.0 | 76.6 | 63.3 | 22.8 | 35.4 | 29.1 |
| | Shadipora | 40.0 | 65.3 | 52.6 | 18.8 | 25.8 | 22.3 |
| | Harwan | 48.0 | 72.0 | 60.0 | 22.1 | 31.7 | 26.9 |
| **Mean** | | **45.8** | **68.9** | **57.5** | **21.3** | **29.8** | **25.5** |
| Bandipora | Patushai | 26.6 | 32.0 | 29.3 | 11.8 | 14.1 | 12.9 |
| | Nadihal | 22.0 | 27.3 | 24.6 | 11.2 | 12.0 | 11.6 |
| | Kemah | 16.0 | 26.6 | 21.3 | 6.1 | 11.8 | 8.9 |
| | Aloosa | 18.0 | 31.3 | 24.6 | 8.2 | 13.6 | 10.9 |
| | Ongam | 22.6 | 32.0 | 27.3 | 11.4 | 14.1 | 12.7 |
| **Mean** | | **21.0** | **29.8** | **25.4** | **9.7** | **13.1** | **11.4** |
| Budgam | Batpora | 29.3 | 42.0 | 35.6 | 13.0 | 20.8 | 16.9 |
| | Sheikhpora | 18.0 | 29.3 | 23.6 | 8.2 | 13.0 | 10.6 |
| | Gangbug | 15.3 | 27.5 | 21.4 | 6.0 | 12.0 | 9.0 |
| | Kremshore | 14.6 | 30.0 | 22.3 | 6.8 | 13.7 | 10.2 |
| | Narkara | 20.6 | 18.6 | 19.6 | 9.8 | 8.1 | 8.9 |
| **Mean** | | **19.5** | **29.4** | **24.4** | **8.7** | **13.5** | **11.2** |
| **Overall mean** | | **34.7** | **47.2** | **41.0** | **16.1** | **20.8** | **18.5** |

### 4.1.3 Alternaria leaf spot

The Alternaria disease incidence on cucumber leaves, irrespective of years, varied from 13.3 to 68.6 per cent with higher disease incidence in 2012 (45.6%) than in 2011 (35.5%) [Table 3]. The mean disease incidence over the years varied from 18.3 to 66.0 per cent. In the year 2011 highest disease incidence was observed at Baramulla (64.0%) and lowest at Kemah (13.3%). However, in 2012 the highest disease incidence was at Pattan and Shalimar (68.6%) and lowest at Kemah (23.3%). Amongst the various districts surveyed the highest mean disease incidence of 56.8 per cent was recorded in Srinagar, closely followed by Baramulla (56.0%) [Fig. 1a]. Least mean disease incidence of 24.5 per cent was recorded in district Bandipora. The data in Table 3 revealed that the disease intensity on cucumber leaves, irrespective of the years, varied from 5.7 to 29.8 per cent. The disease intensity was higher in 2012 (16.1%) than in 2011 (13.3%). The mean disease intensity over the years varied from 7.3 to 29.5 per cent. In 2011, the highest disease intensity was observed at Baramulla (30.9%) and lowest at Kemah (5.7%). However, in 2012 the highest disease intensity was at Shalimar (29.8%) and lowest at Kemah (9.0%). The highest mean disease intensity was observed in district Srinagar (24.4%) closely followed by district Baramulla (23.6%) [Fig 1b]. Least mean disease intensity of 10.4 per cent was noticed in district Bandipora.

### 4.1.4 Powdery mildew

The powdery mildew disease incidence on cucumber leaves, irrespective of the years, varied from 10.6 to 61.3 per cent. The disease incidence was higher in 2012 (39.7%) than in 2011 (33.0%) [Table 4]. The mean disease incidence over the years varied from 15.7 to 60.3 per cent. In 2011, the highest disease incidence was noticed at Janwara (59.3%) and lowest at Kemah (10.6%). However, in 2012 the highest disease incidence was recorded at Janwara (61.3%) and lowest at Kemah (21.3%). Amongst the various districts surveyed, the highest mean disease incidence of 51.8 per cent was noticed in Baramulla followed by Srinagar (45.7%) [Fig. 1a]. Least

**Table 3: Incidence and intensity of Alternaria leaf spot (*Alternaria alternata*) on cucumber leaves at various locations of Kashmir during the years 2011 and 2012**

| District | Location | Disease incidence (%) | | | Disease intensity (%) | | |
|---|---|---|---|---|---|---|---|
| | | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| Baramulla | Sopore | 33.3 | 48.0 | 40.6 | 14.4 | 18.8 | 16.6 |
| | Baramulla | 64.0 | 68.0 | 66.0 | 30.9 | 27.7 | 29.3 |
| | Pattan | 63.3 | 68.6 | 65.9 | 30.5 | 28.6 | 29.5 |
| | Janwara | 53.3 | 66.6 | 59.9 | 22.6 | 25.6 | 24.1 |
| | Seelu | 44.0 | 51.3 | 47.6 | 150. | 22.2 | 18.6 |
| **Mean** | | **51.8** | **60.5** | **56.0** | **22.6** | **24.5** | **23.6** |
| Srinagar | Kawoosa | 54.6 | 63.3 | 58.9 | 23.2 | 27.0 | 25.1 |
| | Dal | 51.3 | 55.3 | 53.3 | 22.5 | 23.0 | 22.7 |
| | Shalimar | 52.0 | 68.6 | 60.3 | 23.3 | 29.8 | 26.5 |
| | Shadipora | 42.0 | 63.3 | 52.6 | 14.5 | 28.5 | 21.5 |
| | Harwan | 51.3 | 66.6 | 56.8 | 23.4 | 28.8 | 26.1 |
| **Mean** | | **50.2** | **63.4** | **56.8** | **21.3** | **27.4** | **24.4** |
| Bandipora | Patushai | 27.3 | 34.6 | 30.9 | 12.0 | 13.0 | 12.5 |
| | Nadihal | 22.0 | 30.0 | 26.0 | 8.5 | 12.6 | 10.5 |
| | Kemah | 13.3 | 23.3 | 18.3 | 5.7 | 9.0 | 7.3 |
| | Aloosa | 15.3 | 29.3 | 22.3 | 5.8 | 15.6 | 10.7 |
| | Ongam | 20.6 | 29.3 | 24.9 | 6.0 | 16.4 | 11.2 |
| **Mean** | | **19.7** | **29.4** | **24.5** | **7.6** | **13.3** | **10.4** |
| Budgam | Batpora | 28.0 | 37.3 | 32.6 | 12.4 | 14.6 | 13.5 |
| | Sheikhpora | 22.0 | 31.3 | 26.6 | 11.2 | 13.0 | 12.1 |
| | Gangbug | 27.3 | 32.6 | 29.9 | 11.8 | 13.6 | 12.7 |
| | Kremshore | 19.3 | 31.3 | 25.3 | 8.6 | 13.0 | 10.8 |
| | Narkara | 19.3 | 24.6 | 21.9 | 9.4 | 11.5 | 10.4 |
| **Mean** | | **23.1** | **31.4** | **27.3** | **10.6** | **13.1** | **11.9** |
| **Overall mean** | | **35.5** | **45.6** | **40.4** | **13.3** | **16.1** | **14.8** |

**Table 4: Incidence and intensity of powdery mildew (*Sphaerotheca fuliginea*) Pollaci] on cucumber leaves at various locations of Kashmir during the years 2011 and 2012**

| District | Location | Disease incidence (%) | | | Disease intensity (%) | | |
|---|---|---|---|---|---|---|---|
| | | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| Baramulla | Sopore | 37.3 | 46.0 | 41.6 | 16.9 | 20.4 | 18.6 |
| | Baramulla | 49.3 | 54.0 | 51.6 | 20.6 | 19.4 | 20.0 |
| | Pattan | 50.0 | 57.3 | 53.6 | 21.3 | 21.4 | 21.3 |
| | Janwara | 59.3 | 61.3 | 60.3 | 23.4 | 23.8 | 23.6 |
| | Seelu | 48.0 | 56.0 | 52.0 | 19.6 | 21.2 | 20.4 |
| **Mean** | | **48.7** | **54.9** | **51.8** | **20.3** | **21.2** | **20.8** |
| Srinagar | Kawoosa | 49.3 | 33.3 | 41.3 | 21.0 | 13.8 | 17.4 |
| | Dal | 47.3 | 58.6 | 52.9 | 20.4 | 24.8 | 22.6 |
| | Shalimar | 38.6 | 55.3 | 46.9 | 18.2 | 23.0 | 20.6 |
| | Shadipora | 39.3 | 43.3 | 41.3 | 18.5 | 18.5 | 18.5 |
| | Harwan | 53.0 | 40.0 | 46.5 | 21.8 | 17.2 | 19.5 |
| **Mean** | | **45.5** | **46.1** | **45.7** | **19.9** | **19.4** | **19.7** |
| Bandipora | Patushai | 25.3 | 27.3 | 26.5 | 11.8 | 13.4 | 12.6 |
| | Nadihal | 20.0 | 28.0 | 24.0 | 7.6 | 13.2 | 10.4 |
| | Kemah | 10.6 | 21.3 | 15.7 | 3.8 | 10.0 | 6.9 |
| | Aloosa | 18.0 | 31.3 | 24.7 | 7.7 | 15.7 | 11.7 |
| | Ongam | 24.0 | 36.6 | 30.2 | 10.9 | 17.6 | 14.2 |
| **Mean** | | **19.7** | **28.9** | **24.2** | **8.3** | **13.9** | **11.1** |
| Budgam | Batpora | 24.0 | 34.0 | 29.0 | 11.3 | 13.3 | 12.3 |
| | Sheikhpora | 23.3 | 33.3 | 28.0 | 10.6 | 13.0 | 11.8 |
| | Gangbug | 16.0 | 29.3 | 22.5 | 6.6 | 12.4 | 9.5 |
| | Kremshore | 14.0 | 25.3 | 19.7 | 6.2 | 11.6 | 8.9 |
| | Narkara | 14.6 | 23.3 | 19.0 | 6.4 | 10.6 | 8.5 |
| **Mean** | | **18.3** | **29.0** | **23.6** | **8.2** | **12.1** | **10.2** |
| **Overall mean** | | **33.0** | **39.7** | **36.3** | **14.1** | **16.6** | **15.4** |

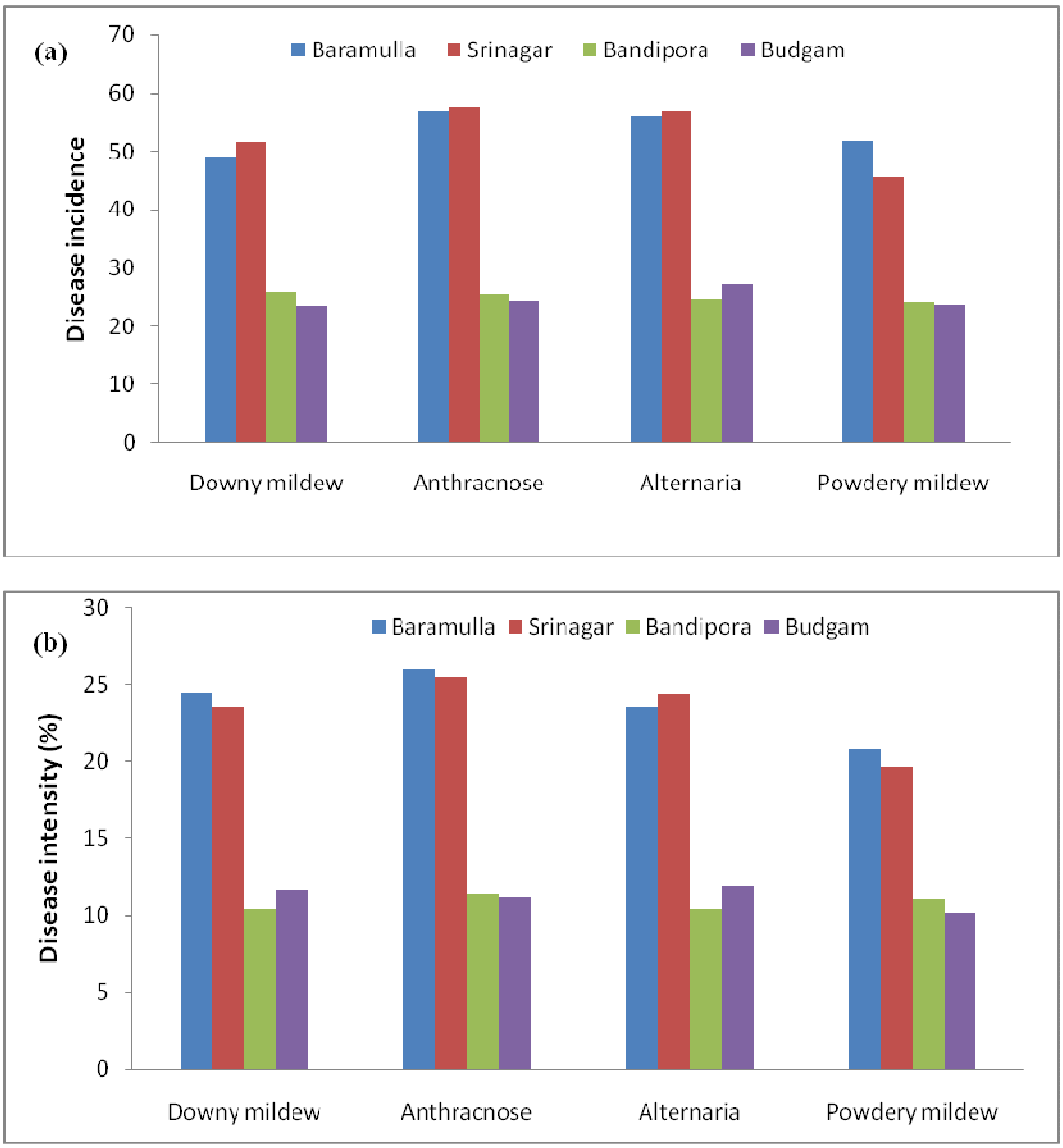



**Fig. 1: Mean disease incidence (a) and intensity (b) of downy mildew, anthracnose, Alternaria leaf spot and powdery mildew on cucumber leaves in various districts of Kashmir**

mean disease incidence of 23.6 per cent was recorded in district Budgam. The disease intensity on cucumber leaves, irrespective of years, varied from 3.8 to 24.8 per cent. The disease intensity was higher in 2012 (16.6%) than in 2011 (14.1%). The mean disease intensity over the years varied from 6.9 to 23.6 per cent. In the year 2011 highest disease intensity was observed at Janwara (23.4%) and least at Kemah (3.8%). However, in 2012 the highest disease intensity was observed at Dal (24.8%) and lowest at Kemah (10.0%). District-wise highest mean disease intensity was observed in Baramulla (20.8%), closely followed by Srinagar (19.7%) [Fig 1b]. Least mean disease intensity of 10.2 per cent was observed in Budgam.

## 4.2 Symptomatological studies

The symptomatology of prevalent diseases under natural conditions of infection in field was studied on unsprayed vines of susceptible cucumber cv. Japanese Long Green. The fungal foliar diseases exhibited typical symptoms which varied with time and the stage of crop growth.

### 4.2.1 Downy mildew

The initial disease symptoms of downy mildew were observed on leaves in the 2$^{nd}$ week of June on adaxial leaf surface in the form of slightly chlorotic lesions (Table 5). The lesions were irregular and water soaked, and measured 0.1 to 0.4 mm in size (Plate 5A). The lesions became irregular to angular in shape with bright yellow colour measuring 0.4 to 0.5 mm in size during mid June (Plate 5B). Observations on 22$^{nd}$ June revealed that the lesions were restricted by veins and measured 0.7 to 0.9 mm in size (Plate 5C). The colour of lesions was dark yellow. A grayish to black growth was noticed on the abaxial leaf surface. Microscopic examination revealed the presence of sporangiophores and sporangia on abaxial leaf surface (Plate 5D). The lesion progression was slow upto the end of 3$^{rd}$ week of June after which it showed curvilinear growth behaviour upto 1$^{st}$ week of July. In last week of June, the lesions on adaxial leaf surface became light brown with average size of 1.5-3.5 mm. More prominent black aerial growth was seen on

**Table 5: Development of downy mildew (*Pseudoperonospora cubensis*) symptoms on cucumber cv. "Japanese Long Green" at Shalimar during 2011**

| Date of observation | Leaf lesion | |
|---|---|---|
| | Size (mm) | Shape and colour |
| 4th June | - | No disease |
| 10th June | ≤0.4 | Slightly chlorotic, water soaked irregular spots |
| 16th June | 0.4-0.5 | Bright yellow, irregular to angular spots |
| 22th June | 0.7-0.9 | Dark yellow grayish to black on the underside (downy growth), angular spots restricted by veins |
| 28th June | 1.5-3.5 | Light brown prominent angular spots and black aerial growth on abaxial side. |
| 4th July | ≥3.5 | Coalescing of brownish angular spots with dense black aerial growth on abaxial side of leaf with irregular necrosis, death of entire leaf |

(A) Slightly chlorotic

(B) Bright yellow

(C)Spots restricted by veins

(D) Downy growth

**Plate-5: Symptomatological development of downy mildew (*Pseudoperonospora cubensis*) on cucumber leaves**

***Plate 5 continued…***

**(E)Light brown spots**

**(F)Coalescing of spots**

**(G) Death of entire leaf**

abaxial side (Plate 5E). The lesions attained a maximum size of 7.0 to 9.4 mm in the 1st week of July. Brownish angular lesions coalesced showing dense black aerial growth on abaxial leaf surface with irregular necrosis (Plate 5F). The affected leaves showed mottled appearance and later died (Plate 5G).

### 4.2.2 Anthracnose

The anthracnose disease was first noticed in the 2nd week of June (Table 6). The symptoms initiated as roughly circular slightly chlorotic pin-head spots ranging from 0.0 to 0.30 mm in size (Plate 6A). The spots turned light brown near the veins and within a week's period measured 0.4 to 0.9 mm in size (Plate 6B). With the passage of time the lesions became irregular and jagged with lesions attaining a size of 1.0 to 2.0 mm (Plate 6C). During the 1st week of July, the lesions were more extensive and dark-reddish coloured having grayish centers. The size of lesions was 2.5 to 5.5 mm and 1 to 2 acervulli were seen in them (Plate 6D). In 2nd week of July acervulli with dark brown setae were observed on the lesions. The average lesion size was 7.5 to 9.0 mm with 3-5 acervulli/leaf lesion. The center of lesions started cracking (Plate 6E). During 3rd week of July leaves became distorted. The centre of lesion was cracked, dropped out and gave shot hole appearance. The average size of lesions reached upto 1.5 cm and, on an average, more than 5 acervulli were seen on leaf lesions (Plate 6F).

### 4.2.3 Alternaria leaf spot

The Alternaria leaf spots appeared in the 3rd week of June as small light green flecks of $\leq$0.4 mm size (Table 7; Plate 7A). During last week of June, the spots became grayish and circular. These spots were surrounded by a yellow halo and measured 0.4-0.9 mm in size (Plate 7B). In 1st week of July, irregular dark brown lesions were formed which measured 1.0 to 1.75 cm in size (Plate 7C). Microscopic examination revealed the presence of conidia. During 2nd week of July, the lesions coalesced and formed irregular necrotic patches of 2.0-3.5 cm

size (Plate 7D). During 3rd week of July, the leaves showed blightened appearance (Plate 7E). The chlorotic lesions measured 4.0 to 4.5 cm in size. In last week of July, the lesions attained a size of 5.0 to 5.3 cm. The affected leaves turned yellow, senescent and ultimately died (Plate 7F).

### 4.2.4 Powdery mildew

During the periodic observations of cucumber plants, the initial disease symptoms were noticed in the 3rd week of July on abaxial leaf surface as small chlorotic spots which measured 0.3 to 0.6 mm in size. The spots covered approximately 2-3.5 per cent leaf area (Table 8; Plate 8A). Three days later, small powdery mildew patches developed and covered 3.5-8 per cent leaf area.

Microscopic observations revealed that the presence of fungal spores (Plate 8B). In 3rd week, whitish, talcum-powder like growth in patches was noticed which covered 8-20 per cent leaf area (Plate 8C). Three days later, patches showed coalescing phenomenon, yellow lesions were prominent and disease covered 20-45 per cent leaf area (Plate 8D). In 4th week of July mycelial mat and tan coloured patches were observed, major portion of leaf was covered by powdery mildew (>50 - <75%) [Plate 8E]. There was blistering of leaves and these blisters covered the entire leaf, the colour of lesions turned brown to dark brown, infected leaves curled and dropped with greater than 75 per cent leaf area covered (Plate 8F).

**Table 6: Development of anthracnose (*Colletotrichum arbiculare*) symptoms on cucumber leaves cv. "Japanese Long Green" at Shalimar during 2011**

| Date of observation | Leaf lesion | | Acervulli/cm$^2$ |
|---|---|---|---|
| | Size (mm) | Shape and colour | |
| 15th June | 0.0-0.3 | Slightly chlorotic pinhead spot | 0 |
| 22th June | 0.4-0.9 | Light brown spot near veins | 0 |
| 29th June | 1.0-2.0 | Irregular lesion and jagged | 0 |
| 6th July | 2.5-5.5 | Lesions prominent with grayish centre and darker reddish | 1-2, acervuli with dark brown setae |
| 13th July | 7.5-9.0 | Lesions more prominent, centre of the lesion started cracking | 3-5, acervuli with dark brown setae |
| 20th July | 12.0-15.0 | Distorted leaves, lesions brown, center of lesion cracked and dropped out, giving the leaf shot-hole appearance | >5, acervuli with dark brown setae |

(A)Slightly chlorotic (B)Light brown spot

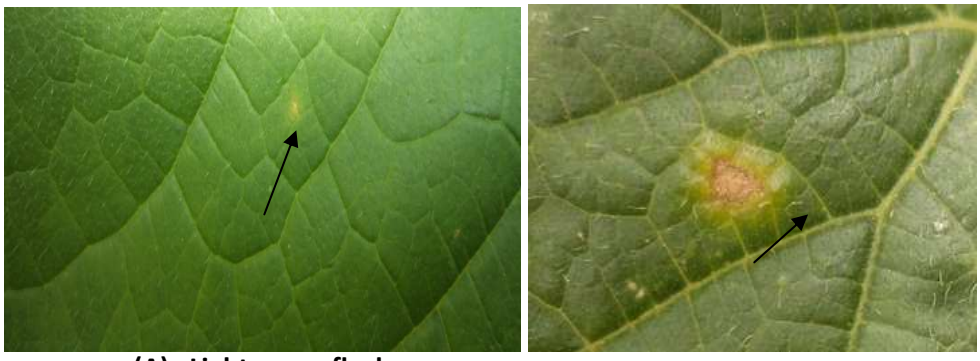
(C) Irregular & jagged (D)Lesions darker reddish

(E)Cracked centre (F)Distorted leaves

**Plate-6: Symptomatological development of anthracnose (*Colletotricum arbiculare*) on cucumber leaves**

**Table 7: Development of Alternaria leaf spot (*Alternaria alternata*) symptoms on cucumber leaves cv. "Japanese Long Green" at Shalimar during 2011**

| Date of observation | Leaf lesion | | Sporulation |
|---|---|---|---|
| | Size | Shape and colour | |
| 19th June | 0.0-0.4 mm | Light green fleck | 0 |
| 27th June | 0.4 -0.9 mm | Grayish lesion surrounded by yellow halo | 0 |
| 4th July | 1.00-1.75 cm | Irregular dark brown lesions | 1-15 |
| 11th July | 2.0-3.5 cm | Lesions coalesce, form irregular necrotic patches | 16-30 |
| 18th July | 4.0-4.5 cm | Leaves appeared blightened | 31-45 |
| 25th July | 5.0-5.3 cm | Leaves became yellowish, senescent and die | >45 |



(A) Light green fleck (B)Yellow halo

(C) Brown lesion (D) Lesions coalesce

(E) Blightened leaves (F) Yellow leaves and senescent

**Plate- 7: Symptomatological development of Alternaria leaf spot (*Alternaria alternata*) on cucumber leaves**

**Table 8: Development of powdery mildew (*Sphaerotheca fuliginea*) symptoms on cucumber leaves cv. "Japanese Long Green" at Shalimar during 2011**

| Date of observation | Leaf area covered (%) | Lesion shape and colour | Conidia/ chain |
|---|---|---|---|
| 17th July | 2.0-3.5 | Small chlorotic spots of 0.2-0.5 mm size | 0 |
| 20thJuly | 5.0-8.0 | Small powdery patches | 1-5 |
| 23th July | 8.0-20.0 | White talcum powder-like growth in patches | 6-10 |
| 26th July | 20.0-45.0 | Patches coalesced, prominent yellow lesions | >10 |
| 29 July | 45-75 | Mycelium of fungus form mats of tan colour, patches coalesced and covered almost entire leaf | >10 |
| 1st August | ≥75 | Entire leaf covered, lesion turn brown to dark brown, Infected leaves curled and dropped | >10 |

(A) Small chlorotic spots

(B) Powdery spot

(C) Growth in patches

(D)Patches coalesce

(E) Lesions turn light brown

(F) Covers whole leaf

**Plate-8: Symptomatological development of powdery mildew (*Sphaerotheca fuliginea*) on cucumber leaves**

## 4.3 Morphological characterization

### 4.3.1 Downy mildew on host

The mycelial growth was observed on the abaxial surface of infected cucumber leaves. The mycelium was hyaline, irregularly branched and measured 4.8-6.4 µm in width (avg. 5.85 µm) [Table 9; Plate 9A]. Sporangiophores observed were dichotomously branched and produced singly or in small groups from the stomata of infected host on abaxial surface. The sporangiophores were hyaline and measured 182.4-380.8 × 3.2-9.6 µm in size (avg. 237.3 × 5.4) (Plate 9B). The sporangia were ovoid to ellipsoidal, thin walled with papilla at distal end and borne singly on pointed tips of sporangiophores at acute angles. The sporangia were grayishish coloured and measured 22.4-38.4 × 12.8-25.6 µm in size (avg. 29.4 × 18.75 µm) [Plate C]. The zoospores were released from the zoosporangium through perforation of sporangial wall (Plate 9 D,E). Some sporangia directly produced germ tube (Plate 9F). The germination was recorded before 5.30 am in the morning. The germination of sporangia was reduced after 8 am. The oospores were spherical or globose, double walled, light brown and measured 38.4-44.8 µm in size (avg. 41.4 µm). The oospores germinated by single germ tube (Plate 9G).

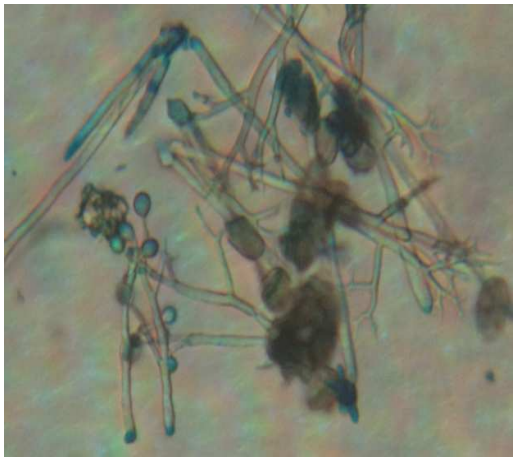
### 4.3.2 Anthracnose

#### 4.3.2.1. On host

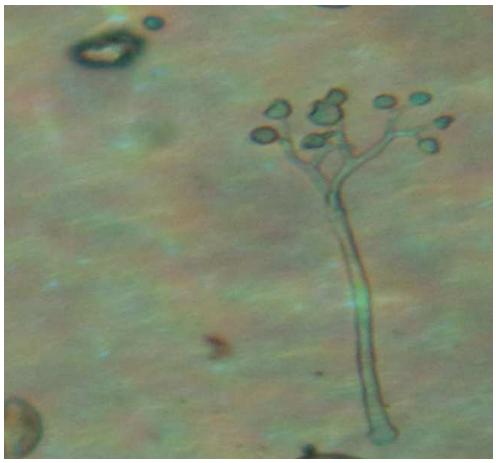
Acervulli were observed on the adaxial leaf surface of infected cucumber; however no hyphae were noticed (Table 10). Acervulli were salmon coloured, slightly raised and saucer shaped. Hair-like 1-3 black setae protruded out from the surface and several conidia were observed (Plate 9E). Conidia were oblong, ovate and single celled with rounded ends. The conidia were hyaline and measured 3.2-6.4 × 3.2-4.8 µm in size (avg. 5.1 × 4.2 µm) and germination of conidia was seen. Setae were 12.8-70.4 × 1.6-6.4 µm (avg. 34.0 × 5.5 µm) in size.

**Table 9: Morphological characters of *Pseudoperonospora cubensis* causing downy mildew of cucumber**

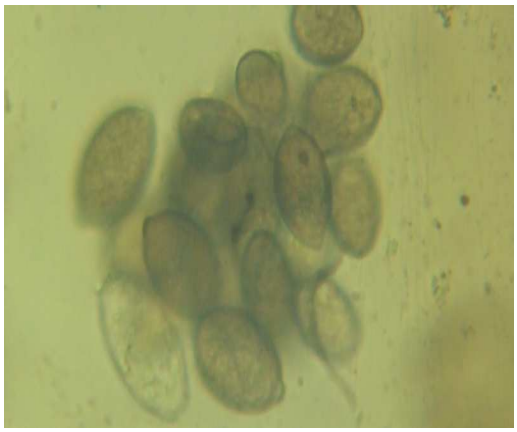
| Thallus part | Physical appearance/shape | Colour | Size (µm) |
|---|---|---|---|
| Hyphae | Irregularly branched | Hyaline | 4.8-6.4 [width] (avg. 5.85) |
| Sporangiophore | Dichotomously branched, produced singly or in small groups from stomata of infected host from abaxial side of leaf | Hyaline | 182.4-380.8 × 3.2-9.6 (avg. 237.3 × 5.4) |
| Sporangia | Ovoid to ellipsoid, thin walled with papilla at distal end, borne singly on pointed tips of sporangiophore at acute angles | Grayish | 22.4-38.4 × 12.8-25.6 (avg. 29.4 × 18.7) |
| Oospore | Spherical or globose double walled | Light brown | 38.4-44.8 (avg. 41.4) |



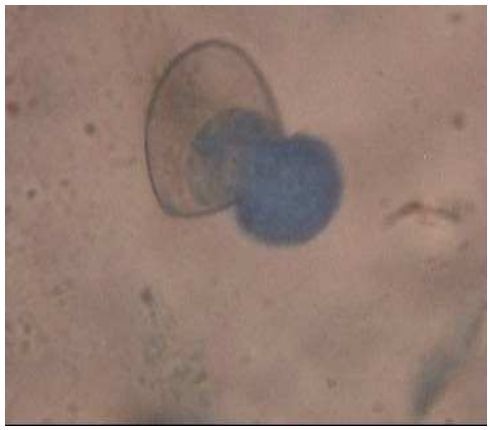
**(A) Irregularly branched 10x**hyphae



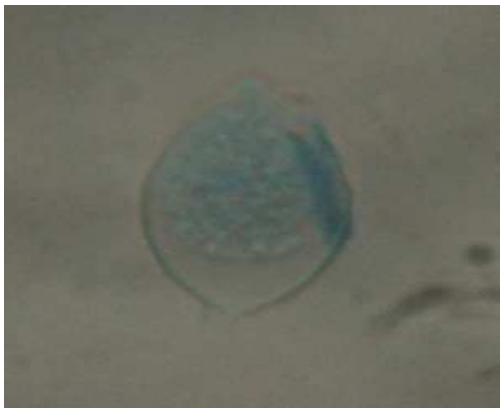
**(B)Sporangiophore 10x**



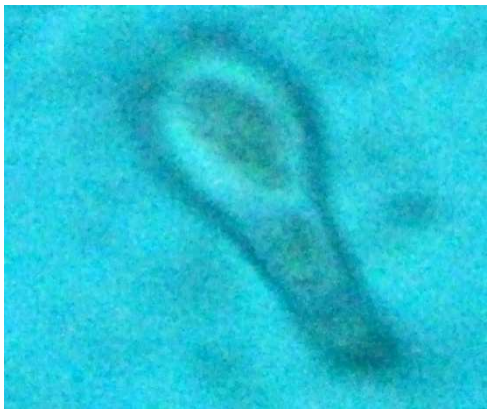
**(C) Ovoid sporangia 400x**



**(D) Release of zoospores 400x**



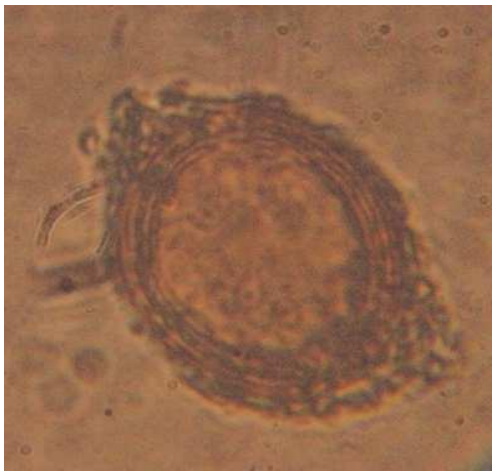
**(E )Zoosporangia 40x**



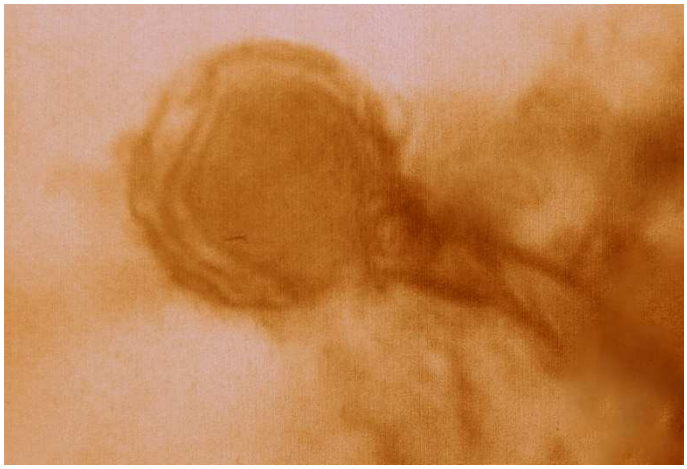
**(F) Germinating sporangia 40x**

**Plate 9: Morphological characters of *Pseudoperonospora cubensis* causing downy mildew of cucumber**

***Plate 9 continued…..***



**(G) Oospore40x** **(H) Magnified view of oospore 100x**

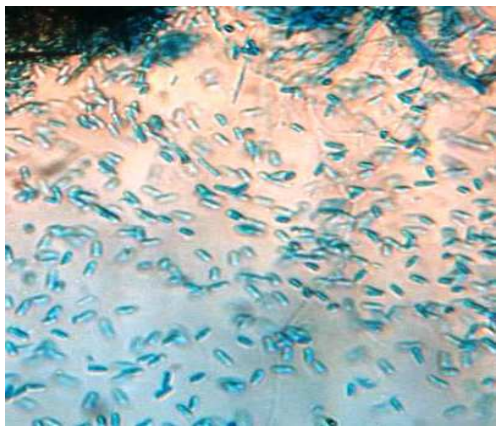


**(I) Germinating oospore 100x**

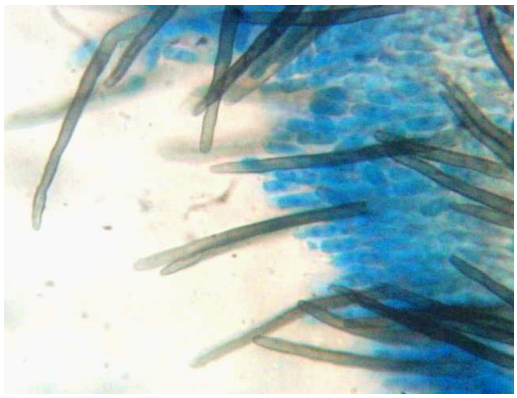
**Table 10: Morphological characters of *Colletotrichum arbiculare* causing anthracnose of cucumber**

| Thallus part | Physical appearance/shape | Colour | Size (μm) |
|---|---|---|---|
| **On host** | | | |
| Acervuli | Slightly raised, saucer shaped, has hair-like black 1-3 setae protruding out from the surface, several conidia seen | Salmon | 12.8-70.4 × 1.6-6.4 (avg. 33.98 × 5.56) |
| Conidia | Oblong, ovate, single celled, with rounded ends | Hyaline | 3.2-6.4 × 3.2-4.8 (avg. 5.1 × 4.5) |
| **In culture** | | | |
| Colony | Radial growth | White to grayish | |
| Hyphae | Septate , branched | Hyaline | 3.2-4.8 (avg. 3.77) |
| Acervuli | Slightly raised, hair like black setae protruding from the surface1-3 setae and several conidia | Black | 12.8-73.6 × 1.6-9.6 (avg.43.9×5.1) |
| Conidia | Single celled | Hyaline | 3.2-9.6 × 3.2-4.8 (avg. 6.1×3.6) |

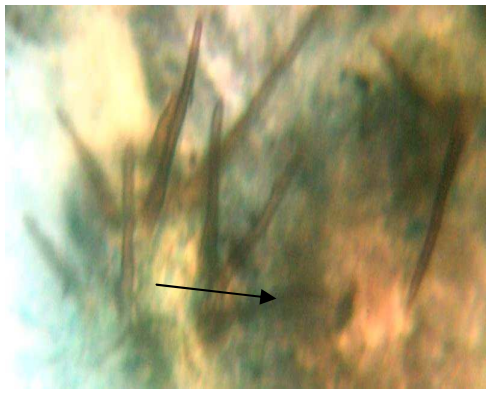
(A) Fungal colony



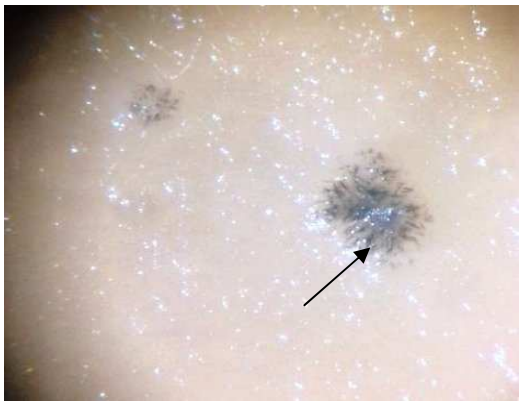
(B) Hyaline mycelium with conidia 10x



(C) Acervulli with setae (40x)



(E) Acervulli on leaf tissue40x



(D) Acervulli on media 10x

**Plate 10: Cultural and morphological characters of *Colletotrichum arbiculare* causing anthracnose of cucumber**

#### 4.3.2.2. In culture media

The fungus causing anthracnose in cucumber grew slowly on oat meal agar medium at 28±1°C. The purified culture on oat meal agar was initially white coloured, with sparse aerial mycelial growth. The colony became grayish within 20 days and showed radial growth (Plate 10A). The mycelium was hyaline, septate and branched. The hypha was 3.2-4.8 µm in width (avg. 3.77 µm). The conidia were single celled, hyaline and measured 3.2-9.6 × 3.2-4.8 µm in size (avg. 6.1 × 3.6 µm) [Plate 10 B]. After three weeks of vegetative growth, the acervulli formation initiated. These were slightly raised and salmon-coloured with 1-3 black hair-like setae embedded in them (Plate10C). Setae measured 12.8-73.6 × 1.6-9.6 µm (avg. 43.9 × 5.1 µm) in size (Plate 10D).

