

**Epidemiology and management of major
diseases of *Capsicum annuum* L. under
polyhouse and field conditions**

THESIS

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In

**AGRICULTURE
(PLANT PATHOLOGY)**

by

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2012

CERTIFICATE – I

This is to certify that the thesis entitled **Epidemiology and management of major diseases of *Capsicum annuum* L. under polyhouse and field conditions** submitted in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE in AGRICULTURE (Plant Pathology)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Ms. Sumita Rathore** under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been acknowledged by her.

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INTRODUCTION

Capsicum peppers are the foremost preferred condiments in the every household of India. These are the fundamental ingredients for an Indian cuisine, used to flavour the soups, stews and sauces. It also increases the palatability of Indian food. (Singh, 1989). Capsicum peppers are used in many dishes in a variety of ways (roasted, fried, deep fried and raw chopped) (<http://en.wikipedia.org/wiki/Bellpepper>). Purselove (1977) reported that green chillies also contain ascorbic acid and rustin, having specific medicinal value. Bell pepper is commonly known as sweet pepper and in Hindi known as Shimla Mirch. Bell pepper is a cultivar group of *Capsicum annuum*, a genus of flowering plant in the nightshade family, Solanaceae. Cultivars of the plant produce fruits in different colours including red, yellow, orange and green (<http://en.wikipedia.org/wiki/Bellpepper>). While the sweet pepper is the member of the genus *Capsicum*, it is the only *Capsicum* that does not produce capsaicin (<http://www.chilliwonders.com/chilli.scoville.htm>). The pungency of chillies is due to an alkaloid capsaicin ($C_{18}H_{27}NO_3$), the active hot principle which is used in pharmaceuticals, cosmetics, food and drinks (Tiwari, 1990). The red colour in fruits at the ripening stage is due to the pigment capsanthin (Nath, 1969). Chillies (*Capsicum* peppers) are valued for pungency. The pungent principle of red pepper (*Capsicum annuum* L.) consist of a mixture of seven closely related methyl vanillyl nonenamindes named capsaicinoides by solvent extraction of the dried fruits and the subsequent removal of the solvent (Tiwari, 1990; Govindrajan, 1985). Capsaicin is a chemical lipophilic that can cause a strong burning sensation when it comes in contact with mucous membrane. While on the other hand, in contrast to hot pepper (chilli), the sweet pepper has a zero rating on Scoville Heat Scale. The lack of capsaicin is due to a recessive gene that eliminates capsaicin (<http://whfoods.com/genpage>). Compared to sweet peppers, hot peppers have more vitamins and nutrients (<http://www.nal.usda.gov/finic/food comp/search>).

Table 1.1 : Composition of hot and sweet pepper

Contents	Hot pepper	Sweet pepper
Water	074.0 g	086.0 g
Energy	094.0 kcal	048.0 kcal
Protein	004.1 g	002.0 g
Fat	002.3 g	000.8 g
Carbohydrate	018.0 g	010.3 g
Fibre	006.0 g	002.6 g
Calcium	058.0 mg	029.0 mg
Phosphorus	101.0 mg	061.0 mg
Iron	002.9 mg	002.6 mg
β -carotene	7,140.0 μ g	180.0 μ g
Thiamin	000.25 mg	000.12 mg
Riboflavin	000.20 mg	000.15 mg
Niacin	002.4 mg	002.2 mg
Ascorbic acid	121.0 mg	140.0 mg

(<http://database.prota.org/PROTA.html/capsicum%20annuum.En.htm>).

Capsicum crop is grown in almost every state of our country. It is commercially cultivated in Andhra Pradesh, Karnataka, Punjab, Bihar, Maharashtra. In Madhya Pradesh, the districts of Khargaon, Khandwa, Chhindwara, Dhar, Shajapur, Mandsaur and Jabalpur are the major chilli producing areas. In recent years the cultivation of sweet pepper has been adopted by progressive farmers under poly house condition. Under Jabalpur conditions due to creation of advanced facility of polyhouse at Department of Horticulture, JNKVV, Maharajpur Farm, Jabalpur, the cultivation of bell pepper could be made possible. Since good economic returns have been experienced the cultivation under polyhouse condition, has

created an awareness among the farmers. However, no systematic information and documentation is available on the prevalence of diseases, especially for the sweet pepper under polyhouse condition, hence the studies were undertaken.

The status and epidemiology of hot chilli diseases has been worked out under natural field conditions (Tiwari, 2010; Kumar, 2011), however, no systematic information is available on the prevalence and subsequent development of diseases of bell pepper under cultivation. The major field problems with hot pepper have been identified. It include fruit rot, die back and tender tip drying caused by *Colletotrichum dematium* and *Alternaria alternata*. The incidence of powdery mildew is also recorded. The chilli crop suffers due to a number of fungal, bacterial and viral diseases that renders its production into stake (Gupta and Thind, 2006; Verma and Sharma, 1999). Among the various fungal diseases, anthracnose, dieback and fruit rot incited by *Colletotrichum* spp. is a limiting factor in Madhya Pradesh (Bhale *et al.*, 2000). The pathogen has been reported from different parts of the country (Thind and Jhooty,1990; Grover and Bansal,1970; Mridha and Siddiqui, 1989). *Alternaria alternata* is becoming, a limiting factor for profitable cultivation. The pathogen has been noticed by several workers (Bhale *et al.*, 2000; Verma and Bhale, 1989; Mehrotra, 1980; Verma and Sharma, 1999). The seed borne nature of these pathogen has been established (Bhale *et al.*, 2001).

The information on the status of diseases of bell pepper (sweet pepper) and its management is scanty as compared to hot peppers especially in the light of development and introduction of new chemical molecules, released during the past years. Hence, the present investigation was undertaken with the following objectives.

1. To investigate the prevalence and development of diseases under protected conditions and natural field conditions
2. To determine the seed associated mycoflora with the sweet pepper and the hot pepper.

3. To determine the efficacy of new fungicides molecules against major diseases of hot pepper.
4. To determine the influence of season on the development of diseases and possible correlation with meteorological data.

REVIEW OF LITERATURE

Peppers (*Capsicum* species) are native to Mexico, Central America and northern-South America. The seeds of peppers were carried to Spain during 1493 and later spread over to other parts of the world including European, African and Asian countries. Among the species *Capsicum annuum* L. is widely used in many dishes in a variety of ways and are a fundamental ingredient for an Indian cuisine too (Singh, 1989). Several species and cultivars of *Capsicum* include *Capsicum baccatum*, *C. chinense*, *C. frutescens*, *C. pubescens* and *C. practernussum*. Bell pepper are commonly known as sweet pepper and *Shimla Mirch* in Hindi (<http://en.wikipedia.org/wiki/Bell-pepper>), while common chilli used in Indian cuisine is known as *hot pepper*. Both hot and sweet peppers are processed into many types of sauces, stews, pickles, relishes and canned products (<http://resources.metapress.com>). The bell and chilli pepper producing countries are China, Indonesia, Turkey, Spain, United States, Nigeria, Egypt, Korea, Netherlands, Romania, Ghana, Italy, Tunisia, Algeria, Hungary, Morocco, Serbia, Japan, Israel and India (<http://en.wikipedia.org>). Mexico and Guatemala are considered as the place of origin of chilli (Singh, 1989). In India, the crop was introduced by Portuguese. Bell (sweet) peppers attained a status of high value crop in India in recent years and occupies a pride place among vegetables (<http://etd.usad>).

Global distribution

A number of pathogen attack the crop and cause various diseases. The crop suffers due to a number of diseases (Chupp and Sherf, 1960; Mehrotra, 1980). The status of major fungal diseases is presented in Table 2.1. The comprehensive account of fungal diseases is well documented (Mukherji and Bhasin, 1986; Gupta and Thind, 2006; Verma and Sharma, 1999; Mehrotra, 1980). Among the major fungal pathogens that attack peppers are ripe fruit rot, anthracnose (*Colletotrichum dematium*), leaf spots (*Alternaria alternata*), fruit rot (species of *Alternaria*, *Colletotrichum*, *Fusarium*, *Phoma capsici*), seedling and

plant blight (*Phytophthora capsici*) and root rot (*Rhizoctonia bataticola* and *Sclerotium rolfsii*).

Distribution of chilli diseases in India

Chilli crop has attained the commercial status especially in Madhya Pradesh, Andhra Pradesh, Maharashtra, Karnataka and Gujarat. The ripe rot and anthracnose (Grover and Bansal, 1970; Thind and Jhooty, 1990), leaf blight and fruit rot by *Phytophthora capsici*, *Phytophthora nicotianae* var *nicotianae* (Sohi et al., 1971; Sharma and Bharadwaj, 1976), frog eye leaf spot by *Cercospora capsici* (Muneem et al., 1995), powdery mildew by *Leveillula taurica*, *Oidiopsis taurica* (Pawar et al., 1985), wet rot by *Choanephora cucurbitarum* (Prabhavathy and Reddy, 1995) have been considered very important. Beside fungal pathogens, wilt caused by bacterium (*Pseudomonas* = *Ralstonia solanacearum*), root knot (*Meloidogyne incognita*) and mosaic virus are wide spread (Table 2.2).

Table 2.1 : Major diseases of hot peppers

Disease	Causal organism
Ripe fruit rot	<i>Colletotrichum dematium</i> <i>Cercospora capsici</i> <i>Corynospora cassicola</i> <i>Chaetomium globosum</i> <i>Gleosporium piperatum</i>
Fruit infection	<i>Fusarium semitectum</i> <i>Choanephora cucurbitarum</i> <i>Phytophthora nicotianae</i> <i>Dreschlera tetramera</i> <i>Cladosporium oxysporum</i> <i>Curvularia lunata</i> <i>Diplodea natalensis</i>
Wilt	<i>Fusarium</i> sp. <i>Verticillium</i> sp.
Bacterial wilt	<i>Ralstonia solanacearum</i>
Virus	Mosaic

Table 2.2 : Important diseases of Capsicum (<http://en.wikipedia.org/wiki/Bell-pepper>)

Bacterial diseases

Bacterial spot	<i>Xanthomonas campestris</i> pv. <i>vesicatoria</i>
Bacterial wilt	<i>Ralstonia solanacearum</i>
Bacterial canker	<i>Clavibacter michiganensis</i> subsp. <i>michiganensis</i>
Syringae seedling blight and leaf spot	<i>Pseudomonas syringae</i> <i>P. syringae</i> pv. <i>syringae</i>
Crown gall	<i>Agrobacterium tumefaciens</i>

Fungal diseases

Fungal diseases	
Anthracnose	<i>Colletotrichum gloeosporioides</i> <i>Colletotrichum capsici</i> <i>Glomerella cingulata</i> [teleomorph] <i>Colletotrichum coccodes</i>
Cercospora (frog-eye) leaf spot	<i>Cercospora capsici</i>
Charcoal rot	<i>Macrophomina phaseolina</i>
Choanephora blight (wet rot)	<i>Choanephora cucurbitarum</i>
Damping-off and root rot	<i>Rhizoctonia solani</i> <i>Phytophthora</i> spp. <i>Fusarium</i> spp. <i>Pythium</i> spp.
Downy mildew	<i>Peronospora tabacina</i>
Fusarium stem rot	<i>Fusarium solani</i>
Fusarium wilt	<i>Fusarium oxysporum</i> f.sp. <i>capsici</i>
Gray leaf spot	<i>Stemphylium solani</i> <i>Stemphylium lycopersici</i>
Gray mold	<i>Botrytis cinerea</i>
Phytophthora blight	<i>Phytophthora capsici</i>
Powdery mildew	<i>Oidiopsis sicula</i> <i>Oidiopsis taurica</i> [synanamorph] <i>Leveillula taurica</i> [teleomorph]
Southern blight	<i>Sclerotium rolfsii</i>
Verticillium wilt	<i>Verticillium albo-atrum</i> <i>Verticillium dahliae</i>
White mold	<i>Sclerotinia sclerotiorum</i>

Nematode diseases

Nematode diseases	
Root knot	<i>Meloidogyne incognita</i> <i>Meloidogyne hapla</i> <i>Meloidogyne javanica</i> <i>Meloidogyne arenaria</i>
Sting nematode	<i>Belonolaimus longicaudatus</i>
Other nematodes	<i>Paratrichodorus</i> spp. <i>Trichodorus</i> spp. <i>Pratylenchus penetrans</i> <i>Nacobbus aberrans</i> <i>Dolichodorus heterocephalus</i> <i>Helicotylenchus dihystra</i> <i>Hemicycliophora arenaria</i> <i>Radopholus similis</i>

Post harvest diseases

Post harvest diseases	
Bacterial soft rot	<i>Erwinia carotovora</i> subsp. <i>carotovora</i> <i>E. carotovora</i> subsp. <i>atroseptica</i> <i>E. chrysanthemi</i> <i>Pseudomonas</i> spp.
Alternaria rot	<i>Alternaria alternata</i>
Botrytis fruit rot	<i>Botrytis cinerea</i>
Rhizopus rot	<i>Rhizopus stolonifer</i>

Abiotic diseases

Abiotic diseases	
Blossom-end rot	Deficiency of calcium in fruit
Sunscald	Exposure of fruit to sunlight and heat

Viral diseases

Viral diseases	
Alfalfa mosaic	genus Alfamovirus, Alfalfa mosaic virus (AMV)
Andean potato mottle	genus Comovirus, Andean potato mottle virus-pepper strain (APMoV)
Beet curly top	genus Curtovirus, Beet curly top virus (BCTV)
Chili leaf curl	Possibly strain of Tobacco leaf curl virus (TLCV)
Chilli veinal mottle	genus Potyvirus, Chilli veinal mottle virus (ChiVMV)
Chino del tomate	genus Begomovirus, Chino del tomate virus (CdTV)
Cucumber mosaic	genus Cucumovirus, Cucumber mosaic virus (CMV)
Pepper golden mosaic complex (previously Texas Pepper, Serrano Golden Mosaic, and Pepper Mild Tigre Viruses)	genus Begomovirus, Serrano golden mosaic virus (SGMV), Pepper mild tigre virus (PMTV), and others
Pepper huasteco	genus Begomovirus, Pepper huasteco virus (PHV)
Pepper mild mottle	genus Tobamovirus, Pepper mild mottle virus (PMMV)
Pepper mottle	genus Potyvirus, Pepper mottle virus (PepMoV)
Pepper veinal mottle	genus Potyvirus, Pepper veinal mottle virus (PVMV)
Potato virus Y	genus Potyvirus, Potato virus Y (PVY)
Sinaloa tomato leaf curl	genus Begomovirus, Sinaloa tomato leaf curl virus (TCLV)
Tobacco etch	genus Potyvirus, Tobacco etch virus (TEV)
Tobacco mosaic and Tomato mosaic	genus Tobamovirus, Tobacco mosaic virus (TMV) and Tomato mosaic virus (ToMV)
Tomato spotted wilt	genus Tospovirus, Tomato spotted wilt virus (TSWV)

Table 2.2(A) : Economically important diseases of hot pepper in India

Disease	Causal organism	Reference
Anthracnose and ripe fruit rot	<i>Colletotrichum capsici</i> <i>C. gleosporoides</i> <i>C. piperatum</i>	Grover and Bansal (1970), Thind and Jhooty (1990)
Leaf blight & fruit rot	<i>Phytophthora capsici</i> <i>Phytophthora nicotianae</i> var . <i>nicotianae</i>	Sohi <i>et al.</i> (1971), Sharma and Bhardwaj (1976)
Powdery mildew	<i>Leveillula taurica</i> <i>Oidiopsis taurica</i>	Pawar <i>et al.</i> (1985)
Frogeye leaf spot	<i>Cercospora capsici</i>	Muneem <i>et al.</i> (1995)

Incidence of *Colletotrichum dematium*

The distribution of ripe rot and anthracnose pathogen in the world and in India is presented in Table 2.3 and 2.4.

The diseases have been reported from USA, Armenia, Canada, Bulgaria, Uganda, Japan, Pakistan, Malaysia, Korea, Sri Lanka, China, Thailand and Poland (Table 2.3).

Table 2.3 : World distribution of anthracnose and ripe rot of hot pepper caused by *Colletotrichum* sp.

Country	Reference
USA	Smith and Crossman (1958)
Armenia	Babayan and Shakhnubaryan (1970)
China	Ling and Lin (1994)
Malaysia	Mazilan and Sariah (1980)
Canada	Illman (1960)
Bulgaria	Khristova (1958)
Japan	Takano <i>et al.</i> (1985)
Sri Lanka	Park (1929)
Thailand	Juanbhanich and Chana (1975)
Uganda	Walter <i>et al.</i> (1974)
Pakistan	Sattar and Hafiz (1952)
Korea	Lee <i>et al.</i> (1986 a,b)

The pathogen was also noticed in almost from all the parts of chilli growing areas of India, including Assam, Andhra Pradesh, Bihar, Karnataka, Maharashtra, Punjab, Odisha, Rajasthan, Tamil Nadu and Jammu & Kashmir (Table 2.4).

Distribution of *Alternaria alternata*

The distribution of fruit rot & tender tip drying disease caused by *Alternaria alternata* in the world and in India is presented (Table 2.5 and 2.6).

Table 2.4 : Distribution of fruit rot and anthracnose in India

State	Reference
Punjab	Thind and Jhoothy (1985)
Bihar	Kumar and Mahmood (1986)
Maharashtra	Joi and Sonone (1980)
Assam	Rathaiah (1983)
Karnataka	Padaganur and Naik (1991)
Rajasthan	Chakravarti and Anil Kumar (1975)
Jammu & Kashmir	Ahmed <i>et al.</i> (1991)
Orissa	Rout and Rath (1972)
Tamil Nadu	Raja and Pillayarswamy (1972)
Andhra Pradesh	Manoharchari and Padmavati (1976)

Table 2.5 : World distribution of *Alternaria alternata*, the cause of leaf spot and fruit rot

Country	Reference
Argentina	Walter <i>et al.</i> (1974)
Bangladesh	Mridha and Siddiqui (1989)
Nigeria and Brazil	Adisa (1985)
Mexico	Leyendecker (1994)
Italy	Sibilia (1957)
USA	Miller <i>et al.</i> (1984)
Pakistan	Sultana <i>et al.</i> (1988)
Iraq	Shawkat <i>et al.</i> (1978)
Romania	Tutunaru and Raicu (1978)

Table 2.6 : Distribution of fruit rot disease caused by *Alternaria alternata* in India

State	Reference
Madhya Pradesh	Hasija (1987)
Maharashtra	Mali and Joi (1985)
Haryana	Chauhan and Duhan (1986)
Andhra Pradesh	Manoharachari and Padmavati (1976)
Tamil Nadu	Sujatha Bai <i>et al.</i> (1993)
Rajasthan	Mathur and Agnihotri (1961)
Uttar Pradesh	Singh and Tandon (1967)

Association with seeds

Ripe rot

The seed borne nature of *Colletotrichum dematium* has been documented and demonstrated by several workers (Kulshrestha *et al.*, 1976; Manoharachari and Padmavati, 1976; Sangehote and Janbhamich, 1984; Nobel and Richardson, 1968; Suryanarayana and Bhombe, 1961; Shawkat *et al.*, 1978; Mridha and Siddiqui, 1989).

Tender tip drying

The seed borne nature of *Alternaria alternata* in *Capsicum annum* has been demonstrated (Suryanarayana and Bhombe, 1961; Monharachari and Padmavati, 1976; Mridha and Siddiqui, 1989; Dhawale and Kadmelwar, 1978).

Association of mycoflora

A numbers of mycoflora have been observed associated with chilli seeds (Suryanarayana and Bhombe, 1961; Ram Nath and Lambat, 1971; Walter *et al.*, 1974; Nobel and Richardson, 1968; Sultana *et al.*, 1988).

The mycoflora found associated with seeds are presented in Table 2.7.

Table 2.7 : List of major pathogens associated with hot pepper seeds

Seed associated pathogen	Reference
<i>Alternaria alternata</i> , <i>Drechslera sarokinensis</i> , <i>D. tetramera</i> , <i>Fusarium equisetii</i> , <i>Fusarium moniliforme</i> , <i>Fusarium semitectum</i> , <i>Curvularia lunata</i> , <i>Phomopsis</i> , <i>Verticillium alboatrum</i> , <i>Aspergillus flavus</i> , <i>Aspergillus niger</i>	Suryanarayana and Bhome (1961), Ram Nath and Lambat (1971), Walter <i>et al.</i> (1974), Nobel and Richardson (1968), Sultana <i>et al.</i> (1988)

Extent of damage

Losses due to *Colletotrichum dematium* and *Alternaria alternata* have been worked out. At Jorhat (Assam), about 32 per cent fruit losses have been reported by Choudhary (1957). Pearson *et al.* (1984) recorded losses up to 17.2%. Whereas, Grover and Bansal (1970) and Singh *et al.* (1977) observed severe losses under conditions of Punjab and Kanpur. Suryananayana and Bhome (1961) reported only 8-12 per cent seed germination due to the seed borne nature of *Colletotrichum* sp. Padaganur and Naik (1991) observed 75.5% seed infection of *C. capsici* in Karnataka.