### 4.3.3 Alternaria leaf spot

#### 4.3.3.1 On host

Hyphae observed on the adaxial surface of infected cucumber leaves were septate, smooth and branched and measured 4.8-6.4 µm in width (avg. 5.1 µm) (Table 11). Hyphae were hyaline to dark olive in colour. Conidiophores were short straight or flexuous in appearance, pale brown to olive brown in colour and measured 25.6-51.2 × 3.2-6.4 µm in size (avg. 40.9 × 4.4 µm). Conidia were ovoid, obclavate and ellipsoid having 1-8 transverse and several longitudinal cross walls with short conical cylindrical club-shaped beak. The colour of conidia was brown to black with size varying from 36.0-64.0 × 9.6-12.8 µm (avg. 59.0-10.2 µm). Germination of conidia observed was either apical or lateral or both (Plate 11 E, F).

#### 4.3.3.2 In culture

The fungus associated with Alternaria leaf spot was grew fast on PDA medium at 25±1°C and covered the entire medium surface within a week. The fungal colony was initially hyaline and turned dark olive within a week (Plate 11A). The mycelium was hyaline to dark olive, septate, branched, smooth and measured 4.8-6.4 µm in width (avg. 5.1 µm) (Plate 11B). Conidiophores were

short, straight or flexuous, sympodial in growth, pale brown to olive brown and measured 28.8-54.4 × 3.2-6.4 µm in size (avg. 50.1 × 5.5 µm) [Plate 11C]. Conidia were brown to black, ovoid, obclavate, ellipsoid, produced in chains, with an apical short conical or cylindrical beak. Conidia measured 36.0-67.2 × 12.8-16.0 µm (avg. 60.5 × 14.0 µm) in size. Conidia (4-5) were produced in a single chain in basipetal order (Plate 11D).

### 4.3.4 Powdery mildew

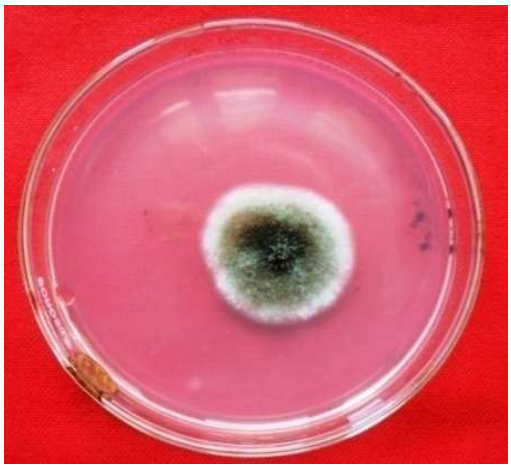
White to gray and fluffy to sparse mycelial growth was observed on adaxial leaf surface of infected cucumber (Plate 12A). The hyphae were thin walled, septate and measured 2-3 µm in width (Plate 12B). Conidiophores were erect, aerial and measured (36-49 × 9.6-16.0 µm) in size (avg. 42.2 × 12.5 µm) [Plate 12C]. Conidia were hyaline, borne in chains, basipetal, ellipsoid to ovoid, one-celled with well-developed fibrosin bodies and measured 22.4-35.2 × 12.8-21.0 µm (avg. 25.6 × 20.0 µm) in size (Plate 12D, E).

### 4.3.5 Identification of pathogen

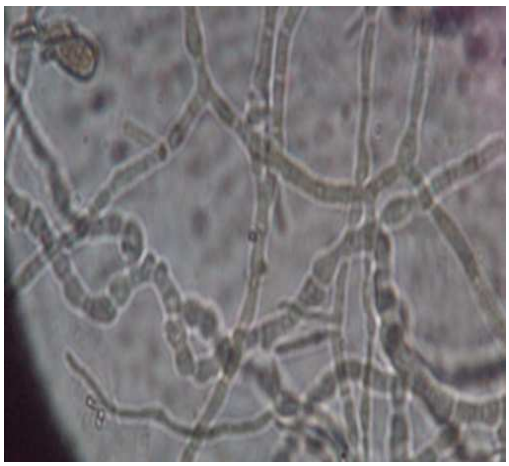
For all the four pathogens, innoculum spray was given to four separate 3-4 leaf stage cucumber plants in moist chamber and same symptoms were observed as on diseased leaf tissues. On the basis of morphological and pathological characteristics and comparison to the authentic description (Tode, 1790), (Ellis, 1971), (Berkeley and Curtis 1868) and (Braun, 1987) the pathogens were identified as *Colletotrichum arbiculare* (Berk. & Mont), *Alternaria alternata* (Fr.) Keissler, *Pseudoperonospora cubensis* (Berk. and Curt.) and *Sphaerotheca fuliginea* Schlechtend.(Fr:) Pollaci respectively. The identity of former two pathogens was further confirmed at Indian Type Collection Centre under the I.D. No. 9282.14. A & B respectively whileas, lateral two being obligate pathogens and was no need of further confirmation.

**Table 11: Morphological characters of *Alternaria alternata* causing Alternaria leaf spot on cucumber**

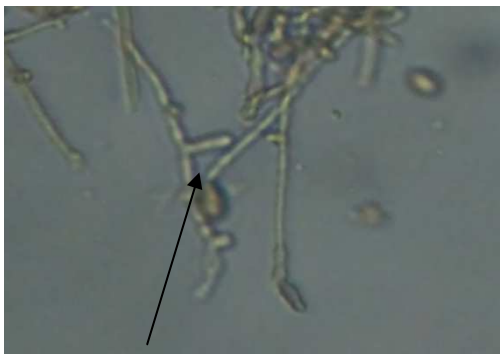
| Thallus part | Physical appearance/shape | Colour | Size (µm) |
|---|---|---|---|
| **On host** | | | |
| Hyphae | Branched, smooth, septate | Hyaline to dark olive | 4.8-6.4 (width) (avg. 5.1) |
| Conidiophore | Short straight or flexuous | Pale brown to olive brown | 25.6-51.2 × 3.2-6.4 (40.9 × 4.4) |
| Conidia | Ovoid, obclavate, ellipsoidal with transverse or ongitudinal cross walls with a short, cylindrical conical beak | brown to black | 26-64 × 9.6-12.8 (avg. 59.0 × 10.2) (width at broadest part) |
| **In culture** | | | |
| Colony | Fast growing, initially colourless, became dark with age, aerial branches, velvety growth | Hyaline to dark olive | |
| Hyphae | Septate, branched, smooth | Hyaline to dark olive | 4.8-6.4 (avg. 5.1) |
| Conidiophore | Short straight or flexuous, sympodial growth | Pale brown to olive brown | 28.8-54.4 × 3.2-6.4 (avg. 50.I × 5.5) |
| Conidia | Ovoid, obclavate, produced in chains, ellipsoidal, club-shaped with an apical beak short, conical and cylindrical | Brown to black | 36.0-67.2 × 12.8-16.0 (avg. 60.5 × 14.0) |



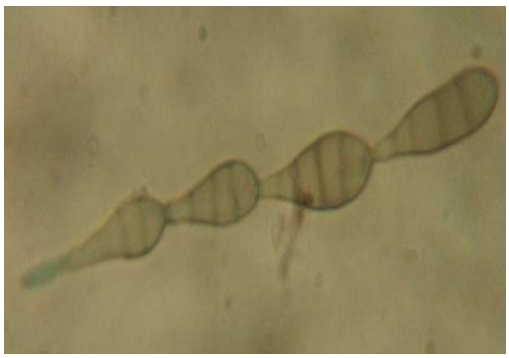
(A) Fungal colony



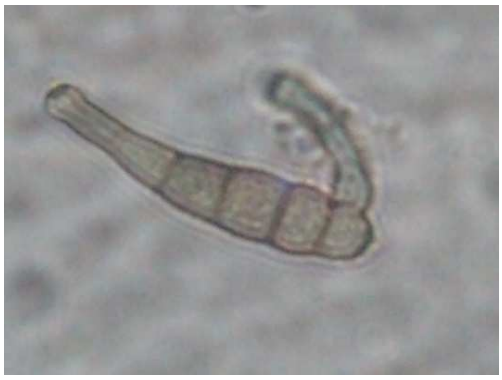
(B)Septate mycelium 40x

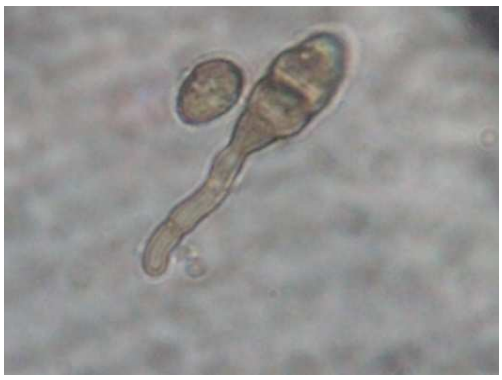


(C) Conidiophore 10x



(D) Conidia in chains 40x



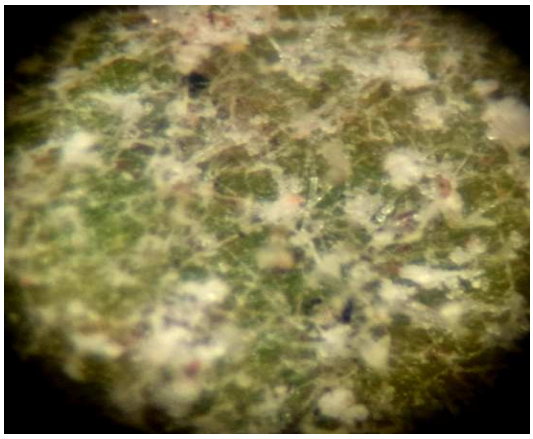


(E& F) Germinating conidia 40x

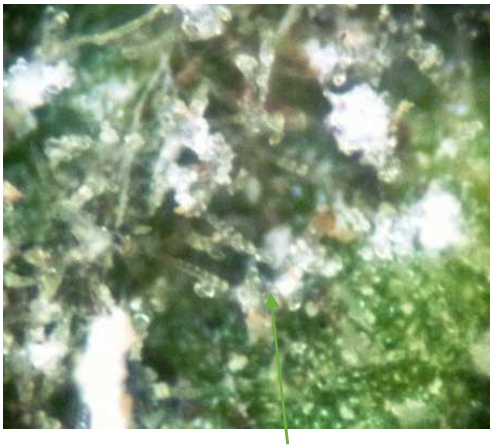
**Plate-11: Morphological characters of *Alternaria alternate* causing Alternaria leaf spot oncucumber**

**Table 12: Morphological characters of *Sphaerotheca fuliginea* causing powdery mildew on cucumber**

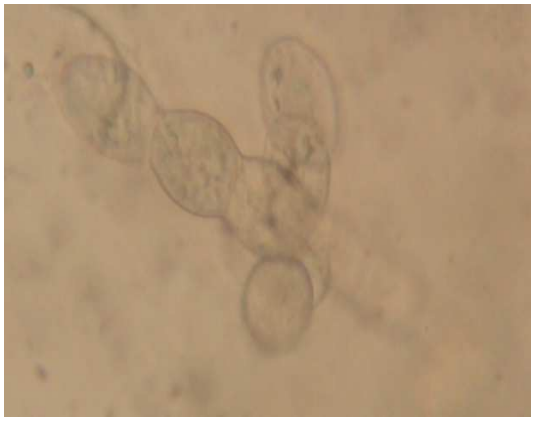
| Thallus part | Physical appearance/shape | Colour | Size (µm) |
|---|---|---|---|
| Hyphae | Over surface of leaf, fluffy to sparse, thin walled and septate | White to gray | 2-3 (width) |
| Conidiophore | Erect, aerial | Hyaline | 36-49 × 9.6-16.0 (avg. 42.2 × 12.5) |
| Conidia | Singly or chains, basipetal order ellipsoid to ovoid well developed fibrosin bodies, one celled | Hyaline | 22.4-35.2 × 12.8-22.0 (avg. 25.6 × 20.0) |



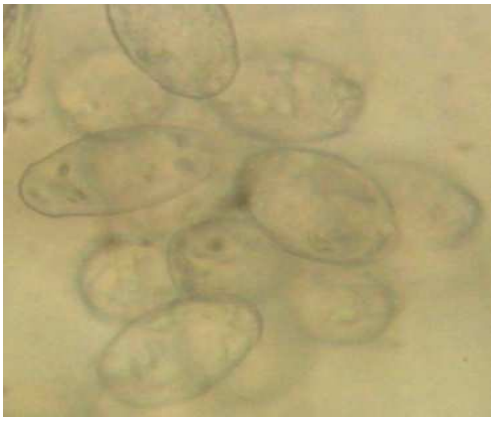
(A) Over surface of leaf with mycelium



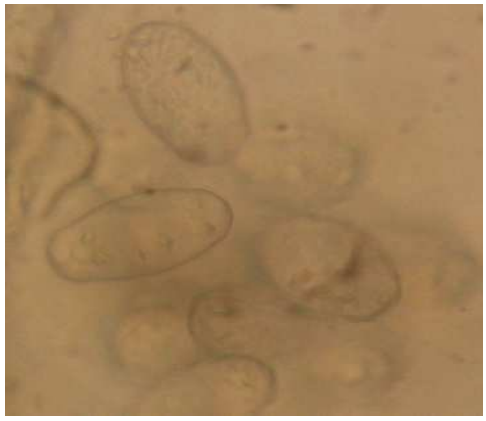
(B) Conidia in chains over surface of leaf



(C) Erect conidiophores with chain of conidia 40x



(D) Conidia 40x



(F) Conidia with fibrosin bodies 40x

**Plate- 12: Morphological characters of *Sphaerotheca fuliginea* causing Powdery mildew on cucumber**

## 4.4 Perpetuation studies

The perpetuation of pathogens *viz., Pseudoperonospora cubensis, Colletotrichum arbiculare, Alternaria alternata* and *Sphaerotheca fuliginea* was studied in the year 2011 on fallen diseased leaves by placing them at variable soil depths.

### 4.4.1 Survival of *Pseudoperonospora cubensis* on overwintered diseased leaves

The observations regarding oospore production in *P. cubensis* and their viability were recorded at fortnightly interval. The oospore production continued till till 2$^{nd}$ fortnight of May when diseased leaves placed on ground (0 cm soil depth) [Table 13]. In March the oospore production was (4.8 ×10$^3$ oospores/cm$^2$ leaf area) which decreased with time. But when diseased leaves were buried in soil, the oospore production was comparatively less and noticed only upto 2$^{nd}$ fortnight of April. The number of oospores produced/cm$^2$ leaf area in overwintered samples kept on ground was more than those kept underground.

The oospore viability showed decrease with time in the diseased samples placed on either on soil surface or at 5 cm soil depth (Table 13). Comparatively, the oospore viability was less in the leaf samples placed underground wherein the viable spores were seen only upto 2$^{nd}$ fortnight of April in comparison to 2$^{nd}$ fortnight of May in the leaves kept on ground.

### 4.4.2 Survival of *Colletotrichum arbiculare* on overwintered diseased leaves

The observations regarding conidial production in *C. arbiculare* and their viability were recorded at fortnightly intervals and results presented in Table 14.

**Table 13: Production of downy mildew oospore in overwintered diseased leaves of cucumber (cv. Japanese Long Green) during the year 2011**

| Period of observation | Fortnight | No. of oospores/cm² leaf area* (× $10^3$) | | Viability (%) | |
|---|---|---|---|---|---|
| | | 0 cm depth | 5 cm depth | 0 cm depth | 5 cm depth |
| March | I | 4.8 | 1.1 | 24.6 | 21.3 |
| | II | 3.9 | 0.7 | 29.3 | 25.3 |
| April | I | 3.0 | 0.4 | 31.3 | 26.0 |
| | II | 2.3 | 0.3 | 28.0 | 23.3 |
| May | I | 2.1 | - | 23.6 | - |
| | II | 1.5 | - | 20.0 | - |
| June | I | • | - | • | - |
| | II | • | - | • | - |
| July | I | - | - | - | - |
| | II | - | - | - | - |

* Mean of three replications each comprising of 20 leaf discs of 1$cm^2$ surface area;

- Indicates completely decomposed leaves

• Indicates no viable oospore present

**Table 14: Production of *Colletotrichum arbiculare* conidia in overwintered diseased leaves of cucumber cv. 'Japanese Long Green' during the year 2011**

| Period of observation | Fortnight | No. of conidia/cm² leaf area* (× $10^6$) | | Viability (%) | |
|---|---|---|---|---|---|
| | | 0 cm depth | 5 cm depth | 0 cm depth | 5 cm depth |
| March | I | 0.9 | 0.5 | 22.6 | 20.0 |
| | II | 1.1 | 0.7 | 28.0 | 26.0 |
| April | I | 2.5 | 1.4 | 34.0 | 31.3 |
| | II | 2.7 | 1.0 | 41.0 | 37.3 |
| May | I | 3.0 | - | 57.3 | - |
| | II | 2.1 | - | 60.0 | - |
| June | I | 1.6 | - | 55.3 | - |
| | II | 0.9 | - | 35.3 | - |
| July | I | - | - | - | - |
| | II | - | - | - | - |

* Mean of three replications each comprising of 20 leaf discs of 1$cm^2$ surface area

- Indicates completely decomposed leaves from which no oospore production was possible

Perusal of data revealed that conidial production in over-wintered diseased leaves continued comparatively for a longer period upto 2nd fortnight of June in disease samples kept on soil surface. The production of conidia decreased when diseased samples were placed under ground. The overwintered leaves placed on soil surface yielded highest number of conidia as compared to those buried ones. In general, conidial production increased with time with maximum production in 1st fortnight of May ($3.0 \times 10^6$ conidia/$cm^2$ leaf area) in samples placed on soil surface. But when placed at 5 cm soil depth, the conidial production was less and noticed only upto 2nd fortnight of April.

The viability of spores showed decline when diseased leaves were placed in soil at 5 cm depth. High spore viability was recorded in overwintered diseased leaves kept on soil surface (0 cm depth) with highest spore viability of 60.0 per cent observed in the 2nd fortnight of May. The viability of spores showed progressive increase with time upto 2nd fortnight of June in the samples on soil surface. The samples placed on soil surface (0 cm depth) showed viability only upto 2nd fortnight of April.

### 4.4.3 Survival of *Alternaria alternata* on overwintered diseased leaves

Perusal of data in Table 15 revealed that the conidial production of *A. alternata* in over-wintered diseased leaves continued for a longer period upto 2nd fortnight of June when kept as such on soil surface. The production of conidia decreased when leaves were burried at 5 cm soil depth. The over-wintered leaves placed on soil surface yielded highest number of conidia as compared to those buried in soil. In general, conidial production increased with time with maximum production in 2nd fortnight of May ($2.7 \times 10^4$ oospores/$cm^2$ leaf area) in leaves placed on soil surface. But when buried the conidia production was less and noticed only upto 2nd fortnight of April.

**Table 15: Production of *Alternaria alternata* conidia on overwintered diseased leaves of cucumber (cv. Japanese Long Green) during the year 2011**

| Period of observation | Fortnight | No. of conidia/cm² leaf area* (× $10^4$) | | Viability (%) | |
|---|---|---|---|---|---|
| | | 0 cm depth | 5 cm depth | 0 cm depth | 5 cm depth |
| March | I | 0.8 | 0.7 | 50.6 | 48.0 |
| | II | 0.9 | 0.8 | 56.0 | 55.3 |
| April | I | 1.8 | 1.1 | 64.0 | 62.0 |
| | II | 2.1 | 1.6 | 68.0 | 65.3 |
| May | I | 2.6 | - | 83.3 | - |
| | II | 2.7 | - | 85.6 | - |
| June | I | 1.9 | - | 87.3 | - |
| | II | 1.6 | - | 92.3 | - |
| July | I | - | - | - | - |
| | II | - | - | - | - |

* Mean of three replications each comprising of 20 leaf discs of 1$cm^2$ surface area

- Indicates completely decomposed leaves from which conidia production could not be assessed

The spore viability exhibited decline when buried in soil at 5 cm depth. High spore viability was recorded in overwintered diseased leaves kept on soil surface with highest spore viability of 92.3 per cent observed in the 2nd fortnight of June. The viability of spores progressively increased with time upto 2nd fortnight of June in the diseased samples kept on soil surface. The samples placed on soil surface (0 cm depth) showed viability only upto 2nd fortnight of April.

### 4.4.4 Survival of *Sphaerotheca fuliginea* on overwintered diseased leaves

The perusal of data presented in Table 16 revealed that the conidial production in over-wintered diseased leaves continued upto 2nd fortnight of March when diseased leaves were placed at as such on soil surface. In general, the conidial production decreased with time with maximum production in 1st fortnight of March ($0.3 \times 10^4$ conidia/ $cm^2$ leaf area) at ground level. No conidia production was noticed in the leaves buried in soil. The conidial viability decreased with time with highest viability of 15.0 per cent observed in the 2nd fortnight of March in leaves kept on soil surface.

## 4.5 Screening of germplasm for disease resistance/susceptibility

### 4.5.1 Downy mildew

The evaluation of 20 cucumber cultivars against downy mildew, conducted in two years 2011 and 2012 under natural epiphytotic conditions, revealed differential response of cultivars to the disease (Table 17). The disease intensity, irrespective of years, varied from 5.77 to 64.89 per cent. The overall mean disease intensity of 32.79 per cent was recorded in the year 2012 and 30.42 per cent in 2011. The highest mean disease intensity was observed in cv. 'Japanese Long Green' followed by cv. Local, SKAU-3 and SKAU-2 with average intensity of 62.66, 55.11, 55.10 and 54.44 per cent, respectively. Least disease intensity was observed in cv. 'Pusa Sanyug', followed by 'Priya' and 'Hybrid-5' with average intensity of 6.89, 7.33, and 8.22 per cent, respectively.

**Table 16: Conidial production of *Sphaerotheca fuliginea* on overwintered diseased leaves of cucumber cv. 'Japanese Long Green' during the year 2011**

| Period of observation | Fortnight | No. of conidia/cm² leaf area* (× $10^4$) | | Viability (%) | |
|---|---|---|---|---|---|
| | | 0 cm depth | 5 cm depth | 0 cm depth | 5 cm depth |
| March | I | 0.3 | 0.0 | 15.0 | 0.0 |
| | II | 0.25 | 0.0 | 11.5 | 0.0 |
| April | I | • | 0.0 | • | 0.0 |
| | II | • | 0.0 | • | 0.0 |
| May | I | • | - | • | - |
| | II | • | - | • | - |
| June | I | • | - | • | - |
| | II | • | - | • | - |
| July | I | - | - | - | - |
| | II | - | - | - | - |

* Mean of three replications each comprising of 20 leaf discs of 1cm$^2$ surface area

- Indicates completely decomposed leaves from which conidia production could not be assessed

• Indicates no conidial production

**Table 17: Field reaction of different cucumber cultivars towards downy mildew disease under natural conditions**

| Cultivars | Disease intensity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | 2011 | | 2012 | | Pooled mean | |
| Sweet Delight | 19.55 | (26.20) | 23.11 | (28.68) | 21.33 | (27.48)[c] |
| AAUC-1 | 33.78 | (35.51) | 36.44 | (37.11) | 35.11 | (36.31)[e] |
| Swarna Ageta | 20.8 | (26.52) | 24.00 | (29.29) | 22.00 | (27.93)[c] |
| Priya | 6.22 | (14.21) | 8.44 | (16.52) | 7.33 | (15.65)[a] |
| S-5 (m) | 31.11 | (33.88) | 35.11 | (36.31) | 33.11 | (35.10)[e] |
| Hybrid-5 | 7.55 | (15.84) | 8.89 | (17.12) | 8.22 | (16.64)[a] |
| Japanese Long Green | 60.44 | (51.02) | 64.89 | (53.65) | 62.66 | (52.32)[i] |
| Poinsette | 27.55 | (31.62) | 31.11 | (33.87) | 29.33 | (32.77)[d] |
| 10/cucu Hybrid-4 | 16.44 | (23.81) | 12.88 | (20.87) | 14.66 | (22.47)[b] |
| S-6 (m) | 31.11 | (33.83) | 34.22 | (35.73) | 32.66 | (34.83)[d] |
| Green Express | 27.55 | (31.62) | 31.11 | (33.87) | 29.33 | (32.77)[d] |
| Khera-90 | 31.33 | (33.88) | 34.66 | (36.05) | 32.89 | (34.97)[d] |
| CH-20 | 28.89 | (32.49) | 31.55 | (34.15) | 30.22 | (33.33)[d] |
| Marketer-76 | 27.11 | (31.33) | 30.66 | (33.60) | 28.89 | (32.49)[d] |
| SKAU-3 | 53.77 | (47.15) | 56.44 | (48.69) | 55.10 | (47.91)[h] |
| S-7 | 28.44 | (32.19) | 31.11 | (33.85) | 29.77 | (33.05)[d] |
| Pusa Sanyug | 5.77 | (13.76) | 8.00 | (16.12) | 6.89 | (15.16)[a] |
| SKAU-2 | 57.70 | (49.45) | 51.11 | (45.61) | 54.44 | (47.53)[g] |
| Hermophrodite | 39.11 | (38.61) | 44.88 | (42.04) | 42.00 | (40.37)[f] |
| Local | 54.22 | (47.4) | 56.00 | (48.43) | 55.11 | (47.91)[h] |
| **Mean** | **30.42** | **(32.52)** | **32.79** | **(34.08)** | **31.55** | **(33.35)** |
| **$CD_{0.05}$** | **6.11** | | **5.58** | | **4.15** | |

*Mean of 3 replications; figures in parenthesis are arc sign transformed values

The disease reaction against downy mildew based on per cent disease intensity revealed that out of 20 cultivars, none of the cultivars was either immune or highly susceptible to the disease (Table 18). However, 4 cultivars Japanese Long Green, Local, SKAU-3 and SKAU-2 were found susceptible. Eleven cultivars S-5 (m), Khera 90, Poinsette, Swarna Ageta, Green Express, S-6(m), Marketer-76, AAUC-1, S-7, CH-20 and Hermophrodite were moderately susceptible and 3 cultivars Hybrid-5, Pusa Sanyug and Priya were tolerant. Further, 2 cultivars 10/cucu Hybrid-4 and Sweet Delight were moderately tolerant.

### 4.5.2 Anthracnose

The 20 cucumber cultivars evaluated against anthracnose disease (*C. arbiculare*) in 2011 and 2012 revealed differential response of cultivars towards anthracnose disease (Table 19). The disease intensity in cultivars varied from 5.77 to 64.44 per cent with overall disease intensity of 34.13 per cent recorded in 2012 and 30.00 per cent in 2011. Maximum disease intensity was in cv. S-7 followed by SKAU-3, Local, SKAU-2 and Japanese Long Green with average intensity of 62.44, 59.55, 59.33, 54.89 and 53.33 per cent, respectively. Least disease intensity was observed in cv. Hybrid-5 followed by cv. Priya and Pusa Sanyug with average intensity of 6.89, 7.33 and 7.33 per cent, respectively. The categorization of cultivars on the basis of disease reaction revealed that out of 20 cultivars, 12 were susceptible and 8 were tolerant (Table 20). Hybrid-5, Pusa Sanyug and Priya were tolerant (rating 1-10%). Five cultivars Swarna Ageta, 10/cucu Hybrid-4, S-6 (m), Green Express and Hermophrodite were rated as moderately tolerant (11-25%). Seven cultivars *viz.*, Sweet Delight, AAUC-1, S-5 (m), Poinsette, Khera-90, CH-20 and Marketer-76 were moderately susceptible (26-50%). The cultivars Japanese Long Green, SKAU-3, S-7, Local and SKAU-2 were susceptible in reaction (51-75%).

**Table 18: Disease reaction of various cucumber cultivars towards downy mildew (based on per cent disease intensity)**

| Reaction category | Leaf area reaction (%) | No. of genotype | Name of cultivar |
|---|---|---|---|
| Immune | 0 | 0 | - |
| Tolerant | 1-10 | 3 | Hybrid-5, Pusa sanyug, Priya |
| Moderately tolerant | 11-25 | 2 | 10/cucu Hybrid-4, Sweet Delight |
| Moderately susceptible | 26-50 | 11 | S-5(m), Khera 90, Poinsette, Swarna Ageta, Green Express, S-6 (m), Marketer-76, AAUC-1, S-7, CH-20, Hermophrodite |
| Susceptible | 51- 75 | 4 | SKAU-2, Japanese Long Green, SKAU-3, Local |
| Highly susceptible | 76-100 | 0 | - |

**Table 19: Field reaction of different cucumber cultivars towards anthracnose under natural inoculum conditions**

| Cultivars | Disease intensity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | 2011 | | 2012 | | Pooled mean | |
| Sweet Delight | 27.11 | (31.36) | 34.66 | (36.04) | 30.89 | (33.71)[d] |
| AAUC-1 | 38.66 | (38.42) | 28.88 | (31.54) | 33.78 | (35.46)[de] |
| Swarna Ageta | 12.89 | (20.96) | 21.33 | (27.49) | 17.11 | (24.26)[c] |
| Priya | 6.22 | (14.21) | 8.44 | (16.67) | 7.33 | (15.65)[a] |
| S-5 (m) | 29.78 | (33.02) | 31.11 | (33.88) | 30.44 | (33.47)[d] |
| Hybrid-5 | 5.77 | (13.61) | 7.99 | (16.30) | 6.89 | (15.16)[a] |
| Japanese Long Green | 51.55 | (45.87) | 55.11 | (47.92) | 53.33 | (46.89)[g] |
| Poinsette | 43.11 | (41.02) | 48.00 | (43.83) | 45.55 | (42.43)[f] |
| 10/cucu Hybrid-4 | 17.33 | (24.46) | 23.11 | (28.66) | 20.22 | (26.65)[c] |
| S-6 (m) | 27.55 | (31.65) | 30.22 | (33.11) | 28.89 | (32.49)[d] |
| Green Express | 15.99 | (23.43) | 19.55 | (26.12) | 17.78 | (24.90)[c] |
| Khera-90 | 36.89 | (37.37) | 38.66 | (38.43) | 37.78 | (37.91)[e] |
| CH-20 | 28.89 | (32.49) | 32.44 | 934.70) | 30.66 | (33.61)[d] |
| Marketer-76 | 30.22 | 933.29) | 35.11 | (36.29) | 32.66 | (34.83)[d] |
| SKAU-3 | 57.77 | 949.45) | 61.33 | (51.53) | 59.55 | (50.50)[h] |
| S-7 | 60.44 | (51.01) | 64.44 | (53.38) | 62.44 | (52.19)[i] |
| Pusa Sanyug | 5.77 | 913.76) | 8.88 | (17.12) | 7.33 | (15.63)[a] |
| SKAU-2 | 53.77 | 947.15) | 56.00 | (48.42) | 54.89 | (47.78)[gh] |
| Hermophrodite | 13.33 | (21.39) | 15.55 | (23.16) | 14.44 | (22.31)[b] |
| Local | 56.89 | (48.94) | 61.77 | (51.79) | 59.33 | (50.36)[h] |
| **Mean** | **31.00** | **(32.64)** | **34.13** | **(34.82)** | **32.56** | **(33.81)** |
| **CD**(P=0.05) | **5.79** | | **8.12** | | **5.30** | |

*Mean of 3 replications; figures in parenthesis are arc sign transformed values

**Table 20: Disease reaction of various cucumber cultivars towards anthracnose (based on per cent disease intensity)**

| Reaction category | Leaf area reaction (%) | No. of genotype | Name of cultivar |
|---|---|---|---|
| Immune | 0 | 0 | - |
| Tolerant | 1-10 | 3 | Priya, Hybrid-5, Pusa Sanyug |
| Moderately tolerant | 11-25 | 5 | Swarna Ageta, 10/cucu Hybrid-4, S-6 (m), Green Express, Hermophrodite |
| Moderately susceptible | 26-50 | 7 | Sweet Delight, AAUC-1, S-5 (m), Poinsette, Khera-90, CH-20, Marketer-76 |
| Susceptible | 51- 75 | 5 | Japanese Long Green, SKAU-3, S-7, Local, SKAU-2 |
| Highly susceptible | 76-100 | 0 | - |

### 4.5.3 Alternaria leaf spot

The evaluation of cucumber cultivars against Alternaria leaf spot (*A. alternata*) under natural epiphytotic conditions revealed differential response to the disease (Table 21). The disease intensity, irrespective of test cultivars, varied from 4.88 to 66.66 per cent. The overall disease intensity of 33.49 per cent was recorded in 2012 and 29.42 per cent in 2011. Maximum disease intensity was recorded in cv. SKAU-3 followed by SKAU-2, Japanese Long Green and Local with average intensity of 68.00, 59.78, 58.00 and 56.67 per cent, respectively. Least disease intensity was observed in Green Express followed by Marketer-76 and Pusa Sanyug with average intensity of 5.55, 6.22 and 8.22 per cent, respectively.

The disease reaction categorization, based on per cent disease intensity, showed that 11 cultivars were susceptible and 9 were tolerant (Table 22). Four cultivars Pusa Sanyug, Green Express and Marketer-76 were rated as tolerant (rating 1-10%). Six cultivars Sweet Delight, CH-20, Priya, Hybrid-5, S-5 (m) and Poinsette were moderately tolerant (11-25%). Seven cultivars 10/cucu Hybrid-4, Swarna Ageta, AAUC-1, S-6 (m), Hermophrodite, S-7 and Khera-90 were moderately susceptible (26-50%). Cultivars Japanese Long Green, SKAU-2, Local and SKAU-3 were susceptible to disease (51-75%).

### 4.5.4 Powdery mildew

The evaluation of cucumber cultivars against powdry mildew (*S. fuliginea*) conducted in 2011 and 2012 under natural epiphytotic revealed differential response to the disease (Table 23). The disease intensity in test cultivars, varied from 4.88 to 76.88 per cent. The overall disease intensity of 37.86 per cent was observed in year 2012 and 35.41 per cent in 2011.