Powdery mildew generally has caused 10-15% yield loss in green house pepper crop (Sabaratnum, 2004).

Pre and post harvest fruit losses of 10 to 75% have been reported (Choudhary, 1957; Higgins, 1930; Ocfemia, 1925; Verma and Krishi, 1974).

Singh (1987) reported the losses ranging from 19.0 to 47.89% while Sanz (1970) observed between 30-40% fruit infection due to *Alternaria* sp. In New Mexico, losses upto 90.0% were recorded due to internal infection of *Alternaria* sp. (Leyendecker, 1994). Reduced seed germination and seed rot due to *Alternaria* sp. has been recorded (Adiver *et al.*, 1987; Dhawale and Kodmelwar, 1978).

Common losses of hot and sweet peppers

Saha and Singh (1988) reported that in favourable weather anthracnose caused damage upto 25%. Roy *et al.* (1997) observed the occurrence of anthracnose on 3-15% fruits in home gardens in Mississippi.

The yield loss of phytophthora infected plants was reported in the range of 43-100% (Liang *et al.*, 1992). In India, Shyam (1969) reported the incidence of fruit rot between 58-100% under conditions of Himachal Pradesh while Bhardwaj (1983) observed incidence between 35-62 and 30-68% on leaves and fruits, respectively.

Powdery mildew

Incidence 81% of powdery mildew disease under polyhouse conditions has been reported from Himachal Pradesh (Gupta *et al.*, 2003) while under open cultivation the disease caused 24.41% yield reductions (Sharmila *et al.*, 2004).

Pathogenicity

Pathogenicity is the ability of a pathogen to cause disease. *Colletotrichum dematium* and *Alternaria alternata* have been recorded on the number of host plants, indicating the ability to produce disease.

Various methods for testing the virulence of seed associated mycoflora have been documented (Agarwal, 2006; Vishnavat, 2009). Roll on culture method, pin prick method; soil inoculation method and fruit injection methods have been used in different crops for testing virulence of range of seed associated mycoflora (Bhale, 1993).

Management

The association of *Colletotrichum dematium* and *Alternaria alternata* with fruit rot, twig drying, tender tip drying and leaf spots has been reported. The seed borne nature of both the fungi has been observed by several workers. The pathogens are transmitted through seeds and responsible for seed rot, seedling decay. The pathogen survives in the plant debris and secondary infection takes

place through air borne inoculum that multiplies on the plant lefts in the soil (Agrios, 2009).

Attempts have been made by several workers to find suitable fungicides for the control of anthracnose pathogen (*Colletotrichum dematium*) including Takano *et al.* (1985), Thind and Jhooty (1980), Rathore (2006), Sharma and Thakre (2004) and fruit rot and twig drying pathogen. *Alternaria alternata*, Khare *et al.* (2002), Parwaiz *et al.* (1968), Singh and Tandon (1967), Miller *et al.* (1984), Jharia *et al.* (1997).

Management of seed associated mycoflora

Management of seed associated *Colletotrichum dematium* and *Alternaria alternata* has been reported by Srinivas *et al.* (2006), Thippeswamy (2007), Prasanna *et al.* (2009), Rahman *et al.* (2004), Mali and Joi (1985), Dhyani *et al.* (1990), Siddarmaiah *et al.* (1980), Prasad (1985), Sultana *et al.* (1988).

Effectiveness of seed treatment with Thiram plus captan (0.3%) in checking the pre- and post-emergence losses and mortality at adult stage was observed by Jharia *et al.* (1997). Among 12 seed dressers tested Thiram was the best against seed borne *Colletotrichum* sp. (Kumar and Mahmood, 1986). Better emergence and vigour was also recorded. Efficacy of Thiram (0.2%) was also observed by Chakravarti and Anil Kumar (1975) and Siddiqui *et al.* (1977). The ripe rot pathogen was controlled by the application of zineb to the chilli seeds (Boswell *et al.*, 1952). Panigrahi and Narain (1971) recorded the efficacy of vitavax, plantvax and zirum.

The efficacy of ferbam, maneb and captan @ 0.5% was confirmed by Crisam and Mesechu (1970) while investigating the leaf spot caused by *Alternaria* sp. on red pepper.

Efficacy of seed treatment with Thiram has been reported against *Alternaria* sp. by Mali and Joi (1985), Dhyani *et al.* (1990) while Kannaiyan *et al.* (1980) recorded the best results with Benlate-T (0.3%).

In Bangladesh, Mridha and Chaowdhary (1990) observed the efficacy of benomyl, mancozeb and vitavax 200 against the seed borne natural infection of *A. alternata* and *C. capsici* at 0.45% after 6 days, Siddaramaiah *et al.* (1980) recommended the use of Thiram (0.3%) while Prasad (1985) observed Triforine (0.15%) the best, as seed treatment against *Alternaria carthemi* in safflower.

Foliar application of fungicides

Management of *Colletotrichum dematium* (= *Colletotrichum capsici*) and *Alternaria alternata* through foliar application of fungicides has been attempted by number of workers throughout the world.

Anthracnose and ripe rot

Extensive studies have been carried out in all the chilli growing areas against this disease (Kumawat, 1997; Ushakiran *et al.*, 2006; Rathore, 2006; Sharma and Thakare, 2004, Rathore, 2004, Udit Narain *et al.*, 2006; Mani *et al.*, 2005, Chander Mohan, 2004; Hegde and Anahosur, 2001; Hingole and Kurandikar, 2009; Jayasekar *et al.*, 1987, Raju and Rao, 1985; Kashyap *et al.*, 2008; Deshmukh *et al.*, 2004; Reddy, 2004; Ekbote, 2005).

Significant reduction due to Mancozeb plus Thiophenate methyl and Carbendazim was noticed (Kumawat, 1997; Ushakiran *et al.*, 2006). Efficacy of application of Carbendazim has been observed (Sharma and Thakare, 2004; Thippeswamy, 2007; Udit Narain *et al.*, 2006; Ekbote, 2005; Reddy, 2004; Rao *et al.*, 2000; Jayasekar *et al.*, 1987). Efficacy of mancozeb was noticed by Rathore (2004), Raju and Rao (1985), Natrajan and Subramanian (1976), Kadu *et al.* (1977), Kashyap *et al.* (2008). Fungicide, thiophenate-methyl has been used for the effective control of ripe rot pathogen by Sharma and Thakare (1999), Kumawat (1997) Sharma and Thakare (2004), Thippeswamy (2007), Udit Narain *et al.* (2006). Whereas, the efficacy of hexaconazole was reported by Hegde and Anahosur (2001).

Alternaria fruit rot

Very few references on chilli fruit rot caused by *Alternaria alternata* are available however, on other crops, information is available. Khare *et al.* (2002) recorded the efficacy of mancozeb (0.2%), chlorothalonil (0.2%), Carbendazim (0.1%) against *Alternaria* leaf spot of chilli. Ghosh *et al.* (2002) reported effectiveness of tridemorph (0.1%) and mancozeb on gerbera. In marigold, minimum disease was noticed after application of propiconazole (0.1%) by Patil *et al.* (2005).

Symptomatology

Symptoms caused various major disease have been studied by several workers and a brief description is presented herewith.

Anthracnose

All growth stages may be affected, including post harvest stages. Symptoms occur primarily on ripening fruit often where fruit is touching the soil or plant debris. On ripe fruit there are small, sunken circular depressions upto 30 mm in diameter. The center of the lesions becomes tan in colour while the tissue beneath the lesion is lighter coloured and dotted with many dark coloured fruiting bodies of the fungus that form concentric rings in the lesion. The salmon coloured areas on the surface in the central portions of the lesions consist of large masses of fungus spores (www.avrdc.org). Typically, symptoms first appear on the surface of ripe fruits as small water-soaked sunken lesions which rapidly expand to form lesions 3 to 4 cm in diameter which often coalesce to encompass much of the fruit surface. Fully expanded lesions are sunken and range from light tan to dark red and have varying amounts of dark stromatic fungal tissue composed of numerous setose or glabrous acervuli that produce pale buff to salmon spore masses either scattered or in concentric rings within the lesions (Choudhary, 1957; Hadden and Black, 1992; Higgins, 1923; Smith and Crossan, 1958). The fungus commonly colonizes the internal cavity of fruits where it can infest and infect seeds. Severely infected seeds may be shriveled and brownish with reduced germinability (Grover and Bansal, 1970). Anthracnose appears on peppers as sunken spots, often with a mass of yellow or

pinkish spores. Promoted by hot and moist conditions, anthracnose occurs most often on ripe fruit, but can also infect immature fruits, stems and leaves (<http://www.ehow.com>).

Anthracnose caused by *Colletotrichum* spp. is a major problem of ripened fruits. The fungus produces dark, sunken spots upto 2.5 cm across on sweet pepper. The spots occur on green and ripe fruits and their surface may be covered in moist weather with salmon pink mass of spores. The fungus is seed borne (<http://www.infonet-biovision.org>).

Powdery mildew

Older plants and lower leaves are the first to show evidence of powdery mildew infection. The fungus only infects the leaves not the fruit or stem of pepper plants. Typical powdery mildew symptoms include fluffy, white patches of powdery mildew on the underside of leaves. These patches may turn brown rather than remaining white. The top surface of the leaf may appear normal or have diffuse, yellow patches which correspond to the mildew colonies on the lower surface (Sabaratnum, 2004).

Chlorotic blotches or spots that may become necrotic with time appear on the upper leaf surface. When lesions are numerous they may coalesce resulting in a general chlorosis of the leaves. On the lower leaf surface, the lesions develop a necrotic flecking and generally, but not always, are covered with a white to gray powdery growth. The disease progresses from the older to younger leaves and shedding of the foliage is a prominent symptom (Dixon, 1978; Palti, 1988).

Leveillula taurica infects only leaves. Light yellow or yellow green spots on the upper leaf surface, which later become brown, and scarce white mould on the lower surface are the main characteristics. Powdery mildew infected plant parts may be chlorotic and distorted. Premature defoliation and poor growth are common features of severely infected plants (Palti, 1971; Sitterly, 1978; Braun, 1995).

The symptom of powdery mildew disease are first appeared as small white powdery patches on lower surface of older leaves which progresses from older leaves to the younger leaves in both seedling and fruiting stage. When infection is severe they also appeared on top side of the leaves. Infected area of leaves dry up and dropped upto 90-100% in severe cases. No disease symptoms were observed on stems and fruits (Patel *et al.*, 2011).

Yellowish blotches or spots appear on the upper leaf surface. The leaf surface is covered with a white to grey powdery fungal growth. The disease progresses from the older to younger leaves and shedding of the foliage is pronounced. Leaf defoliation leads to reduction in size and number of fruits. It also results being sun-burned. The disease is favoured by warm, humid and dry weather. The fungus causing powdery mildew also attacks eggplants and tomatoes (<http://www.infonet-biovision.org>).

Phytophthora blight

Damping off of young seedlings; root and crown rot; blight on leaves is reported (Berke *et al.*, 2003).

The disease can be divided into two phases, a crown rot phase and an aerial blight phase. In the crown rot phase of the disease, a black girdling lesion occurs at the soil line. Infection occurs at the axil of a branch and stem with a 2-3 inch black, girdling lesion developing on the stem. All of the leaves on the branch above the lesion wilt and eventually the entire plant dies (<http://vegetablemdonline.ppath.cornell.edu>).

Development of diseases

Investigation on incremental development of diseases of peppers have been worked out by several workers in the different parts of the world. A brief review on the aspect is presented.

Fruit rot and dieback

The fungus (*Alternaria alternata*) commonly colonizes wounded or senescent tissue (Shef and McNab, 1986). Conidia require moisture to germinate and

optimal mycelial growth occurs at 26-28°C. Optimum temperature ranges from 24-28°C.

Anthraco

The optimum temperature for fruit infection is reported to be 20-24°C with fruit surface wetness, although infection may occur from 10-30°C (www.avrdc.org).

Powdery mildew

The disease is favoured when large day/night temperature and humidity fluctuations occur, which promote periods of leaf wetness. Development of *Leveillula taurica* is favoured by warm (25°C) and dry (less than 80% RH) days followed by humid (greater than 85% RH) night periods. Temperature of 25°C are associated with a higher rate of disease development compared to temperature of 18-20°C. Young plants are less susceptible than older plants (www.avrdc.org).

Pepper powdery mildew infection occur over a wide temperature range (19-33°C) with high or low humidity (Sabaratnum, 2004).

Incidence

Anthraco

The longer the period of fruit surface wetness, the greater incidence of the anthracnose severity is reported overhead irrigation will favour development of anthracnose because of increased relative humidity and increased duration of dew periods (www.avrdc.org). Anthracnose incidence on pepper fruits ranged from 5 to 75% has been reported (Hadden, 1989).

Seeds can become infected. When the applications of chlorothalonil (Bromo 500 @ 3.8 ml/litre) and Maneb (Manex 4F @ 1.9 ml/litre) significant reduction in the incidence of infection was observed as compared to unsprayed check treatments (Hartman and Wang, 1992).

Powdery mildew

Plant spacings and luxuriant plant growth arising from high nitrogen levels are likely to faster and greater disease development (www.avrdc.org).

The relative humidity favouring infection by powdery mildew fungi and development of the disease differs from species to species (Coyier, 1985 a,b).

The disease occurs on pepper in warm climates both dry and humid, but rarely in cool climates. Leaf shedding is more pronounced at low humidity. Severe defoliation results in a reduction in size and number of fruit (Dixon, 1978).

Among the diseases, powdery mildew was the most severe with 84.17% disease severity while the incidence of Fusarium wilt and Cercospora leaf spot was 8.33 and 2.0%, respectively (Gupta *et al.*, 2003).

Phytophthora blight

Most cases of the crown rot phase occur in July and August in the lower areas of the field and from there the disease can spread to adjoining areas of the field. *Phytophthora* is considered a weather event disease, meaning that heavy rainfall (in excess of 2 inches) leading to saturated soil is critical for infections to occur. Generally soil temperatures are >18.3°C and air temperatures are in the range of 23.8-29.4°C. The aerial phase of *Phytophthora* blight occurs later in the season as the spores produced on the lesions of plants infected in the crown rot phase.

MATERIAL AND METHODS

The present studies were undertaken to investigate the prevalence of diseases of bell pepper (sweet pepper) and hot pepper. Management of pepper diseases through a combination of new molecules of fungicides was attempted under natural field conditions. The material used and methods followed are described herewith.

General

Cleaning and sterilization of apparatus

The glassware used during the course of investigation were of Corning and Borosil make. Prior to use, each glassware was cleaned with chromic acid solution.

Preparation of chromic acid solution

Sulphuric acid	300 ml
Potassium dichromate	80 g
Distilled water	400 ml

The glassware was cleaned with chromic acid solution followed by thorough washing with detergent powder and finally rinsed with normal tap and/or distilled water as per need. The dried glasswares were sterilized in an autoclave at 1.05 kg/cm² (15 lb per square inch) for 15 minutes, whereas, soil at 1.05 kg/cm² for 180 minutes.

Plastic trays were surface disinfested with 0.1% NaOCl (Sodium hypochlorite solution) followed by thorough washing with sterilized water.

The inoculation needle, forcep and biological needle were surface disinfested by dipping in alcohol and there after heating over a flame.

The inner surface of the growth chamber and clean-air-system was disinfested by using ultra violet lamps and spray of formaldehyde solution. Prior

to use safety precaution were adopted while using ultra violet lamp and formaldehyde solution.

Media

The ingredients of media used during the course of investigation are:

Potato Sucrose Agar (PSA)

Peeled and sliced potato	200 g
Sucrose	20 g
Agar-agar	20 g
Distilled water	1000 ml

Incubation chamber

The incubation chamber was used to provide optimum condition for the isolated mycoflora from seed and different plant parts including stem and fruits of hot and sweet pepper. The internal dimensions of the chamber were length 3.0 m, width 0.75m and height 0.90m. Two sets of Philips 40 W day light tubes were provided in the chamber, horizontally at the height of 40 cm. Alternative cycles of 12 hr light and dark periods were maintained.

Seed germination chamber

To provide the optimum conditions for the hot and sweet pepper seed germination, the walk-in-seed germination chamber was used, the internal dimensions of the chamber were 6.1 feet height, length 8.7 feet and width 5.7 feet. The chamber was provided with light sources and the system of the maintaining the temperature and humidity.

The temperature was adjusted with the help of two air conditioners (1.0 ton) capacity. The humidity was created with the help of rotor-humidity creator where the water molecules were broken in to the small particles resulting in the fog. The wall of the chamber are made of stainless steel and provided with insulation by PUF. The insulation maintained the inside temperature during peak variations.

Meteorological data

During 2011-12, the data on rainfall, relative humidity, minimum-maximum temperature were obtained from the Meteorological Observatory, College of Agricultural Engineering, JNKVV, Jabalpur.

Table 3.1 : The weekly weather condition data from July 2011-May 2012

Standard weeks		Temperature (°C)		Relative humidity (%)		Rainfall (mm)
		Max.	Min.	Morn.	Eve.	
June 2011	22	41.8	25.6	48	20	000.0
	23	40.1	26.4	61	28	015.4
	24	39.6	25.2	73	37	023.4
	25	31.0	22.5	89	84	253.2
July	26	27.4	22.8	90	80	091.3
	27	32.8	23.8	86	61	015.2
	28	32.0	23.5	92	71	046.4
	29	30.3	22.8	93	83	429.1
August	30	29.9	22.7	90	70	119.2
	31	31.1	23.6	92	82	140.0
	32	28.7	22.7	93	85	118.5
	33	29.8	22.7	92	78	057.6
	34	30.9	22.9	93	70	014.6
September	35	31.5	22.8	96	71	150.6
	36	29.5	22.6	94	80	221.6
	37	29.7	22.4	93	73	092.2
	38	30.8	21.9	93	67	041.0
October	39	31.3	20.8	86	56	000.0
	40	32.2	18.6	90	47	005.2
	41	32.4	19.1	92	43	000.0
	42	32.6	15.8	89	31	000.0
	43	31.8	13.9	87	30	000.0

Standard weeks		Temperature (°C)		Relative humidity (%)		Rainfall (mm)
		Max.	Min.	Morn.	Eve.	
November	44	31.0	11.0	86	24	000.0
	45	31.8	12.1	89	29	000.0
	46	30.9	12.4	89	28	000.0
	47	29.4	11.3	92	33	000.0
December	48	27.2	09.6	89	36	000.0
	49	28.8	11.1	90	34	000.0
	50	25.3	07.2	89	35	000.0
	51	24.8	05.3	90	24	000.0
	52	24.9	07.4	89	32	000.0
Jan. 2012	1	23.0	12.0	95	69	028.6
	2	20.2	6.3	93	41	000.0
	3	23.7	7.1	90	36	000.0
	4	21.5	9.0	89	57	013.2
February	5	20.8	8.0	91	46	007.6
	6	26.4	8.8	89	30	000.0
	7	27.6	10.4	90	42	000.0
	8	30.5	9.8	86	28	000.0
March	9	30.1	10.4	86	24	000.0
	10	30.8	11.6	76	18	000.0
	11	31.8	13.2	69	23	000.0
	12	35.1	13.0	66	14	000.0
April	13	37.3	15.3	68	14	000.0
	14	37.8	20.2	49	17	000.0
	15	39.4	18.5	45	14	000.0
	16	38.7	20.2	47	17	000.0
May	17	38.7	21.1	43	18	000.0
	18	38.8	19.7	44	23	000.0
	19	40.2	24.3	49	21	000.0
	20	40.9	24.8	35	16	000.0

Standard weeks	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max.	Min.	Morn.	Eve.	
21	43.2	24.2	30	12	000.0
June 22	44.1	24.3	31	13	008.8

Location of the site

The field experimentations were conducted at Research Experimental Area, Department of Horticulture, JNKVV, Jabalpur. The investigation were conducted on the crop grown during 2011-12 at Jabalpur. The location site lies between 22°49' and 22°80' North latitude and 78°21' and 80°58' East longitude at an altitude of 411.78 meter above the mean sea level.

Status of the disease

The prevalence of bell pepper diseases was determined in the ventilated polyhouse at experimental field, Department of Horticulture, JNKVV, Jabalpur.

The status of hot pepper diseases was determined at Jabalpur in the experimental area, nearby backyard gardens/kitchen gardens. The distribution and occurrence by hot pepper diseases was recorded at Maharajpur Farm and Krishi Nagar.