**Table 21: Field reaction of various cucumber cultivars towards Alternaria leaf spot under natural conditions**

| Cultivars | Disease intensity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | 2011 | | 2012 | | Pooled mean | |
| Sweet Delight | 13.33 | (21.39) | 16.89 | (24.23) | 15.10 | (22.83)[b] |
| AAUC-1 | 31.55 | (34.15) | 35.55 | (36.58) | 33.56 | (35.37)[c] |
| Swarna Ageta | 32.00 | (34.42) | 37.77 | (37.88) | 34.89 | (36.17)[c] |
| Priya | 16.00 | (32.52) | 19.11 | (25.86) | 17.55 | (24.74)[b] |
| S-5 (m) | 16.44 | (23.77) | 21.33 | (27.40) | 18.88 | (25.70)[b] |
| Hybrid-5 | 15.11 | (22.83) | 18.66 | (25.55) | 16.89 | (24.22)[b] |
| Japanese Long Green | 56.00 | (48.43) | 60.00 | (50.74) | 58.00 | (49.58)[e] |
| Poinsette | 17.33 | (24.42) | 20.88 | (26.94) | 19.11 | (25.88)[b] |
| 10/cucu Hybrid-4 | 35.11 | (36.30) | 38.22 | (38.16) | 36.66 | (37.24)[c] |
| S-6 (m) | 42.66 | (40.76) | 53.33 | (46.89) | 48.00 | (43.83)[d] |
| Green Express | 4.88 | (12.73) | 6.33 | (14.21) | 5.55 | (13.60)[d] |
| Khera-90 | 32.44 | (34.69) | 42.66 | (40.71) | 37.55 | (37.73)[c] |
| CH-20 | 15.11 | (22.80) | 18.67 | (25.59) | 16.89 | (24.22)[b] |
| Marketer-76 | 4.88 | (12.73) | 7.55 | (15.69) | 6.22 | (14.35)[a] |
| SKAU-3 | 69.33 | (56.42) | 66.66 | (54.71) | 68.00 | (55.53)[f] |
| S-7 | 31.55 | (34.13) | 41.77 | (40.23) | 36.67 | (37.20)[c] |
| Pusa Sanyug | 7.55 | (15.84) | 8.89 | (17.26) | 8.22 | (16.64)[a] |
| SKAU-2 | 58.67 | (49.98) | 60.89 | (51.29) | 59.78 | (50.62)[e] |
| Hermophrodite | 32.89 | (34.96) | 36.89 | (37.34) | 34.89 | (36.18)[f] |
| Local | 55.55 | (48.17) | 57.77 | (49.46) | 56.67 | (48.81)[c] |
| **Mean** | **29.42** | **(32.07)** | **33.49** | **(34.34)** | **31.45** | **(33.02)** |
| **CD**(P=0.05) | **5.58** | | **7.17** | | **4.57** | |

*Mean of 3 replications; figures in parenthesis are arc sign transformed values

**Table 22: Disease reaction of various cucumber cultivars towards Alternaria leaf spot (based on per cent disease intensity)**

| Reaction category | Leaf area reaction (%) | No. of genotypes | Name of cultivar |
|---|---|---|---|
| Immune | 0 | 0 | - |
| Tolerant | 1-10 | 3 | Pusa Sanyug, Green Express, Marketer- 76. |
| Moderately tolerant | 11-25 | 6 | Sweet Delight, CH-20, Priya, Hybrid-5. S-5 (m), Poinsette. |
| Moderately susceptible | 26-50 | 7 | 10/cucu Hybrid-4, Swarna Ageta, AAUC-1, S-6 (m), S-7, Hermophrodite, Khera-90. |
| Susceptible | 51- 75 | 4 | Japanese Long Green, SKAU-2, Local, SKAU-3 |
| Highly susceptible | 76-100 | 0 | - |

**Table 23: Field reaction of different cucumber cultivars towards powdery mildew under natural conditions**

| Cultivars | Disease intensity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | 2011 | | 2012 | | Pooled mean | |
| Sweet Delight | 14.22 | (21.96) | 13.33 | (21.30) | 13.77 | (21.77)[b] |
| AAUC-1 | 52.89 | (46.64) | 56.00 | 948.43) | 54.44 | (47.53)[h] |
| Swarna Ageta | 57.66 | (47.66) | 59.11 | (50.23) | 56.89 | (48.94)[h] |
| Priya | 4.88 | (12.73) | 6.22 | (14.21) | 5.55 | (13.60)[a] |
| S-5 (m) | 55.55 | (48.17) | 56.89 | (48.94) | 56.22 | (48.55)[h] |
| Hybrid-5 | 7.11 | (15.04) | 7.55 | (15.84) | 7.33 | (15.70)[a] |
| Japanese Long Green | 54.66 | (47.66) | 60.44 | (51.01) | 57.55 | (49.33)[h] |
| Poinsette | 36.89 | (37.30) | 38.66 | (38.36) | 37.78 | (37.91)[f] |
| 10/cucu Hybrid-4 | 21.33 | (27.49) | 23.11 | (28.71) | 22.22 | (28.10)[d] |
| S-6 (m) | 19.55 | (26.05) | 24.44 | 929.42) | 22.00 | (27.92)[d] |
| Green Express | 30.22 | (33.12) | 36.88 | (37.35) | 33.55 | (35.36)[e] |
| Khera-90 | 33.77 | (35.46) | 37.78 | (37.85) | 35.78 | (36.71)[ef] |
| CH-20 | 31.11 | (33.83) | 33.78 | (35.44) | 32.44 | 934.70)[e] |
| Marketer-76 | 8.00 | (16.38) | 8.88 | (17.32) | 8.44 | (16.88)[a] |
| SKAU-3 | 57.33 | (49.21) | 63.55 | (52.85) | 60.44 | (51.02)[i] |
| S-7 | 52.89 | (46.63) | 55.55 | (48.17) | 54.22 | 947.40)[gh] |
| Pusa Sanyug | 12.44 | (20.64) | 15.55 | (23.20) | 14.00 | (21.93)[bc] |
| SKAU-2 | 79.55 | (63.12) | 76.88 | (61.30) | 78.22 | (62.16)[k] |
| Hermophrodite | 16.00 | (23.55) | 19.11 | (25.85) | 17.55 | (24.74)[c] |
| Local | 62.22 | (52.07) | 63.55 | (52.86) | 62.89 | (52.44)[j] |
| **Mean** | **35.41** | **(35.24)** | **37.86** | **(36.93)** | **36.56** | **(36.13)** |
| **CD**(P=0.05) | **7.67** | | **7.34** | | **3.50** | |

*Mean of 3 replications; The figures in parenthesis are arc sign transformed values

Maximum disease intensity was recorded in cultivar SKAU-2 followed by Local and SKAU-3 with average disease intensity of 78.22, 62.89 and 60.44 per cent, respectively. Least disease intensity was observed in cv. Priya followed by Hybrid-5 and AAUC-1 with average intensity of 5.55, 7.33 and 8.44 per cent, respectively. The disease reaction categorization, based on per cent disease intensity, revealed 12 cultivars to be susceptible and 8 tolerant to the disease (Table 24). Three cultivars Hybrid-5, Pusa Sanyug and AAUC-1 were rated tolerant (rating 1-10%) and five cultivars Sweet Delight, 10/cucu Hybrid-4, Pusa, Sanyug, Hermophrodite and S-6 (m) were moderately tolerant (11-25%). Four cultivars Green Express, CH-20, Poinsette and Khera-90 were moderately susceptible (26-50%). Seven cultivars SKAU-3, Swarna Ageta, S-7, S-(m), Marketer-76, Local, and Japanese Long Green were susceptible (51-75%). One cultivar SKAU-2 was highly susceptible.

### 4.5.5 Ranking of cultivars based on multiple disease reaction

All the cultivars were ranked based on their disease reaction in each disease category. Cultivars Priya, Hybrid-5 and Pusa Sanyug scored less and were ranked as the best cultivars, followed by Sweet Delight, 10/cucu Hybrid and Green Express which were ranked second. These varieties showed better resistance against these diseases than other varieties. The cultivar SKAU-2 ranked $8^{th}$ rank whereas SKAU-3, Local and Japanese Long Green were placed on $7^{th}$ rank with regard to their multiple disease reaction. The remaining cultivars were placed in $3^{rd}$ to $6^{th}$ rank.

**Table 24: Disease reaction of various cucumber cultivars towards powdery mildew, based on per cent disease intensity**

| Reaction category | Leaf area reaction (%) | No. of genotypes | Name of cultivars |
|---|---|---|---|
| Immune | 0 | 0 | - |
| Tolerant | 1-10 | 3 | Marketer-76, Hybrid-5, Priya |
| Moderately tolerant | 11-25 | 5 | Sweet Delight, S-6 (m), 10/cucu Hybrid-4, Pusa Sanyug, Hermophrodite. |
| Moderately susceptible | 26-50 | 4 | Green Express, CH-20, Poinsette, Khera-90. |
| Susceptible | 51- 75 | 7 | SKAU-3, Swarna Ageta, S-7, S-(m), Local, Japanese Long Green. AAUC-1 |
| Highly susceptible | 76-100 | 1 | SKAU-2 |

**Table 25: Ranking of cultivars based on multiple disease reaction**

| Cultivars | Disease reaction category | | | | Total score | Mean score | Rank |
|---|---|---|---|---|---|---|---|
| | Downy mildew | Anthracnose | Alternaria | Powdery mildew | | | |
| Sweet Delight | 3 | 2 | 2 | 2 | 9 | 2.25 | II |
| AAUC-1 | 2 | 3 | 3 | 4 | 12 | 3.00 | V |
| Swarna Ageta | 2 | 3 | 3 | 4 | 12 | 3.00 | V |
| Priya | 1 | 2 | 1 | 1 | 5 | 1.25 | I |
| S-5 (m) | 3 | 2 | 3 | 4 | 12 | 3.00 | V |
| Hybrid-5 | 1 | 2 | 1 | 1 | 5 | 1.25 | I |
| Japanese Long Green | 4 | 4 | 4 | 4 | 16 | 4.00 | VII |
| Poinsette | 3 | 2 | 3 | 3 | 11 | 2.75 | IV |
| 10/cucu hybrid-4 | 2 | 3 | 2 | 2 | 9 | 2.25 | II |
| S-6 (m) | 2 | 3 | 3 | 2 | 10 | 2.20 | III |
| Green Express | 2 | 1 | 3 | 3 | 9 | 2.25 | II |
| Khera-90 | 3 | 3 | 3 | 3 | 12 | 4.00 | V |
| CH-20 | 3 | 2 | 3 | 3 | 11 | 2.75 | IV |
| Marketer-76 | 3 | 1 | 3 | 2 | 11 | 2.75 | IV |
| SKAU-3 | 4 | 4 | 4 | 4 | 16 | 4.00 | VII |
| S-7 | 4 | 3 | 3 | 4 | 14 | 3.50 | VI |
| Pusa Sanyug | 1 | 1 | 1 | 2 | 5 | 1.25 | I |
| SKAU-2 | 4 | 4 | 4 | 5 | 17 | 4.25 | VIII |
| Hermophrodite | 2 | 3 | 3 | 2 | 10 | 2.50 | III |
| Local | 4 | 4 | 4 | 4 | 16 | 4.00 | VII |

Score: Immune = 0; Tolerant = 1; Moderately tolerant = 2; Moderately susceptible = 3; Susceptible = 4; Highly susceptible = 5

## 4.6 Disease management studies

### 4.6.1 Effect of SAR chemicals on cucumber diseases

#### 4.6.1.1 Downy mildew

##### 4.6.1.1.1 Effect of single spray at cotyledon stage

The perusal of Table 26 revealed that the intensity of downy mildew was slightly higher (22.55%) in the year 2012 than in 2011(20.99%) [Fig 2]. The spray of SAR chemicals at cotyledon stage significantly lowered disease intensity as compared to water sprayed check. The disease intensity ranged from 14.99 to 23.83 per cent in SAR chemical treatments as compared to 27.33 per cent in check indicating that all the SAR chemicals were effective in reducing the disease intensity. Least disease intensity was observed in 2,6-dichloroisonicotinic acid (INA), followed by sodium bicarbonate ($NaHCO_3$). These were followed by benzothiadazol-S-methyl (BTH), β-amino butyric acid (BABA) and potassium bicarbonate ($KHCO_3$) with disease intensity of 21.6, 22.83 and 23.83 per cent, respectively.

##### 4.6.1.1.2 Effect of two sprays of SAR chemicals [at cotyledon stage and 15 days later]

The study revealed that the overall disease intensity was higher (11.21%) in the year 2012 than in 2011 (8.60%) [Table 27, Fig. 3]. SAR chemical sprays significantly lowered disease intensity (6.16-8.66%) as compared to water sprayed check (22.5%) with least intensity observed in INA sprayed plants. This was followed by BTH, $KHCO_3$ and BABA with disease intensity of 6.66, 7.66 and 8.66 per cent, respectively. All the SAR sprays were statistically at par.

##### 4.6.1.1.3 Effect of two sprays of SAR chemicals [sprayed at 15 day intervals starting 15 days after cotyledon stage]

The effect of two sprays of SAR chemicals, 1$^{st}$ spray 15 days after cotyledon stage and 2$^{nd}$ one 15 days later, revealed that all the treatments significantly lowered disease intensity as compared to check [Table 28, Fig. 3]. The disease intensity ranged from 28.33 to 32.83 per cent in SAR chemical

**Table 26: Effect of single spray of SAR chemicals at cotyledon stage on severity of downy mildew**

| SAR chemicals (ppm) | Disease severity (%)* | | |
|---|---|---|---|
| | 2011 | 2012 | Pooled mean |
| BTH @ 100 | 20.66 (4.54) | 21.66 (4.65) | 21.16 (4.60) |
| BABA @ 1000 | 22.66 (4.76) | 23.00 (4.79) | 22.83 (4.77) |
| $NaHCO_3$ @ 100 | 19.66 (4.43) | 21.33 (4.61) | 20.50 (4.52) |
| INA @ 1000 | 14.33 (3.78) | 15.66 (3.95) | 14.99 (3.87) |
| $KHCO_3$ @ 100 | 23.33 (4.83) | 24.33 (4.93) | 23.83 (4.88) |
| Control (water spray) | 29.33 (5.41) | 30.33 (5.50) | 29.83 (5.46) |
| **Mean** | **(21.66)** | **(22.71)** | **(21.18)** |
| CD(P=0.05) | (0.73) | (0.49) | (0.34) |

*Mean of three replication; figures within parenthesis are square root transformed values

**Table 27: Effect of two sprays of SAR chemicals (at cotyledon stage and 15 days later) on severity of downy mildew**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | Cotyledon stage | | | After 15 days | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 6.33 (2.51) | 8.00 (2.82) | **7.17 (2.67)** | 5.66 (2.37) | 8.66 (2.94) | **6.66 (2.58)** |
| BABA @ 1000 | 5.66 (2.37) | 7.66 (2.76) | **6.67 (2.58)** | 7.66 (2.76) | 9.66 (3.10) | **8.66 (2.94)** |
| $NaHCO_3$ @ 100 | 5.00 (2.23) | 7.66 (2.76) | **6.17 (2.48)** | 6.00 (2.44) | 8.66 (2.94) | **7.33 (2.70)** |
| INA @ 1000 | 4.66 (2.15) | 5.66 (2.37) | **5.16 (2.27)** | 5.33 (2.30) | 7.00 (2.64) | **6.16 (2.48)** |
| $KHCO_3$ @ 100 | 5.33 (2.30) | 7.00 (2.64) | **6.16 (2.48)** | 7.00 (2.64) | 8.33 (2.88) | **7.66 (2.76)** |
| Control (water spray) | 11.00 (3.31) | 13.33 (3.65) | **12.00 (3.46)** | 20.00 (4.47) | 25.00 (5.00) | **22.50 (4.74)** |
| **Mean** | **(6.33)** | **(8.21)** | **(7.22)** | **(8.60)** | **(11.21)** | **(9.82)** |
| CD(P=0.05) | **(0.65)** | **(0.56)** | **(0.55)** | **(0.46)** | **(0.20)** | **(0.62)** |

*Mean of three replication; figures within parenthesis are square root transformed values

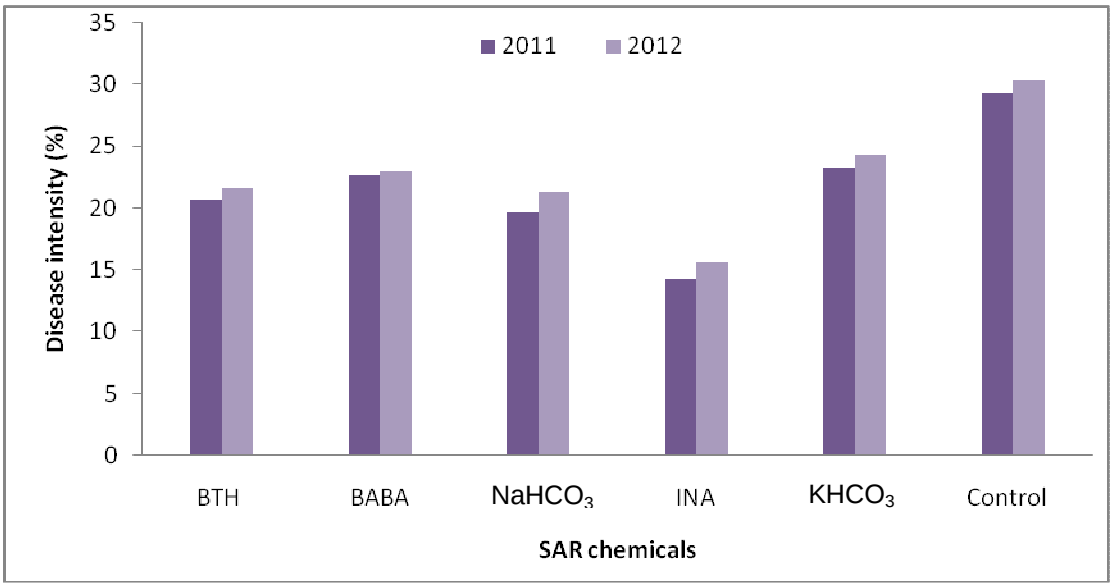



**Fig. 2: Effect of SAR chemicals at cotyledon stage on the intensity of downy mildew on cucumber under controlled conditions**

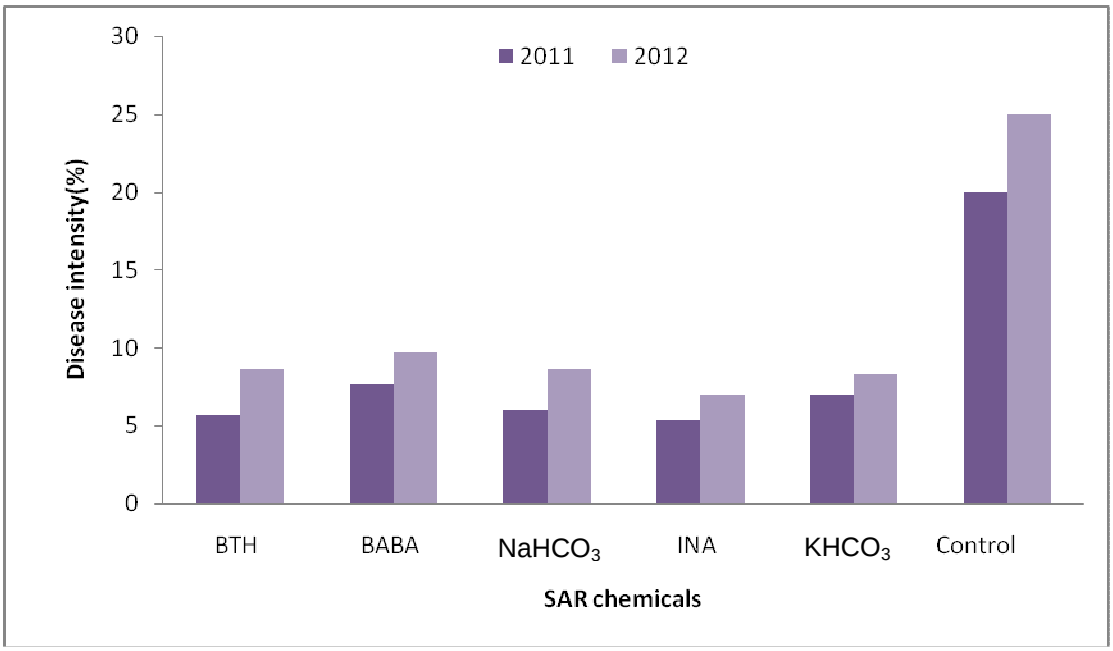



**Fig. 3: Effect of two sprays of SAR chemicals (at cotyledon stage and 15 days later) on disease severity of downy mildew**

treatments as compared to 35.66 per cent in check indicating that all the SAR chemicals, except $KHCO_3$, were significantly effective in reducing the disease intensity. Least disease intensity was observed in INA treatment which was at par with BTH having 29.33 per cent disease intensity. These were followed by $NaHCO_3$, BABA and $KHCO_3$ with disease intensity of 30.33, 32.33 and 32.83 per cent, respectively.

#### 4.6.1.1.4 Effect of two sprays of SAR chemicals [sprayed at 30 day intervals starting 30 days after cotyledon stage]

The perusal of Table 29 revealed that all the SAR chemicals sprayed at 30 day intervals starting from 30 days after cotyledon stage significantly lowered disease intensity as compared to check (Fig. 4). In SAR spray treatments the disease intensity ranged from 30.49 to 34.66 per cent as compared to 44.16 per cent in check showing that all SAR chemicals were effective in minimizing the disease intensity. INA spray was most effective in reducing downy mildew intensity (30.49%), followed by BTH (32.66%) and $NaHCO_3$ (33.33%) treatments. All these sprays were at par with one another. INA treatment proved significantly superior over BABA (34.33%) and $KHCO_3$ (34.66%).

### 4.6.1.2 Anthracnose

#### 4.6.1.2.1 Effect of single spray at cotyledon stage

The perusal of Table 30 indicated that anthracnose was higher (8.21%) in the year 2012 than in 2011 (6.94%) [Fig. 5]. The spray of SAR chemicals at cotyledon stage significantly lowered disease intensity as compared to water sprayed check. The disease intensity in SAR chemical treatments ranged from 4.16 to 8.33 per cent in comparison to 13.83 per cent in check indicating that all SAR chemicals were effective in lowering the disease intensity. Least disease intensity was recorded in BABA sprayed plants. BABA was followed by INA with disease intensity of 5.49 per cent which, in turn, was significantly at par with BTH (6.00% disease intensity). These were followed by $NaHCO_3$ and $KHCO_3$ with the disease intensity of 7.66.83 and 8.33 per cent, respectively.

**Table 28: Effect of two sprays of SAR chemicals at 15 day intervals on disease severity of downy mildew**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | First spray | | | Second spray | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 18.66 | 21.33 | **20.00** | 28.00 | 30.66 | **29.33** |
| | (4.31) | (4.61) | **(4.47)** | (5.29) | (5.53) | **(5.41)** |
| BABA @ 1000 | 20.67 | 21.00 | **20.83** | 31.00 | 33.66 | **32.33** |
| | (4.54) | (4.58) | **(4.56)** | (5.56) | (5.80) | **(5.68)** |
| $NaHCO_3$ @ 100 | 18.00 | 21.66 | **19.83** | 29.33 | 31.33 | **30.33** |
| | (4.24) | (4.65) | **(4.45)** | (5.41) | (5.50) | **(5.50)** |
| INA @ 1000 | 15.66 | 17.33 | **16.50** | 27.00 | 29.66 | **28.33** |
| | (3.95) | (4.16) | **(4.06)** | (5.19) | (5.44) | **(5.32)** |
| $KHCO_3$ @ 100 | 21.33 | 22.66 | **22.00** | 30.00 | 31.66 | **30.83** |
| | (4.61) | (4.76) | **(4.69)** | (5.47) | (5.62) | **(5.55)** |
| Control (water spray) | 24.33 | 27.33 | **25.66** | 36.33 | 37.33 | **35.66** |
| | (4.93) | (5.22) | **(5.06)** | (6.02) | (6.10) | **(6.06)** |
| **Mean** | **(19.77)** | **(21.88)** | **(20.80)** | **(30.27)** | **(32.30)** | **(31.13)** |
| CD(P=0.05) | (0.35) | (0.32) | (0.46) | (0.40) | (0.27) | (0.34) |

*Mean of three replication; figures within parenthesis are square root transformed values

**Table 29: Effect of two sprays of SAR chemicals at 30 day intervals on disease severity of downy mildew**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | First spray | | | Second spray | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 20.33 | 22.67 | **21.50** | 31.00 | 33.66 | **32.66** |
| | (4.50) | (4.76) | **(4.63)** | (5.56) | (5.80) | **(5.71)** |
| BABA @ 1000 | 21.00 | 23.33 | **22.17** | 33.33 | 35.33 | **34.33** |
| | (4.58) | (4.83) | **(4.70)** | (5.77) | (5.94) | **(5.85)** |
| $NaHCO_3$ @ 100 | 20.00 | 21.66 | **20.83** | 32.33 | 34.33 | **33.33** |
| | (4.47) | (4.65) | **(4.56)** | (5.68) | (5.85) | **(5.77)** |
| INA @ 1000 | 18.00 | 19.66 | **18.83** | 29.66 | 31.33 | **30.49** |
| | (4.24) | (4.43) | **(4.33)** | (5.44) | (5.59) | **(5.52)** |
| $KHCO_3$ @ 100 | 22.00 | 24.00 | **23.00** | 33.00 | 35.66 | **34.66** |
| | (4.69) | (4.89) | **(4.79)** | (5.74) | (5.97) | **(5.88)** |
| Control (water spray) | 24.33 | 25.66 | **25.00** | 43.33 | 45.00 | **44.16** |
| | (4.93) | (5.06) | **(5.00)** | (6.58) | (6.70) | **(6.64)** |
| **Mean** | **(20.94)** | **(22.83)** | **(21.83)** | **(33.77)** | **(35.88)** | **(34.93)** |
| CD(P=0.05) | (0.31) | (0.23) | (0.35) | (0.31) | (0.24) | (0.32) |

*Mean of three replication; figures within parenthesis are square root transformed values

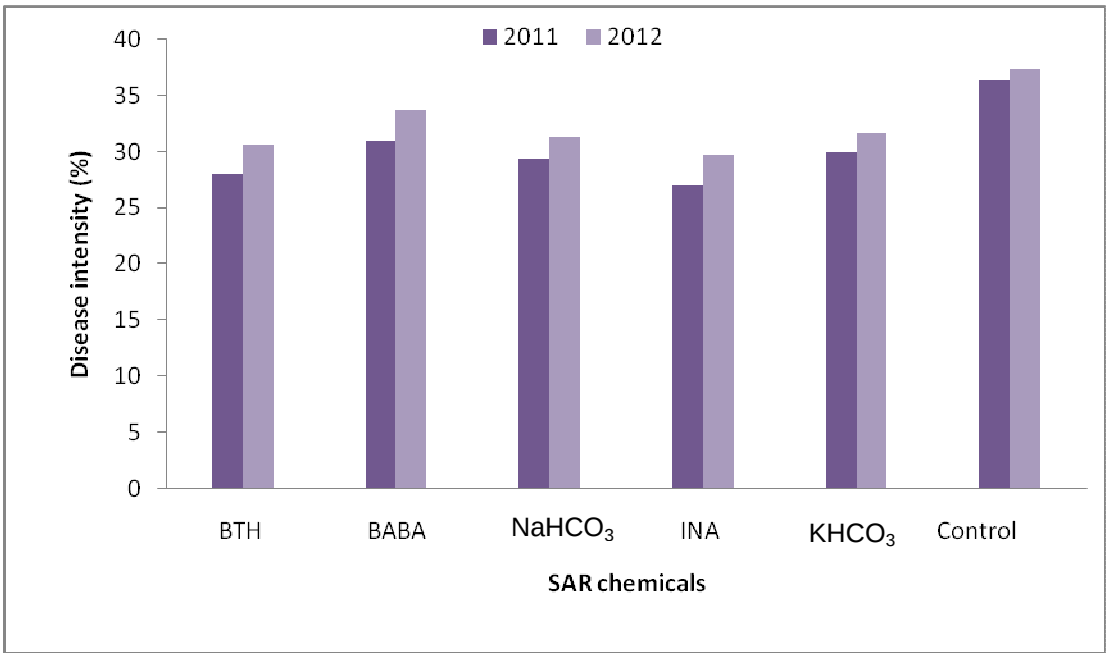



**Fig. 4: Effect of two sprays of SAR chemicals at 15 days interval on disease severity of downy mildew**

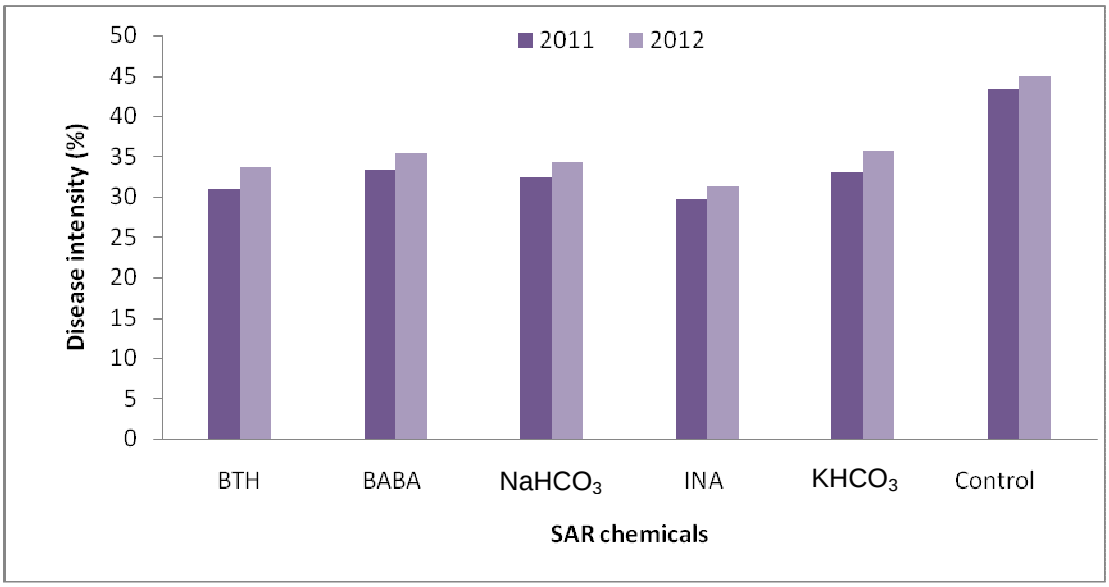



**Fig. 5: Effect of two sprays of SAR chemical compounds at 30 days interval on disease severity of downy mildew**

#### 4.6.1.2.2 Effect of two sprays of SAR chemicals [sprayed at cotyledon stage and 15 days later]

The study on the effect of SAR chemicals at cotyledon stage and 15 days later revealed that the overall disease intensity was higher (6.49%) in 2012 than in the year 2011 (5.83). Least disease intensity of 2.83 per cent was observed in BABA sprayed plants. It was followed by INA, $NaHCO_3$, BTH and $KHCO_3$ treatments with disease intensity of 4.49, 4.66, 5.49 7.00 per cent, respectively [Table 31, Fig. 6]. Except $NaHCO_3$, all the chemical sprays were at par. SAR chemicals sprays significantly lowered disease intensity (2.83-7.00%) as compared to water sprayed check (13.0%).

#### 4.6.1.2.3 Effect of two sprays of SAR chemicals [sprayed at 15 day interval starting 15 days after cotyledon stage]

The effect of two spray SAR chemicals, 1st spray 15 days after cotyledon stage and 2nd spray 15 days later, indicated that all the treatments significantly lowered disease intensity as compared to check [Table 32, Fig. 8]. The disease intensity in SAR chemical treatments ranged from 14.33 to 19.66 per cent as compared to 31.00 per cent in check indicating that all the SAR chemicals significantly reduced disease intensity. Least disease intensity was seen in BABA treatment which was at par with INA having 15.00 per cent disease intensity. These were followed by BTH, $NaHCO_3$ and $KHCO_3$ with anthracnose intensity of 17.33, 18.49 and 19.66 per cent, respectively. Except $KHCO_3$, all the sprays were statistically at par with one another.

#### 4.6.1.2.4 Effect of two sprays of SAR chemicals sprayed at 30 day intervals starting from 30 days after cotyledon stage

The perusal of Table 33 revealed that all SAR chemicals sprayed at 30 day intervals starting from 30 days after cotyledon stage significantly lowered disease intensity in comparison to check (Fig. 9). In SAR spray treatments the disease intensity ranged from 14.66 to 21.33 per cent as compared to 39.00 per cent in check indicating that all SAR activators were effective in lowering the disease intensity. BABA spray was most effective in minimizing anthracnose intensity (14.66%) which was followed by BTH (18.33%), INA (19.66%), $NaHCO_3$ (20.49%) and $KHCO_3$ (21.33%) treatments. BTH and INA were at par with each other.

**Table 30: Effect of single spray of SAR chemicals at cotyledon stage on disease severity of anthracnose**

| SAR chemicals (ppm) | Disease severity (%)* | | |
|---|---|---|---|
| | 2011 | 2012 | Mean |
| BTH @ 100 | 4.66 (2.15) | 7.33 (2.70) | **6.00 (2.44)** |
| BABA @ 1000 | 3.66 (1.91) | 4.66 (2.15) | **4.16 (2.03)** |
| $NaHCO_3$ @ 100 | 7.00 (2.91) | 8.33 (2.88) | **7.66 (2.76)** |
| INA @ 1000 | 5.33 (2.30) | 5.66 (2.37) | **5.49 (2.34)** |
| $KHCO_3$ @ 100 | 7.66 (2.76) | 9.00 (3.00) | **8.33 (2.88)** |
| Control (water spray) | 13.33 (3.65) | 14.33 (3.78) | **13.83 (3.71)** |
| **Mean** | **6.94** | **8.21** | **7.57** |
| CD(P=0.05) | **(0.51)** | **(0.48)** | **(0.44)** |

*Mean of three replication; figures within parenthesis are square root transformed values

**Table 31: Effect of two sprays of SAR chemicals (sprayed at cotyledon stage and 15 days later) on disease severity of anthracnose**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | Cotyledon stage | | | After 15 days | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 2.33 (1.52) | 2.66 (1.63) | **2.49 (1.57)** | 5.33 (2.30) | 4.66 (2.15) | 5.49 (2.34) |
| BABA @ 1000 | 1.33 (1.15) | 2.33 (1.52) | **1.83 (1.35)** | 2.33 (1.52) | 3.33 (1.82) | 2.83 (1.68) |
| $NaHCO_3$ @ 100 | 2.66 (1.63) | 3.66 (1.91) | **3.16 (1.77)** | 3.66 (2.91) | 5.66 (2.37) | 4.66 (2.15) |
| INA @ 1000 | 2.00 (1.41) | 2.33 (1.52) | **2.16 (1.46)** | 4.33 (2.08) | 4.66 (2.15) | 4.49 (2.11) |
| $KHCO_3$ @ 100 | 3.33 (1.82) | 3.66 (2.91) | **3.49 (1.86)** | 6.66 (2.58) | 7.33 (2.70) | 7.00 (2.64) |
| Control (water spray) | 5.33 (2.30) | 4.66 (2.15) | **5.00 (2.23)** | 12.67 (3.55) | 13.33 (3.65) | 13.00 (3.60) |
| **Mean** | **2.83** | **3.21** | **3.02** | **5.83** | **6.49** | **6.24** |
| CD(P=0.05) | **0.57)** | **(0.29)** | **(0.31)** | **(0.80)** | **(0.65)** | **(0.38)** |

*Mean of three replication; figures within parenthesis are square root transformed values

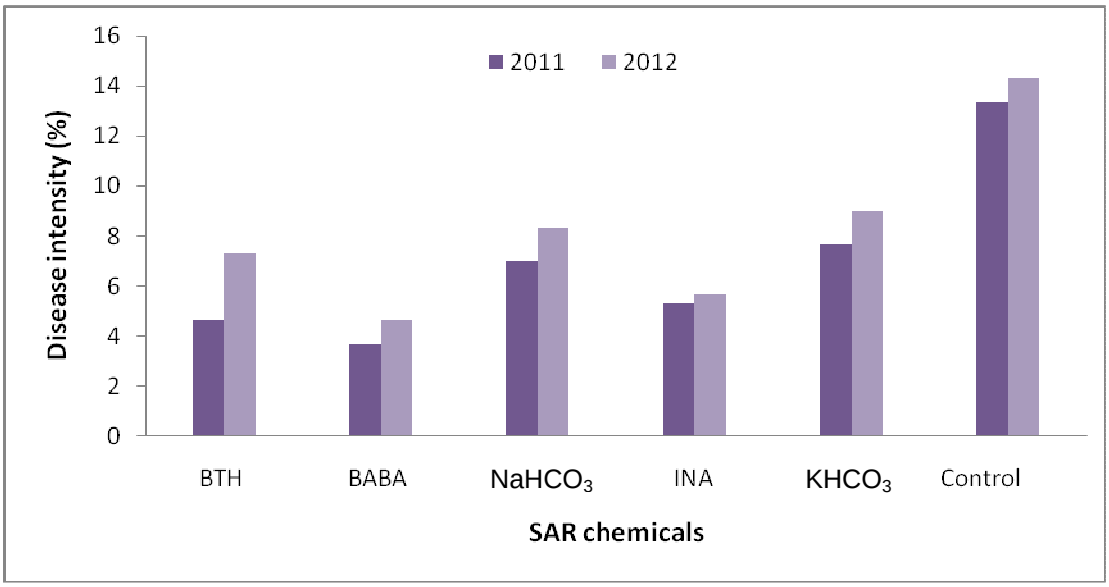



**Fig. 6: Effect of single spray of SAR chemical compounds at cotyledon stage on disease severity of anthracnose**

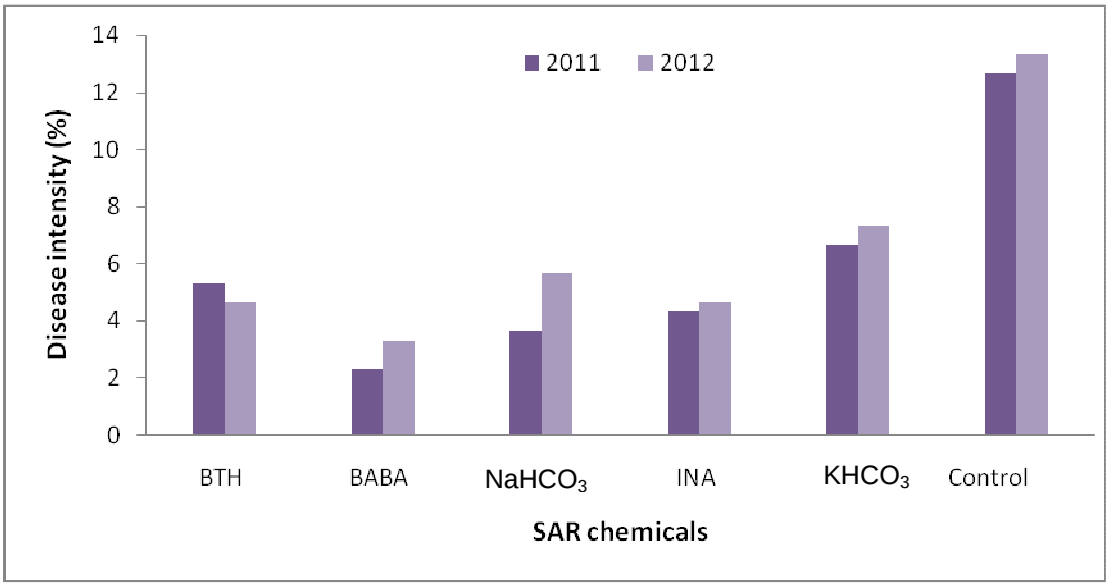



**Fig. 7: Effect of two sprays of SAR chemical compounds (cotyledon stage and 15 days later) on disease severity of anthracnose**

**Table 32: Effect of two sprays of SAR chemicals [sprayed at 15 day intervals starting 15 days after cotyledon stage] on disease severity of anthracnose**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | First spray | | | Second spray | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 12.66 (3.55) | 14.00 (3.74) | **13.33 (3.65)** | 16.00 (4.00) | 18.66 (4.31) | **17.33 (4.16)** |
| BABA @ 1000 | 11.00 (3.31) | 11.66 (3.41) | **11.33 (3.36)** | 13.00 (3.60) | 15.33 (4.91) | **14.33 (3.78)** |
| $NaHCO_3$ @ 100 | 13.00 (3.60) | 15.00 (3.87) | **14.00 (4.74)** | 17.66 (4.20) | 19.33 (4.39) | **18.49 (4.30)** |
| INA @ 1000 | 13.33 (3.65) | 12.66 (3.55) | **12.00 (3.46)** | 14.00 (3.74) | 16.00 (4.00) | **15.00 (3.87)** |
| $KHCO_3$ @ 100 | 15.66 (4.95) | 17.33 (4.16) | **16.49 (4.66)** | 19.00 (4.35) | 20.33 (4.50) | **19.66 (4.43)** |
| Control (water spray) | 22.66 (4.76) | 24.00 (4.89) | **23.33 (4.83)** | 30.66 (5.53) | 31.33 (5.59) | **31.00 (5.56)** |
| **Mean** | **14.71** | **15.77** | **15.08** | **18.38** | **20.16** | **19.30** |
| CD(P=0.05) | **(0.46)** | **(0.42)** | **(0.31)** | **(0.33)** | **(0.35)** | **(0.40)** |

*Mean of three replication; figures within parenthesis are square root transformed values