Incidence of disease

The incidence of major diseases was recorded on randomly selected 100 plants in a particular field and polyhouse. The diseases were identified initially on the basis of typical field symptoms. During the study, total and infected plants were counted to calculate the disease incidence as per the formula.

$$PDI = \frac{TIP}{TPO} \times 100$$

Where,

PDI = Percent disease incidence i.e. per cent plant exhibiting symptoms

TIP = Total number of infected plants

TPO = Total number of plants observed

Collection of pepper plant parts

During study infected leaves, fruits and stem were collected in paper envelopes and brought to the laboratory. The samples so collected were numbered and stored in paper envelopes at 4°C to avoid any further deterioration.

Isolation, purification and identification of fungi

Fruits, twigs, leaves and seeds from infected plants/fruits were collected from different locations. Isolations were made to determine the associated mycoflora. The diseased plant parts were cut into small pieces. Surface sterilized with 0.1% NaOCl for 30 seconds followed by three regular washings with sterilized water and thereafter placed in Petri dishes containing 17-20ml of solidified PSA mixed with small quantity of streptopenicillin to avoid bacterial contamination. The Petri dishes were incubated at $25 \pm 2^{\circ}\text{C}$. After 4 to 7 days incubation, the developing fungi were subcultured on PSA medium and purified by using hyphal tip method.

The isolated fungi were identified with the help of available fungi identification keys and on the basis of morphological characteristics of the colony, mycelium and conidia.

Test of virulence

The pathogenicity test of isolated *Colletotrichum dematium* and *Alternaria alternata* was conducted under field and protected condition. The test was performed by fruit inoculation.

Technique under natural field conditions

Fruit inoculation technique

On semi-ripe and complete red ripe fruits of hot pepper and bell pepper, the cultures of *Colletotrichum dematium* and *Alternaria alternata* were inoculated

by pin prick, injection and tooth pick method. Observations on symptom development were recorded. In pin prick and tooth-pick method, the pricks were made with the help of sterile needles and sharpen tooth picks and later the needles and tooth picks were loaded with inoculum. The needles and tooth picks were touched, separately and individually with the fungal culture plates, so that the mycelial bits and spores were stucked / adhered on the surface of the needles/tooth picks, and then inserted into the skin (pericarp) of the fruits. The spore and mycelial bit suspension was prepared in the culture tube and 2 ml of the spore suspension was injected in the fruits with the help of disposable syringe using the needle number 22.

Symptoms

The symptoms of diseases were recorded under field conditions and the progressive development of the diseases, including anthracnose and alternaria fruit rot and twig infection and powdery mildew was recorded.

Management

The fungicides and their combination were employed for the management studies under lab condition. The fungicides included copper oxy chloride, Carbendazim, Mancozeb, Carboxin + Thiram, Mancozeb + Carbendazim, Mancozeb + Thiophenate methyl. Untreated pepper seeds served as control. Pre-determined seed samples with known infection were used.

Treatment of pepper seeds

The required quantity of fungicides was measured and sprinkled over the pepper (both hot and sweet) seeds kept in polythene bags. The fungicide and seeds were gently shaken for uniform coating. The fungicides treated seeds were spread over a butter paper and later air dried capsicum seeds were placed on the top of the blotter (Standard Blotter method) and sown in the sterile sand (Grow Out Test).

Management of seed associated mycoflora

The seeds of pre tested variety Jawahar Mirch 283 (JM 283) having maximum natural infection of *Colletotrichum dematium* and *Alternaria alternata* was used. The seeds were treated with individual fungicides and observations were recorded on the associated mycoflora adopting Standard Blotter method (ISTA, 1996).

Standard blotter method

Fungicide treated seeds were used. Untreated seeds served as control. In this method, three circular blotter papers of the size of the Petri dish were cut and dipped in sterilized water. Excess water was dripping-off and soaked sheets were placed in each Petri dish. Twenty-five pepper seeds were placed in each Petri dish with the help of sterilized forceps under aseptic conditions of inoculation chamber. In the outer circle, 16 seeds were placed, 8 in the inner circle and one in the center so as to allow in the equal distance between the seeds. Seeded plates were kept for the incubation in the chamber. Fungi were identified by making slides and observing under microscope on eight day of incubation with the help of identification manuals.

Grow Out Test

Well cleaned sterilized sand was used in a pre disinfected plastic tray to determine the influence of fungicidal seed treatment on the germination. Counted seeds were sown in the tray at equal distance. Thereafter the seeded trays were placed in the walk-in-germination chamber. Seed emergence was recorded after eight days.

Management of fruit and plant diseases

Management of fruit rot & leaf spot, dieback of hot pepper caused by *Colletotrichum dematium* and *Alternaria alternata* was attempted under field conditions at Maharajpur Farm, JNKVV, Jabalpur.

Treatment details

Hot pepper variety	Jawahar Mirch 283
Date of nursery sowing	14 October
Date of planting	14 November
Plot size	2.4x 2 m
Plot to plot distance	40 x 40 cm
Row to row distance	40 x 40 cm
Number of plants/plot	30 plants
Fungicide combination and doses	
Fungicide	5
Replication	6

Fungicides

Fungicide	Formulation	Dosage ml / 100 L water
Difenoconazole 25%	EC	25
Difenoconazole 25%	EC	50
Difenoconazole 25%	EC	75
Difenoconazole 25%	EC	100
Difenoconazole 25%	EC	200
Azoxystrobin 23%	SC	50
Azoxystrobin 23%	SC	100
Azoxystrobin 23%	SC	150
Azoxystrobin 23%	SC	200
Azoxystrobin 23%	SC	400
Kitazin 48%	EC	200
Tebuconazole 25%	EC	100
Kitazin 48% + Tebuconazole 25%	EC	200
	EC	100
Control	-	No spray

RESULTS

Investigations were made to determine the distribution of major diseases of capsicum. The group, *Capsicum annuum* L. comprises hot and sweet peppers. The sweet peppers are also known as bell pepper (Shimla Mirch) while the commonly used chilli is known as hot pepper (Plate 1 and 2). The presence and lack of capsaicin is the major differentiating characteristics of the group. The pungent principle is absent in sweet pepper which is a common cultivar of *Capsicum annuum* that produces fruits in different colours including red, yellow, orange and green (Plate 3). Management aspects were also investigated.

Prevalence of Diseases

Incidence of diseases was observed at different locations in the crop grown during September-October 2011 and January-February 2012. The incidence of diseases was recorded in the research experimental fields and kitchen gardens where the vegetable cultivation is undertaken throughout the year.

Measurement of Diseases

The prevalence of diseases was recorded on randomly selected plants in a particular field. The diseases were identified on the basis of field symptoms.

Incidence of Diseases

During September – October

Location wise

Incidence of diseases was recorded at 15 location during the period, that include 12 locations of kitchen gardens at Krishi Nagar, Suhagi and Maharajpur, 3 location of research experimental field.

Table 4.1 : Incidence of diseases of hot pepper during September –October 2011 at Jabalpur

Location	No	Per cent disease incidence						
		Anthracnose		Alternariosis		Powdery mildew	Phytophthora Blight	Rhizoc. Root rot
		Fruit rot	Die back	Fruit rot	Tender tip drying			
Krishi Nagar	1	19	27	08	11	00	13	06
	2	15	23	05	12	00	15	12
	3	14	23	10	10	03	13	11
	4	06	15	08	13	05	18	10
	5	11	09	09	12	00	05	08
Suhagi	1	14	18	06	10	00	14	07
	2	07	02	10	11	00	10	07
	3	12	11	06	13	03	13	13
Maharajpur	1	15	18	04	10	00	07	11
	2	13	16	05	10	11	02	09
	3	10	15	09	12	11	02	08
	4	10	11	06	15	12	00	13
Farm	1	23	35	10	17	10	12	07
	2	13	19	08	11	03	06	03
	3	17	16	08	14	07	11	09
Average		13.2	17.2	7.4	12.0	4.3	9.4	8.9

The data presented in Table 4.1 indicate that during September, October, 2011, eight major diseases of hot pepper were observed under field conditions. Fruit rot & die back caused by *Colletotrichum dematium* (= *Colletotrichum capsici*), tender tip drying & fruit rot (*Alternaria alternata*), powdery mildew (*Leveillula taurica*), stem and leaf blight (*Phytophthora capsici*), root rot (*Rhizoctonia solani*).

The incidence of fruit rot ranged from 6.0-19.0% in kitchen garden being maximum at Krishi Nagar while it ranged 13.0-23.0% at Maharajpur Farm. The average incidence was 13.2%. The die back was maximum at Krishi Nagar (27.0%) and minimum (2.0%) at Suhagi. In research fields, the incidence of die-back ranged from 16.0-35.0% where the vegetable cultivation is being undertaken continuously since several years. The *Alternaria* fruit rot incidence ranged from 4.0-10.0% being maximum at a location of Suhagi village while in the research fields incidence ranged from 8.0-10.0%. The tender tip drying ranged from 10.0-13.0% in the kitchen gardens and 11.0-17.0% in the research fields. The fruit rot and downward necrosis caused by both the fungi were widespread and recorded at every location (Table 4.1).

Among the 15 locations powdery mildew was recorded at 9 locations. The incidence ranged from 3.0-12.0%, being maximum at a location of Maharajpur as observed during September-October 2011. Leaf blight and stem infection due to *Phytophthora capsici* was observed in the ranged of 2.0-18.0%. The root rot caused by *Rhizoctonia solani* was observed in the range of 3.0-13.0%.

In hot peppers, initially *Rhizoctonia* root rot was observed when the soil moisture was moderate, with the on-set of monsoon and subsequent increase in atmospheric relative humidity, the incidence of *phytophthora* blight was noticed, with the advent of decreased temperature the fruit rot and dieback were initiated.

During January-February 2012

Location wise

Investigation on the incidence of diseases of hot pepper was made at 5 locations in the kitchen garden of Krishi Nagar and 3 locations at Maharajpur Farm. During the period incidence of fruit rot caused by *Colletotrichum dematium* ranged from 2.0-3.0% in Krishi Nagar whereas the die back ranged from 4.0-9.0%. The tender tip drying caused by *Alternaria alternata* was recorded in the range of 6.0-19.0% and the fruit rot from 3.0-12.0%.

In the kitchen gardens of Krishi Nagar powdery mildew, Phytophthora blight and Rhizoctonia root rot were not observed. In research fields, where the vegetable cultivation is undertaken since last several years, the incidence of *Colletotrichum* fruit rot was upto 13.0%, die-back upto 15.0%, *Alternaria* fruit rot upto 12.0% and tender tip drying upto 15.0% was observed (Table 4.2).