**Table 33: Effect of two sprays of SAR chemicals sprayed at 30 day intervals on disease severity of anthracnose**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | First spray | | | Second spray | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 13.33 (3.65) | 12.00 (3.46) | **12.66 (3.55)** | 18.00 (4.24) | 18.66 (4.31) | **18.33 (4.28)** |
| BABA @ 1000 | 11.00 (3.31) | 11.66 (3.41) | **11.33 (3.36)** | 14.00 (3.74) | 14.66 (3.82) | **14.66 (3.82)** |
| $NaHCO_3$ @ 100 | 13.66 (3.69) | 14.33 (3.78) | **14.00 (3.74)** | 19.66 (4.43) | 21.33 (4.61) | **20.49 (4.52)** |
| INA @ 1000 | 13.33 (3.65) | 13.66 (3.69) | **13.49 (3.67)** | 19.00 (4.35) | 20.33 (4.50) | **19.66 (4.43)** |
| $KHCO_3$ @ 100 | 15.33 (3.91) | 15.66 (4.95) | **15.49 (3.93)** | 21.00 (4.58) | 21.60 (4.64) | **21.33 (4.61)** |
| Control (water spray) | 23.33 (4.83) | 25.66 (5.06) | **24.48 (4.94)** | 38.33 (6.19) | 39.66 (6.29) | **39.00 (6.24)** |
| **Mean** | **14.99** | **15.49** | **15.24** | **21.66** | **22.70** | **22.24** |
| CD(P=0.05) | **(0.44)** | **(0.45)** | **(0.22)** | **(0.32)** | **(0.48)** | **(0.20)** |

*Mean of three replication; figures within parenthesis are square root transformation

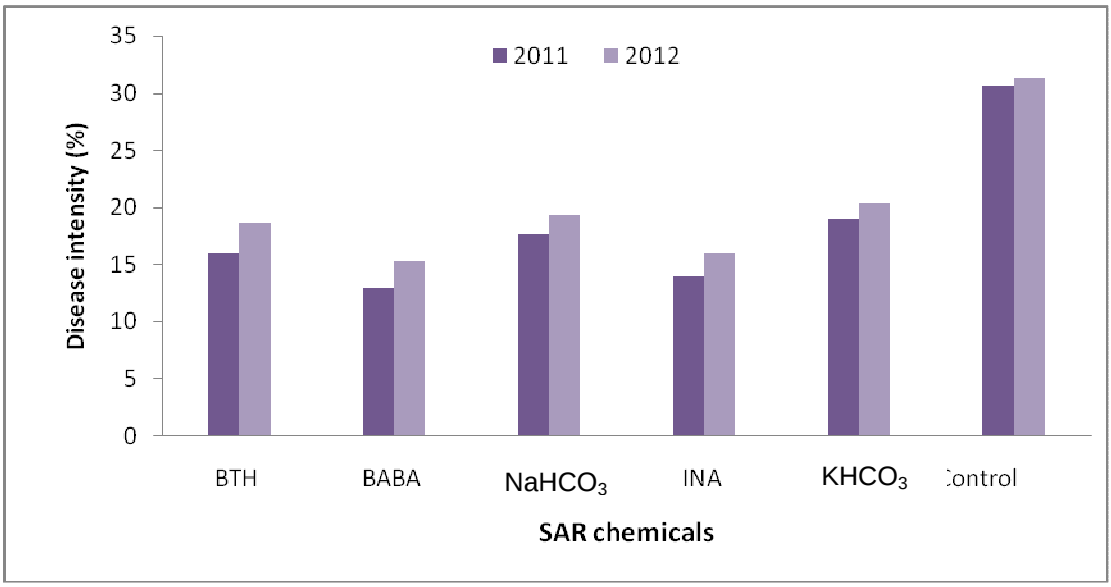



**Fig. 8: Effect of two sprays of SAR chemical compounds at 15 days interval on disease severity of anthracnose**

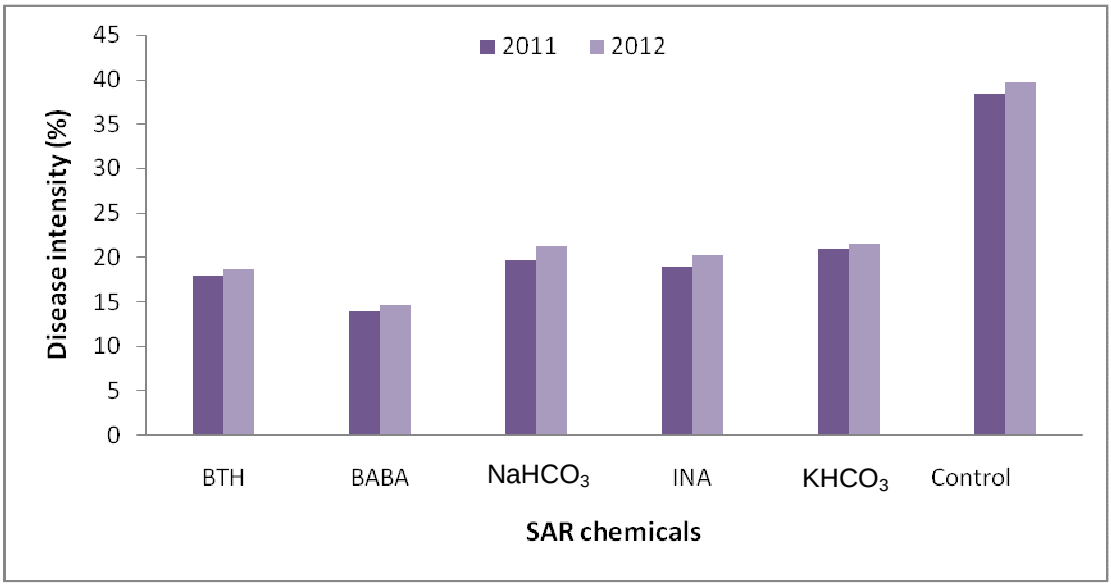



**Fig. 9: Effect of two sprays of SAR chemical compounds at 30 days interval on disease severity of anthracnose**

#### 4.6.1.3 Alternaria leaf spot

##### 4.6.1.3.1 Effect of single spray at cotyledon stage

The perusal of Table 34 indicated that Alternaria leaf spot intensity was higher (9.49%) in 2012 than in 2011(8.61%) [Fig. 10]. Spray of SAR chemicals at cotyledon stage significantly lowered disease intensity as compared to water sprayed check. The disease intensity ranged from 6.83 to 8.66 per cent in SAR chemical treatments in comparison to 15.00 per cent in check indicating that all SAR chemicals were effective in lowering disease intensity. Least disease intensity was noticed in BABA sprayed plants which was followed by INA (disease intensity, 7.00%). These were followed by BTH, $KHCO_3$ and $NaHCO_3$ with disease intensity of 7.33, 8.16 and 8.66 per cent, respectively.

##### 4.6.1.3.2 Effect of two sprays of SAR chemicals [sprayed at cotyledon stage and 15 days later]

The study on the effect of SAR chemicals at cotyledon stage and 15 days later revealed that the overall disease intensity was higher (6.49%) in 2012 than in 2011 (5.83%) [Table 35, Fig. 11]. SAR chemical sprays significantly lowered disease intensity (4.50-6.33%) as compared to water sprayed check (15.50%) with least disease intensity in BABA sprayed plants. This was followed by INA, BTH, $KHCO_3$ and $NaHCO_3$, with disease intensity of 4.66, 5.33, 5.83 and 6.33 per cent, respectively. BABA, BTH and INA sprays were at par with one another.

##### 4.6.1.3.3 Effect of two sprays of SAR chemicals [sprayed at 15 day intervals starting 15 days after cotyledon stage]

The effect of two spray SAR chemicals, $1^{st}$ spray 15 days after cotyledon stage and $2^{nd}$ spray 15 days later, indicated that all SAR treatments significantly lowered Alternaria disease intensity as compared to check (Table 36, Fig. 12). The disease intensity ranged from 23.66 to 30.00 per cent in SAR chemical treatments as compared to 39.83 per cent in check. Least disease intensity was noticed in BABA treatment which was at par with INA having 24.50 per cent disease intensity. These were followed by BTH, $KHCO_3$ and $NaHCO_3$ with Alternaria leaf sopt intensity of 25.66, 28.33 and 30.00 per cent, respectively.

**Table 34: Effect of single spray of SAR chemicals sprayed at cotyledon stage on disease severity of Alternaria leaf spot**

| SAR chemicals (ppm) | Disease severity (%)* | | |
|---|---|---|---|
| | 2011 | 2012 | Mean |
| BTH @ 100 | 7.00 (2.64) | 7.66 (2.76) | **7.33 (2.70)** |
| BABA @ 1000 | 6.00 (2.44) | 7.66 (2.76) | **6.83 (2.61)** |
| $NaHCO_3$ @ 100 | 7.66 (2.77) | 9.66 (3.10) | **8.66 (2.94)** |
| INA @ 1000 | 6.00 (2.44) | 8.00 (2.82) | **7.00 (2.65)** |
| $KHCO_3$ @ 100 | 7.66 (2.76) | 8.66 (2.94) | **8.16 (2.85)** |
| Control (water spray) | 14.66 (3.82) | 15.33 (3.91) | **15.00 (3.87)** |
| **Mean** | 8.16 | 9.49 | **8.83** |
| CD(P=0.05) | **(0.70)** | **(0.45)** | **(0.43)** |

*Mean of three replication; figures within parenthesis are square root transformed values

**Table 35: Effect of two sprays of SAR chemicals (at cotyledon stage and 15 days later) on disease severity of Alternaria leaf spot**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | Cotyledon stage | | | After 15 days | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 3.33 (1.82) | 4.33 (2.08) | **3.83 (1.95)** | 5.00 (2.23) | 5.66 (2.37) | **5.33 (2.30)** |
| BABA @ 1000 | 2.33 (1.52) | 4.66 (2.15) | **3.50 (1.87)** | 4.33 (2.08) | 4.66 (2.15) | **4.50 (2.12)** |
| $NaHCO_3$ @ 100 | 3.33 (1.82) | 5.66 (2.37) | **4.50 (2.12)** | 6.66 (2.52) | 6.00 (2.44) | **6.33 (2.51)** |
| INA @ 1000 | 3.00 (1.73) | 4.33 (2.08) | **3.67 (1.91)** | 4.00 (2.00) | 5.33 (2.30) | **4.66 (2.15)** |
| $KHCO_3$ @ 100 | 3.66 (1.91) | 4.66 (2.15) | **4.16 (2.03)** | 5.33 (2.30) | 6.33 (2.51) | **5.83 (2.41)** |
| Control (water spray) | 5.66 (2.37) | 6.33 (2.51) | **6.00 (2.44)** | 15.33 (3.91) | 15.66 (3.95) | **15.50 (3.93)** |
| **Mean** | 3.55 | 4.99 | **4.27** | 6.77 | 7.27 | **7.02** |
| CD(P=0.05) | **(0.39)** | **(0.38)** | **(0.41)** | **(0.25)** | **(0.46)** | **(0.28)** |

*Mean of three replication; figures within parenthesis are square root transformed values

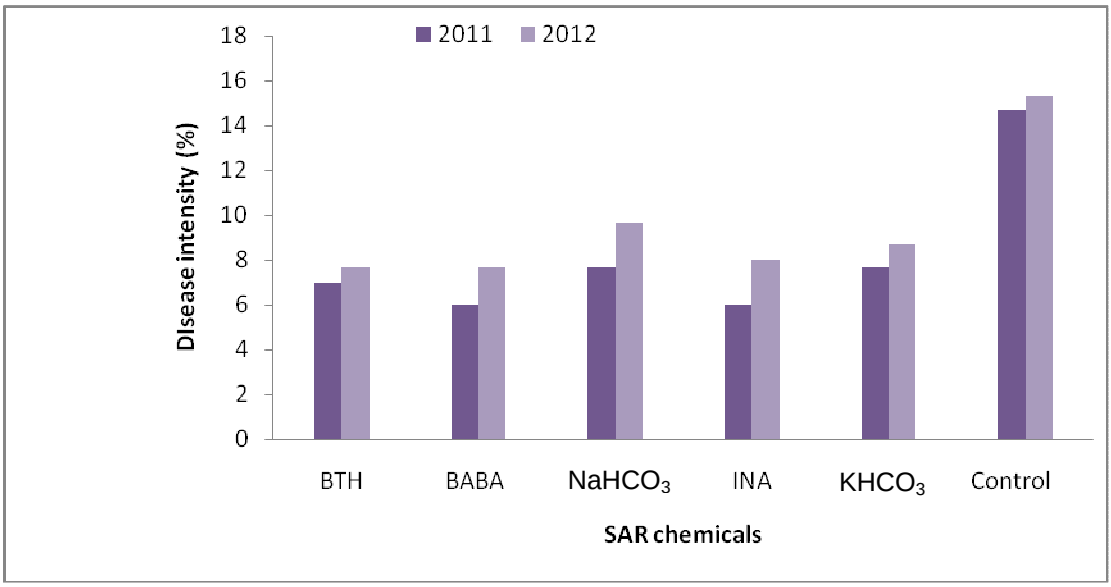



**Fig. 10: Effect of single spray of SAR chemical compounds at cotyledon stage on disease severity of Alternaria leaf spot**

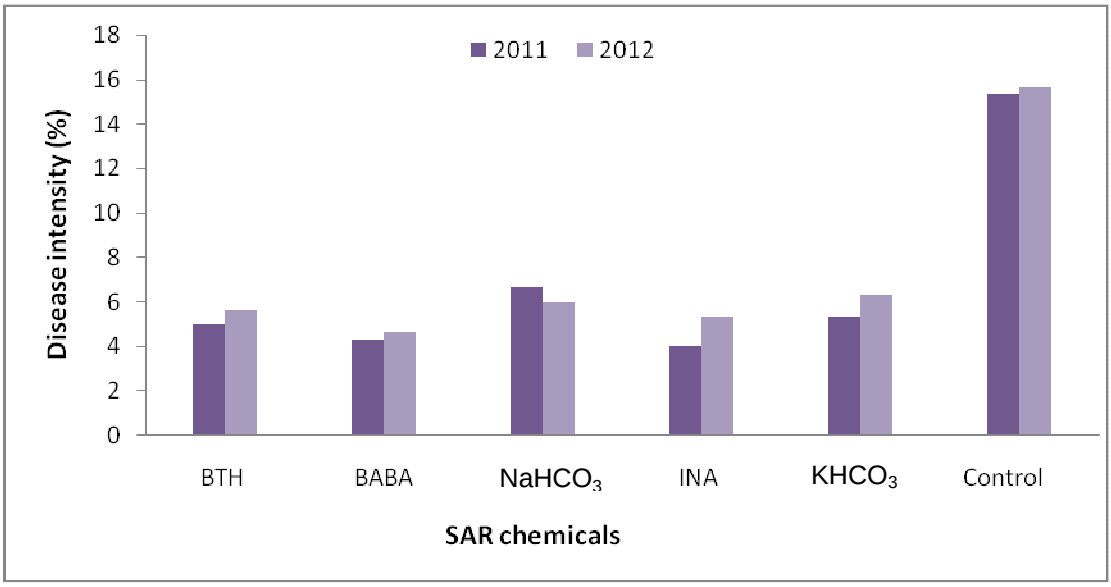



**Fig. 11: Effect of two sprays of SAR chemicals (at cotyledon stage and 15 days later) on disease severity of Alternaria leaf spot**

#### 4.6.1.3.4 Effect of two sprays of SAR chemicals [sprayed at 30 day intervals starting 30 days after cotyledon stage]

The perusal of Table 37 revealed that all the SAR chemicals sprayed at 30 day intervals starting from 30 days after cotyledon stage significantly lowered Alternaria leaf spot disease intensity as compared to check (Fig. 13). The disease intensity was higher (44.05%) in 2012 than in 2011 (41.94%). In SAR spray treatments the disease intensity ranged from 31.66 to 47.33 per cent as compared to 61.33 per cent in check indicating that all SAR activators were effective in lowering disease intensity. BTH spray was most effective in minimizing powdery mildew intensity (31.66%), followed by $NaHCO_3$ (35.00%), $KHCO_3$ (39.33%), INA (42.66%) and BABA (47.33%), respectively.

### 4.6.1.4 Powdery mildew

#### 4.6.1.4.1 Effect of single spray at cotyledon stage

The perusal of Table 38 revealed that the powdery mildew intensity was slightly higher (26.49%) in the year 2012 than in 2011 (24.22%) [Table 38; Fig. 14]. The spray of SAR chemicals at cotyledon stage, except BABA, significantly lowered disease intensity as compared to water sprayed check. Powdry mildew intensity ranged from 22.33 to 27.00 per cent in SAR chemical treatments as compared to 30.66 per cent in check. Least disease intensity was seen in BTH which was followed by $NaHCO_3$ with disease intensity of 23.33 per cent. These were followed by $KHCO_3$, INA, and BABA with disease intensity of 23.66, 26.16 and 27.00 per cent, respectively.

#### 4.6.1.4.2 Effect of two sprays of SAR chemicals [sprayed at cotyledon stage and 15 days later]

The study on the effect of two sprays of SAR chemicals sprayed at cotyledon stage and 15 days later revealed that the overall powdry mildew disease intensity was higher (25.38%) in the year 2012 than in 2011 (23.49%) [Table 39, Fig. 15]. SAR chemical sprays significantly lowered disease intensity (20.33-

25.16%) as compared to check (34.50%) with least disease intensity in BTH and $NaHCO_3$ sprayed plants. These were followed by $KHCO_3$, INA and BABA with disease intensity of 21.33, 24.50 and 25.16 per cent, respectively. Except BABA, all the SAR sprays were at par.

#### 4.6.1.4.3 Effect of two sprays of SAR chemicals [sprayed at 15 day intervals starting 15 days after cotyledon stage]

The effect of two sprays of SAR chemicals, 1st spray 15 days after cotyledon stage and 2nd spray 15 days later, indicated that all the treatments significantly lowered mildew intensity as compared to check (Table 40, Fig. 16). In SAR spray treatments the disease intensity ranged from 23.83 to 26.66 per cent in comparison to 43.33 per cent in check indicating all SAR chemicals were effective in lowering powdry mildew intensity. BTH spray was most effective in minimizing disease intensity (23.83%), followed by $NaHCO_3$ (24.00%), $KHCO_3$ (24.66%) and INA (25.83%) treatments. Except BABA, all SAR sprays were at par with one another.

#### 4.6.1.4.4 Effect of two sprays of SAR chemicals [sprayed at 30 day intervals starting 30 days after cotyledon stage]

The perusal of Table 41 revealed that all the SAR chemicals sprayed at 30 day intervals, starting 30 days after cotyledon stage, significantly lowered disease intensity as compared to check (Table 41, Fig. 17). The disease intensity ranged from 44.05 to 41.94 per cent in SAR chemical treatments as compared to 39.83 per cent in check indicating that all SAR chemicals effectively reduced disease intensity. Least disease intensity was noticed in BABA treatment which was at par with INA having 24.50 per cent disease intensity. These were followed by BTH, $KHCO_3$ and $NaHCO_3$ with disease intensity of 25.66, 28.33 and 30.00 per cent, respectively.

**Table 36: Effect of two sprays of SAR chemicals sprayed at 15 day intervals on disease severity of Alternaria leaf spot**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | First spray | | | Second spray | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 16.00 (4.00) | 18.66 (4.31) | **17.33 (4.16)** | 25.00 (5.00) | 26.33 (5.13) | **25.66 (5.06)** |
| BABA @ 1000 | 16.00 (4.00) | 17.33 (4.16) | **16.66 (4.08)** | 23.00 (4.79) | 24.33 (4.93) | **23.66 (4.86)** |
| $NaHCO_3$ @ 100 | 19.00 (4.35) | 20.33 (4.50) | **19.66 (4.43)** | 28.66 (5.35) | 31.33 (5.59) | **30.00 (5.47)** |
| INA @ 1000 | 15.33 (3.91) | 15.33 (4.91) | **15.83 (3.97)** | 24.33 (4.93) | 24.66 (4.96) | **24.50 (4.94)** |
| $KHCO_3$ @ 100 | 18.00 (4.24) | 18.66 (4.31) | **18.33 (4.28)** | 28.00 (5.29) | 28.66 (5.35) | **28.33 (5.32)** |
| Control (water spray) | 26.00 (5.09) | 27.33 (5.22) | **26.00 (5.09)** | 39.33 (6.27) | 40.33 (6.35) | **39.83 (6.31)** |
| **Mean** | 18.38 | 19.60 | **18.96** | 28.05 | 29.27 | **28.66** |
| CD(P=0.05) | **(0.33)** | **(0.32)** | **(0.632** | **(0.39)** | **(0.31)** | **(0.23)** |

*Mean of three replication; figures within parenthesis are square root transformed values

**Table 37: Effect of two sprays of SAR chemicals sprayed at 30 day intervals on disease severity of Alternaria leaf spot**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | First spray | | | Second spray | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 17.00 (4.12) | 18.33 (4.28) | 17.66 (4.20) | 30.00 (5.47) | 31.33 (5.59) | **30.66 (5.53)** |
| BABA @ 1000 | 16.00 (4.00) | 17.33 (4.16) | 16.66 (4.08) | 26.66 (5.16) | 28.33 (5.32) | **27.49 (5.24)** |
| $NaHCO_3$ @ 100 | 19.66 (4.43) | 21.00 (4.58) | 20.33 (4.50) | 35.00 (5.91) | 36.33 (6.02) | **35.66 (5.97)** |
| INA @ 1000 | 16.00 (4.00) | 16.66 (4.08) | 16.33 (4.04) | 29.00 (5.38) | 29.66 (5.44) | **29.33 (5.41)** |
| $KHCO_3$ @ 100 | 17.66 (4.20) | 18.33 (4.28) | 18.00 (4.24) | 31.00 (5.56) | 31.66 (5.62) | **31.33 (5.59)** |
| Control (water spray) | 25.00 (5.00) | 26.33 (5.13) | 25.66 (5.06) | 48.00 (6.92) | 48.66 (6.97) | **48.33 (6.95)** |
| **Mean** | 18.55 | 19.66 | 19.10 | 33.27 | 34.32 | **33.80** |
| CD(P=0.05) | **(0.54)** | **(0.47)** | **(0.23)** | **(0.36)** | **(0.24)** | **(0.17)** |

*Mean of three replication; figures within parenthesis are square root transformed values

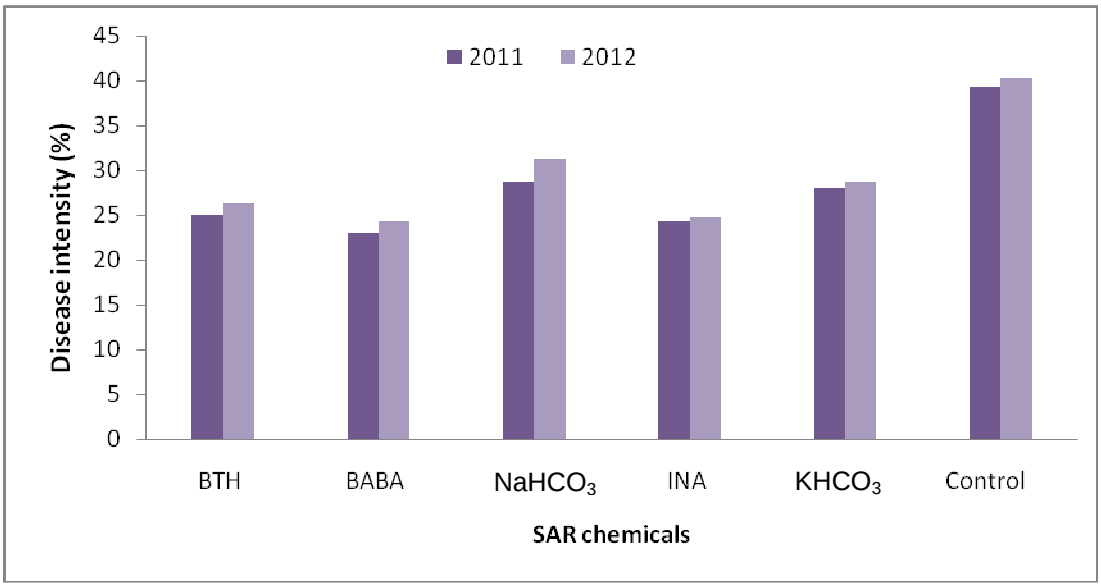



**Fig. 12:Effect of two sprays SAR chemical compounds at 15 days interval on disease severity of Alternaria leaf spot**

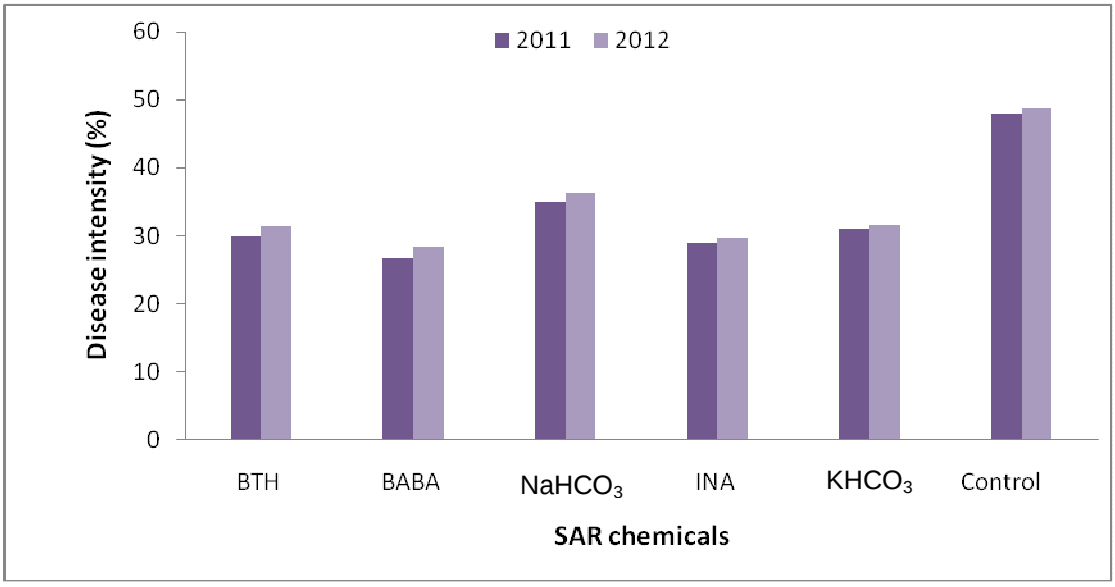



**Fig. 13:Effect of two sprays SAR chemical compounds at 30 days interval on disease severity of Alternaria leaf spot**

**Table 38: Effect of single spray of SAR chemicals sprayed at cotyledon stage on disease severity of powdery mildew**

| SAR chemicals (ppm) | Disease severity (%)* | | |
|---|---|---|---|
| | 2011 | 2012 | Mean |
| BTH @ 100 | 21.00 (4.58) | 23.66 (4.86) | **22.33 (4.72)** |
| BABA @ 1000 | 26.00 (5.09) | 28.00 (5.29) | **27.00 (5.19)** |
| $NaHCO_3$ @ 100 | 22.33 (4.75) | 24.33 (4.92) | **23.33 (4.83)** |
| INA @ 1000 | 21.99 (4.65) | 24.33 (4.93) | **23.66 (4.86)** |
| $KHCO_3$ @ 100 | 25.33 (5.03) | 27.00 (5.19) | **26.16 (5.11)** |
| Control (water spray) | 29.00 (5.38) | 31.66 (5.62) | **30.66 (5.53)** |
| **Mean** | 24.22 | 26.49 | **25.52** |
| CD(P=0.05) | **(0.47)** | **(0.38)** | **(0.40)** |

*Mean of three replication; figures within parenthesis are square root transformed values

**Table 39: Effect of two sprays of SAR chemicals [sprayed at cotyledon stage and 15 days later] on disease severity of powdery mildew**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | Cotyledon stage | | | After 15 days | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 0.33 (0.57) | 0.66 (0.81) | **0.50 (0.70)** | 19.33 (4.39) | 22.33 (4.72) | 20.33 (4.50) |
| BABA @ 1000 | 0.33 (0.57) | 1.00 (1.00) | **0.66 (0.81)** | 24.33 (4.93) | 26.00 (5.09) | 25.16 (5.01) |
| $NaHCO_3$ @ 100 | 0.33 (0.57) | 1.00 (1.00) | **0.66 (0.81)** | 19.00 (4.35) | 21.66 (4.65) | 20.33 (4.50) |
| INA @ 1000 | 1.00 (1.00) | 0.66 (0.81) | **0.83 (0.91)** | 23.33 (4.83) | 25.66 (5.06) | 24.50 (4.94) |
| $KHCO_3$ @ 100 | 0.33 (0.57) | 0.66 (0.81) | **0.50 (0.70)** | 20.00 (4.47) | 22.66 (4.76) | 21.33 (4.61) |
| Control (water spray) | 1.00 (1.00) | 1.66 (1.20) | **1.33 (1.15)** | 35.00 (5.91) | 34.00 (5.83) | 34.50 (5.87) |
| **Mean** | 0.55 | 0.94 | **0.74** | 23.49 | 25.38 | 24.35 |
| CD(P=0.05) | (N.S) | (N.S) | **(N.S)** | (0.36) | (0.35) | 0.46 |

*Mean of three replication; figures within parenthesis are square root transformed values

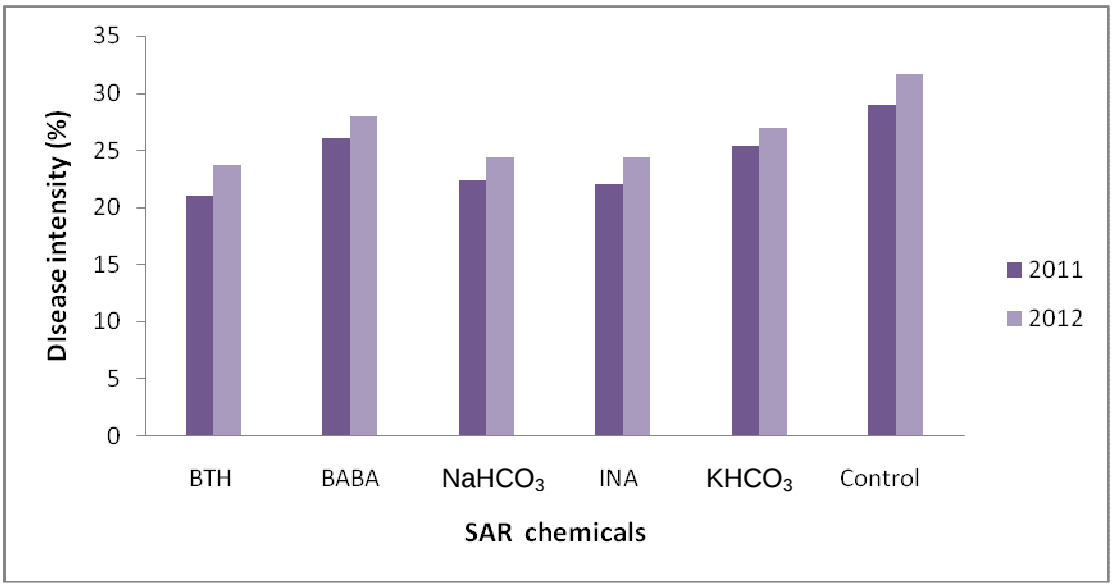



**Fig. 14:Effect of single spray of SAR chemical compounds at cotyledon stage on disease severity of powdery mildew**

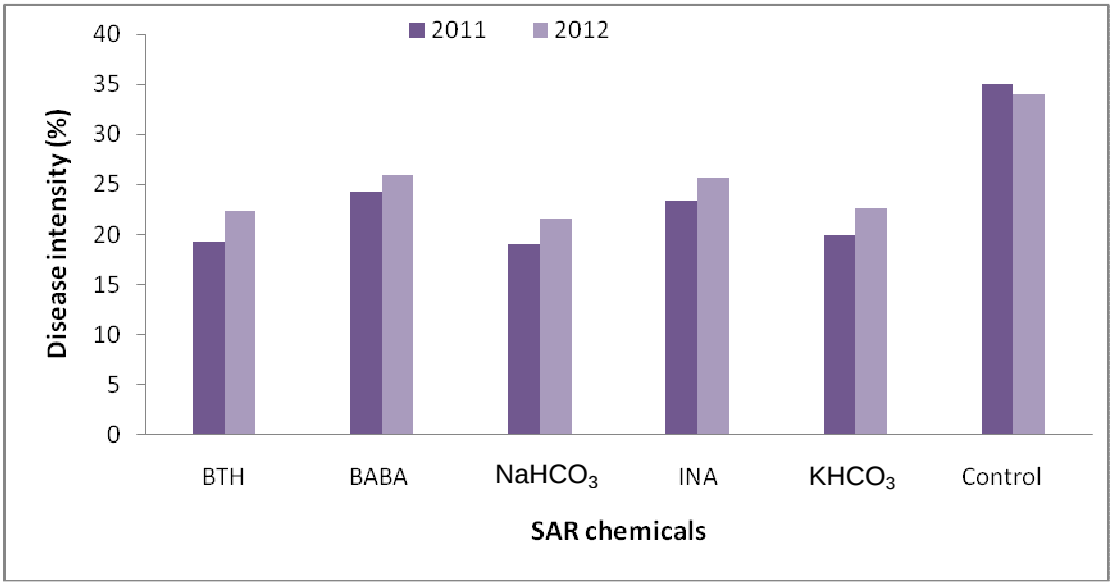



**Fig. 15: Effect of two sprays of SAR chemicals (at cotyledon stage and 15 days later) on disease severity of powdery mildew**

**Table 40: Effect of two sprays SAR chemicals sprayed at 15 day intervals on disease severity of powdery mildew**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | First spray | | | Second spray | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 9.66 | 12.00 | **10.83** | 23.33 | 24.33 | **23.83** |
| | (3.10) | (3.46) | **(3.29)** | (4.83) | (4.93) | **(4.88)** |
| BABA @ 1000 | 11.66 | 13.66 | **12.66** | 25.66 | 27.66 | **26.66** |
| | (3.41) | (3.69) | **(3.55)** | (5.06) | (5.25) | **(5.16)** |
| $NaHCO_3$ @ 100 | 9.66 | 13.00 | **11.33** | 23.66 | 24.33 | **24.00** |
| | (3.10) | (3.60) | **(3.36)** | (4.86) | (4.93) | **(4.89)** |
| INA @ 1000 | 12.33 | 14.33 | **13.33** | 25.33 | 26.33 | **25.83** |
| | (3.51) | (3.78) | **(3.65)** | (5.03) | (5.13) | **(5.08)** |
| $KHCO_3$ @ 100 | 10.33 | 12.00 | **1 1.16** | 23.66 | 25.66 | **24.66** |
| | (3.21) | (3.46) | **(3.34)** | (4.86) | (5.06) | **(4.96)** |
| Control (water spray) | 13.33 | 15.67 | **14.50** | 42.00 | 44.66 | **43.33** |
| | (3.65) | (3.95) | **(3.80)** | (6.48) | (6.68) | **(6.58)** |
| **Mean** | 11.16 | 13.44 | **12.30** | 27.27 | 28.82 | **28.05** |
| CD(P=0.05) | (0.32) | (0.37) | **(0.39)** | (0.37 | (0.44) | **(0.26)** |

*Mean of three replication; figures within parenthesis are square root transformed values

**Table 41: Effect of two sprays of SAR chemicals sprayed at 30 day intervals on disease severity of powdery mildew**

| SAR chemicals (ppm) | Disease severity (%)* | | | | | |
|---|---|---|---|---|---|---|
| | First spray | | | Second spray | | |
| | 2011 | 2012 | Mean | 2011 | 2012 | Mean |
| BTH @ 100 | 12.66 | 13.33 | **13.00** | 31.66 | 33.00 | **31.66** |
| | (3.55) | (3.65) | **(3.60)** | (5.62) | (5.74) | **(5.62)** |
| BABA @ 1000 | 13.66 | 15.00 | **14.33** | 46.33 | 48.33 | **47.33** |
| | (3.69) | (3.87) | **(3.70)** | (6.80) | (6.95) | **(6.87)** |
| $NaHCO_3$ @ 100 | 12.66 | 14.66 | **13.67** | 34.33 | 35.66 | **35.00** |
| | (3.55) | (3.82) | **(3.69)** | (5.85) | (5.97) | **(5.91)** |
| INA @ 1000 | 14.33 | 16.00 | **15.16** | 41.33 | 44.00 | **42.66** |
| | (3.78) | (4.00) | **(3.89)** | (6.42) | (6.63) | **(6.53)** |
| $KHCO_3$ @ 100 | 11.66 | 13.66 | **12.66** | 38.33 | 40.33 | **39.33** |
| | (3.41) | (3.69) | **(3.55)** | (6.19) | (6.35) | **(6.27)** |
| Control (water spray) | 16.66 | 18.33 | **17.50** | 59.66 | 63.00 | **61.33** |
| | (4.08) | (4.28) | **(4.18)** | (7.72) | (7.93) | **(7.83)** |
| **Mean** | **13.60** | **15.16** | **14.38** | **41.94** | **44.05** | **42.88** |
| CD(P=0.05) | **(0.32)** | **(0.34)** | **(0.35)** | **(0.42)** | **(0.51)** | **(0.28)** |

*Mean of three replication; figures within parenthesis are square root transformed values

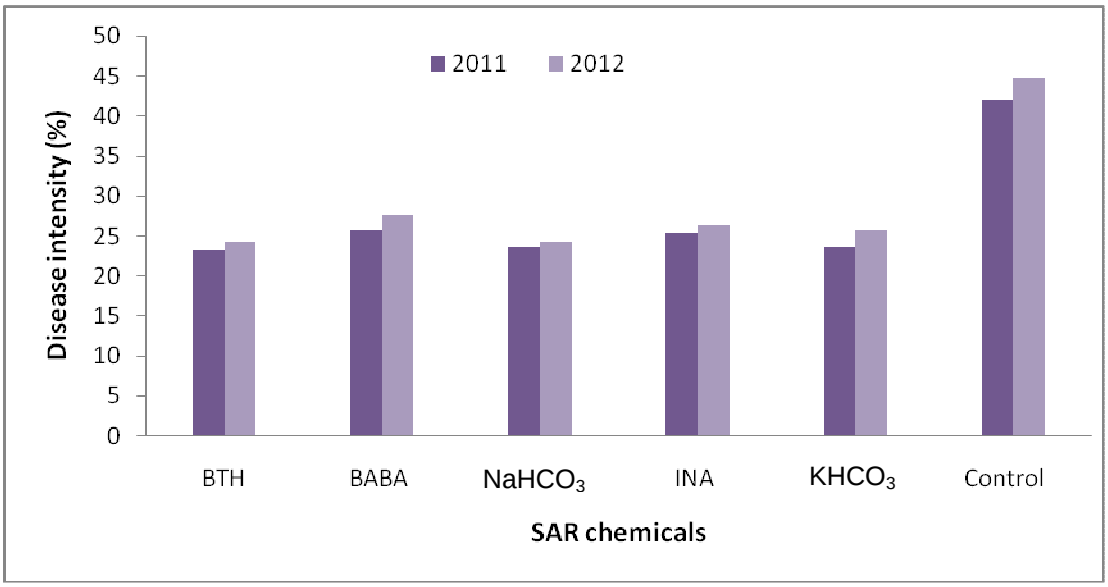



**Fig. 16:Effect of two sprays SAR chemical compounds at 15 days interval on disease severity of powdery mildew**

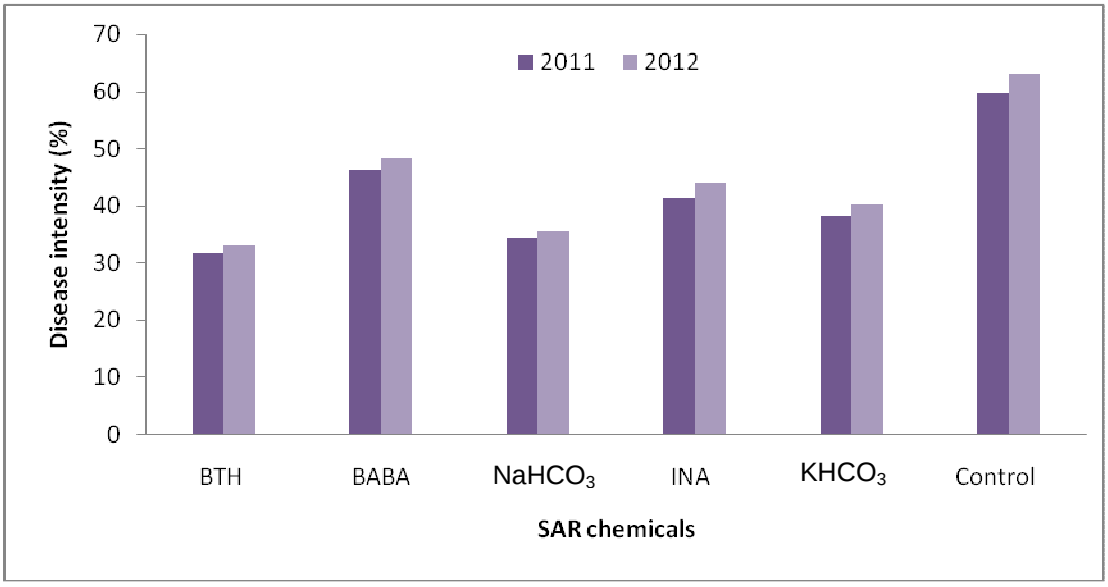



**Fig. 17:Effect of two sprays SAR chemical compounds at 30 days interval on disease severity of powdery mildew**

### 4.6.2 Effect of fungitoxicants on cucumber diseases

Various fungitoxicant combinations including a biocontrol agent were evaluated under field conditions at recommended concentrations. The fungitoxicants and biocontrol agent were divided into various sets. Each set represented three sprays of fungitoxicants done at 20 day intervals. The first spray was done on 15$^{th}$ June. After third spray disease intensity of downy mildew, anthracnose, Alternaria leaf spot and powdery mildew was recorded 20 days later.