Table 4.2 : Incidence of diseases of hot pepper during January-February 2012 at Jabalpur

Location	No	Anthracnose		Alternariosis		Powdery mildew	Phytophthora Blight	Rhizoc. Root rot
		Fruit rot	Die back	Fruit rot	Tender tip drying			
Krishi Nagar	1	3	9	12	19	0	0	0
	2	2	5	8	15	0	0	0
	3	3	6	11	11	0	0	0
	4	2	4	3	8	0	0	0
	5	3	5	6	6	0	0	0
Maharajpur Farm	1	7	5	11	13	0	0	0
	2	13	15	5	13	0	0	0
	3	10	8	9	15	0	0	0
Average		5.3	7.1	8.1	12.5	0	0	0

Variety wise

Incidence of diseases of hot pepper was investigated on 6 available varieties grown at Research Experimental Field, Maharajpur Farm, Jabalpur. Maximum dieback (40.0%) and fruit rot (25.0%) caused by anthracnose fungi were observed in JM 218 while minimum fruit rot and dieback, 7.0 and 11.0% were observed in Pusa Jwala. Among the varieties, least (5.0%) fruit rot due to *Alternaria alternata* was recorded in Pant C1 whereas, minimum (6.0%) tender tip drying disease was observed in Pusa Jyoti. Powdery mildew was not recorded in Pusa Jyoti and Pant C1. (Table 4.3).

Table 4.3 : Incidence of diseases of hot pepper in different varieties during September –October 2011

Variety	Percent disease incidence						
	Anthracnose		Alternariosis		Powdery mildew	Phytophthora Blight	Rhizoc. Root rot
	Fruit rot	Die back	Fruit rot	Tender tip drying			
JM 218	25	40	12	15	06	08	03
JM 283	23	39	17	18	10	12	04
Mahyco	11	17	14	19	11	14	00
Pusa Jwala	07	11	09	11	02	00	05
Pusa Jyoti	09	12	06	06	00	00	11
Pant C1	10	13	05	13	00	02	00

Stem infection, leaf blight and fruit rot due to *Phytophthora capsici* was maximum (14.0%) and least (2.0%) in Mahyco and Pant C1, respectively. The disease was not recorded in Pusa Jwala and Pusa Jyoti. The incidence of

Rhizoctonia root rot ranged from 3.0-11.0%. The diseases were not recorded in Pant C1 (Table 4.3).

Symptomatology

The identification of diseases observed on hot and sweet pepper was initially made based upon the field symptoms. Anthracnose, tender tip drying and Rhizoctonia root rot, Phytophthora blight and powdery mildew were observed on hot peppers. On the peppers diseases observed were anthracnose, powdery mildew, and blight on fruits (Plate 4, 5, 6, 7, 8, 9).

Hot pepper

Tender tip drying (*Alternaria alternata*)

On leaves and fruits

The fungus, developed small, isolated, scattered and pale brown lesions. From downward to upward infection was noticed in the necrotic tissues concentric rings developed to produce target board effect. There was a narrow chlorotic zone around the spots. On the fruits irregular concentric rings of necrotic tissues appeared. The pericarp became grey. In badly infected fruits, the seeds were also infected. The pericarp became very thin and papery. The necrotic portion was covered with mouldy growth of *Alternaria alternata* which was dark grey brown to black velvety (Plate 9).

On stem

The tender twig drying symptoms were very conspicuous and could be distinguished on the basis of white wash symptoms. The twigs became silvery white in contrast of brown chocolate colored tender tip (die back) as in case of plants infected with *Colletotrichum dematium*. Irregular brown specks were common (Plate 4, 7, 8).

On seeds and seedlings

Infected seeds were smaller in size having brown to black blemishes on seed coat. Infected seed had poor ability to germinate. Seedlings of 10 day old

had shown the pale brown discoloration of young stem. In severe cases the grey mycelium was observed on the infected portion (Plate 10).

Anthracnose (*Colletotrichum dematium*)

On stem and twigs

A brown demarcation line separated the infected portion from healthy ones. The die-back condition was conspicuous. Circular to irregular shaped spots appeared on leaf lamina. The dead portion contained fruiting bodies (Plate 4, 5).

On fruits

The infection was observed on semi-ripe and ripe fruits. The colour of full ripe fruits changed due to the infection. It changed to straw coloured from normal red colour. At initial stage small black brown spots appeared and later spread in the direction of long axis, thus becoming more or less elliptical. In certain cases the acervuli were arranged in circular fashion. Numerous black infected seed with profuse mycelium and stromatic bodies were observed when the infected fruit was cut open. On semi-ripe fruit the symptoms were confusing, necrotic spots appeared in the beginning later that covered the entire fruit (Plate 4).

On seeds and seedlings

Infected seeds were brown rusty, shrunk and smaller. Just beneath the pericarp stromatic bodies with profuse mycelial growth were observed. Seedlings of 5-8 days old exhibited brown discoloration on young stem. Black mass of scattered acervuli was noticed on rotted seedlings after 10 days (Plate 10).

Rhizoctonia root rot (*Rhizoctonia solani*)

Initially the symptoms resembled the damping-off symptoms. The fungal infection was observed on the stem, confined to the collar region. The infected plants exhibited pale brown dry lesions with circular rings at soil level. The infection resulted in stunted growth with dull green leaves followed by wilting of the plants. The stem portion could be broken easily at the infected area.

Powdery mildew

The symptoms of the disease first appeared as white to light grey-coloured spots on the older leaves that progressed to upper leaves. Chlorotic spots were noticed on the upper surface of the leaves, while the corresponding lower surface covered with white to grey powdery growth of the fungus. Later the lower surface of the leaves turned necrotic.

Sweet pepper

Powdery mildew (*Leveillula taurica*)

On leaves

The pathogen was observed on the lower side of the leaves of older plants. Upon close inspection of the underside of the older leaves fluffy, white patches of powdery mass of the fungus was recorded. These patches turned brown rather than remaining white with the advancement of time. The top surface of the leaves appeared normal at the initial stage, however, had diffuse, yellow patches that corresponded to the mildew colonies on the lower surface. Severely infected leaves withered and drop-off. Shedding of the foliage was prominent symptom.

On stem and fruits

The symptoms did not observed on the fruits and stem portion.

Anthrachnose (*Colletotrichum dematium* = *C. capsici*)

On fruits

The infection of the fungus was prominent on semi-ripen to ripening fruit. Small sunken depressions were recorded. The sunken depressions had a corky appearance. The centre of the lesions became tan in colour while the tissues beneath the lesions were light coloured. The depressed sunken lesions were dotted with several dark coloured fruiting bodies of the fungus which were arranged naturally in concentric rings (Plate 6).

On foliage and stem

On foliage and stem symptoms appeared as small, irregularly shaped grey brown spots with dark brown edges. Fungal fruiting bodies were formed in concentric rings. The infected tissues were corky.

Rhizoctonia root rot (*Rhizoctonia solani*)

Initially the symptoms resembled the damping off symptoms. The fungal infection was observed on the stem, confined to the collar region. The infected plants exhibited pale brown dry lesions with circular rings at soil level. The infection resulted in stunted growth with dull green leaves followed by wilting of the plants. The stem portion could be broken easily at the infected area.

Phytophthora blight (*Phytophthora* spp.)

Initially symptoms on stem due to infection of *Phytophthora* spp. were recorded especially in water saturated soil. The infected stem had dark discolouration and pith was completely destroyed. Blighting of leaves was recorded. The infected plants died quickly.

Identification

On plant

The identification of *Colletotrichum dematium* and *Alternaria alternata* was made on the basis of research reports and key provided by Sutton (1980) and Kulshreshtha *et al.* (1977). Initially the fungal colony was pink, later become black brown on potato sucrose agar medium. The mycelium was brown, septate and branched. The fruiting bodies acervuli, were dark black, globose and abundantly scattered on the host surface that contained numerous conidia and setae. The setae were black to brown, broader at the base and pointed at tips. The setae were larger than conidial mass. The length of setae was in the range of 60.5 to 190.5 μm . The conidia were hyaline, single celled, curved with both ends, pointed and were pink in mass. The size of the conidia ranged from 22.8-27.50 x 3.5-6.3 μ .

***Alternaria alternata* (Fr.) Keissler**

On the basis of morphological and cultural character on described by Ellis (1971) and Subramaniam (1971), the identification of isolated *Alternaria* sp. was done. The mycelium was aerial varying from fluffy, cottony to closely tuft. The pigmentation was grey, olive green and almost black in old culture. Mycelium was closely septate. The conidia were light, olive brown to dark brown smooth, muriform with 3-6 transverse septa and 1-3 longitudinal septa. The conidia were variable in shape and size. It ranged from 30.2-42.8 x 10.6 – 13.2 μ . The conidia were observed in chain, the size of the beak ranged from 10.20 x 2.6 μ m. The conidiophores were simple, erect, olive brown, septate often with scars and swellings. On the basis of symptoms, morphological and conidial characteristics, the isolated fungi were identified as *Alternaria alternata* (Fr.) Keissler and *Colletotrichum dematium* (Pers ex Fr.) Grove.

Colletotrichum capsici (Sydow) Butler and Bisby is the well adopted and known name assigned to the fungus, however, Kulshreshtha *et al.* (1976) and Nobel and Richardson (1968) have listed and considered as *Colletotrichum dematium*.

Seed associated mycoflora

On the basis of habit characters and fruiting bodies mycoflora were identified. Help of keys developed by Kulshreshtha *et al.* (1976); Ahmed and Reddy (1993); Ram Nath *et al.* (1970), Barnett (1965), Tiffany and Gilman (1954), Booth (1971) was taken for identification of the associated mycoflora.

***Colletotrichum dematium* (Pers. ex Fr.) Grove**

Examination under stereoscopic binocular microscope

The fungus was characterized by the scattered presence of acervuli or in groups, with numerous black brown setae (thin black hair like spines). Setae were longer than conidial mass of dull white to pale yellow orange. After few days of incubation (beyond 10 days) profuse growth of white mycelium was observed

on seeds. Acervuli exuded spores in pale, smoke gray mass. The colour of the acervular mass ranged from pale to bright orange.

Examination under binocular microscope

A bit of fungal mass growing on capsicum seeds was transferred on the micro slide from the growing seeds. Conidia of *Colletotrichum dematium* were hyaline, fusoid, ends were typically slightly tapering and measured 20-27 x 3-4 μ . Setae were trichiform brown to light black, 78-219 x 5-8 μ , setae were 1 to 5 septate swollen at the base.