Except powdery mildew the disease intensity of remaining three diseases was higher in the year 2012 than in 2011 [Table 42 and 43]. Except three sprays of *Amplomyces quisqualis* all fungitoxicant combinations reduced the diseases in cucumber as compared to check during both the years (Fig. 18). During the year 2011 minimum disease intensity of the four diseases of 6.22, 7.55, 5.77 and 9.33 per cent respectively was observed in plants treated with pyraclostrobin + boscalid 38 WG @ 0.2 per cent followed by 2$^{nd}$ spray with captan + hexaconazole 75 WP @ 0.3 per cent and 3$^{rd}$ spray with metiram + pyraclostrobin 60 WG @ 0.2 (Table 42). The treatment set chlorothalonil 75 WP @ 0.3 per cent followed by 2$^{nd}$ spray of metalaxyl Mz 72 @ 0.25 per cent and 3$^{rd}$ spray with tebaconazole 25 EC @ 0.05 per cent was proved as second best treatment set for downy mildew and Alternaria leaf spot with 8.44 and 7.55 per cent disease intensity whileas treatment set of mancozeb 75 WP @ 0.3 followed by 2$^{nd}$ spray with captan 50 WP @ 0.3 per cent and 3$^{rd}$ spray with dinocap 48 EC @ 0.3 per cent was observed as second best treatment set for anthracnose and powdery mildew with 9.55 and 10.11 per cent disease intensity respectively. The treatment set cymoxanil 50 WP @ 0.2 per cent followed by 2$^{nd}$ spray with tridemorph 50 WP @ 0.3 per cent and 3$^{rd}$ spray with difeconazole 25 EC @ 0.03 per cent depicted 20.33, 17.55, 12.44 and 14.33 per cent disease intensity in all the four diseases respectively. The treatment sets wherein bioagents was included in spray schedule proved comparatively less effective than chemical fungitoxicants but all were significantly effective over control.

**Table 42: Effect of fungitoxicant sprays on multiple diseases in cucumber cv. 'Japanese Long Green' (year 2011)**

| Treatment | Per cent disease intensity | | | |
|---|---|---|---|---|
| | Downy mildew | Anthracnose | Alternaria leaf spot | Powdery mildew |
| Mancozeb 75 WP fb captan 50 WP fb dinocap 48 EC | 14.00 (3.86) | 9.55 (3.24) | 17.44 (4.29) | 10.11 (3.33) |
| Cymoxanil 50 WP fb tridemorph 50 WP fb difenconazole 25 EC | 20.33 (4.16) | 17.55 (4.30) | 12.44 (3.66) | 14.33 (3.91) |
| Chlorothalonil 75 WP fb metalaxyl MZ 72 fb tebaconazole 25 EC | 8.44 (3.03) | 13.11 (3.75) | 7.55 (2.88) | 15.88 (4.10) |
| Pyraclostrobin + boscalid 38 WG) fb captan + hexaconazole 75 WP fb metiram + pyraclostrobin 60 WG | 6.22 (2.64) | 7.55 (2.88) | 5.77 (2.55) | 9.33 (3.20) |
| *Amplomyces quisqualis* fb *A. quisqualis* fb *A. quisqualis* | 32.66 (5.80) | 30.44 (5.60) | 33.77 (5.89) | 20.55 (4.64) |
| Tridemorph 50 WP fb *A. quisqualis* fb *A. quisqualis* | 23.56 (4.94) | 26.22 (5.20) | 23.55 (4.94) | 20.00 (4.58) |
| Dinocap 48 EC fb tridemorph 50 WP fb *A. quisqualis* | 21.33 (4.71) | 24.88 (5.08) | 22.22 (4.81) | 14.77 (3.96) |
| Check (water spray) | 39.11 (6.33) | 31.11 (5.66) | 35.33 (6.02) | 24.44 (5.03) |
| **CD (P=0.05)** | **2.11** | **2.30** | **2.19** | **1.30** |

*Mean of three replications; Figures within parenthesis are square root transformed values; fb = followed by

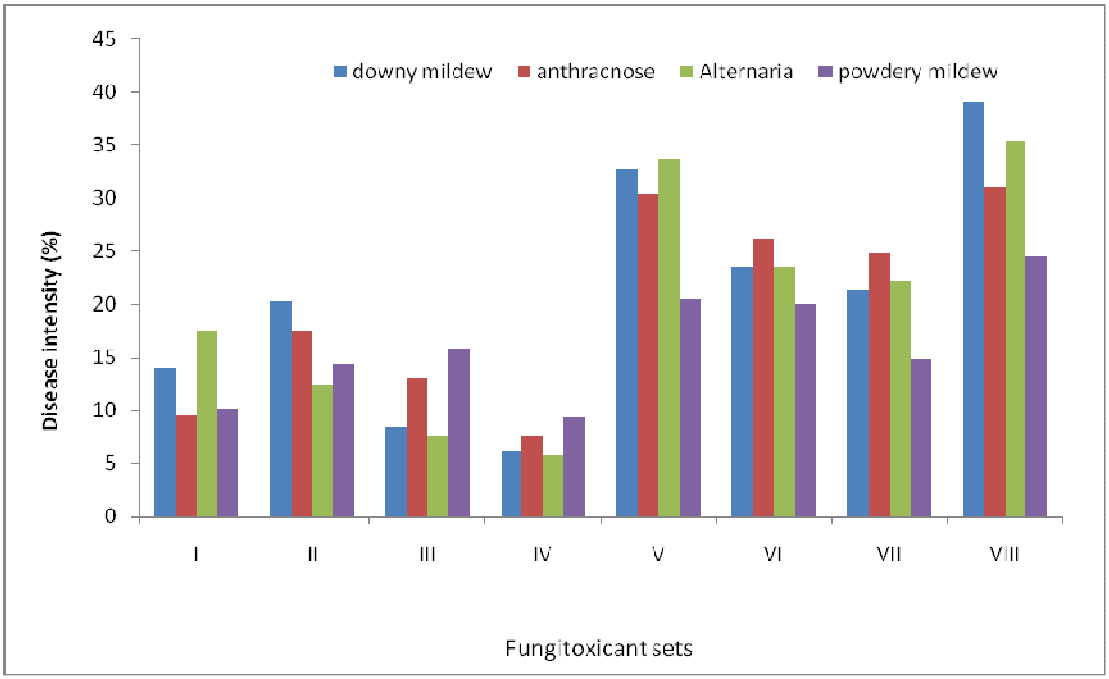



**Fig. 18: Effect of fungitoxicant sprays on multiple diseases in cucumber cv. 'Japanese Long Green' (year 2011) [**I = mancozeb 75 WP fb captan 50 WP fb dinocap 48 EC; II = cymoxanil 50 WP fb tridemorph 50 WP fb difenconazole; III = chlorothalonil 75 WP fb metalaxyl Mz 72 fb tebaconazole 25 EC; IV = pyraclostrobin+boscalid 38 WG fb captan+hexaconazole 75 WP metiram+ pyraclostrobin 60 WG; V=*Amplomyces quisqualis* fb *A. quisqualis* fb *A. quisqualis*; VI= tridemorph50 WP fb *A. quisqualis* fb *A. quisqualis* ;VII = dinocap48 EC fb tridemorph50 WP fb *A. quisqualis*; VIII = check] fb=**followed by**

During the year 2012 minimum disease intensity of the four diseases of 8.00, 8.00, 6.66 and 10.22 per cent respectively was observed in plants treated with pyraclostrobin + boscalid 38 WG @ 0.2 per cent followed by 2nd spray with captan + hexaconazole 75 WP @ 0.3 per cent and 3rd spray with metiram + pyraclostrobin 60 WG @ 0.2 (Table 43, Fig. 19 ). The treatment set chlorothalonil 75 WP @ 0.3 per cent followed by 2nd spray of metalaxyl Mz 72 @ 0.25 per cent and 3rd spray with tebaconazole 25 EC @ 0.05 per cent was proved as second best treatment set for downy mildew and Alternaria leaf spot with 10.22 and 8.44 per cent disease intensity whileas treatment set of mancozeb 75 WP @ 0.3 followed by 2nd spray with captan 50 WP @ 0.3 per cent and 3rd spray with dinocap 48 EC @ 0.3 per cent was observed as second best treatment set for anthracnose and powdery mildew with 9.77 and 13.11 per cent disease intensity respectively. The treatment set cymoxanil 50 WP @ 0.2 per cent followed by 2nd spray with tridemorph 50 WP @ 0.3 per cent and 3rd spray with difeconazole 25 EC @ 0.03 per cent depicted 20.77, 17.33, 12.88 and 14.66 per cent disease intensity in all the four diseases respectively. The treatment sets wherein bioagents was included in spray schedule proved comparatively less effective than chemical fungitoxicants but all were significantly effective over control.

The minimum mean disease intensity of the four diseases of 7.11, 7.88, 6.22 and 9.77 per cent respectively was observed in plants treated with pyraclostrobin + boscalid 38 WG @ 0.2 per cent followed by 2nd spray with captan + hexaconazole 75 WP @ 0.3 per cent and 3rd spray with metiram + pyraclostrobin 60 WG @ 0.2 (Table 44). The treatment set chlorothalonil 75 WP @ 0.3 per cent followed by 2nd spray of metalaxyl Mz 72 @ 0.25 per cent and 3rd spray with tebaconazole 25 EC @ 0.05 per cent was proved as second best treatment set for downy mildew and Alternaria leaf spot with 9.33 and 8.00 per cent disease intensity whileas treatment set of mancozeb 75 WP @ 0.3 followed by 2nd spray with captan 50 WP @ 0.3 per cent and 3rd spray with dinocap 48 EC @ 0.3 per cent was observed as second best treatment set for anthracnose and

powdery mildew with 9.66 and 11.61 per cent disease intensity respectively. The treatment set cymoxanil 50 WP @ 0.2 per cent followed by 2nd spray with tridemorph 50 WP @ 0.3 per cent and 3rd spray with difeconazole 25 EC @ 0.03 per cent depicted 20.55, 17.44, 12.66 and 14.50 per cent disease intensity in all the four diseases respectively. The treatment set of dinocap @ 48 EC followed by 2nd spray with tridemorph @ 50 WP and 3rd spray with *A. quisqualis* was more effective in controlling powdery mildew with respect to other three diseases.

**Table 43: Effect of fungitoxicant sprays on multiple diseases in cucumber cv. 'Japanese Long Green' (year 2012)**

| Treatment | Per cent disease intensity | | | |
|---|---|---|---|---|
| | Downy mildew | Anthracnose | Alternaria leaf spot | Powdery mildew |
| Mancozeb 75 WP fb captan 50 WP fb dinocap 48 EC | 14.22 (3.90) | 9.77 (3.28) | 18.44 (4.40) | 13.11 (3.69) |
| Cymoxanil 50 WP fb tridemorph 50 WP fb difenconazole 25 EC | 20.77 (4.66) | 17.33 (4.25) | 12.88 (3.72) | 14.66 (3.95) |
| Chlorothalonil 75 WP fb metalaxyl MZ 72 fb tebaconazole 25 EC | 10.22 (3.33) | 13.33 (3.77) | 8.44 (3.03) | 18.44 (4.40) |
| Pyraclostrobin + boscalid 38 WG) fb captan + hexaconazole 75 WP fb metiram + pyraclostrobin 60 WG | 8.00 (2.94) | 8.00 (2.96) | 6.66 (2.71) | 10.22 (3.33) |
| *Amplomyces quisqualis* fb *A. quisqualis* fb *A. quisqualis* | 34.22 (5.93) | 30.66 (5.62) | 35.11 (6.00) | 20.77 (4.66) |
| Tridemorph 50 WP fb *A. quisqualis* fb *A. quisqualis* | 24.44 (5.02) | 25.33 (5.11) | 24.44 (5.02) | 20.44 (4.63) |
| Dinocap 48 EC fb tridemorph 50 WP fb *A. quisqualis* | 22.66 (4.85) | 24.44 (5.03) | 22.44 (4.85) | 16.88 (4.22) |
| Check (water spray) | 40.66 (6.45) | 32.00 (5.74) | 36.00 (6.08) | 24.22 (5.01) |
| **CD (P=0.05)** | **2.38** | **2.61** | **2.47** | **2.48** |

*Mean of three replications; Figures within parenthesis are square root transformed values; fb = followed by

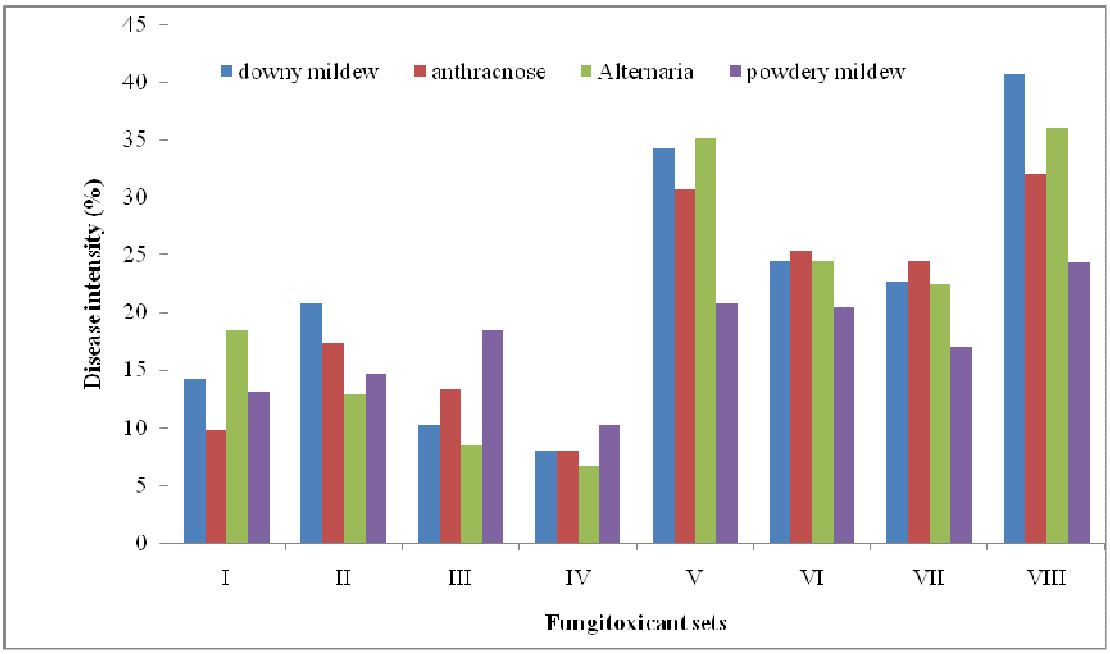



**Fig. 19: Effect of fungitoxicant sprays on multiple diseases in cucumber cv. 'Japanese Long Green' (year 2012) [**I = mancozeb 75 WP fb captan 50 WP fb dinocap 48 EC; II = cymoxanil 50 WP fb tridemorph 50 WP fb difenconazole; III = chlorothalonil 75 WP fb metalaxyl Mz 72 fb tebaconazole 25 EC; IV = pyraclostrobin+boscalid 38 WG fb captan+hexaconazole 75 WP metiram+ pyraclostrobin 60 WG; V=*Amplomyces quisqualis* fb *A. quisqualis* fb *A. quisqualis*; VI= tridemorph50 WP fb *A. quisqualis* fb *A. quisqualis* ;VII = dinocap 48 EC fb tridemorph50 WP fb *A. quisqualis*; VIII = check]fb=**followed by**

**Table 44: Effect of fungitoxicant sprays on multiple diseases in cucumber cv. 'Japanese Long Green' (two years mean data)**

| Treatment | Per cent disease intensity | | | |
|---|---|---|---|---|
| | Downy mildew | Anthracnose | Alternaria leaf spot | Powdery mildew |
| Mancozeb 75 WP fb captan 50 WP fb dinocap 48 EC | 14.11 (3.88) | 9.66 (3.26) | 17.94 (4.35) | 11.61 (3.54) |
| Cymoxanil 50 WP fb tridemorph 50 WP fb difenconazole 25 EC | 20.55 (4.64) | 17.44 (4.29) | 12.66 (3.69) | 14.50 (3.93) |
| Chlorothalonil 75 WP fb metalaxyl MZ 72 fb tebaconazole 25 EC | 9.33 (3.21) | 13.22 (3.77) | 8.00 (2.99) | 17.16 (4.26) |
| Pyraclostrobin + boscalid 38 WG) fb captan + hexaconazole 75 WP fb metiram + pyraclostrobin 60 WG | 7.11 (2.84) | 7.77 (2.96) | 6.22 (2.68) | 9.77 (3.28) |
| *Amplomyces quisqualis* fb *A. quisqualis* fb *A. quisqualis* | 33.44 (5.86) | 30.55 (5.61) | 34.44 (5.95) | 20.66 (4.65) |
| Tridemorph 50 WP fb *A. quisqualis* fb *A. quisqualis* | 24.00 (5.00) | 25.77 (5.17) | 24.00 (5.00) | 20.22 (4.60) |
| Dinocap 48 EC fb tridemorph 50 WP fb *A. quisqualis* | 22.00 (4.79) | 24.66 (5.06) | 22.33 (4.84) | 15.83 (4.10) |
| Check (water spray) | 39.88 (6.39) | 31.55 (5.70) | 35.66 (6.05) | 24.33 (5.03) |
| **CD (P=0.05)** | **1.02** | **0.94** | **0.50** | **2.06** |

*Mean of three replications; Figures within parenthesis are square root transformed values; fb = followed by

**Plate 13: Fungitoxicant sprayed plants**

**Plate 14: Unsprayed Plants (Check plants)**

**Chapter – 5**

# DISCUSSION

Cucumber (*Cucumis sativus* L.), world-wide the 4th most widely grown vegetable crop, is cultivated in Kashmir valley during *kharif* (summer) season. The crop is prone to a number of biotic stresses which inflict considerable yield losses under natural epiphytotic conditions. Amongst them, the fungal diseases frequently posed serious threat to its successful cultivation as these impose severe reduction in cucumber fruit yield and quality.

During preliminary field survey the foliar fungal diseases observed on cucumber were downy mildew, anthracnose, Alternaria leaf spot, powdery mildew, ulocladium leaf spot, septoria leaf spot and scab and of these the first four were frequently encountered which prevailed in all the districts surveyed. Downy mildew was encountered most frequently in cucumber growing areas of Kashmir valley and prevailed in all the districts surveyed but in a varying magnitude. This disease was more severe in 2012 than in 2011 which may be ascribed to more conducive conditions for pathogenic growth *viz.*, favourable temperature, high relative humidity and more rainfall during the cropping period. A mean maximum temperature of 29.1ºC, mean minimum temperature of 14.0°C, relative humidity of 30.9 per cent and rainfall of 58.7 mm was recorded during 2011 whereas in 2012 a mean maximum temperature of 27.3ºC, minimum temperature of 13.7°C, relative humidity of 47.3 per cent and a rainfall of 65.3 mm was recorded (Appendix I). Conducive temperature and more relative humidity and precipitations appears to have favoured disease development. Thomas (1977), Rotem *et al.* (1978) and Reuveni and Raviv (1997) found a mean temperature of 15°C (range: 5-30°C) and presence of leaf moisture ideal for inducing infection and disease spread. Downy mildew incidence ranged from 16.0 to 69.3 per cent (avg. 34.0%) in 2011 and 22.0 to 67.3 per cent (41.3%) in 2012 whereas the intensity varied from 8.2 to 20.3 per cent (avg.14.1%) in 2011 and 9.9

to 36.2 per cent (17.6%) in 2012. The occurrence of downy mildew has been reported from all the continents of north and south hemispheres wherever cucumber is grown (Bains and Sharma, 1986; Lebeda, 1990; Thakur and Mathur, 2002). The disease affects the foliar part of plants (Thomas, 1996). During survey high disease incidence of 63.6 per cent and intensity of 32.6 per cent was observed in Dal, followed by Janwara with disease incidence and intensity of 63.3 and 31.1 per cent, respectively. High disease in these locations could be attributed to more plant density and improper sanitation. The least disease incidence (20.6%) and intensity (9.5%) was recorded at Kemah where farmers practiced crop rotation, maintained proper plant density and better field management. The moist weather and faulty management were considered as pre-disposing factors for mildew disease development in cucumber (Lebeda and Urban, 2004; Hansen, 2009).

Anthracnose was also found in all the major cucumber growing areas of surveyed districts of Srinagar, Baramulla, Bandipora and Budgam, though in a varying proportions. However, disease was more severe in 2012 than in 2011. The disease incidence ranged from 14.6 to 62.6 per cent (avg. 34.7%) during 2011 and 18.6 to 76.6 per cent (47.2%) in 2012. However, the disease intensity varied from 6.0 to 29.7 per cent (avg. 16.1%) during 2011 and 8.1 to 35.4 per cent (avg. 20.8%) in 2012. The high disease severity during 2012 could be attributed to high rain fall, more number of rainy days and high relative humidity. The observation is in agreement with Monroe *et al.* (1997) and Goldberg (2004). The anthracnose disease in cucmber has been reported worldwide wherever cucurbits are grown (Palenchar *et al.*, 2009). The disease affects foliar parts of plants (Delhaut and Stevens, 2004). During survey higher anthracnose incidence of 63.3 per cent and intensity of 29.1 per cent was observed in Shalimar followed by Janwara with disease incidence of 60.3 per cent but highest intensity was observed in Pattan (28.8%). High disease severity observed at various locations could be attributed to the practice of maintaining high plant density, non-disposal of plant debris and

use of disease susceptible varieties. High plant density creates high relative humidity in microclimate of plants which favours disease development. During survey least disease incidence (19.6%) and intensity (8.9%) was recorded in Narkara which may be ascribed to the use of hybrid varieties and better field management practiced by the farmers of the area. Variations in anthracnose severity due to variation in environmental conditions have been reported by Thompson and Jenkins (1985) and Zitter *et al.* (1998).

The preliminary field survey revealed Alternaria leaf spot as one of the important fungal foliar diseases of cucumber in Kashmir valley as it prevailed in all cucumber growing areas surveyed. The disease was more severe in 2012 than in 2011 with disease incidence varying from 13.3 to 64.0 per cent (avg. 35.5%) in 2011 and 23.3 to 68.6 per cent (avg. 45.6%) in 2012. The disease intensity varied from 5.7 to 30.9 per cent (avg.13.3%) during 2011 and 9.0 to 29.8 per cent (avg.16.1%) in 2012. The high disease severity during 2012 may be ascribed more conducive temperature, more precipitation, more rainy days and high relative humidity. Similar findings have been reported by Martin and Fernandez (2006), Garibaldi *et al.* (2007) and Hubballi *et al.* (2010). Alternaria leaf spot occurs on cucumber crop worldwide (Simmons, 1992). Of the locations surveyed, higher disease incidence (66.0%) and intensity (29.1%) was recorded at Baramulla and Pattan locations, respectively, which may be attributed to the practice of maintaining less plant spacing, leading to high relative humidity in plant microclimate, and non-disposal of plant debris. The least disease incidence (18.3%) and intensity (7.3%) was recorded in Kemah of district Bandipora which could be attributed to the better field management practices followed by the growers in the area. The moist weather accompanied by conducive temperature conditions favour leaf spot disease in cucumber (Balai and Ahir, 2013).

Powdery mildew was prevalent in cucumber growing areas in all the surveyed districts and disease was more severe in 2012 than in 2011. The high disease severity in 2012 could be attributed to more precipitation and high relative

humidity. Similar findings have been reported by Hajlaoui and Belanger (1991), Wang *et al.* (2009) and Zhang (2011). The disease on cucumber crop occurs worldwide causing huge loss (Khan and Khan, 1992; Reuveni and Reuveni, 2000 b). During survey high disease incidence of 60.3 per cent and intensity of 23.6 per cent was noticed in Janwara, whereas least disease incidence (15.7%) and intensity (6.9%) was observed in Kemah. Less disease at Kemah may be ascribed to the better management practices followed and use of disease resistant varieties. These observations are supported by Lebeda *et al.* (2009) Del Pino *et al.* (2002).

The first appearance of downy mildew disease symptoms were noticed in the 2$^{nd}$ week of June as slightly chlorotic, water soaked and irregular spot of 0.1 to 0.4 mm size on adaxial leaf surface, which gradually increased in size with age and attained a maximum size of 7-9 mm in the 1$^{st}$ week of July. Similar observations have been reported by Lebeda (1986), Palti and Cohen (1980). The lesions became angular due to growth restriction by veins and the colour changed from slightly chlorotic to bright yellow and finally to brown (Savory *et al.*, 2011). The typical angular chlorotic lesions bound by leaf veins on foliage with characteristic grayish to black growth and coalescing of brownish angular spots observed are in agreement with Rotem *et al.* (1978).

The first appearance of anthracnose disease symptoms was observed in 2$^{nd}$ week of June as slightly chlorotic and pinhead spot of 0.0 to 0.3 mm size on leaf surface. Similar observations have been reported by Li (2014). The lesions gradually increased with age and attained a size of 12-15 mm in 3$^{rd}$ week of July. In 1$^{st}$ week of July acervulli were observed. Lesions became irregular jagged and centre of the lesion cracked and dropped out to give shot hole appearance. The colour changed from slightly chlorotic to darker reddish and finally brown. However, in 3$^{rd}$ week of June, characteristic grayish to black growth of fungus appeared on corresponding abaxial leaf surface and the brownish angular spots coalesced. These characteristic symptoms observed under natural conditions were identical with those of Schwartz and Gent (2007).

The first appearance of Alternaria leaf spots appeared in the 3rd week of June as small light green flecks of 0.0-0.4 mm size. During last week of June, spots became grayish, circular surrounded by a yellow halo and measured 0.4-0.9 mm in size. In the 1st week of July, irregular dark brown lesions of 1.0-1.75 cm size were formed. Microscopic examination revealed the presence of spores. The affected leaves turned yellow, senescent and ultimately died. Similar symptoms were observed by Vakalounakis and Malathrakis (1988) and Vakalounakis (1990).

The powdery mildew appeared in the 3rd week of July as small chlorotic spots on adaxial side of leaves which measured 0.3 to 0.6 mm in size. The spots covered approximately 2.0-3.5 per cent leaf area. Three days later, small powdery mildew patches developed and covered 3.5-8 per cent leaf area. The fungus showed fast abrupt growth on leaf surface and in last week of July white talcum-like mycelial mat and tan coloured patches developed to cover major portion of leaf (>45-75%). Ultimately blistering of leaves, curling and brown coloured lesions were noticed and the disease covered >75 per cent leaf area. The symtoms observed were in line with Koike *et al.* (2007) and Fujiwara *et al.* (2009).

The pathogens responsible for downy mildew, anthracnose, leaf spot and powdery mildew were identified as *Pseudoperonospora cubensis* (Berk & Curtis) (Berk. and Curtis, 1868)], *Colletotrichum arbiculare* (Berk & Mont) (Tode, 1790), *Alternaria alternata* (Fr.) Keissler (Ellis, 1971) and *Sphaerotheca fuliginea* (Schlechtend. Fr.) Pollaci (Braun, 1987), respectively, on the basis of their morphological characters. *P. cubensis* formed irregularly branched hyaline hyphae which measured 4.8-(5.85)-6.4 µm in width. Sporangia were 182.4-(237.3)-380.8 × 3.2-(5.4)-9.6 µm in size on dichotomously branched sporangiophore. The hyaline sporangiophores produced 4-5 branches at acute angles to the main stem and each branch produced 2 or sometimes 3 secondary branches. Ovoid to ellipsoid thin walled sporangia with papilla at distal end measured 22.4-(29.4)-38.4 × 12.8-(18.75)-25.6 µm. These morphological characteristics are in conformity with Palti (1975), Rotem *et al.* (1978), Cohen (1981) and Choi *et al.*

(2005). Similar to the finding of Palti and Cohen (1980), sporangia in present study gave rise to zoospores which were released at distal end of zoosporangium opposite to its attachment, through an opening in papilla. Some sporangia germinated directly by giving rise to germ tube. The finding is in conformity with Cohen (1977; 1981). Similar to the observation of Michelmore (1981) and Mahrisi and Siradhana (1984) the oospores were light brown, spherical, globose, double walled and measured 38.4-(41.4)-44.8 µm in size. In present study the oospores germinated by single germ tube terminating in a pyriform sporangium. Popular (1981) and Zhang *et al.* (2006) also have reported similar fashion of germination of oospores

*Colletotrichum arbiculare,* the fungus responsible for anthracnose, was studied both on host as well as in culture. The fungus on oat meal agar medium grew slowly. The culture was initially white coloured with sparse aerial mycelial growth. The mycelium was hyaline, septate and branched with hypha of 3.2-(3.77)-4.8 µm width. Acervulli were formed 3 weeks after vegetative growth in culture. However, no mycelial growth was seen on host. The pathogen formed acervulli in culture as well as on the adaxial surface of infected cucumber leaves. Acervulli were salmon coloured, slightly raised and saucer-shaped with 1-3 hair-like black setae which measured 12.8-(33.9) -70.4 × 1.6-(5.5)-6.4 µm in size on host and 12.8-(43.9)-73.6 × 1.6-(5.1)-9.6 µm in culture. Conidia were hyaline, oblong, ovate and single celled and measured 3.2-(6.0)-6.4×3.2 (5.1)-6.4 µm in size on host and 3.2-(6.1)-9.6 × 3.2-(3.63)-4.8 µm in size in culture. Similar descriptions of acervulli and hyphae have been given by Cano *et al.* (2004), Kumar and Hyde, (2004), Photita *et al.* (2004) and Agrios (2005).

The pathogen responsible for leaf spot produced septate, smooth, branched and hyaline to dark olive coloured hyphae of 4.8-(5.1)-6.4 µm width on adaxial surface of infected cucumber leaves. Similar morphological characters of pathogen were observed in culture. Conidiophores, both on host and culture, were short straight or flexuous in appearance and pale brown to olive brown. These

measured 25.6-(40.9)-51.2 × 3.2-(4.4)-6.4 µm in host and slightly bigger in culture 28.8-(50.1)-54.4 × 3.2-(5.5)-6.4 µm. Both on host and in culture the conidia were brown to black, ovoid, obclavate or ellipsoid having 1-8 transverse and several longitudinal cross walls with short conical, cylindrical club-shaped beak produced in chains. The size of conidia in host was 16.0-(59.0)-64.0 × 9.6-(10.2)-12.8 µm and in culture slightly larger i.e. 16.0-(60.5)-67.2 × 12.8-(14.0)-16.0 µm. Germination of conidia was either apical or lateral or both. Conidia (4-5) were produced in a single chain in basipetal order. The morphological characters of the pathogen are in line with the description of Ellis (1971).

The powdery mildew pathogen *Sphaerotheca fuliginea* formed white to gray and fluffy to sparse mycelial growth on adaxial surface of infected cucumber leaves. The hyphae were thin walled, septate and measured 2-3 µm in width. Conidiophores were erect, aerial and measured 36-(42.2)-49) × 9.6- (12.5)-16.0 µm. Conidia were hyaline, borne singly or in chain, basipetal, ellipsoid to ovoid, one-celled with well developed fibrosin bodies and measured 22.4-(25.6)-35.2 ×12.8-(20.0)-21 µm in size. The finding is in conformity with Braun (1987). Similar to the observations of Braun, (1987) and Pawar *et al.* (2009) the mycelium was uninucleate, erect conidiophore, 80-146 mm long, conidia borne in chains (4-7), oblate or ovoid, containing irregular shaped fibrosin bodies and 21-37 x 15-23 mm size

The present study established that downy mildew pathogen *Pseudoperonospora cubensis* in Kashmir overwinters as oospores on diseased leaves. This is in agreement with Colucci and Holmes (2010). The diseased leaves on ground surface exhibited maximum oospore production in June coinciding with the susceptible phenological stage of cucumber plant. Royle and Kremheller (1981) and Zhang *et al.* (2006) have reported oospore as primary source of infection in disease initiation. The leaves buried at 5 cm depth in soil exhibited viable oospores only upto 2$^{nd}$ week of April as the leaves decomposed fast during the period. This may perhaps be due to the intense microbial activity at 5 cm

depth which favoured quick decomposition. The proportion of oospores and their viability was less in the samples at 5 cm depth in soil as compared to the samples kept at surface. Decrease in oospore viability with due to burial seems because of the microbial action on nutrient coating of oospore (Meyers and Cook, 1972; Lafon and Bullit, 1981).

The anthracnose pathogen, *Colletotrichum arbiculare*, perpetuated as acervulli throughout the winter season on diseased leaves. The diseased leaves on ground surface exhibited abundant conidial production from April to May while leaves buried at 5 cm soil depth showed viable spores only upto the 2$^{nd}$ week of April, there-after leaves decomposed and pathogen could not be isolated. It seems that greater aerobic respiration at 5 cm depth favoured quick decomposition of leaves. The proportion of spores and their viability was less in buried samples than in above ground leaf samples. These observations are in line with Lafon and Bullit (1981). Buried leaves decayed more rapidly and exhibited decrease in the number and viability of spores. Vizvary and Warren (1982) and Lipps (1983;1985) have reported that in absence of decaying plant material, lysing of the spore and mycelia of *Collectotrichum graminicola* occured rapidly due to competition from other fungal soil inhabitants. Our findings are supported by Casela and Frederiksen (1993) who reported that in presence of ample debris, fungal material can effectively overwinter for longer periods and serve as a source of primary inoculum for the following season. *Colletotrichum* overwinter in soil on decaying plant residues as mycelium and acervuli (Singh and Singh, 1982; Casela and Frederiksen, 1993; Bergstrom and Nicholson 1999; Sukno *et al.*, 2008).

The study revealed that leaf spot pathogen, *Alternaria alternata*, perpetuated as conidia throughout the winter season on diseased leaves. The diseased leaves kept at ground surface exhibited abundant conidial production from March to June. The leaves buried at 5 cm depth had viable spores only upto 2$^{nd}$ week of April as the leaves decomposed and pathogen could not be isolated.

Greater aerobic respiration at 5 cm depth appeared to favour the fast decomposition of leaves. The proportion of spores and their viability was less in buried samples which is supported by Lafon and Bullitt (1981). *Alternaria* overwinters in soil and on decaying plant residues as mycelium and conidia (Rotem, 1994; Dubey and Patel, 2000; Pradip and Prajapati, 2005).

In present study, the powdery mildew pathogen, *S. fuliginea,* perpetuated as conidia on diseased leaves only upto 2$^{nd}$ fortnight of March and their viability was also confined to this month only. In comparison, the leaves buried at 5 cm depth had no conidia present on leaves. It is presumed that the pathogen may survive on some collateral hosts or may be carried by wind currents during the growing season of the crop. Greater aerobic respiration at 5 cm depth favoured quick leaf decomposition. Eastburn and Ribbing (1999) reported that sources of infection may be spores produced on greenhouse vine crops or on perennial or other hosts grown in the field in frost-free areas of the far south during the winter and are believed to be blown northward during the spring and early summer.