***Fusarium moniliformae* J. Shed (*Gibberella fujikuroi*) (Sawada) Itoin & KN Kumar**

Examination under stereoscopic binocular microscope

On incubated seeds, white aerial, profusely branched mycelium was observed that covered the entire seed surface. Sporodochia were produced. Bead like structure on the mycelium were noticed. Conidia were in chains.

Examination under binocular microscope

Macro and micro-conidia were produced. Micro-conidia were produced abundantly on micro-conidiophores, which were unbranched. Micro-conidia were hyaline, single celled, slightly curved 2.5-3.5 x 5-11 μ . Macro-conidiophores were fusoid with pointed ends, hyaline 3.5-4.5 x 1.25-65 μ . Chlamydospores were observed.

***Alternaria alternata* (Fr.) Keissler (*Alternaria tenuis* C.G. Nees)**

Examination under stereoscopic binocular microscope

On incubated seeds chain of dark brown conidia of variable lengths were observed. The chains normally branched at the beak of a spore. Woolly appearance of the fungal growth was also observed. Conidia produced in acropetal succession. The colour of colony was olive green to brown. Mycelium was produced in abundance.

Examination under binocular microscope

Hyphae were dark brown, thick, septate and branched. Dark pigmented conidia were produced on conidiophores. Conidia have transverse and longitudinal (oblique) septa, muriform, with an elongated terminal cell. Conidia often have a short conical beak, which may be one third of the length of the conidia. Conidia measured 10-18 x 20-65 micron. Surface walls were smooth or veruculose and pale brown in colour.

***Aspergillus flavus* Link ex Fr.**

Examination under stereoscopic binocular microscope

On incubated seeds, *Aspergillus flavus* was noticed as a compact globose to radiate conidial heads in shades of green. The mycelium may be submerged in the seed coat. It forms tough felt mass. Light to dark green ball like structures supported on stalks were visible conidiophores stood erect on the seed surface.

Examination under binocular microscope

Conidia were hyaline, single celled, produced in chains, typically globose, 3-6 micron in diameter. Conidiophores were simple, unbranched, transparent and smooth, radiating phialid were formed on the apex of conidiophores inflated into a vesicle.

***Aspergillus niger* Van Teighem**

Examination under stereoscopic binocular microscope

Abundant conidial heads produced which were in shades of dark brown-black. Conidiophores stood erect on the seed surface. Conidial heads initially appeared as globose, than split into several irregular or well defined columns of conidial chains. Conidial heads were black. Ascomata produced on seed surface appear as bright orange woolly balls.

Examination under binocular microscope

Mycelium was hyaline to white. Conidiophores arising from seed coat were hyaline to light brown, long, tan, unbranched, erect and brittle. These

terminated in an inflated apex upon which radiating phialids were formed. Conidia were single celled, dark brown, globose. Ascomata are thick walled, hard and contained numerous hulle cells.

Pathogenicity test

The test of virulence of isolated *Alternaria alternata* and *Colletotrichum dematium*, responsible for fruit rot disease of hot and sweet peppers was conducted under field and protected conditions. The test was performed by fruit inoculation technique on the intact fruits.

Inoculation of fruits

Hot peppers

The inoculum (culture) of *Colletotrichum dematium* and *Alternaria alternata* were placed by pin prick, injection, tooth pick method and placement of cultures (spores and mycelium). Two varieties of hot pepper, Jawahar Mirch 218 and Jawahar Mirch 283 were observed for symptom development.

Colletotrichum dematium

Inoculation was made on semi ripe and ripen fruits. Inoculum insertion through tooth pick method was the best as the symptoms of infection were observed on sixth to ninth day of inoculation in both the varieties JM 218 and JM 283 on ripen fruits. The tooth picks were loaded with inoculum and a puncture was made on the skin. Fungal fruiting bodies (acervuli) were noticed on the inoculated portion. In tooth pick method symptoms were observed on 8th day on semi-ripen fruits. Inoculum insertion through pin pricks was also promising as the symptoms were observed on 7th day in ripen fruits. The method in which the culture was simply placed (without injury) on the surface of the fruits was comparatively less effective as the symptoms appeared after fourteen days in semi ripen and ripen fruits (Table 4.4).

Table 4.4 : Efficacy of methods for testing the pathogenicity of *Colletotrichum dematium* on intact fruits of hot peppers

Method	Symptoms expressed after days							
	Fruits of Jawahar Mirch 218				Fruits of Jawahar Mirch 283			
	Semi Ripe	Ripe	Av Temp (°C)	Av RH %	Semi Ripe	Ripe	Av Temp (°C)	Av RH %
Spore suspension injection	12	11	25.9	80	13	11	25.9	80
Inoculum insertion through pin pricks	08	07			07	07		
Inoculum insertion through tooth pick	08	06			08	06		
Surface placement of spores and wrapping with moist cotton	14	12			14	11		
No Inoculum	0	0			0	0		

Alternaria alternata

Inoculum insertion through tooth pick was the most promising as the symptoms appeared between 7-8 days on ripen fruits whereas in pin prick method it took about 8-9 days for symptoms development. It took about 11-14 days to produce symptoms when the culture (spores and mycelium suspension) was injected with the help of hypodermic syringe using needle no. 22. When the culture was placed on the surface of fruits and the portion was wrapped with moist cotton, it took about 13-15 days for expression of symptoms (Table 4.5).

Table 4.5 : Efficacy of methods for testing the pathogenicity of *Alternaria alternata* on intact fruits of hot peppers

Method	Symptoms expressed after days							
	Fruits of Jawahar Mirch 218				Fruits of Jawahar Mirch 283			
	Semi Ripe	Ripe	Av Temp (°C)	Av RH %	Semi Ripe	Ripe	Av Temp (°C)	Av RH %
Spore suspension injection	11	11	25.9	80	14	11	25.9	80
Inoculum insertion through pin pricks	08	08			08	09		
Inoculum insertion through tooth pick	09	07			08	08		
Surface placement of spores and wrapping with moist cotton	15	13			14	13		
No Inoculum	0	0			0	0		

Sweet pepper

Similar set of methods was attempted on two varieties of sweet pepper (Aditi and Gold Carbon) under polyhouse conditions. Observations were made on the development of the symptoms and confirmation on the association of the target fungus.

Colletotrichum dematium

On semi ripe and completely ripe fruits, the inoculum (culture) of *Colletotrichum dematium* was inserted on two varieties of sweet pepper. Inoculum insertion through tooth pick method was the most promising as the symptom appeared on 7th day of inoculation on ripen fruits as compared to 8 and 9 days for semi-ripen fruits. In pin prick method the development of the symptoms appeared between 8-9 days whereas in spores suspension injection

method it took about 11-15 days for symptom development. In control no inoculum was used (Table 4.6).

Table 4.6 : Efficacy of methods for testing the pathogenicity of *Colletotrichum dematium* on intact fruits of sweet peppers

Method	Symptoms expressed after days							
	Fruits of Jawahar Mirch 218				Fruits of Jawahar Mirch 283			
	Semi Ripe	Ripe	Av Temp (°C)	Av RH %	Semi Ripe	Ripe	Av Temp (°C)	Av RH %
Spore suspension injection	14	11	34.2	44	15	11	34.2	44
Inoculum insertion through pin pricks	08	09			08	08		
Inoculum insertion through tooth pick	09	07			08	07		
Surface placement of spores and wrapping with moist cotton	17	13			18	13		
No Inoculum								

Alternaria alternata

The test of virulence for *Alternaria alternata* on variety Aditi and Gold Carbon was conducted on the intact fruits under poly house conditions. Inoculum insertion through tooth pick method proved the best on the symptoms (infection occurred) on 6th day of inoculation, in the ripen fruits of Aditi. Symptoms appeared between 13-17 days in surface placement of culture method, 12-13 days in spore suspension injection method and 7-9 days in inoculum insertion through pin prick method (Table 4.7).

Table 4.7 : Efficacy of methods for testing the pathogenicity of *Alternaria alternata* on intact fruits of sweet peppers

Method	Symptoms expressed after days							
	Fruits of Aditi				Fruits of Gold Carbon			
	Semi Ripe	Ripe	Av Temp (°C)	Av RH %	Semi Ripe	Ripe	Av Temp (°C)	Av RH %
Spore suspension injection	13	12	34.2	44	13	12	34.2	44
Inoculum insertion through pin pricks	08	07			09	08		
Inoculum insertion through tooth pick	07	06			07	06		
Surface placement of spores and wrapping with moist cotton	16	13			17	13		
No Inoculum	0	0			0	0		

Progressive development of Diseases

Hot pepper

Fruit rot and die-back (*Colletotrichum dematium*)

The observations on the incidence of fruit rot and die-back were recorded on the progressive development under field conditions. The development of diseases was recorded on fixed plant method basis. Randomly 100 plants were selected and tagged for incremental development diseases. The observations on the incidence of diseases was recorded at weekly interval, at the initiation of disease appearance till maximum incidence.

Fruit rot

Data presented in the Table 4.8 indicate that maximum fruit rot (23.0%) was observed in the 38th standard week and continued till 40th week. The initiation of fruit rot was observed by the end of last week of August, 2011 (34th week). The incidence was 5.0 and 8.0% during 36th and 37th week, that increased dramatically from 8.0 to 23.0% during 38th week. During this week about two-and-half times increase in the incidence of fruit rot was noticed. The temperature range was minimum 21.9 to 22.4 (22.1°C) and maximum 29.7 to 30.8 (30.5%) and relative humidity was 93.0% in the morning.

Table 4.8 : Progressive development of fruit rot and dieback caused by *Colletotrichum dematium* in hot pepper as observed under field conditions(var. JM 283)

Month	Week	Standard Week	Percent Disease Incidence		Temp (°C)		Rainfall (mm)	%Relative Humidity	
			Fruit rot	Die Back	Max	Min		Morn	Eve
August 2011	I	30	0.0	0.0	29.9	22.7	119.2	90	70
	II	31	0.0	0.0	31.1	23.6	140.0	92	82
	III	32	0.0	0.0	28.7	22.7	118.5	93	85
	IV	33	0.0	2.0	29.8	22.7	057.6	92	78
	V	34	1.0	6.0	30.9	22.9	014.6	93	70
September 2011	I	35	2.0	15.0	31.5	22.8	150.6	96	71
	II	36	5.0	32.0	29.5	22.6	221.6	94	80
	III	37	8.0	39.0	29.7	22.4	092.2	93	73
	IV	38	23.0	39.0	30.8	21.9	041.0	93	67
October 2011	I	39	23.0	39.0	31.3	20.8	000.0	86	56
	II	40	23.0	39.0	32.2	18.6	005.2	90	47

Die-back

The incidence of die-back was increased upto (39.0%) in 3rd week of September (37th week). The temperature range was 22.4-29.7 (26.05%) and the relative humidity was 93.0% in the morning.