Exploitation of inherent resistance or tolerance of a plant to pathogen is the most economic and eco-friendly disease management srategy. Three cultivars (Hybrid-5, Pusa Sanyug and Priya) were found tolerant whereas two cultivars (10/cucu Hybrid-4 and Sweet delight) were moderately tolerant downy mildew. The remaining cultivars exhibited either moderately susceptible or susceptible reactions. These results are in agreement with Gupta *et al.* (2014) who during screening of 22 cucumber cultivars found ‘Poinsette’ and ‘Cucumber Long Green’ moderately susceptible and susceptible to downy mildew, respectively. Contrarily, Vliet and Meysing (1974) reported ‘Poinsett’ as resistant while Angelov (1994) found ‘Poinsett’ moderately resistant.

Studies to identify cucumber cultivars having tolerance to *Colletotrichum arbiculare* under natural conditions revealed three cultivars (Priya, Hybrid-5 and Pusa Sanyug) to be tolerant whereas five cultivars (Swarna Ageta, 10/cucu Hybrid-4, S-6 (m), Green Express and Hermophrodite) were moderately

tolerant. Remaining cultivars were either moderately susceptible or susceptible in reaction. Wehner and Amand 1995 reported 27 cultivar resistant against anthracnose under different environmental conditions. Three cultivars (Pusa Sanyug, Green express and Marketer-76) exhibited tolerance to *Alternaria alternata* which is with agreement with Cavatorta *et al.* (2007) who reported 'Marketer 76' resistant to this disease. Six cultivars [Sweet Delight, CH-20, Priya, Hybrid-5, S-5 (m) and Poinsette] were moderately tolerant. The remaining cultivars were either moderately susceptible or susceptible. Studies to identify the cucumber cultivars showing tolerance to powdery mildew pathogen, *S. fuliginea*, under natural conditions revealed three cultivars 'Marketer-76', 'Hybrid-5' and 'Priya' as tolerant cultivars, which is in agreement with Cavatorta *et al.* (2007) who reported 'Marketer 76' resistant to this disease. The cultivars 'Sweet Delight', 'S-6 (m)', '10/cucu Hybrid-4', 'Pusa Sanyug' and 'Hermophrodite' were moderately tolerant and the ones either moderately susceptible or susceptible.

The cultivars showing moderate tolerance to tolerant reaction can be used in hybridization programme to evolve cultivars possessing desirable traits, besides resistance to pathogens. When all the cultivars were ranked based on their on multiple disease reaction, the cultivars 'Priya', 'Hybrid-5' and 'Pusa Sanyug' were found tolerant to mos t of the major diseases followed by 'Sweet Delight', '10/cucu Hybrid' and 'Green Express'. These genotypes can be recommended for use under temperate agro-climatic conditions of Kashmir.

The use of SAR activators for disease control is a safe plant protection method. SAR chemicals have neither any toxic effect on pathogen, plant and animals nor show any inhibitory effect on defense mechanisim i.e. these do not develop resistance and provide long lasting protection to plants (Kessman *et al.*, 1994; Kuc, 2001). SAR activators are effective against a wide variety of pathogens and inhibit pathogenic growth by hypersensitive response (Sticher *et al*., 1997). SAR chemicals in the present study significantly lowered foliar disease intensity as compared to check. Evaluation of SAR chemicals at various growth

stages indicated that downy mildew disease was generally higher in 2012 than in 2011. INA and BTH significantly reduced the disease as compared to check. These finding are supported by Tally *et al.* (1999) who reported BTH as an effective inducer of resistance in tobacco against fungal pathogens. Other chemicals tested *viz.*, BABA, $NaHCO_3$ and $KHCO_3$ were also effective in lowering downy mildew disease though not at par with INA and BTH. These results are in agreement with Cohen (2002) and Hamiduzzaman *et al.* (2005) who reported BABA as effective SAR inducer. Fallik *et al.* (1996), Kareem (2007) and Karem *et al.* (2013) have reported $KHCO_3$ effective against downy mildew in cucumber. Plant activators do not act directly on the pathogen but rather activate the defense mechanisms in plant (Glynn, 2001). When SAR is activated a normally compatible plant-pathogen interaction is converted into an incompatible one (Uknes *et al*., 1992; Mauch-Mani and Slusarenko, 1996). Potassium from $KHCO_3$ enters into the fungal cells and disturbs the potassium ion balance, and causes the cell wall to collapse (Anonymous, 1998).

Evaluation of SAR chemicals at various growth stages against anthracnose revealed that the disease intensity was generally higher in the year 2012 than in 2011. Further, BABA and INA were most effective in reducing the disease which is in agreement with Kovats *et al.* (1991) who reported BABA as an effective inducer of SAR against anthracnose of cucumber. Sticher *et al.* (1997), Godard *et al.* (1999) and Oostendorp *et al.* (2001) have reported BTH as an effective inducer of resistance in plants against broad spectrum fungal pathogens. Other SAR chemicals *viz.*, BTH, $NaHCO_3$ and $KHCO_3$ were also effective in controlling the disease though not at par with BABA and INA. These results are in agreement with Yamaguchi (1998) and Reuveni and Reuveni (1998) who reported that various natural and synthetic agents including simple salt solutions are useful in controlling plant diseases under field conditions and induce systemic resistance in several plant species against various pathogens. Gottstein and Kuc (1989) reported that phosphate solutions induce SAR in cucumber

against *C. lagenarium,* which supports our findings. Hofstetter and Bob (1993) also found $NaHCO_3$ effective in reducing anthracnose disease in cucurbit.

SAR chemicals tested at various growth stages agaist Alternaria leaf spot disease revealed BABA and INA as the most effective SAR inducers which is in agreement with Jakab *et al.* (2001), Gozzo (2003), Vallad and Goodman (2004) and Raut and Borkar (2014) who found BABA as an effective inducer of resistance against Alternaria leaf blight pathogen, followed by INA, than other SAR chemicals. Other chemicals *viz.*, BTH, $NaHCO_3$ and $KHCO_3$ also effectively minimized disease but were not superior to BABA and INA. Punja and Grogan (1982), Smilanick and Margosan (1999) and Janisiewicz and Peterson (2005) have reported that sodium bicarbonate and potassium bicarbonate have curative property and effectively induce plant resistance when in direct contact with pathogen. Karabulut *et al.* (2003) and Smilanick *et al.* (2006) reported $KHCO_3$ effective against various fungal diseases including *Alternaria* pathogen.

SAR used aginst powdery mildew disease revealed that all the chemicals significantly lowered disease intensity as compared to check (Sticher *et al.*, 1997; Ye *et al.*, 1995). BTH and $NaHCO_3$ proved most effective SAR chemical which is inline with Liu *et al.* (2006) and Bayoumi and Hafez (2006) who found BTH as most effective SAR activator. Homma *et al.* (l98l) found the use of $NaHCO_3$ (2%) inhibitory to the conidial germination of *Sphaerotheca fuliginea* on cucumber by 95 per cent. Other SAR chemicals *viz.,* INA and $KHCO_3$ also effectively reduced powdery mildew disease though less effectively than BTH and $NaHCO_3$. Ziv and Zitter (1992) reported that $NaHCO_3$ and $KHCO_3$ have curative properties that cause the collapse of mycelial walls and shrinkage of conidia and conidiophores. $KHCO_3$ enters into the fungal cells, causes wall collapse and disrupts fungal cell integrity (Anonymous, 1998). Our finding that sodium and potassium salts are effective SAR inducer is in conformity with Gottstein and Kuc (1989), Reuveni *et al.* (1998), Manandhar *et al.* (1998) and Reuveni and Reuveni (2000). Of the SAR chemicals evaluated BABA was least effective which is in agreement with Vogt

and Buchenauer (1997) and Bokshi *et al.* (2005) who opined that BABA reduced powdery mildew to some degree in cucumber and melon.

Field evaluation of various fungitoxicants showed that all the biocides tested at recommended concentrations significantly reduced all the major diseases prevalent in Kashmir. The disease intensity in the year 2012 was higher than in 2011. The fungitoxicants were grouped in seven sets with each set sprayed three times with same or different fungitoxicant combinations. The overall mean downy mildew intensity in fungitoxicant treated plants ranged from 7.11 to 24.00 per cent against 39.88 per cent in check. Among the fungitoxicant sets tested, treatment combination of pyraclostrobin + boscalid 38 WG followed by 2$^{nd}$ spray with captan + hexaconazole 75 WP and 3$^{rd}$ spray with metiram + pyraclostrobin 60 WG exhibited least disease intensity. However, this spray set was at par with chlorothalonil 75 WP followed by 2$^{nd}$ spray metalaxyl MZ 72 and 3$^{rd}$ spray with tebaconazole 25 EC. The findings are in agreement with Wong and Wilcox (2001) who reported the sprays of azoxystrobin, mancozeb and metalaxyl most effective in minimizing the disease caused by *Plasmopara viticola.* Pyraclostrobin belongs to same group azoxystrobin. Ammermann *et al.* (2000), Herms *et al.* (2002) and Koehle *et al.* (2003) found pyraclostrobin effective against a broad range of pathogens. Gupta *et al.* (1993), Gupta and Shyam (1998) and Sharma *et al.* (2003) found ridomil effective in controlling downy mildew in cucumber. Chaudhry *et al.* (2009) reported that metalaxyl + chlorothalonil as effective fungicise against downy mildew in cucumber. In present study, the spray of other fungicidal sets *viz.*, mancozeb 75 WP followed by 2$^{nd}$ spray with captan 50 WP and 3$^{rd}$ spray with dinocap 48 EC and cymoxanil 50 WP followed by 2$^{nd}$ spray with tridemorph 50 WP and 3$^{rd}$ spray with difeconazole 25 EC also proved effective in combating downy mildew. Gupta and Jarial (2014) found the combination of metalaxyl and mancozeb effective against downy mildew while Anonymous (2004) reported mancozeb more effective than difenconazole 25 EC. Gisi (2002) have found strobilurins, carbamates, benzothiadiazoles, chlorothalonil and mancozeb

effective in reducing the downy mildew disease.

The mean anthracnose disease intensity in fungitoxicant treated plants ranged from 7.77 to 24.66 per cent as against 31.55 per cent in check. Among the fungitoxicant sets tested *viz*., pyraclostrobin + boscalid 38 WG followed by 2nd spray with captan + hexaconazole 75 WP and 3rd spray with metiram + pyraclostrobin 60 WG depicted least disease intensity. However, this spray set was at par with mancozeb 75 WP followed by 2nd spray with captan 50 WP and 3rd spray with dinocap 48 EC. The next set chlorothalonil 75 WP followed by 2nd spray with metalaxyl MZ 72 and 3rd spray with tebaconazole 25 EC was at par with above two sets. The findings are in agreement with Anesiadis (2003) who found that pyraclostrobin effectively controlled anthracnose as it possess preventive curative and eradicant properties in various crops. Zitter (1987) found the combination of chlorothalonil and mancozeb effective against anthracnose on watermelon. Sherf and Macnab (1986) and Gullino *et al.* (2010) also reported mancozeb, captan and chlorothalonil as effective fungitoxicant against anthracnose in cucumber. The other spray sets *viz.*, cymoxanil 50 WP followed by 2nd spray with tridemorph 50 WP and 3rd spray with difenconazole 25 EC; and tridemorph 50 WP followed by two sprays of *A. quisqualis* also proved effective in reducing anthracnose disease. However, three sprays of *A. quisqualis* did not show any significant control as compared to check.

The overall disease intensity of Alternaria leaf spot in fungitoxicant treated plants ranged from 6.22 to 24.00 per cent against 35.66 per cent in check. The fungitoxicant set pyraclostrobin + boscalid 38 WG followed by 2nd spray with captan + hexaconazole 75 WP and 3rd spray with metiram + pyraclostrobin 60 WG showed least disease intensity. This was at par with sparay set of chlorothalonil 75 WP followed by 2nd spray metalaxyl MZ 72 and 3rd spray with tebaconazole 25 EC. The results are in agreement with Wong and Wilcox (2002), Michailides *et al.* (2005), Pasche *et al.* (2005), Malandrakis *et al.* (2006), Bhattiprolu (2010) and Chattannavar *et al.* (2010) who reported captan +

hexaconazole 75 WP effective in controlling Alternaria leaf spot in cotton. Reuveni and Sheglov (2002) observed that pyraclostrobin effectively controlled the conidial germination of *A. alternata* in Red Delicious apple. Singh and Singh (2006) found hexaconazole followed by mancozeb and chlorothalonil very effective against Alternaria. In present study spray with mancozeb 75 WP followed by 2nd spray with captan 50 WP and 3rd spray with dinocap 48 EC; and cymoxanil 50 WP followed by 2nd spray with tridemorph 50 WP and 3rd spray with difeconazole 25 EC were also effective against leaf spot disease. Batta (2000) have reported the effectiveness of difenconazole against *A. alternata* in fig. In present study bioagent sprays alone or in combination with fungitoxicants were least effective. The leaf sopt diseases caused by *Alternaria* spp. have effectively been managed by fungitoxicant use (Surviliene *et al.,* 2006, Peres and Timmer, 2006; MacDonald *et al.,* 2007).

The overall disease intensity of powdery mildew in fungitoxicant treated plants varying from 9.77 to 20.66 per cent as compared to 24.33 recorded in check. Amongst fungitoxicant combinations sets, pyraclostrobin + boscalid 38 WG followed by 2nd spray with captan + hexaconazole 75 WP and 3rd spray with metiram + pyraclostrobin 60 WG proved best combination in minimizing the powdry mildew disease. The finding is in agreement with Margot *et al.* (1998), Hermann (1998), Reuveni (2000 a,b), Khunti *et al.* (2002) and Koehle *et al.* (2003) who reported hexaconazole as effective fungitoxicant against powdery mildew. In present study the spray set of mancozeb 75 WP followed by 2nd spray with captan 50 WP and 3rd spray with dinocap 48 EC; cymoxanil 50 WP followed by 2nd spray with tridemorph 50 WP and 3rd spray with difenconazole 25 EC; and dinocap 48 EC followed by 2nd spray with tridemorph 50 WP and 3rd spray with *A. quisqualis* proved significantly effective in suppressing the disease. Nagaraja and Naik (1998) have reported difenconazole as effective fungicide against powdery mildew of pea. Three sprays of *A. quisqualis* also gave significant disease control against check which is in agreement with Hashioka and Nakai

(1980), Sundheim and Krekling (1982) and Veerhar *et al.* (1996) who reported that *A. quisqualis* effectively control powdery mildew disease in cucumber.

In present study bioagent *Amplomyces quisqualis,* sprayed alone or in combination with fungitoxicants, was least effective against the diseases studied except powdery mildew. *A. quisqualis* is host specific and affects only powdery mildew fungi by parasitizing the fungal hyphae of pathogen. Similar observations have been reported by Hashioka and Nakai (1980), Sundheim and Krekling (1982), Flak *et al.* (1995) and Kiss *et al.* (2004) who observed *A. quisqualis* to be host specific which parasitizes only powdery mildew fungus.

**Chapter – 6**

# SUMMARY AND CONCLUSION

The investigations on prevalent major fungal diseases of cucumber in Kashmir were carried out during the year 2011 and 2012 and the results are summarized hereunder:

In Kashmir valley, downy mildew, anthracnose, Alternaria leaf spot and powdery mildew are the most prevalent prominent diseases afftecting cucumber production. Survey conducted in four districts of Kashmir during 2011 and 2012 revealed higher disease incidence and intensity in the year 2012 than in 2011. The overall mean disease incidence and intensity of downy mildew was 37.5 and 15.8 per cent, respectively, with highest incidence (51.5%) in district Srinagar and highest intensity (24.5%) in Baramulla and least incidence (23.5%) in Budgam and least intensity (10.4%) in Bandipora. The overall mean incidence and intensity of anthracnose was 41.0 and 18.5 per cent, respectively, with highest incidence (57.5%) in Srinagar and higher intensity (26.0%) in district Baramulla and least disease incidence (24.4%) and intensity (11.2%) in Budgam. The anthracnose disease incidence ranged from 14.6 to 62.6 per cent during 2011 and 18.6 to 76.6 per cent in 2012 while disease intensity varied from 6.0 to 29.7 per cent during 2011 and 8.1 to 35.4 per cent in 2012. The overall mean disease incidence and intensity of Alternaria leaf spot was 40.4 and 14.8 per cent, respectively, with highest mean disease incidence and intensity of 56.8 and 24.4 per cent in Srinagar and least incidence (24.5%) and intensity (10.4%) in Bandipora. The highest disease incidence (51.8%) and intensity (20.8%) of powdey mildew was in Srinagar and least incidence (23.6%) and intensity (10.2%) in Budgam.

Downy mildew disease symptoms appeared in the 2$^{nd}$ week of June as slightly chlorotic, water-soaked irregular spots on adaxial leaf surface, later turned bright yellow and became irregular to angular but restricted by veins. Grayish to

black cottony growth, developed on corresponding baxial leaf surface, indicated the presence of sporangia and sporangiophores. Affected leaves turned dark brown and caused death of entire leaf. In case of anthracnose, the disease was noticed in 2nd week of June as roughly circular slightly chlorotic pin-head spots. The spots turned light brown near veins and within two weeks became irregular and jagged with lesions attaining a size of 1.0 to 2.0 mm. The dark brown acervulli with black setae in them were seen in the 1st week of July. Later the center of lesions cracked and dropped out giving the leaf a shot hole appearance. Alternaria leaf spot was noticed in 3rd week of June as small light green flecks which later became grayish and circular spots of 0.4-0.9 mm size surrounded by yellow halo. In the 1st week of July, the irregular dark brown lesions of 1.0 to 1.75 cm size were formed. The affected leaves turned yellow, senescent and ultimately died. The powdery mildew appeared in the 3rd week of July as small chlorotic spots of 0.3-0.6 mm size on adaxial leaf surfaces. The spots later developed small powdery mildew patches. The fungus showed abrupt growth and in the last week of July white talcum-like mycelial mat and tan coloured patches developed to cover major portion of the leaf. The leaves curled and formed brown colour lesions which covered more than 75 per cent leaf area.

Downy mildew pathogen, *Pseudoperonospora cubensis,* formed hyaline, irregularly branched hyphae measured 4.8-6.4 µm in width. Sporangiophores produced singly or in small groups from stomata of infected host on abaxial surface were dichotomously branched and hyaline. Grayish sporangia borne singly on pointed tips of sporangiophores at acute angles were ovoid to ellipsoidal, thin walled with papilla at distal end and measured 22.4-38.4×12.8-25.6 µm in size. Zoospores were released from zoosporangium. Some sporangia directly produced germ tube. The light brown oospores of 38.4-44.8 µm size were spherical or globose, double walled and germinated by single germ tube. The cucumber anthracnose pathogen, *Colletotrichum arbiculare,* formed acervulli on infected leaves and no mycelia were observed on host. The mycelium on oat meal

agar showed sparse aerial growth and was hyaline, septate, branched, initially white and became grayish within 20 days. The hypha was 3.2-4.8 µm wide. The acervulli were salmon colour slightly raised and saucer shaped with hair-like 1-3 black setae. The Alternaria leaf spot pathogen, *Alternaria alternata* formed mycelium and conidia on adaxial leaf surface. The hyphae were hyaline to dark brown, smooth and branched. Conidiophores were short straight or flexuous in appearance, pale brown to olive. Conidia were ovoid, obclavate and ellipsoid having 1-8 transverse and several longitudinal cross walls with short conical, cylindrical club-shaped beak. Conidial germination was either apical or lateral. The powdery mildew pathogen, *Sphearotheca fuliginea* was observed as white to gray and fluffy to sparse mycelial growth on adaxial leaf surface. The hyphae were thin walled and septate Conidiophores were erect and aerial. Conidia were hyaline, borne singly or in chains, basipetal, ellipsoid to ovoid, one-celled with well developed fibrosin bodies.

The downy mildew pathogen perpetuated winter on fallen diseased leaves lying on field in the form of oospores. The diseased leaves on ground surface exhibited maximum oospore production ($4.8 \times 10^3$) during the 1st week of March but viability was maximum in 1st week of April. The anthracnose pathogen perpetuated on over-wintered diseased leaves. The diseased leaves placed on ground surface exihibited maximum spores ($3.0 \times 10^6$) in the 1st fortnight of May but viability was maximum in 2nd fortnight of May. The Alternaria leaf spot pathogen perpetuated on over-wintered diseased leaves. The conidial production was maximum ($2.7 \times 10^4$) in the 2nd fortnight of May but conidial viability was maximum (92.3%) in 2nd week of June. The powdery mildew pathogen was not able to perpetuate throughout winter on diseased leaves. The diseased leaves placed on soil surface showed maximum conidial production ($0.3 \times 10^4$) in 2nd fortnight of March. The conidial viability decreased with time with highest conidial viability of 15.0 per cent observed on the leaves kept on ground in the 2nd fortnight of March. After March no conidial production was seen.

Of the 20 cucumber cultivars screened against downy mildew only three cultivars 'Hybrid-5', 'Pusa Sanyug' and 'Priya' were tolerant while two cultivars '10/cucu Hybrid-4' and 'Sweet Delight' were moderately tolerant and rest either moderately susceptible, susceptible or highly susceptible. Cultivars 'Hybrid-5', 'Pusa Sanyug' and 'Priya' were tolerant to anthracnose while cultivars 'Swarna Ageta', '10/cucu Hybrid-4', 'S-6 (m)', 'Green Express and 'Hermophrodite' were moderately tolerant. 'Pusa Sanyug', 'Green Express' and 'Marketer-76' were tolerant to Alternaria leaf spot while 'Sweet Delight', 'CH-20', 'Priya', 'Hybrid-5', 'S-5(m)' and 'Poinsette' were moderately tolerant.Cultivars 'Hybrid-5', 'Pusa Sanyug' and 'AAUC-1' were tolerant to powdery mildew while 'Sweet Delight', 'S-6(m)', '10/cucu Hybrid-4', 'Pusa Sanyug' and 'Hermophrodite' were moderately tolerant. On overall ranking basis against multiple foliar disease reactions, the cultivars 'Priya', 'Hybrid-5' and 'Pusa Sanyug' were found tolerant to most of the major foliar diseases followed by 'Sweet Delight', '10/cucu Hybrid-4' and 'Green Express'.

SAR sprays at different crop growth stages revealed INA, BABA and BTH to be the most effective SAR activators. Generally all the test SAR activators proved significantly effective in minimizing all the four foliar diseases. In case of powdery mildew the most effective SAR activator was $NaHCO_3$ followed by INA in 1$^{st}$ treatment, but in 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ treatment BTH was followed by $NaHCO_3$ and $KHCO_3$ respectively

Thirteen fungitoxicants and a biocontrol agent were evaluated at recommended doses in different combination under field conditions as three spray schedule against multiple diseases in cucumber. All the test combinations, except *Amplomyces quisqualis*, proved effective in minimizing most of the foliar diseases. *A. quisqualis* was effective only against powdery mildew. Among the fungitoxicant sets tested pyraclostrobin + boscalid 38 WG followed by 2$^{nd}$ spray with captan + hexaconazole 75 WP and 3$^{rd}$ spray with metiram + pyraclostrobin 60 WG proved significantly superior over other biocides in reducing all the major diseases *viz.*, downy mildew, anthracnose, Alternaria leaf spot and powdery

mildew with 7.11, 7.77, 6.22 and 9.77 per cent disease intensity against their checks 39.88, 31.55, 35.66 and 24.33 per cent, respectively. Chlorothalonil 75 WP followed by 2nd spray of metalaxyl MZ 72 and 3rd spray of tebaconazole 25 EC was 2nd best toxicant against downy mildew and Alternaria leaf spot with 9.33 and 8.00 per cent disease intensity. However, mancozeb 75 WP followed by 2nd spray with captan 50 WP and 3rd spray with dinocap 48 EC proved 2nd best treatment combination against anthracnose and powdery mildew with 9.66 and 11.61 per cent disease intensity. In light of the present investigations, it is deduced that:

- Downy mildew, anthracnose, Alternaria leaf spot and powdery mildew are major` foliar fungal diseases of cucumber in cucumber growing areas of Kashmir valley.
- The causal pathogens for downy mildew, anthracnose, Alternaria leaf spot and powdery mildew were identified as *Pseudoperonospora cubensis, Colletotrichum arbiculare, Alternaria alternata* and *Sphaerotheca fuliginea*, repsectively.
- The downy mildew pathogen pertetuated on diseased leaves as oospores whereas anthracnose perpetuated as acervulli and conidia, Alternaria leaf spot pathogen as conidia. However, powdery mildew fungi perpetuated as conidia only upto 2nd fortnight of March and may perpetuate on some collateral hosts.
- Natural resistance of varying degree was observed in the germplasm tested under Kashmir conditions. Cultivars ‘Pusa Sanyug’, ‘Hybrid-5’ and ‘Priya’ were tolerant to the most of these foliar diseases.
- SAR chemicals, especially BABA, INA and BTH, significantly lowered all the major foliar fungal diseases.
- The multiple foliar fungal diseases in cucumber can effectively be managed by three foliar sparys of pyraclostrobin + boscalid 38 WG, followed 2nd spray of captan + hexaconazole 75 WP and 3rd spary of metiram + pyraclostrobin 60 WG. The 1st spray should be done on 15th June and repeat after 20 days.

# LITERATURE CITED


Abul-Hayja, Z., Williams, P.H. and Peterson, C.E. 1978.Inheritance of resistance to anthracnose and target leaf spot in cucumbers. *Plant Disease Reporter* **62**: 43-45.

Ackermann, P. 1990. Occurrence and protection against cucurbit downy mildew in Czechoslovakia. **In** : *Cucurbit downy mildew* (Eds. A. Lebeda) Czechoslovak Scientific Society for Mycology by Czechoslovak Academy of Sciences, pp.51-61.

Adinarayana, M., MahaLakshmi, M.S. and Koteswara, R. 2013. Field efficacy of new fungicide, Taqat 75 WP against foliar fungal diseases of Blackgram.*Journal of Biopesticides* **6**(1): 46-48.

Agrios, G.N. 2005. *Plant Pathology.* 5th Edition, Elsevier Academic Press, USA, pp 903.

Akram, M. and Khan, A.M. 1978. Studies on the cucurbit powdery mildew vs. varietal screening of some cultivated cucurbits to *S. fuliginea. Indian Phytopathology* **30**(1) : 121-123.

Akram, M. and Khan, A. M. 1985. Host range studies of *Sphaerotheca fuliginea* (Schlect) Poll. II. *Journal of the Indian Botanical Society* **64**(4) : 388-387.

Albert, G., Gurzet, J. and Drandarevski, C.A. 1987. Dimethomorph (CME 151), a noval curative fungicide. *Proceedings of Crop Protection and Pest Disease,* pp 17-24.

Ammermann, E., Lorenz, G., Schelberger, K., Mueller, B., Kirstgen, R. and Sauter, H. 2000. BAS 500 F the new broad-spectrum strobilurin fungicide. **In** : *Proceedings of the BCPC Conference on Pests and Diseases*, BCPC, Farnham, Surrey, UK, **2** : 541-548.

Anesiadis, T., Karaoglanidis, G.S. and Tzav-ella-Klonary, K. 2003. Protective, curative and erradicant activity of the strobilurin fungicide azoxystrobin against *Cercospora beticola* and *Erysiphe betae*. *Journal of Phytopathology* **151** : 647-651.

Angelov, D. 1994. Inheritance of resistance to downy mildew, *Pseudoperonospora cubensis* (Berk. & Curt.) Rostow Rep. 2nd Natl. Symp.*Plant Immunity* **3**: 99-105.

Angelov, D., Georgiev, P. and Krasteva, L. 2000. Two races of *Pseudoperonospora cubensis* on cucumbers in Bulgaria. pp 81-83. **In** : *Proceedings of Cucurbitaceae* (Eds. N., Katzir and H.S., Paris). ISHS Press, Maale Ha Hamisha, Israel.

Anonymous, 1998. Kaligreen, potassium bicarbonate soluble powder for control of powdery mildew. Toagosei co. Ltd. l-14-1, Nishi Shimbashi, Minato-ku Tokyo 105-8419, Japan.

Anonymous, 1998a. Production Year Book. FAO, Rome, Italy **52** : 130.

Anonymous, 2004. Annual Report (2003-2004), Ayub Agriculture Research Institute, Faisalabad : 177-178.

Anonymous, 2007. Powdery Mildews. Central Science Laboratory, Sand Hutton York. www.csl.gov.uk.

Anonymous. 2014. Agricultural Research Data Book. Indian Agricultural statistics Research Institute. Library Avenue, Pusa New Delhi. Pp266.

*Arx, J.A. von 1957. Die Arten der Gattung *Colletotrichum* Cda. *Phytopathologische Zeits-chrift* **29**: 413-468.

Avenot, H., Morgan, D.P. and Michailides, T.J. 2008. Resistance to pyraclostrobin, boscalid and multiple resistance to Pristine (pyraclostrobin + boscalid) fungicide in *Alternaria alternata* causing alternaria late blight of pistachios in California. *Plant Pathology* **57**: 135-140.

Avenot, H., Sellam, A. and Michailides, T.J. 2009. Characterization of mutations in the membrane-anchored subunits AaSDHC and AaSDHD of succinate dehydrogenase from *Alternaria alternata* isolates conferring field resistance to the fungicide boscalid. *Plant Pathology* **58**: 1134 -1143.

Babadoost, M. 1989. Alternaria leaf spot or Blight of cucurbits. **In** : *Plant Disease Reporter University of Illinois Extension Service*. p. 1.

Bains, S.S. and Sharma, N.K. 1986. Differential response of certain cucurbits to isolates of *Pseudoperonospora cubensis* and characteristics of identified races. *Phytophylactica* **18**: 31-33.

Bains, S.S. and Singh, H.1996. Occurrence of *Alternaria alternata* in downy mildew lesions of cucurbits.*Indian Journal of Mycology and Pathology* **26**(1):92-93.

Bains, S.S., Sokhi, S.S. and Jhooty, J.S. 1977. *Melothria maderaspatona.* A new host of *Pseudoperonospora cubensis*.*Journal of Mycology and Plant Pathology* **7**: 86.

Balai, L.P. and Ahir, R.R. 2013. Role of temperature and relative humidity on mycelial growth of *Alternaria alternata* infecting brinjal. *Trends in Biosciences* **6**: 307-308.

Barnes, W.C. 1961. Multiple disease resistance in cucumber. *Proceedings of American Society of Horticulture* **77**: 419-423.

Barnes, W.C. and Epps, W.M. 1952. Two types of the anthracnose resistance in cucumbers.*Plant Disease Reporter* **36**: 479-480.

Batta, Y.A. 2000. Alternaria leaf disease on fig trees : varietal susceptibility and effect of some fungicides and *Trichoderma*. *The Islamic University Journal* **8**(2) : 83-97.

Baxter, A.P., Westhuizen, von der G.C.V. and Eicher, A. 1983. Morphology and taxonomy of South African isolations of Colletotrichum. *South African Journal of Botany* **2**: 259-289.

Bayoumi, Y.A. and Hafez, Y.M. 2006. Effect of organic fertilizers combined with benzo (1, 2, 3) thiadiazole-7-carbothioic acid S-methyl ester (BTH) on the cucumber powdery mildew and the yield production. *Acta Biologica Szegediensis* **50**(3-4): 131-136.

Bedlan, G. 1989. First detection of oospores of *Pseudoperonospora cubensis* (Berk et Curt.) Rost.on glasshouse cucumbers in Austria. *Pflantzenschutzber-ichte* **50**: 119-120.

Bergstrom, G.C. and Nicholson, R.L. 1999. The biology of corn anthracnose: Knowledge to exploit for improved management. *Plant Disease* **83**: 596-608.

Berkeley, M.S. and Curtis, A. 1868. *Peronospora cubensis*. J. Linn. *Social Botany* **10** : 363.

Bhattiprolu, S.L. 2010. Efficacy of Taqat against fungal leaf spot diseases of cotton. *Journal of Cotton Research Development* **24**(2): 243-244.

Biradar, S.V. 2002. Studies on *Colletotrichum gloeosporioides* (Penz.)Penz & Sacc., *Botryodiplodia theobromae* Pat.and*Fusarium semitectum* Berk. and

Rav. causing fruit rot of custard apple (*Annona squamosa* L.). M.Sc. (Agri.) Thesis, Unvi. Agric. Sci., Dharwad (India).

Bishnoi, U.R. and Payyavula, R.S. 2003. Effect of plant activators on disease and yield in tomato and canola. *Plant Disease* **87**:234-237.

Bokshi, A.I., Morris, S.C., McDonald, K. and McConchie, R.M. 2005. Application of INA and BABA control pre and postharvest diseases of melons through induction of systemic acquired resistance. *Acta Horticulturae* **694** : 417- 419.

Bolay, 2005. The powdery mildews from Switzerland (Erysiphaceae) Cryptogam *Helv.* **20**: 1-176.

Boyadzhiev, K.H., Angelo, D. and Vitanov, N. 1983. Chemical control trial against downy mildew, *Perenospora destructor* Berk. *Review of Plant Pathology* **62**: 325.

Bradeen, J.M., Staub, J.E., Wye, C., Antonise, R. and Peleman, J. 2001. Toward an expanded and integrated linkage map of cucumber (*Cucumis sativus* L.).*Genome* **44**: 111-119.

Braun, U. 1987. A monograph of the Erysiphales (powdery mildews). *Beih. Nova Hedwigia* **89** : 1-700.

Braun, U., Cook, R.T.A., Inman, A.J. and Shin, H.D. 2002.The taxonomy of the powdery mildew fungi. **In** : *The powdery mildews: a comprehensive treatise* (Eds. R.R., Bélanger, W.R., Bushnell, A.J., Dik and T.L., Carver), pp. 13-55. St. Paul: APS.

Brock, P.M., Inwood, J.R.B. and Deverall, B.J. 1994. Systemic induced resistance to *Alternaria macrospora* in cotton (*Gossypium hirsutum*). *Australasian Plant Pathology* **23** : 81-85.

Buonaurio, R., Scarponis, L., Ferrara, M., Sidott, P. and Bertona, A. 2002. Induction of systemic acquired resistance in pepper plants by acibenzolar-S. methyl against bacterial spot disease. *European Journal of Plant Pathology* **108** : 41-49.

Bush, L.V. and Walker, J.C. 1958. Studies on cucumber anthracnose. *Phytopathology* **48** : 302-304.

CABI. 2014. *Colletotrichum orbiculare* datasheet report. Crop Protection Compendium.www.cabi.org/cpc/

Call, A.D. and T.C. Wehner. 2010. Search for resistance to the new race of downy mildew in cucumber, *Cucurbitaceae* 2010 Proceeding. ASHS Press, Alexandria,VA. p. 112-115.

Cano, J., Guarro, J. and Gene, J. 2004. Molecular and morphological identification of *Colletotrichum* species of clinical interest. *Journal of Clinical Microbiology* **42**(6) : 2450-2454.

Caruso, F.L. and Kuc, J. 1979. Induced resistance of cucumber to anthracnose and angular leaf spot by *Pseudomonas lachrymans* and *Colletotrichum lagenarium. Physiology and Plant Pathology* **14**:191-201.

Casela, C.R. and Frederiksen, R.A. 1993. Survival of *Colletotrichum graminicola* Sclerotia in sorghum stalk residues. *Plant Disease***77** : 825-827.

Cavatorta, J., Moriarty, G., Henning, M., Glos, M., Kreitinger, M. and Munger, H.M. 2007. Marketmore 97': A Monoecious Slicing Cucumber Inbred with Multiple Disease and Insect Resistances. *Hortscience* **42**(3): 707-709.

Chattannavar, S.N., Hosagoudar, G.N. and Ashtaputre, S.A. 2010. Chemical and biological management of major foliar diseases of cotton. *Karnataka Journal of Agricultural Sciences***23**(4): 599-601.

Chaudhry, S.U., Iqbal, J. and Mustafa, A. 2009. Efficacy of different fungicides for the control of downy mildew. *The Journal of Animal and Plant Science* **19**(4) : 202-204.

Choi, Y.J., Hong, S.B. and Shin, H.D. 2005. A re-consideration of *Pseudoperonospora cubensis* and *P. humuli* based on molecular and morphological data. *Mycological Research* **109** : 841-848.

Chupp, C. and Sherf, A.F. 1960. Vegetable diseases and their control.The Ronald Press Company, New York, USA. pp 267-269.

Cohen, Y. and Rotem, J. 1971. Field and growth chamber approach to epidemiology of *Pseudoperonospora cubensis* on cucumbers. *Phytopathology* **61** : 736-737.

Cohen, Y. 1977. The combined effects of temperature, leaf wetness and inoculum concentration on infection of cucumbers with *Pseudoperonospora cubensis*. *Canadian Journal of Botany* **55** : 1478-1487.

Cohen, Y. 1981. Downy mildew of cucurbits. **In** :*The Downy Mildews* (Ed. Spencer, D.M.), pp. 341-354. London: Academic Press.

Cohen, Y. 2002. β-aminobutyric acid-induced resistance against plant pathogens. *Plant Disease* **86** : 448- 457.

Cohen, Y., Meron, I., Mor, N. and Zuriel, S. 2003. A new pathotype of *Pseudoperonospora cubensis* causing downy mildew in cucurbits in Israel. *Phytoparasitica* **31** : 458-466.

Colucci, S.J. and Holmes, G.J. 2010. Downy Mildew of Cucurbits. *The Plant Health Instructor*.The American Phytopathological Society. DOI: 10.1094/PHI-I-2010-0825-01.

Conti, G.G., Pianezzola, A., Arnold, A., Volinie, G. and Moffi, D. 1996. Possible involvement of salicylic acid in systemic acquired resistance of C*ucumis sativus* against *S. fuliginea. European Journal of Plant Pathology* **102**(6) : 537-544.

*Corda, A.C.I. 1831. *Die Pilze Deutschlands* (ed. J. Sturm). Deutschlands Flora, 3. Abtheilung **3**: 1-144.

Cosme, B.R., Josefina, L.F., Raúl, A.M., María, M. R., Dolores, Armando, C.F.J José Benigno, V.T. Sary Mell, L.S.F. and Raymundo Saúl, G.E. 2012. Characterization of powdery mildew in cucumber plants under greenhouse conditions in the Culiacan Valley, Sinaloa, Mexico. *African Journal of Agricultural Research* **7(**21) : 3237-3248.

Crouch, J.A. and Beirn, L.A. 2009. Anthracnose of cereals and grasses. *Fungal Diversity* **39**: 19-44.

Crump, A. 2009. Anthracnose.Integrated pest management program. University of California State-wide Integrated Pest Management Program Agriculture and Natural Resources in South Australia and New South Wales. *Australian Plant Pathology* **18**: 35-37.

*D'Ercole, N. 1975. La peronoospora del cetriolo in coltura protetta. *Inf. Fitopathol.* **25**:11-13.

Damm, U., Cannon, P.E., Liu, F., Barreto, A.W., Gautimsim, E. and Crous, P.W 2013. The *Colletotrichum arbiculare* species complex: Important pathogens of field crops and weeds. *Fungal Diversity* **61**:29-59.

Davidse, L.C. 1986. Benzimidazoles, fungicides mechanism of action and biological impact.*Annual Review of Phytopathology* **24** : 43-65.

Day, B. and Hausbeck, M. 2009. Epidemiology of downy mildew : a regional and molecular approach. *Phytopathology* **99** : 172.

Dean, R., VanKan, J., Pretorius, Z. A and Hammod, K. E. 2012. The Top 10 fungal pathogens in molecular plant pathology. *Molecular Plant Pathology*, pp 414-430.

DeWaard, A., Georgopoulos, S.G., Hollomon, D.W., Ishii, H., Leroux, P., Ragsdale, N.N. and Schwinn, F.J. 1993. Chemical control of plant diseases: problems and prospects. *AnnualReview of Phytopathology* **31** : 403-423.

Del Pino, D., Olalla, L., Pérez-García, A., Rivera, M.E., García, S., Moreno, R., de Vicente, A. and Torés, J.A. 2002. Occurrence of races and pathotypes of cucurbit powdery mildew in southeastern Spain. *Phytoparasitica* **30** : 1-8.

Delahaut, K. and Stevenson, W. 2004. Vine crop disorder : Anthracnose. Cooperative Extension Publishing.www.cecommerce.uwex.edu. p.2.

Descalzo, R.C., Rahe, J.E. and Mauza, B. 1990.Comparative efficacy of induced resistance for selected diseases of greenhouse cucumber.*Canadian Journal of Plant Pathology* **12** : 16-24.

Doijode, S.D. 2001. *Seed storage of horticultural crops*. Haworth Press. ISBN 1-56022-901-2 pp. 281.

Dubey and Patel, 2000. Mode of perpetuation and spread of Alternaria Blight of Broad bean. *Indian Phytopathology* **53**(2) : 175-177.

Eastburn, D.M. and Ribbing, L.D. 1999. Powdery mildew of Cucurbits.Department of Crop Sciences, University of Illinois at Urbana, 1-2 pp.

Egel, D.S. 2014. Vegetable diseases: Anthracnose of cucumber, muskmelon, and watermelon. Purdue Extension BP-180-W, Purdue University. https://www.extension.purdue.edu/

El-Gamal, N.G. 2003.Usage of some biotic and abiotic agents for induction of resistance to cucumber powdery mildew under plastic house conditions. *Egyptian Journal of Phytopathology* **31** : 129-140.

Ellis, M.B. and Holiday, P. 1970. Description of pathogenic fungi and bacteria: Alternaria.*Cucurbit Genetics Cooperative Report* **12** : 1-4.

Ellis, M.B. 1971. Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew, Surrey, England, 464-497 pp.

Ellis, M.B. 1976. More Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew, Surrey, England, pp.411-427.

El-Naggar, M.A., El-Deeb, H.M. and Ragab, S. 2012. Applied Approach for controlling powdery mildew disease of cucumber under plastic Houses. *Pakistan Journal of Agriculture Engineering and Veterinary Science* **28**(1) : 54-64.

Emmons, C.W. 1930. *Cicinobolus casatii*, A case study in host parasite relationships. *Bulletin Torrey Botany Club* **57** : 421-441.

Fallik, E.S., Grinberg, and Ziv, O. 1996. Potassium bicarbonate reduces postharvest decaydevelopment on bell pepper fruits. *Journal of Horticulture Science* **71** : 21-127.

FAOSTAT 2006. Available at:http://www.faostat.fao.org.

FAOSTAT, 2013. Area and production of cucumber and Gherkhins. http://faostat3.fao.org/download/Q/QC/E.

Farr, D.F and Rossman, A.Y. 2013. Fungal databases, systematic mycology and microbiology laboratory, ARS, USDA. http://nt.ars.grin.gov/fungal databases.

Farr, D.F., Bills, G.F., Chamuris, G.P. and Rossman, A.Y. 1989. Fungi on plants and plant products in the United States. St. Paul, Minnesota, USA: APS Press, 1252 pp.

Ferreira, A.S. and Warren, H.L. 1982. Resistance of sorghum to *Colletotrichum graminicola. Plant Disease* **66**: 773-775.

Fazio, G., Staub, J.E., and Stevens, M.R. 2003.Genetic mapping and QTL analysis of horticultural traits in cucumber (*Cucumis sativus* L.) using recombinant inbred lines. *Theoretical and Applied Genetics* **107** : 864-874.

Flak, S.P., Gadoury, D.M., Pearson, R.C. and Seem, R.C. 1995. Partial control of grape powdery mildew by the mycoparasite *A. quisqualis*. *Plant Disease* **79** : 483-490.

Friedrich, L., Lawton, K., Ruess, W., Masner, P. and Specker, N. 1996. A benzothiadiazole derivate induces systemic acquired resistance in tobacco. *Plant Journal* **10**: 61-70.

Fujiwara, K., Fujii, T. and Park, J.S. 2009. Comparison of foliar spray efficacy of electrolytically ozonated water and acidic electrolyzed oxidizing water for controlling powdery mildew infection on cucumber leaves. *Ozone: Science and Engineering* **31** : 10-14.

Gaikward, A.P. and Karkeli, M.S. 1994. Control of Downy mildew of cucurbits with new fungicides.*Journal of Maharashtra Agricultural University* **19**(3) : 445-446.

Garibaldi, A., Gilardi, G. and Gullino, M.L. 2007.First report of Alternaria leaf spot on Camellia in Italy.*Plant Disease* **91** : 324.

*Ghebretinsae, A.G., Thulin, M. and Barber, J.C. 2007. Nomenclatural changes in *Cucumis* (Cucurbitaceae). *Novon* **17** : 176-178.

Gisi, U. 2002. Chemical control of downy mildews. **In**: *Advances in downy mildew research* (Eds. P.T.N., Spencer-Phillips, U., Gisiand A., Lebeda), Dordrecht, Kluwer Academic Publishers **1** : 119-159.

Glynn, C.P. 2001. Induction of systemic acquired disease resistance in plants: potential implications for disease management in urban forestry. *Journal of Arboriculture* **27**: 181-192.

Godard, J.P., Ziadi, S., Monot, C., Le Corre, D. and Silue, D. 1999. Benzothiadiazole (BTH) induces resistance in cauliflower (*Brassica oleracea* var. *botrytis*) to downy mildew of crucifers caused by *Peronospora parasitica*. *Crop Protection* **18** : 397-405.

Goldberg, N.P. 2004. *Anthracnose of Cucurbits*. Cooperative Extension. College of Agriculture and Home Economics.www.cahe.nmsu.edu .p 2.

Gomez, K.A and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. Second Edition A Wiley- Inter Science Publication, John Wiley and Sons, Inc. New York, pp. 680.

Gottstein, H.D. and Kuc, J. 1989. Induction of systemic resistance to anthracnose in cucumber by phosphates. *Phytopathology* **79** : 176-179.

Gozzo, F. 2003. Systemic acquired resistance in crop protection: from nature to a chemical approach. *Journal of Agriculture and Food Chemistry* **51** : 4487-4503.

Grand, L.F. 1978. Perithecia of *S. fuliginea* on cucurbits in North Carolina. *Mycologia* **79** :484-486.

Groves, J.W. and Skolko, A.J. 1944. Notes on seed-borne fungi; II. Alternaria. *Canadian Journalof Botany* **22** : 219-234.

Grunden, E., Chen, W.D. and Crane, J.L. 2001. Fungi colonizing microsclerotia of *Verticillium dahliae* in urban environments. *Fungal Diversity* **8**: 129-141.

Gullino, M.L., Tinivella, F., Garibaldi, A., Gregory, M., Kemmitt, G.M., Bacci, M. and Sheppard, B. 2010. Mancozeb Past, Present, and Future. The American Phytopathological Society. *Plant Disease* **94**(9) : 1176-1087

Gupta, S., Upadhyay, R.N., Kumar, S. and Razdan, V.K. 2014. Integrated disease management module for management of downy mildew of cucumber. *Indian Phytopath*ology **67**(3) : 268-273.

Gupta, S.K., Shyam, K.R. and Dohroo, N.P. 1993. Effect of fungicides on severity of downy mildew and yield of cucumber (*Cucumis sativus* L) in Himachal Pradesh. *Pestology* **17**(3) : 37-39.

Gupta, S.K. and Shyam, K.R. 1998. Protective activity of fungicides against downy mildew of cucumber.*Plant Disease Research* **13**(1) : 60-61.

Gupta, S.K. and Jarial, K. 2014. Efficacy of some fungicides against downy mildew of cucumber. *International Journal of Farm Sciences* **4**(1) :72-75.

Hafez, Y.M., Fodor, J. and Király, Z. 2004. Establishment of systemic acquired resistance confers reduced levels of superoxide and hydrogen peroxide in TMV-infected tobacco leaves. *Acta Phytopathology Entomology Hungry* **39**: 347-359.

Hajlaoui, M.R. and Bélanger, R.R. 1991. Comparative effects of temperature and humidity on the activity of three potential antagonists of rose powdery mildew. *Netherland Journal of Plant Pathology* **97** : 203-208.

Hamiduzzaman, H.H., Jakab, G.L., Barnavon, J.M., Neuhaus and Mauch-Mani, B. 2005. "β-aminobutyric acid (BABA)-induced resistance against downy mildew in grapevine acts through the potentiation of callose formation and JA signaling". *Molecular Plant-Microbe Interaction* **18** : 819-829.

Hansen, M.A. 2009. Downy Mildew of Cucurbits. Extension Plant Pathologist, Department of Plant Pathology, Virginia Polytechnic Institute and State University, USA. www.ext.vt.edu.

Harfoush, D.I. and Salama, D.A. 1992. Induction of systemic resistance to powdery mildew in cucumber leaves by seed soaking application with cobalt. *Annual Agricultural Science Mansoura University* **17** : 3555-3565.

Hashioka, Y. and Nakai, Y. 1980. Ultrastructure of pycnidial development and mycoparasitism of *Amplomyces quisqualis* parasitic on *Erisiphales. Transaction of the Mycological Society of Japan* **21** : 329-338.

Hashmi, A.A. 1994. *Horticultural Insect Pest Management of Vegetables.* National Book Foundation of Pakistan, Islamabad. p. 633.

Hegazi, M.A. and El-Kot, G.A. 2008. Biological control of powdery mildew on zinnia (*Zinnia elegans* L.) using some biocontrol agents and plant extracts. *Journal of Agricultural Science* **2** : 221-230.

Hermann, D., Fischer, W., Knauf-Beites, G., Steinemann, A., Margot, P., Gisi, U. and Laird, D. 1998. Behavior of the new strobilurin fungicide trifloxystrobin on and in plants.*Phytopathology* **88** : 37 (Abstr.)

Herms, S., Seehaus, K., Koehle, H. and Conrath, U. 2002. A strobilurin fungicide enhances the resistance of tobaccoagainst tobacco mosaic virus and *Pseudomonas syringae*pv*tabaci*. *Plant Physiology* **130**: 120-27.

Hirata, K. 1955. On the shape of germ tubes of Erysipheae (II). *Bulletin ofAgriculture, Niigata University* **7** : 24-36.

Hofstetter and Bob. 1993. Homemade pesticides. *The New Farm*.pp 14-16. www.attar.ncat.org.

Holmes, G.J. and Ojiambo, P. 2009. Chemical control of cucurbit downy mildew: a summary of field experiments in the U.S. *Phytopathology* **99** :171.

Holmes, G.J. and Thomas, C. 2009. The history and re-emergence of cucurbit downy mildew.*Phytopathology* **99** : 1-17.

Holmes, G.J., Main, C.E. and Keever, Z.T. III. 2004. Cucurbit downy mildew: a unique pathosystem for disease forecasting. **In**: *Advances in Downy Mildew Research* (Eds. P.T.N. Spencer-Phillips and M. Jeger). Kluwer Academic Publishers, Dordrecht **2** : 69-80.

Homma, Y., Arimoto and Misato, Y.T. 1981. Effect of sodium bicarbonate on each growth stage of cucumber powdery mildew fungus (*Sphaerotheca fuliginea*) in its life cycle. *Journal of Pesticide Science*, pp. 201-209.

Hongmin, R., Wang, Y., Wei, J. and Cao, K. 2009. Establishment and application of bioassay method for screening fungicides against cucumber powdery mildew. *Frontiers of Agriculture in China* **3**(4):425-430.

Horejsi, T., Box, J.M. and Staub, J.E. 1999. Efficiency of randomly amplified polymorphic DNA to sequence characterized amplified region marker conversion and their comparative polymerase chain reaction sensitivity in cucumber. *Journal of the American Society for Horticultural Science* **124** : 128-135.

Huang, Y., Deverall, Tang, W.H. and Wu, F.W. 2000. Foliar application of acibenzolar S methyl and protection of post harvest rock melons from disease. *European Journal of Plant Pathology* **106** :651-656.

Huang, S., Li, R., Zhang, Z., Li, L., Gu, X., Fan, W., Lucas, W.J. and Wang, W. 2009. The genome of the cucumber, *Cucumis sativus* L. *Nature Genetics* **41**: 1275-1281.

Hubballi, M., Nakkeeran, S., Raguchander, T., Ananad, T. and Samiyappam, R. 2010.Effect of environmental conditions on growth of *Alternaria alternata* causing leaf blight of onion. *World Journal of Agricultural Sciences* **6**: 171-177.

Humpherson, J.F.M. and Phelps, K. 1989. Climatic factors influencing spore production in *Alternaria brassicae* and *Alternaria brassicicola*. *Annual Applied Biology* **114** : 449-458.

Hyde, K.D., Cai, L., Cannon, P.F., Crouch, J.A., Crous, P.W and Damm, U. 2009. *Colletotrichum* – names in current use. *Fungal Diversity* **39**: 147-183.

Inaba, T.T., Morinaka and Hamaya, E. 1986. Physiological races of *Pseudoperonospora cubensis* isolated from cucumber and musk-melon in

Japan. *Bulletin of National Institute of Agro-Environmental Science* **2**: 35-43.

Inbar, M., Doostdar, H., Sonoda, R.M., Leibee, G.L. and Mayer, R.T. 1998. Elicitors of plant defensive system reduce insect densities and disease incidents. *Journal of Chemical Ecology* **24** : 135-149.

Iwata, Y. 1941. Specialisation in *Pseudoperonospora cubensis* (Berk. and Curt.) Rostow. I. Comparative studies on the pathogenicities on the fungi from *Cucumis sativus* L. and Cucurbita moschata Duch. *Annales of Phytopathological Society of Japan* **11** : 101-113.

Jakab, G., Cottier, V., Toquin, V.G., Rigoli, G.L., Zimmerli, J.P., Metraux and Mauch-Mani, B. 2001. Aminobutyric acid-induced resistance in plants. *European Journal of Plant Pathology* **107** : 29-37.

Janisiewicz, W.J. and Peterson, D.L. 2005. Experimental bin drenching system for testing biocontrol agents to control post harvest decay of apples. *Plant Disease* **89** : 487-490.

Janke, C., Petre, C. and Helling, A. 1977. On the occurrence of the mildew genere *Erysiphae* and *Sphaerotheca* on cucumber in the German Democratic Republic. *German Democratic Republic* **13**(4) : 263-269.

Jarvis, W.R. and Slingsby, K. 1977. The control of powdery mildew of greenhouse cucumber by water spray and *Amplomyces quisqualis. Plant Disease Reporter* **61** : 728-730.

Jenkins, S.F. and Winstead, N.N. 1962. Morphology, taxonomy and sexuality of the ascogenous stages of two *Colletotrichum* spp. that attack cucurbits.*Phytopathology* **52** : 15.

Johnston, A. and Booth, C. 1983. *Plant Pathologist's Pocket Book*. Commonwealth Mycological Institute Kew, Surrey England pp 439.

Jones, J.P. 1978. Disease threshold for many downy mildew and target leaf spot of cucurbits and late blight of tomato. *Plant Disease Reporter* **62** : 689-802.

Kalloo, G. 1997. Proceedings of the 16th Group Meeting on Vegetable Research (lCAR) held at TNAU, Coimbatore pp. 111-112.

Kanetis, L., Holmes, G.J. and Ojiambo, P.S. 2009. Survival of *Pseudoperonosporacubensis* sporangia exposed to solar radiation. *Plant Pathology* **59** : 313-323.

Karabulut, O.A., Bursa, G. and Mansour, M. 2003. Near-harvest applications of *metschnikowia fructicola,* ethanol, and sodium bicarbonate to control post harvest diseases of grape in Central California. *Plant Disease* **87** : 1384-1389.

Kareem, A.E.F. 2007. Potassium or sodium bicarbonates in combination with Nerol for controlling early blight disease of potato plants under laboratory, greenhouse and field conditions. *Egypt Journal Phytopathol*ogy **35**: 73- 86.

Karem, F.A., Kader, M.M., Fotouh, Y.O., Abd-Alla, M.A., El-Mougy, N.S., El-Mohamedy, R.S. and El-Gama, N.G. 2013. Induction of Systemic Resistance in faba bean against chocolate spot diseases severity using chemical inducers under field conditions. *Journal of Applied Sciences Research* **9**(6) : 4006-4014.

Katiyar, A., Kant, S., Chauhan, S.S.and Alka, S. 2001. Chemical control of Alternaria leaf spot of bottle gourd. *Annual Plant Protection Science* **9**(2): 339-341.

Keinath, A.P and DuBose, V.B. 2004. Evaluation of fungicides for prevention and management of powdery mildew on watermelon. *Crop Protection* 23-35.

Keinath, A.P., Holmes, G.J., Everts, K.L., Egel, D.S. and Langston, D.B. 2007. Evaluation of combinations of chlorothalonil with azoxystrobin, harpin, and disease forecasting for control of downy mildew and gummystem blight on melon. *Crop Protection* **26** : 83-88.

Kessman, H., Stuab, T., Hoffman, C., Maetzke, T., Herzog, J., Ward, E., Uknes, S. and Ryals, J. 1994. Induction of systemic disease quried disease resistance in plant by chemicals.*Annual Review of Phytopathology* **32**:439-459.

Khan, A.U. and Khan, A.M. 1992. Incidence and severity of cucurbit powdery mildew in Uttar Pradesh. *Indian Phytopathology* **45**(2) :190-193.

Khan, M.W. 1976. Studies on the cucurbit powdery mildew intensity and identity of cucurbit powdery mildew in Bihar. *Indian Phytopathology* **29** : 210-212.

Khan, M.W. and Khan, A.M. 1970. Studies on the cucurbit powery mildew. I. Perithecial production in cucurbit powdery mildew in northern India. *Indian Phytopathology* **23** : 497-502.

Khan, M.W., Akram, M. and Khan, A.M. 1972. Perithecial stage of certain powdery mildew including some new records.*Indian Phytopathology* **25** : 220-224.

Khan, M.W. and Sharma, G.K. 1995. Taxonomic evaluation of anamorph characters in identification of powdery mildew fungi on cucurbits. *Indian Phytopathology* **45** : 314-324.

Khunti, J.P., Bhoraniya, M.F. and Vora, V.D. 2002. Management of powdery mildew and cercospora leaf spot of mung bean by some systemic fungicides. *Journal of Mycology and Plant Pathology* **32**(1) : 103-105.

Kirrane, E.F., Hoppin, J.A., Kamel, F., Umbach, D.M., Boyes, W.K., DeRoos, A.J., Alavanja, M. and Sandler, D.P. 2005. Retinal degeneration and other eye disorders in wives of farmer pesticide applicators enrolled in the agricultural study. *American Journal of Epidemiology* **161** : 1020-1029.

Kiss, J.C., Russell, O., Szentivanyi, X.X. and Jeffries, P. 2004. Biology and biocontrol potential of *Ampelomyces* mycoparasites, natural antagonist of powdery mildew fungi. *Biocontrol Science Technology* **14** : 635-651.

Kiss, L. 1998. Natural occurrence of *Ampelomyces* intracellular mycoparasites in mycelia of powdery mildew fungi. *New Phytolpathology* **140** : 709-714.

Koehle, H., Grossmann, K., Jabs, T., Gerhard, M., Kaiser, W., Glaab, J., Conrath, U., Seehaus, K. and Herms, S. 2003. Physiological effects of the strobilurin fungicide. *Plants*, pp. 214-219

Koike, S.T., Gladder, P. and Paulus, A.O. 2007. Vegetable diseases - a colour handbook. London, UK. Manson Publishing Ltd. pp. 220-228.

Kovats, K., Binder, A., and Hohl, H.R. 1991. Cytology of induced systemic resistance of tomato to *Phytophthora infestans*. *Planta* **183** : 491-496.

Kubo, Y. and Takano, Y. 2013. Dynamics infection-related morphogenesis and pathogenesis in *Colletotrichum orbiculare*. *Journal of Genetic Plant Pathology* doi:10.1007/s10327-013-0451-9.

Kuc, J. 2001. Concepts and direction of induced systemic resistance in plants and its application.*European Jouranal of Plant Pathology* **107**:7-12.

Kucharek, T. 2000. *Downy mildew of cucurbits.* Co-operative Extension Service, University of Florida, U.S.A. pp 32.

Kumar, A., Gour, H.N., Sharma, P. and Shah, R. 2012. Investigations on variability and eco-friendly management of *Alternaria alternata* causing tomato blight. *Vegetos*. **25** : 52-58.

Kumar, D.S.S. and Hyde, K.D. 2004. Biodiversity and tissue recurrence of endophytic fungi in *Tripterygium wilfordii*. *Fungal Diversity* **17** : 69-90.

Kumar, G.S., Kamanna, B.C. and Benagi, V.I. 2011. Management of chrysanthemum leaf blight caused by *Alternaria alternata* (fr.) Keissler under field condition. *Plant Archieves* **11** : 553-555.

Kumar, N.R., Rai, A.B. and Rai, M. 2008. Export of cucumber and Gherkin from India: performance, destinations, competitiveness and determinants. *Agricultural Economics Research Review* **21**: 130-138.

Kumbhar, G.B. and Chaudhary, K.G. 1979. Storage decay of sweet orange and control measures. *Journal Maharashtra Agricultural University* **4** : 230-231.

Lafon, R. and Bullit, J. 1981 Downy mildew of vine. **In**: *The Downy mildews* (Ed. D.M., Spencer). Academic Press, pp 601-614.

Lange, L., Eden, U. and Olson, L.W. 1989. Zoosporogenesis in *Pseudoperonospora cubensis*. The causal agent of cucurbit downy mildew. *Nordic Journal of Botany* **8** : 497- 504.

Langoo, N.A. 2006. Studies on Downy mildew *Pseudoperonospora cubensis* (Berk. and Curt) of cucumber in Kashmir. M.Sc. (Agri) Thesis submitted to Post Graduate Faculty, SKUAST-K, Shalimar, Kashmir, p.112 .

Lebeda, A., Sedláková, B., Krístková, E. and Vysoudil, M. 2009. Long-lasting changes in the species spectrum of cucurbit powdery mildew in the Czech Republic- influence of air temperature changes or random effect. *Plant Protection Science* **45** : 41-47.

*Lebeda, A.1990. Biology and ecology of cucurbit downy mildew. **In** : *Cucurbit downy mildew* (Eds. A. Lebeda). Czechoslovak Scientific Society for Mycology by Czechoslovak Academy of Sciences). Praha, Czechoslovakia, pp 13-45.

Lebeda, A. 1986. Epidemic occurrence of *Pseudoperonospora cubensis* in Czechoslovakia. Temperate Downy Mildews. *Newsletter* **4** :15-17.

Lebeda, A. 1999. *Pseudoperonospora cubensis* on *Cucumis* spp and *Cucurbita* spp- resistance breeding aspects. *Acta Horticulturae* **492** :363- 370.

Lebeda, A. and Cohen, Y. 2011. Cucurbit downy mildew (*Pseudoperonospora cubensis)* biology, ecology, epidemiology, host-pathogen interaction and control. *European Journal of Plant Pathology* **129**:157-192.

Lebeda, A. and Schwinn, F.J. 1994. The downy mildews - an overview of recent research progress.*Journal of Plant Diseases and Protection* **101** : 225-254.

Lebeda, A. and Urban, J. 2004. Disease impact and pathogenicity variation in Czech populations of *Pseudoperonospora cubensis*. **In**: *Progress in cucurbit genetics and breeding research* (Eds. A. Lebeda and H.S. Paris) *Proceedings of Cucurbitaceae, the 8th EUCARPIA Meeting on Cucurbit*

*Genetics and Breeding*. Olomouc: Palacký University in Olomouc, Czech Republic, pp 267-273.

Lebeda, A. and Urban, J. 2007. Temporal changes in pathogenicity and fungicide resistance in *Pseudoperonospora cubensis* populations. *Acta Horticulturae* **731** : 327-336.

Lebeda, A. and Widrlechner, M.P. 2003. A set of Cucurbitaceae taxa for differentiation of *P. cubensis* pathotypes. *Journal of Plant Diseases and Protection* **110** : 337-349.

Lenne, J.M. 2002. Some major plant diseases. **In**: *Plant Pathologist's Pocket Book* (Eds. J.M., Waller,J.M. Lenné and S.J. Waller). 3rd edn. CABI, Wallingford, UK, pp 4-18.

Letham, D.B. and Priest, M.J. 1989. Occurrence of cleistothecia of *Sphaerotheca fuliginea* on cucurbits in South Australia and New South Wales. *Australian Plant Pathology* **18** : 35-37.

*Leveille, J.H. 1851. Organisation et disposition méthodique des espèces qui composent le genre *Erysiphe*. *Annales des Sciences Naturelles, Botanique, 3e Serie* **15**: 109-179.

Li, Y. 2014. Anthracnose of cucumber. The Connecticut Agricultural Experiment station www.ct.gov/caes. pp 1-2.

Lin, T., Ishizaka, M. and Ishii, H. 2009. Acibenzolar-s-methyl-induced systemic resistance against anthracnose and powdery mildew diseases on cucumber plants without accumulation of phytoalexins. *Journal of Phytopathology* **157** : 40-50.

Lin, T.C. and Ishii, H. 2009. Accumulation of $H_2O_2$ in xylem fluids of cucumber stems during ASM-induced systemic acquired resistance involves

increased LOX activity and transient accumulation of shikmic acid. *European Journal of Plant Pathology* **125** : 119-130.

Linde, D.C., Bridges, W.C and Rhodes, B.B. 1990.Inheritance of resistance in cucumber to race 2 of *Colletotricum lagenarium. Theoretical Applied Genetics* **79** : 13-16.

Lindenthal, M., Steiner, U., Dehne, H.W. and Oerke, E.C. 2005. Effect of downy mildew development on transpiration of cucumber leaves visualized by digital infrared thermography. *Phytopathology* **95** : 233-240.

Lipps, P.E. 1983. Survival of *Colletotrichum graminicola* in infested corn residues in Ohio. *Plant Disease* **67** : 102-104.

Lipps, P.E. 1985. Influence of inoculum from buried and surface corn residues on the incidence of corn anthracnose. *Phytopathology* **75** : 1212-1216.

Liu, M., Ma, Q., Fu, W.D and Tang, W.H. 2006. Systemic resistance against *Sphaerotheca fuliginea* in cucumber by cell fungal fragments of *Flammulina velutipes.* Laboratory of plant protection resources and pest management, China. *Cucurbit Genetics Cooperative Report* **28(**29) : 7-11.

Louws, F.J., Wilson, M., Campbell. H.L., jones, D.A., Shoemaker, J.B., Sahin, P.B. and Miller, S.A. 2001. Field control of bacterial spot and bacterial speck of tomato using a plant activator. *Plant Disease* **85** : 481-488.

Love, S.L. and Rhodes, B.B. 1991. R309, a selection of *Citrullus colocynthis* with multigenic resistance to *Colletotrichum lagenarium* race 2. *Cucurbit Genetic Cooperative Report* **14**: 92-95.

Lu, B.S., Hyde, K.D., Ho, W.H., Tsui, K.M., Taylor, J.E., Wong, K.M., Yanna and Zhou, D.Q. 2000. Checklist of Hong Kong fungi. *Fungal Diversity Research Series* **5**: 1-207.

Lucas, G.B. 1975. Diseases of tobecco. Edn. Univ. North Carolina Press, USA, pp. 267-295.

MacDonald, W., Peters, R.D. and Lacroix, R.H.C. 2007. Effect of strobilurin fungicides on control of early blight (*Alternaria solani*) and yield of potatoes grown under two N fertility regimes. *Phytoprotection* **88**(1) : 9-15.

Maclennan, D.H., Kuc, J. and William, E. B. 1963. Chemotherapy of the apple scab disease with butyric acid derivatives. *Phytopathology* **53**: 1261-1266.

Mahrisi, R.P. and Siradhana, B.S. 1984. On the occurrence of oospores of *Pseudoperonospora cubensis* in Rajasthan India. *Indian Phytopathology* **37** : 323-325.

Maia, G.S. 2012.isolation, identification and characterization of cucurbit powdery mildew in North Central Florida. M.Sc. Thesis submitted to the graduate school of the University of Florida. pp.188.

Malandrakis, A., Markoglou, A.N., Nikou, D.C., Vontas, J.G. and Ziogas, B.N. 2006. Biological and molecular characterization of laboratory mutants of *Cercospora beticola* resistant to Qo inhibitors.*European Journal of Plant Pathology* **116**(2) : 155-66.

Malik, K.A., Khan, W.M., Akram, M. and Khan, A. 1973. Perithecial stage of certain powdery mildew including some new records-II. *Indian Phytopathology* **26** :698-699.

Mamgain, A., Roychowdhury, R. and Tah, J. 2013. Alternaria pathogenicity and its strategic controls. *Research Journal of Biology* **1** : 1-9.

Manandhar, H.K., Jorgensen, H.J., Mathur, S.B. and Smedegaard-Petersen, V. 1998. Resistance to rice blast induced by ferric chloride, di-potassium hydrogen phosphate and salicylic acid. *Crop Protection* **17** : 323-329.

Mangala, U.N., Subbarao, M. and Ravindrababu, R. 2006. Host range and resistance to *Alternaria alternata* leaf blight on chilli. *Journal of Mycology and Plant Pathol*ogy **36**(1): 84-85.

Margot, P., Huggenberger, F., Amrein, J., Weiss, B., 1998. CGA279202: a new broad spectrum strobilurin fungicide. *Proceedings of the BCPC Conference on Pests and Diseases*. BCPC, Farnham, Surrey, UK, **2** : 375-382.

Martin, J.E. and Fernandez, H.S. 2006. First Report of Alternaria brown spot of Citrus caused by *Alternaria alternata* in Peru. *Plant Disease* **90** : 686.

Martin, T., Wohner, R.V., Hummel, S., Willmitzer, L. and Frommer, W.B. 1991. The GUS reporter system as a tool to study plant gene expression. **In**: *GUS Protocols: Using the GUS Gene as a Reporter of Gene Expression* (Ed. S.R. GaIIagher), Academic Press, San Diego, CA, USA, pp 23-43.

Mason, E.W. 1928. Annotated account of fungi received at the Imperial Bureau of Mycology. I & II (Fascicles), Kew, Surrey, England, p. 34.

Masoodi, M.A. 2003. Agriculture in Jammu and Kashmir-A perspective. Mohisarw Book Series, Srinagar, pp 336.

Mauch-Mani, B. and Slusarenko, A.J. 1996. Production of salicylic acid precursors is a major function of phenylalanine ammonia-lyase in the

resistance of Arabidopsis to *Peronospofa parasitica*. *Plant Cell* **8**: 203-212.

McGrath, M.T. 1996. Successful management of powdery mildew in pumpkin with disease threshold-based fungicide programs. *Plant Disease* **80**:910-916.

McGrath, M.T. 1997. *Powdery mildew of cucurbits*. Cooperative Extension, Cornell University.pp. 732.30.nysipm.cornell.adu/facsheet.vegs.pdf.

McGrath, M.T. and Thomas, C.E. 1996. Powdery mildew. **In** : *Compendium of Cucurbit Disease* (Eds.T.A. Zitter, D.L.Hopkin and C.E. Thomas), APS press, American Pathological Society, Minnesota, USA. pp 28-30.

*Medvedeva, N.I. and Medvedev, A.V. 1983. Agronomic and biological assessment of cucumber varieties with potential for breeding for resistance to downy mildew. *Trudypo Prikladnoj Botanike, Genetike i Selekcii* **77** : 25-28.

Meera, M.S., Shivanna, M.B., Kageyama, K. and Hyakumachi, M. 1995. Responses of cucumber cultivars to induction of systemic resistance against anthracnose by plant growth promoting fungi. *European Journal of Plant Pathology* **101** : 421-430.

Mehrotra, R.S. 1980. *Plant Pathology.*Tata McGraw-Hill Publishing Company Ltd. 759 pp.

Metraux J.P. 2001. Systemic acquired resistance and salicylic acid: current state of knowledge. *European Journal of Plant Pathology* **107** : 13-18.

Meyers, J.A. and Cook, R.J. 1972. Induction of chlamydospore formation in *Fusarium solani* by abrupt removal of organic carbon substrate. *Phytopathology* **62**:1148-1153.

Michailides, T.J., Morgan, D.P., Felts, D. and Reyes, H. 2005. Chemical control of Alternaria late blight of California pistachio in 2005. **In**: *California Pistachio Commission Production Research Reports*, Crop Year 2005, 238.

Michelmore, R.W. 1981. Sexual and asexual sporulation in the downy mildews. **In** : *The Downy Mildews* (Ed. D.M. Spencer), London: Academic, pp. 165-181.

Mishra, A.N. and Siradhana, B.S. 1957. Outbreaks and new records. *FAO Plant Protection Bulletin* **5**: 145-146.

Mohsan, M., Intizar-ul-Hassan, M. and Ali, L. 1985.Chemotheraptic management of Alternaria black spot (*Alternaria alternata*) in mangofruits. *Journal of Agricultural Research* **49** : 499-506.

Monroe, J.S., Santini, J.B. and Latin, R. 1997. A model defining the relationship between temperature and leaf wetness duration, and infection of watermelon by *Colletotrichum orbiculare. Plant Disease* **81**(7) : 739-742.

Morishita, M., Sugiyama, K., Saito, T. and Sakata, Y. 2003. Powdery mildew resistance in cucumber. *Japan Agricultural Research Quarterly* **37** : 7-14.

Morsy, S.M., Elham, A.D. and Gehad, M.M. 2009. Effect of garlic and onion extracts or their intercropping on suppressing damping-off and powdery mildew diseases and growth characteristics of cucumber. *Egyptian Journal of Phytopathology* **37** : 35-46.

Mosa, A.A. 1997. Effect of foliar application of phosphate on cucumber powdery mildew. *Annals of Agricultural Science Ain Shams University Cairo* **42** : 241-255.

Mossler, M.A. and Nesheim, O.N. 2005. Florida crop/pest management profile: squash. Electronic Data Information Source of UF/IFAS Extension (EDIS).CIR 1265. http://edis.ifas.ufl.edu/.

Moyer, C. and Peres, N.A. 2008. Evaluation of bio fungicides for control of powdery mildew of gerbera daisy. *Proceedings of Florida. State Horticultural Society* **121** : 389-394.

Mucharromah, E. and Kuc. J. 1991. Oxalate and phosphates induce systemic resistance against diseases caused by fungi, bacteria and viruses in cucumber. *Crop Protection* **10** : 265-270.

Mueller, D.S., Y.C., Hung, R.D. Oetting, M.W. Val Iersel and Buck, J.W. 2003. Evaluation of electrolyzed oxidizing water for management of Powdery mildew on Gerbera Daisy. *Plant Disease* **87**(8) : 965-969.

Munger, H.M. 1988. Improving the level of powdery mildew resistance in cucumber. *Cucurbit Genetics Cooperative Report* **11**:22.

Murthy, K.K., Shenoi, M.M. and Sreenivas, S.S. 2003. Perpetuation and host range of *Alternaria alternata* causing brown spot disease of tobacco. *Indian Phytopathology* **56**(2) : 138-141.

Nagaraja, A. and Naik, K.S. 1998. Chemical control of powdery mildew and *Choanephora* rot of peas. *Pestology* **22** : 5-7.

Naylor, V.D. and Leonard, K.J. 1977. Survival of *Colletotrichum graminicola* in infected corn stalks in North Carolina. *Plant Disease Report* **61**: 382-383.

Neeraj and Verma, S. 2010. Alternaria diseases of vegetable crops and new approaches for its control. *Asian Journal of Experimental Biological Sciences* **1** : 681-692.

Neergaard, P. 1945. Danish Species of *Alternaria* and *Stemphylium*. London, UK: Oxford University Press. p. 560

Nene, Y.L. and Thapliyal, P.N. 1982. Fungicides in plant diseases control. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, pp. 163.

Oerke, E.C., Steiner, U., Dehne, H.W. and Lindenthal, M. 2006. Thermal imaging of cucumber leaves affected by downy mildew and environmental conditions. *Journal of Experimental Botany* **57** : 2121-2132.

Oichi, W., Matsuda, Y., Nonomura, T., Toyoda, H., Xu, L. and Kusakari, S. 2006. Formation of conidial pseudochains by tomato powdery mildew *Oidium neolycopersici*. *Plant Disease* **90** : 915-919.

Ojiambo, P., Kanetis, L. and Holmes, G. 2009. Forecasting long distance movement of *Pseudoperonospora cubensis* and the Cucurbit IPMPIPE. *Phytopathology* **99** : 171.

Oostendorp, M., Kunz, W., Dietrich, B. and Staub, T. 2001. Induced disease resistance in plants by chemicals. *European Journal of Plant Pathology* **107** : 19-28.

Orober, M.J. Siegrist, U. and Buchenauer, H. 2002. Mechanisms of phosphate-induced disease resistance in cucumber. *European Journal of Plant Pathology* **108** : 345-353.

Otten, P. and Paul 1997. Can kitchen products control powdery mildew? *Northern Berlin News Fall* (www. attar. Pub/backingsoda.html).

Ovadia, A., Biton, R. and Cohen, Y. 2000. Induced resistance to downy mildew and *Fusarium* wilt in cucurbits. **In** : *Proceedings of 7$^{th}$ EUCARPIA Meeting on Cucurbit Genetics and Breeding* (Eds. N.,Katzir, and H.S., Paris). *Acta Horticulturae* **510** : 55-59.

Palenchar, J., Danielle, D., Treadwell, Lawrence, E., Datnoff, Amanda, J., Gevens, and Vallad Gary, E. 2009. Cucumber Anthracnose in Florida. Institute of Food and Agricultural Sciences, Florida Cooperative Extension Service University of Florida http://edis.ifas.ufl.edu. pp 226.

Palenchar, J., Treadwell, D.D., Datnoff, L.E., Gevens, A.J. and Vallad, G.E. 2012. Cucumber Anthracnose in Florida. Plant Pathology Department, Florida Cooperative Extension Service.http://edis.ifas.ufl.edu . pp. 266.

Palenius, N., Hopkins, H.G. and Cantliffe, D.J. 2006. Powdery Mildew of Cucurbits in Florida.Available at http://edis.ifas.ufl.edu/hs321.

Palti, J. 1975. *Pseudoperonospora cubensis* (Berk & Curtis) Rost. CMI. *Descriptions of Pathogenic Fungi and Bacteria* **457** : 1-2.

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

Panchbhai, S.D., Reddy, M.S. and Singh, S.D. 1991. A repeatable method of germination of oospore of *Sclerospora graminicola* and its significance in downy mildew disease.*Indian Journal of Plant Protection* **19**: 101-103.

Pasche, J.S., Piche, L.M. and Gudmestad, N.C. 2005. Effect of the F129L mutation in *Alternaria solani* on fungicides affecting mitochondrial respiration. *Plant Disease* **89** : 269-278.

Pawar, V.P. and Patil, V.A. 2011. Occurrence of powdery mildew on some wild plants from Khandesh region of Maharashtra state. *Recent Research in Science and Technology* **3** : 94-95.

Pawar, V.P., Chaudhari, K.G. and Nannavre, P.S. 2009. Morphological characterization of casual organism [*Sphaerotheca fuliginea* (Schlecht)

Pollaci] on *Luffa cylindrica* powdery mildew. *An International Research Journal Jaipur* **7**:162.

Peres, N.A.and Timmer, L.W. 2006. Evaluation of the Alter Rater model for spray timing for control of Alternaria brown spot on *Murcott tangor* in Brazil. *Crop Protection* **25** : 454-460.

Pervaiz, A.A., Soltani, N., Cuppels. and Lazarovits, D.A.G. 2002. Reduction of bacterial spot disease severity on tomato and pepper plants with foliar applications of ammonium lignosulfonate and potassium phosphate. *Plant Disease* **86** :1232-1236.

Photita, W., Lumyong, S., Lumyong, P., Mckenzie, E.H.C. and Hyde, K.D. 2004. Are some endophytes of *Musa acuminata* latent pathogens? *Fungal Diversity* **16** : 131-140.

Pitrat, M., Dogimont, C. and Bardin, M. 1998. Resistance to fungal diseases of foliage in melon. **In** : *Cucurbitaceae '98* (Ed. J.D. McCreight) ASHS Press, Alexandria, VA, USA, pp 167-173.

Popular, C. 1981. Epidemiology of Downy mildew. **In** : *The Downy Mildews* (Ed. D.M. Spencer), Academic Press Inc. London, UK, pp 57-106.

Portz, D., Koch, E. and Slusarenko, A.J. 2008. Effects of garlic (*Allium sativum*) juice containing allicin on *Phytophthora infestans* and downy mildew of cucumber caused by *Pseudoperonospora cubensis. European Journal of Plant Pathology* **122**(1) :197-206.

Pradip, K. and Prajapati, C.R. 2005. Role of diseased plant debris, seed and Soil in perpetuation of Alternaria bight in radish. *Annals of Plant Protection Sciences* **13**(2) : 418-421.

Prasad, Y. and Naik, M.K. 2003. Evaluation of genotypes, fungicides and plant extracts against early blight of tomato caused by *Alternaria solani*. *Indian Journal of Plant Protection* **31**(2): 49-53.

Punja, Z. and Grogan, R.G. 1982. Effects of inorganic salts carbonate-bicarbonate anions, ammonia, and the modifying influence of ph on sclerotia germination of *Sclerotium rolfsii*. *Phytopathology* **72** : 635-639.

Qi, T., Yao, J., Hao, C. and Ma, Q. 2013. Histological studies of *Colletotrichum orbiculare* on the susceptible and resistant cucumber cultivars. *Cucurbit Genetics Cooperative Report* **36**: 4-6.

Ramakrishnan, T.S., Srinivastav, K.V. and Sundaram, N.V. 1952. Addition to the Fungus of Madras XIII. *Proceedings of Indian Academy of Science* **36**:85-95.

Raut, S.A. and Borkar, S.G. 2014. PR-proteins accumulation in tomato plant due to application of resistance inducing chemicals during period of induced resistance against alternaria leaf blight. *Science International*, pp. 72-75.

Ren, G.L., Yang, Z.Q., He, H.L., Cai, R. and Pan, J.S. 2013. Molecular map-ping of non-lateral gene in cucumber. *Acta Horticutural Sinica* **40**: 1375-1381.

*Renner, S.S., Schaefer, H. and Kocyan, A. 2007. Phylogenetics of *Cucumis* (Cucurbitaceae): Cucumber (*C. sativus*) belongs in an Asian/Australian clade far from melon (*C. melo*). *BMC Evolutionary Biology* **7**:58.

Reuveni, M. 2000a. Activity of trifloxystrobin against powdery mildew and downy mildew diseases of grapevines. *Canadian Journalof Plant Pathology* **23** : 52-59.

Reuveni, M. and Reuveni, R. 2000. Prior inoculation with non-pathogenic fungi

induces systemic resistance to powdery mildew on cucumber plants. *European Journal of Plant Pathology* **106** : 633-638.

Reuveni, M. 2000b. Efficacy of trifloxystrobin (Flint), a new strobilurin fungicide, in controlling powdery mildews on apple, mango and nectarine, and rust on prune fruits.*Crop Protection* **19** : 335-341.

Reuveni, M. and Sheglov, D. 2002. Effects of azoxystrobin, difenocona-zole, polyoxin B (polar) and trifloxystrobin on germination and growth of *Alternaria alternata* and decay in red delicious apple fruit. *Crop Protection* **21** : 951-955.

Reuveni, M., Agapov, V.andReuveni, R. 1997. A foliar spray of micronutrient solutions induces local and systemic protection against powdery mildew (*Sphaerotheca fuliginea*) in cucumber plants. *European Journal of Plant Pathology* **103**: 581-588.

Reuveni, M., Agapov, V. and Reuveni, R. 1993. Induction of systemic resistance to mildew and growth increase in cucumber by phosphates. *Biological Agriculture and Horticulture* **9** : 305-315.

Reuveni, M., Cohen, M. and Itach, N. 2006. Efficacy of foliar sprays of phosphates in controlling powdery mildew in field grown nectarine, mango trees and grape vine. *Crop Protection* **25** : 318-323.

Reuveni, R., and Raviv, M. 1997. Control of downy mildew in greenhouse-grown cucumbers using blue photoselective polyethylene sheets. *Plant Disease* **81** : 999-1004.

Reuveni, R. and Reuveni, M. 1998. Foliar-fertilizer therapy aconcept in integrated pest management.*Crop Protection* **17** :111-118.

Reuveni, R., Dor, G. and Reuveni, M. 1998. Local and systemic control of powdery mildew (*Leveillula taurica*) on pepper plants by foliar spray of mono-potassium phosphate. *Crop Protection* **17** : 703-709.

Reuveni, R., Dor, G., Rauveni, M. and Tuzum, S. 2000. Systemic resistance against *S. fuliginea* in cucumber plants exposed to phosphate in hydroponics system and its control by foliar spray of mono- potassium phosphate. *Crop Protection* **19**(5):355-361.

Robinson, R.W. and Decker-Walters, D.S. 1997. *Cucurbits.* CAB international New York, USA.

Romero, A.M., Kousik, C.S. and Ritchie, D.F. 2001.Resistance to bacterial spot in bell pepper induced by acibenzolar-s-methyl. *Plant Disease* **85** : 189-194.

Ronzon-Tran, C. and Clerjeau, M. 1988. Techniques for formation, maturation and germination of *Plasmopara viticola* oospore under natural conditions. *Plant Disease* **72**: 938-941.

Rotem, J., Cohen, Y. and Bashi, E. 1978. Host and environmental influences on sporulation *in vivo*. *Annual Reviewof Phytopathology* **16** : 83-101.

Rotem, J. 1994. The Genus *Alternaria:* Biology, epidemiology and pathogenicity. APS Press, St. Paul, Minnesota, USA, pp 9-10.

Royle, D.J. and Kremheller, H.T. 1981. Downy mildew of the hop. **In** : *The Downy Mildews* (Ed. D.M., Spencer). Academic Press, New York, USA. 395-419.

Saenz, G.S. and Taylor, J.W. 1999. Phylogeny of the Erysiphales (powdery mildews) inferred from internal transcribed spacer ribosomal DNA sequences. *Canadian Journal of Botany* **77**: 150-168.

Saha, L.R. 2002. *Hand Book of Plant Pathology*. 1st Edition, Kalyani Publishers. New Delhi, p. 928.

Sahu, D.K., Khare, C.P., Singh, H.K. and Thakur, M.P. 2013.Evaluation of newer fungicide for management of early blight of tomato in Chhattisgarh. *The Bioscan* **8** : 1255-1259.

Saito, K. and Takeda, K. 1984. Studies on breeding of apple. VIII. Genetic analysis of resistance to Alternaria blotch (*Alternaria mali* R.) in apple. *Japan Journal of Breeding* **34** : 197-207.

Sakata, Y., Kubo, N., Morishita, M., Kitadani, E., Sugiyama, M. and Hirai, M. 2006. QTL analysis of powdery mildew resistance in cucumber (*Cucumis sativus* L.). *Theoretical and Applied Genetics* **112** : 243-245.

Sankar, N.R., Nagalakshmi, M., Devamma and Giridhar, D. 2012. First report of *Alternaria alternata* causing leaf spot on *Rumex vesicarius* in India. *Australasian Plant Dis*ease **7**: 17-18.

Savory, E.A., Granke, L.L., Quesada-Ocampo, L.M., Varbanova, M., Hausbeck, M.K. and Day, B. 2011. The cucurbit downy mildew pathogen: *Pseudoperonosporacubensis*. *Molecular Plant Pathology* **12**(3): 217-226.

Schalau, 2010. *Powdery Mildew on Vegetables Agriculture & Natural Resources*. University of Arizona. Arizona Cooperative Extension, Yavapai County. p. 2 https://ag.arizona.edu/yavapai.

Schirra, M., D'hallewin, G., Ben-Yehoshua, S. and Fallik, E. 2000. Host-pathogen interactions modulated by heat treatment. *Postharvest Biology and Technology* **21**: 71-85.

Schwartz, H.F. and Gent, D.H. 2007.*Cucurbits.*Alternaria Blight and Spot (Cucumber, Melon, Pumpkin, Squash, and Zucchini). pp 1-3.http:// anr.ext.wuv.edu/r/download/57038.

Seebold, K. 2010. Foliar diseases of cucurbits. Plant Pathology Fact Sheet. Cooperative Extention Service. University of Kentuky, pp 1-4.

Serquen, F.C., Bacher, J. and Staub, J.E. 1997. Mapping and QTL analysis of horticultural traitsina narrow cross in cucumber (*Cucumis sativus* L.) using randorn-amplified polymorphic DNA markers. *Molecular Breeding* **3**: 257-268.

Shanmugavelu, K.G. 1989. Cucumber. **In**: *Production Technology of Vegetable Crops*. Oxford and IBH Pub. Co. Pvt. Ltd., New Dehli, India. pp. 748-54.

Sharma, D.R., Gupta, S.K. and Shyam, K.R. 2003. Studies on downy mildew of cucumber caused by *Pseudoperonospora cubensis* and its management. *Journal of Mycology and Plant Pathology* **33**(2) : 246-251.

Shen, S., Goodwin, P.H. and Hsiang, T. 2001. Infection of *Nicotiana* species by the anthracnose fungus, *Colletotrichum orbiculare*. *European Journal of Plant Pathology* **107** : 767-773.

Shenoy, B.D., Jeewon, R. and Hyde, K.D. 2007. Impact of DNA sequence-data on the taxonomy of anamorphic fungi. *Fungal Diversity* **26**: 1-54.

Sherf, A.F. and Macnab, A.A. 1986. Cucurbits. **In** : *Vegetable diseases and their control*. 2nd Edition. A Wiley- Interscience Publication, USA, pp 709.

Shetty, N. and Wehner, T.C. 2002. Screening the cucumber germplasm collection for fruit yield and quality. *Crop Science* **42** : 2174-2183.

Shetty, N.V., Wehner, T.C., Thomas, C.E., Doruchowski, R.W. and Shetty, V.K.P. 2002. Evidence for downy mildew races in cucumber tested in Asia, Europe and North America. *Science of Horticulture* (Amsterdam) **94** : 231-239.

Shishkoff, N. 1999: Using host, mating strategy and ascus type to understand the species complex *Sphaerotheca fusca*. **In** : *The first international powdery mildew conference,* Palais des Papes, Avignon, France, Abstracts. p. 18.

*Sidlauskiene, A., Rasinskiene, A. and Surviliene, E. 2003. Effect of various protection means on Alternaria diseases of tomato, cucumber and cabbage seed plants. *Sodininkyste-ir- Darzininkyste* **22**(3): 388-394.

Siegrist, J., Orober, M. and Buchenauer, H. 2000. β-Aminobutyricacid-mediated enhancement of resistance in tobacco to tobacco mosaic virus depends on the accumulation of salicylic acid. *Physiological and Molecular Plant Pathology* **56** : 95-106.

Simmons, E.G. 1992. Alternaria taxonomy: current status, viewpoint, challenge. **In**: *Alternaria Biology, Plant Diseases and Metabolites* (Eds. J. Chelkowskiand A. Visconti), Netherlands, Amsterdam. Elsevier Science Publishers, pp 1-35.

Singh, K. and Rai, M. 2003. Evaluation of chemicals against Alternaria leaf spot of brinjal. *Annual Plant Protection Science* **11**(2): 394-395.

Singh, P.C. and Singh, D. 2006. *In vitro* evaluation of fungicides against *A. alternata*. *Annual Plant Protection Science* **14**(2) : 462-524.

Singh, D.P. and Singh, A. 2005.*Disease and insect resistance in plants*. Science Publishers, Enfield (NH), USA, pp 417.

Singh, N. 2008. Sustainable management of redrot disease of sugarcane. *Indian Sugar* **58**: 21-30.

Singh, N. and Singh, K. 1982. Formation of resting structures by the *Colletotrichum falcatum* in soil. *Current Science* **51**: 102-104.

Singh, N.P., Bhardwaj, A.K., Kumar, A. and Singh, K.M. 2004. *Modern Technology on Vegetable Production.* 1st Edition, Army Printing Press. India, pp 366.

Singh, P.P. and Sokhi, S.S. 1989. 1st report of occurrence of oospores of *Pseudoperonospora cubensis* on 2 *cucurbitaceous* hosts. *Current Science* **58**: 1330-1331.

Singh, P.P. and Thind, T.S. 2001. Diseases of cucurbits and their management. **In**: *Disease of Forests and Vegetables and their Management.* 1st Edition (Ed. T.S. Thind). Kalyani Publishers, New Delhi, pp 290-305.

Singh, P.P., Thind, T.S. and Lal, T. 1996. Reaction of some muskmelon genotype against *Pseudoperonospora cubensis* under field and artificial epiphytic conditions.*Indian Phytopathology* **49** : 188-190.

Singh, S.P. 1997. *Principles of Vegetable Production.*1st Edition, Agrotech Publishing Academy, New Delhi, pp 288.

Sitterly, W.R. 1973. *Cucurbit* spp. **In**: *Breeding plants for disease resistance* (Ed. R.R., Nelson). The Pennsylvania State University Press, University Park. pp 287-306.

Sitterly, W.R. and Keinath, A.P. 1996. Anthracnose.**In** :*Compendium of Cucurbit Diseases* (Eds. T.A., Zitter, D.L., Hopkins and C.E. Thomas), APS Press, St. Paul, MN, USA, pp 24-25.

*Skalický, V. 1961. *Peronoplasmopara cubensis*. **In**: *Diseases of Vegetable Crops* (Eds. J. Benada and J. Spacek) Praha, Czechoslovakia. *Agricultural Phytopathology* **3**: 390-393.

Smilanick, J.L. and Margosan, D.A. 1999. Control of citrus green mold by carbonate and bicarbonate salts and the influence of commercial postharvest practices on their efficacy. *Plant Disease* **83** : 139-145.

Smilanick, J.L., Mansour, M.F. and Sorenson, D. 2006. Pre- and postharvest treatments to control green mold of citrus fruit during ethylene de-greening. *Plant Disease* **90** : 89-96.

Smith, S. and Cartwright, R. 2014. *Plant Health Clinic News*. Department of Plant Protection. Division of Agriculture. University Cooperative Extension Service. Arkansas, USA.p. 4.

Sohi, H.S. and Nayar, S.K. 1969. Some records of fungi from India-I. *Indian Phytopathology* **22**: 410-412.

Srivastava, M.P., Chandra, S. and Tondon, R.N. 1964. Post harvest diseases of some fruits and vegetables. *Proceeding of National Academy ScienceIndia* **34**: 339-342.

Staub, J., Barczynaka, H., Van Kleineww, D., Palmer, M., Lakowska, E. and Dijkhuizen, A. 1989. Evaluation of cucumber germplasm for six pathogens. **In**: Proceedings *of Cucurbitaceae* (Ed. C.E. Thomas) **89** : 149-153.

Stevens, F.L. 1931. The ascigerous stage of *Colletotrichum lagenarium* induced by ultra-violet irradiation. *Mycologia* **23**(2): 134-139.

Sticher, L., Mani, M.B. and Metraux, J.P. 1997. Systemic acquired resistance. *Annual Review of Phytopathology* **35** : 235-270.

Subramanian, C.V. 1971. Hyphomycetes. I.C.A.R., New Delhi, India, pp 801-820.

Sukno, S.A., Garcıa, V.M., Shaw, B.D. and Thon, M.R. 2008. Root infection and systemic colonization of maize by *Colletotrichum graminicola*. *Applied and Environmental Microbiology* **74** : 823-832.

Sundheim, L. and Krekling, T. 1982. Host-parasite relationships of the hyperparasite *A. quisqualis* and its powdery mildew host *Sphaerotheca fuliginea*. I. Scanning electron microscopy". *Phytopathology* **104** : 202-210.

*Surviliene, E., Valiuskaite, A. and Raudonis, L. 2006. Effect of fungicides on Alternaria diseases of carrot. **In** : *Plant protection. Strategy and tactics of plant protection* (Eds. L.I., Trepashko and S.V., Soroka). Materials of the Scientific Conference, Minsk, Belarus, 319-321.

Sutton, B.C. 1992. The genus Glomerella and its anamorph *Colletotrichum*. **In** : *Colletotrichum: Biology, Pathology and Control* (Eds. J.A. Bailey and M.J. Jeger), CAB International, Wallingford, UK, pp 1-26.

Suzuki, M. and Saito, A. 2010. Mass-screening of mutants resistant to Alternaria blotch from in vitro-cultured apple shoots irradiated with X-rays. **In** : *Mass Screening Techniques for Selecting Crops Resistant to Disease*.(Eds. R.Afza,Cássia, A. A. de, Albuquerque, F.C. de and Amusa, N.A. *et al.*). International Atomic Energy Agency.Vienna International Centre Austria, pp 343.

Tabira, H., Otani, H., Shimomura, N., Kodama, M., Kohmoto, K. and Nishimura, S. 1998. Light-induced insensitivity of apple and Japanese pear leaves to AM-toxin from *Alternaria alternata* apple pathotype. *Annual Phytopathology Society of Japan* **55**: 567-578.

Takamatsu, S. 2004. Phylogeny and evolution of the powdery mildew fungi (Erysiphales, Ascomycota) inferred from nuclear ribosomal DNA sequences. *Mycoscience* **45**: 147-157.

Takamatsu, S., Heluta, V., Havrylenko, M., and Divarangkoon, R. 2009. Four powdery mildew species with catenate conidia infect Galium: molecular and morphological evidence. *Mycology Research* **113**:117-129.

Tasiwal, V., Benagi, V.I., Yashoda., Hegde, R., Kamanna , B.C. and Naik, K.R. 2009. *In vitro* evaluation of botanicals, bioagents and fungicides against anthracnose of papaya caused by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.*Karnataka Journal of Agricultural Science* **22**(4): 803-806.

Tesoriero, L. 2004. Integrated management of greenhouse cucumber and capsicum diseases. Horticultural Australia Ltd. Elizabeth Macarthur Agricultural Institute (EMAI), Camden, Australia. 1-54. horticulture@ horticulture.com.au.

Thakur, R.P. and Mathur, K. 2002. Downy mildews of India. *Crop Protection* **21** : 333-345.

Thomas, C.E. 1977. Influence of dew on downy mildew of cantaloupe in South Texas. *Phytopathology* **67** : 1368-1369.

Thomas, C.E. 1996. Downy mildew. **In** : *Compendium of Cucurbit Diseases* (Ed. T.A. Zitter). Cornell University Press, Ithaca, NY.pp 25-27.

Thomma, B.P.H.J. 2003. *Alternaria* spp. from general saprophyte to specific parasite. **In** : *Pathogen profile Molecular Plant Pathology* **4**(4) : 225-236.

Thompson, D.C. and Jenkins, S.F. 1985. Influence of cultivar resistance, initial disease, environment, and fungicide concentration and timing on

anthracnose development and yield loss in pickling cucumbers. *Phytopathology* **75** : 1422-1427.

Timchenko, V.I. 1979. Disease of onion. *Review of Plant Pathology* **58** : 439.

*Tode, H.J. 1790. *Fungi Mecklenbergensis Selecti* **1**: 1-64.

Tomy, P. 1997. Laboratory evaluation of fungicides against C. *gloeosporioides* causing black leaf spot in mulberry. *Pestology* **21** : 22-23.

Trigiano, R.N., Windham, M.T. and Windham, A.S. 2004. *Plant Pathology*. Concepts and Laboratory Exercises. CRC Press, Boca Raton, Florida, USA, 413 pp.

Tripathi, S.P., Singh, R.Y. and Yadav, G.R. 1995. Chemical control of powdery mildew disease of bottle gourd.*Recent Horticulture* **2**(2) : 151-152.

Troisi, M., Bertetti, D., Garibaldi, A., and Gullino, M. L. 2010. First report of powdery mildew caused by *Golovinomyces cichoracearum* on gerbera (*Gerbera jamesonii*) in Italy.*Plant Disease* **94**:130-130.

Uknes, S., Mauch-Mani, B., Mayer, M., Potter, S., William, S., Dincher, S., Chandler, D., Slusarenko, A., Ward, E. and Ryals, J. 1992. Acquired resistance in Arabidopsis *Plant Cell* **4** : 645-56.

Urban, J. and Lebeda, A. 2006. Fungicide resistance in cucurbit downy mildew - methodological, biological and population aspects. *Annals of Applied Biology* **149**:63-75.

Vakalounakis, D.J. 1990. *Alternaria alternata* f.sp. *cucurbitae*, the cause of a new leaf spot disease of melon (*Cucumis melo*). *Annals of Applied Biology* **117**(3):507-513.

Vakalounakis, D.J. and Malathrakis, 1982. A cucumber disease caused by fungus *Alternaria alternata*. **In** : *II Proceeding Conference Protected Vegetables and Flowers*. Crete, Greece, pp 54-55.

Vakalounakis, D.J. and Malathrakis, 1988.A cucumber disease caused by *Alternaria alternata* and its control.*Journal of Phytopathology* **121**: 325-336.

Vallad, G.E. and Goodman, R.M. 2004. Systemic acquired resistance and induced systemic resistance in conventional agriculture. *Crop Science* **44** : 1920-1934.

Vashishta, B.R. 1999. *Fungi*. 9th Edition, S. Chand and Co. Ltd., New Delhi. p 512.

Veerhar, M.A., Hijwegen, T. and Zadoks, J.C. 1996. Glasshouse experiments on biocontrol of cucumber powdery mildew (*Sphaerotheca fuliginea*) by *Verticilium lecanii* and *Sporothrix rugulosa*. *Biological Control* **16** : 79-81.

Verhaar, M.A., Ostergaard, K.K., Hijwegen, T. and Zadoks, J.C. 1997. Preventative and curative applications of *Verticillium lecanii* for biological control of cucumber powdery mildew. *Biocontrol Science and Technology* **7**: 543-551.

Verma, N. and Verma, S. 2010. Alternaria diseases of vegetable crops and new approaches for its control. *Asian Journal of Experimental Biological Science* **1**(3): 681-692.

Vizvary, M.A. and Warren, H.L. 1982. Survival of *Colletotrichum graminicola* in soil.*Phytopathology* **72** : 522-525.

Vliet, V., G.J.A. and Meysing, W.D. 1974. Inheritance of resistance to *Pseudoperonospora cubensis* Rost. in cucumber (*Cucumis sativus* L.). *Euphytica* **23** : 251-255.

Voglmayr, H. 2003. Phylogenetic study of *Peronospora* and related genera based on nuclear ribosomal ITS sequences. *Mycological Research* **107** : 1132-1142.

Vogt, W. and Buchenauer, H. 1997. Enhancement of biological control by combination of antagonistic fluorescent *Pseudomonas* strains and resistance inducers against damping off and powdery mildew in cucumber.*Journal of Plant Disease Protection* **104**: 272-280.

Wagh, P., Sinha, S., Singh, H.K. and Khar, U.K. 2013. Pathogenic behaviour of *Alternaria alternata* and phytotoxicity of its culture filtrates on *Lepidium sativum*: a medicinal herb of immense pharmacological potential. *The Bioscan* **8** : 643-647.

Walker, J.C. 1969. Downy Mildew of Cucurbits. **In** : *Plant Pathology*. McGraw. Inc. New York, pp. 226-270.

Walz, A. and Simon, O. 2008.β-aminobutyric acid-induced resistance in cucumber against biotrophic and necrotrophic pathogens. *Journal of Phytopathology* **157** : 356-361.

Wang, C.M., Zhou, W., Li, C.X., Chen, H., Shi, Z.Q and Fan, Y.J. 2009. Efficacy of osthol, a potent coumarin compound, in controlling powdery mildew caused by *Sphaerotheca fuliginea.Journal of Asian Natural Products Research* **11**(9): 783-791.

Warren, H.L. 1977. Survival of *Colletotrichumgraminicola* in corn kernels. *Phytopathology* **67**: 160-162.

Wasilwa, L.A., Correll, J.C., Morelock, T.E. and McNew, R.E. 1993. Reexamination of races of the cucurbit anthracnose pathogen *Colletotricum orbiculare*. *Phytopathology* **83** : 1190-1193.

Watanabe, T. and Tamura, M. 1952.Studies on the perfect stage of the causal fungus of the anthracnose of cucumber.*Annual Phytopathological Society of Japan* **16**: 137-140.

Waterhouse, G.M. and Brothers, M.P. 1981. The taxonomy of *Pseudoperonospora*. *Mycological Papers* **148** : 1-28.

Watson and Napier 2009. Prime fact 832, Diseases of Cucurbit Vegetables. pp 6. http://www.dpi.nsw.gov.au/.

Watt, B.A. 2004. Alternaria leaf blight of cucurbits.Insect and plant disease diagnostic. United State Cooperative Extension. Department of agriculture. University of Maine cooperative extension pp.1-2.http://pmo. umext. maine.edu /pdffactshts/alternaria.pdf.

Wehner, T.C. and Amand, St. P.S. 1995. Anthracnose resistance of the cucumber germplasm collection in North Carolina field tests. *Crop Science* **35** (1):228-236.

Wehner, T.C. and Maynard, D.N. 2003.Cucurbitaceae (Vine Crops).**In**: *The Encyclopedia of Life* (Eds. L. John Wiley & Sons), Nature Publishing, London, UK. **1** : 228-236.

Wehner, T.C. and Robinson, R.W. 1991. A brief history of the development of cucumber cultivars in the U.S. *Cucurbit Genetics Cooperate Report* **14** : 1.

Wehner, T.C. and Shetty, N.V. 1997. Downy mildew resistance of the cucumber germplasm collection in North Carolina field tests.*Crop Science* **37** : 1331-1340.

Whitaker, T.W. and Davis, G.N. 1962. *Curcurbits botany, cultivation and utilization.* Inter Science Publishers, Inc., New York. pp. 168-169.

Williams, G. and Pat, W. 1993. Baking soda and horticultural oil vs. powdery mildew. HortIdeas. May. p. 51 http://www.attra.org/attra-pub/bakingsoda.html

Wong, F.P. and Wilcox, W.F. 2002. Sensitivity to azoxystrobin among isolates of *Uncinula necator* : baseline distribution and relationship to myclobutanil sensitivity. *Plant Disease* **86** : 394-404.

Wong, P.F. and Wilcox, F.W. 2001. Comparative physical modes of action of azoxystrobin, mancozeb and metalaxyl against *Plasmopara viticola* (grapevine downy mildew). *Plant Disease* **85** : 649-656.

Wyszogrodzka, A.J., Williams, P.H. and Peterson, C.E. 1987. Multiple-pathogen inoculation of cucumber (*Cucumis sativus* L.) seedlings. *Plant Disease* **71**: 275-280.

Yadav, S.T. and Patil, B.P. 2008. Weather relation of downy mildew and fruit yield modeling in cucumber. *Journal of Agro Meteorology* **10**(1):104-105.

Yamaguchi, I. 1998. Activators of systemic acquired resistance. **In** : *Fungi-cidal activity: Chemical and biological approaches to plant protection* (Eds. D.H. Hutson and J. Miyamoto), Wiley & Sons Inc., New York. pp 193-219.

Yarwood, C.E. 1932. *Amplomyces quisqualis* on clove mildew (Abstra.) *Phytopathology* **22** : 31.

*Yarwood, C.E. 1978. History and taxonomy of powdery mildews.**In**: *The Powdery Mildews* (Ed. D.M. Spencer), Academic Press, London, pp 1-37.

Ye, X.S., Strobel, N. and Kuc, J. 1995. Induced systemic resistance (ISR): activation of natural defense mechanisms for plant disease control as part of integrated pest management (IPM). **In**: *Novel Approaches to Integrated Pest Management* (Ed. R. Reuveni), CRC Press, Boca Raton, Florida, USA, pp 95-113.

YuanYuan, Z., GuangHui, D., ZhiYuan, Z. and SuXin, J. 2008. Control effect on cucumber powdery mildew and antifungal compounds of *Euphorbia humifusa* Wiild. *Journal of Shanghai Jiaotong University Agricultural-Science* **26**(3):200-203.

*Zacha, V., Janyska, A. and Holman, B. 1985. Epifytócia plesne uhorkovej (*Pseudoperonospora cubensis* (Berk. & Curt.) Rost.) v ČSSR vroku. *Sborník ÚVTIZ-Ochranarostlin* **21** : 226.

Zaker, M. and Ommati, F. 1991. Observation of oospores of *Pseudoperonospora cubensis* on cucumber leaves in Iran. *Iran Journal of Plant Pathology* **27**: 62-63.

Zhang, S. 2011. Evaluation of microbial products for management of powdery mildew on summer squash and cantaloupe in Florida. *Plant Disease* **95**(4) : 461-468.

*Zhang, S.Q. 2005a. The inheritance and AFLP marker of downy mildew and powdery mildew resistance in cucumber (*Cucumis sativus* L.). Ph.D

dissertation, Northwest A & F University. (in Chinese).www. sciencedirect.com/science/article/pii/S1671292707601813.

Zhang, X.H. 2005b. Research on control methods of cucumber powdery mildew in greenhouse and lab. *Journal of Hebei Normal University* **29**(2): 190-192.

Zhang, W., Dick, W.A. and Hoitink, H.A.J. 1996. Compost-induced system acquired resistance in cucumber to pythium root rot and anthracnose. *Phytopathology* **86** :1066-1070.

Zhang, Y.J., Qin, Z.W. and Zhou, X.Y. 2006. Study on the over-wintering of cucumber downy mildew in Heilongjiang province of China. **In** : *27th International Horticultural Congress & Exhibition*, COEX (Convention & Exhibition), Seoul, Korea. pp. 13-19.

Zhao, C.J., Li, M., Han, X., Zhan, G.Z. and Wang, Y. 2007. Analysis and monitoring for epidemic system as a basis for cucumber downy mildew warning in green house. *Progress of Information Technology in Agriculture*, pp 527-532.

Zhou, X.H., Wan, H.J., Qian, C.T. and Chen, J.F. 2008. Development and characterization of *Cucumis sativus* hystrix introgression lines exhibiting resistance to downy mildew. **In**: *Cucurbitaceae*. *Proceedings of the IXth EUCARPIA Meeting on Genetics and Breeding of Cucurbitaceae* (Ed. M. Pitrat) Avignon: NRA, pp 353-358.

Zitter, T.A.1987. Anthracnose of Cucurbits. **In**: *Vegetable crops*. Department of Plant Pathology. Cooperative Extension. New York. Cornell University. Pp 1-2. http://vegetablemdonline.ppath.cornell.edu/

Zitter, T.A., Hopkins, D.L. and Thomas, C.E. 1998. Compendium of Cucurbit Diseases.St. Paul, Minnesota, APS Press, p. 87.

Ziv, O. and Zitter, T.A. 1992. The effect of bicarbonates and film-forming polymers on cucurbit foliar disease. *Plant Disease* **76** : 513-517.

---

*Original not seen.

**Appendix I**

**Monthly meteorological data for the years 2011 and 2012 during May-July**

| Months | Mean temperature (°C) | | Relative humidity (%) | Total rainfall (mm) |
|---|---|---|---|---|
| | Maximum | Minimum | | |
| **2011** | | | | |
| May | 27.46 | 10.29 | 19.80 | 55.00 |
| June | 30.00 | 14.80 | 42.00 | 56.00 |
| July | 29.95 | 16.90 | 31.00 | 65.00 |
| Mean | 29.1 | 13.99 | 30.93 | 58.66 |
| **2012** | | | | |
| May | 23.25 | 10.00 | 56.00 | 69.00 |
| June | 28.00 | 12.80 | 35.00 | 63.00 |
| July | 30.61 | 18.21 | 51.00 | 64.00 |
| Mean | 27.28 | 13.67 | 47.33 | 65.33 |

**Appendix II**

| S. No. | Common Name | Trade Name | Chemical Name |
|---|---|---|---|
| 1 | Mancazeb 75WP | Dithene M-45 | Zinc manganese ethylene bisdithiocarbamate |
| 2 | Captan 50WP | Captaf 50 WP | N-(trichloromethylthio)-4-cyclohexne-1,2-dicarboximide |
| 3 | Dinocap 48 EC | Karathene | 2-Butenoic acid, 2-isoodyl-4,6,2-dinitrophenyl ester |
| 4 | Cymoxanil 50 WP | Cymoxanil | 2-cyano-N-[(ethylamino) carnonyl]-2-methoxymino, acetamide |
| 5 | Tridemorph 50 WP | Calixin | 4-alkyl-2,6-dimethylmorpholine |
| 6 | Difeconazole 25 EC | Score 25 EC | 1-[[2-[4-(4-chlorophenoxy)-2-chlorophenyl]-4-methyl-1,3-dioxolan-2yl]methyl]-1H-1,2-4-triazole |
| 7 | Cholorothalonil 75 WP | Kavach 75 WP | Tetrachloroisphthalonitrile |
| 8 | Metalaxyl MZ 72 | Ridomil Gold MZ | Methyl N-(2,6-dimethylphenyl)-N-(methoxyacetyl)DL-alaninate |
| 9 | Tebeconazole 25EC | Tebeconazole 25 EW | [(RS)-1-p-chlorophenyl]-4,4-dimethyl-3-(1H-1,2,4-triazol-1-ylmethyl)pentan-3-ol |
| 10 | Pyraclostrobin + boscalid 38 WG | Pristine | [2-[[[l-(4-chlorophenyl)-lH-pyrazol- 3-yl]oxy]methyl]phenyl] methoxycarbamate and 2-Chloro-N-(4'-chlorobiphenyl-2-yl) nicotinamide |
| 11 | Captan +hexaconazole 75 WP | Taqat | N-(trichloromethylthio)-4-cyclohexne-1,2-dicarboximide and (RS )-2-(2,4-Dichlorophenyl)-l-(lH-l,2,4-triazol-l-yl) hexan-2-ol |
| 12 | Metiram + pyraclostrobin 60 WG | Cabrio top | Tris[ammine[ethylenebis(dithiocarbamato)]zinc(2+)] [tetrahydro-1,2,4,7-dithiadiazocine-3,8-dithione] and [2-[[[l-(4-chlorophenyl)-lH-pyrazol- 3- yl]oxy]methyl]phenyl] methoxycarbamate |
| 13 | *Ampelomyces quisqualis* | AQ10 | *Amplomyces quisqualis* (Fungal parasite) |

**Sher-e-Kashmir**
**University of Agricultural Sciences & Technology of Kashmir**
**Faculty of Horticulture, Division of Plant Pathology**

# CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. V.K. Razdan, Professor & Head, Division of Plant Pathology, SKUAST-Jammu during thesis Viva-Voce examination held on 14.10.2015 have been incorporated in the final manuscript entitled **"Studies on fungal foliar diseases of cucumber (*Cucumis sativus* L.) in Kashmir valley"** submitted by **Ms. Shanaz Yousuf (Regd. No. 2009-268-D) of Plant Pathology discipline.**

**( Dr. G.H. Dar )**
Chairman
Advisory Committee