The initiation of die-back (2.0%) was recorded by the end of August 2011 and it increased to 6.0, 15.0% in the 1st week of September. Thereafter the incidence was almost doubled (15.0 to 32.0%) and reached upto 39% from end of the September, 37th week onward till 39-40 week. During 1st week of September to 2nd week i.e. within 15 days about 372.2mm rains were received, as compared to 14.6 to 221.6 mm during 34th to 36th week. The amount of rainfall with corresponding temperature provided sufficient humidity that enhanced the incidence of die-back of hot pepper caused by *Colletotrichum dematium* under field conditions (Table 4.8).

Fruit rot and tender tip drying (*Alternaria alternata*)

Tender tip drying

Under field conditions tender tip drying caused by *Alternaria alternata* was initially observed (1.0%) during last week of December (51 and 52 week). The incidence was 5.0 and 8.0% during the 1st week of January 2012 and it increased upto 19% in the 3rd week when the temperature was 23.7°C with corresponding humidity 90 to 93% (Table 4.9).

Fruit rot

Maximum fruit rot (12.0%) was observed by the end of January 2012 (4th week onwards). The initial symptoms of fruit rot were prominent in the first week of January that average temperature 21.6°C (20.2-23.0⁰ C) and 94.0% relative humidity (93.0-95.0%). The fruit rot incidence remained 12.0% from 4th to 6th week (Table 4.9).

Table 4.9 : Progressive development of fruit rot and tender tip drying caused by *Alternaria alternata* in hot pepper as observed under field conditions

Month	Week	Standard Week	Percent Disease Incidence		Temp(°C)		Rainfall (mm)	%Relative Humidity	
			Fruit rot	Tip drying	Max	Min		Morn	Eve
December 2011	I	48	00	00	27.2	09.6	000.0	89	36
	II	49	00	00	28.8	11.1	000.0	90	34
	III	50	00	00	25.3	07.2	000.0	89	35
	IV	51	00	01	24.8	05.3	000.0	90	24
	V	52	02	05	24.9	07.4	000.0	89	32
January 2012	I	01	05	08	23.0	12.0	028.6	95	69
	II	02	09	17	20.2	6.3	000.0	93	41
	III	03	10	19	23.7	7.1	000.0	90	36
	IV	04	12	19	21.5	9.0	013.2	89	57
February 2012	I	05	12	19	20.8	8.0	007.6	91	46
	II	06	12	19	26.4	8.8	000.0	89	30

Powdery mildew

Incidence of powdery mildew (11.0%) was noticed in the 3rd week of October 2011 with corresponding humidity 92% and average temperature 25.7°C (19.1-32.4°C). The incidence was remained prominent upto 43rd week. The observations were made under field conditions in JM 283 (Table 4.10).

Table 4.10 : Progressive development of powdery mildew in hot pepper as observed under field conditions(var. JM 283)

Month	Week	Standard Week	Percent Disease incidence	Temp(°C)		Rainfall (mm)	%Relative Humidity	
				Max	Min		Morn	Eve
October 2011	I	39	00	31.3	20.8	000.0	86	56
	II	40	02	32.2	18.6	005.2	90	47
	III	41	11	32.4	19.1	000.0	92	43
	IV	42	10	32.6	15.8	000.0	89	31
	V	43	11	31.8	13.9	000.0	87	30

Incidence of diseases

Under field conditions

Hot pepper

Fruit rot (*Colletotrichum dematium*)

Analysis of data pertaining to the incidence indicate that maximum fruit rot (23%) was observed during 38, 39 and 40th week. The incidence was maximum during the last week of September till second week of October 2011, it was corresponded with average minimum temperature (20.4°C), average maximum temperature (31.4°C), average humidity (89.6%) in the morning and 56.6% in the evening (Table 4.11).

Table 4.11 : Maximum incidence of diseases of hot pepper under field conditions during 2011-12 at Jabalpur

Month	Week	Standard Week	Maximum Disease incidence	Temp(°C)		Rainfall (mm)	%Relative Humidity	
				Max	Min		Morn	Eve
Fruit rot (<i>Colletotrichum dematium</i>)								
September 2011	IV	38	23.0	30.8	21.9	041.0	93	67
October 2011	I	39	23.0	31.3	20.8	000.0	86	56
	II	40	23.0	32.2	18.6	005.2	90	47
Average				31.4	20.4	-	89.6	56.6
Die-back(<i>Colletotrichum dematium</i>)								
September 2011	III	37	39.0	29.7	22.4	092.2	93	73
	IV	38	39.0	30.8	21.9	041.0	93	67
October 2011	I	39	39.0	31.3	20.8	000.0	86	56
Average				30.6	21.7		90.6	65.3
Tip drying (<i>Alternaria alternata</i>)								
January 2012	III	3	19.0	23.7	7.1	000.0	90	36
	IV	4	19.0	21.5	9.0	013.2	89	57
February 2012	I	5	19.0	20.8	8.0	007.6	91	46
Average				22.0	8.03		90	46.3
Fruit rot (<i>Alternaria alternata</i>)								
January 2012	IV	4	12.0	21.5	9.0	013.2	89	57
February 2012	I	5	12.0	20.8	8.0	007.6	91	46
	II	6	12.0	26.4	8.8	000.0	89	30
Average				22.9	8.6		89.6	44.3
Powdery mildew (<i>Leveillula taurica</i>)								
October 2011	V	43	11.0	31.8	13.9	000.0	87	30

Die-back (*Colletotrichum dematium*)

The incidence of die-back was maximum (39.0%) as observed from the 3rd week of September till 1st week of October with standard week 37, 38 and 39, respectively. During this period average minimum temperature was (21.7°C) and maximum temperature (30.6°C), average humidity 90.6% in the morning and 65.3% in the evening (Table 4.11).

Tip drying (*Alternaria alternata*)

During 3rd and 4th week of January 2012 and 1st week of February 2012, corresponded with 3, 4 and 5 standard week, the tip drying caused by *Alternaria alternata* was maximum (19%).

During this period the average minimum temperature was 8.03°C, maximum temperature 22.0°C with average relative humidity 90.0% in the morning and 46.3% in the evening. During this period 20.8 mm rainfall was received (Table 4.11).

Fruit rot (*Alternaria alternata*)

Maximum fruit rot (12.0%) was recorded during standard week 4th , 5th and 6th i.e. last week of January to the first fortnight of February 2012. The average minimum temperature was 8.6°C and maximum temperature 22.9°C, 89.6% average humidity in the morning and 44.3% in the evening. During this period 20.8 mm rainfall was received (Table 4.11).

Powdery mildew (*Leveillula taurica*)

Incidence of powdery mildew was maximum (11.0%) during 43rd standard week as observed in the late October 2011. During this period minimum temperature was 13.9°C, maximum temperature 31.8°C, morning humidity 87.0% and evening relative humidity was 30.0% (Table 4.11).

Under ventilated poly house conditions

Sweet pepper

Data presented in Table 4.12 indicate the prevalence of Phytophthora blight, powdery mildew and anthracnose fruit rot. The incidence of Phytophthora blight ranged from 2.0-5.0%, powdery mildew 2.0-9.0% and anthracnose fruit rot 3.0-15.0% during 1st week of April to 3rd week of May 2012 (Table 4.12).

Table 4.12 : Incidence of diseases of bell pepper under ventilated poly house conditions at Jabalpur during 2012

Disease	Percent disease incidence range		Time of Disease initiation	Time of maximum disease incidence
	Aditi	Gold carbon		
Phytophthora stem infection & leaf blight	2.0 - 4.3	1.5 -5.0	April First week	May First week
Powdery mildew	3.0-7.0	2.0-9.0	May First week	May Second week
Anthracnose fruit rot	6.0-9.0	3.0-15.0	April Second week	May Third week

Management

Through seed treatment

Management of seed associated *Colletotrichum dematium* and *Alternaria alternata* was attempted by seed dressing with fungicides and employing standard blotter method (on top of the paper). The seeds from naturally infected sample were used. Seed sample with known infection were used (Plate 10).

Hot pepper

Colletotrichum dematium

Seeds of hot pepper variety JM 283 were derived from the preidentified seed lot and treated with respective fungicide separately. The association of

Colletotrichum dematium was 22.0% in untreated seeds that served as control. The percent infection of fungus in different fungicide treated seed ranged upto 2.0% as observed under stereoscopic binocular microscope after the incubation of 7 days. Practically no association of the fungus was recorded in seeds treated with copper oxy chloride(0.25%), mancozeb(0.25%), carboxin + thiram (0.2%) mancozeb + carbendazim (0.25%) and mancozeb + thiophenate methyl (1.0, 1.50, 1.75, 2.0 and 2.25 g/kg of seed) (Table 4.13 and Plate 10).

Table 4.13 : Influence of seed dressing with fungicides on the associated *Colletotrichum dematium* with hot pepper seeds using the Standard Blotter method (ISTA, 1996)

Fungicide	Concentration (g per Kg of seed)	Per cent infection of <i>Colletotrichum dematium</i>	Per cent seed germination
Copper oxy chloride	2.5	0.0	88
Carbendazim	2.0	1.0	83
Mancozeb	2.5	0.0	88
Carboxin + Thiram	2.0	0.0	89
Mancozeb + Carbendazim	2.5	0.0	89
Mancozeb + Thiophenate methyl	1.0	0.0	84
Mancozeb + Thiophenate methyl	1.25	2.0	82
Mancozeb + Thiophenate methyl	1.50	0.0	84
Mancozeb + Thiophenate methyl	1.75	0.0	84
Mancozeb + Thiophenate methyl	2.0	0.0	86
Mancozeb + Thiophenate methyl	2.25	0.0	85
Control	0.0	22	78

Alternaria alternata

Effectiveness of copper oxy-chloride, carboxin + thiram, mancozeb + carbendazim, mancozeb + thiophenate methyl in controlling the target fungus *Alternaria alternata* was recorded. No infection of fungus, with chilli seeds was observed on incubated seeds treated with these fungicides.

Table 4.14 : Influence of seed dressing with fungicides on the associated *Alternaria alternata* with hot pepper seeds using the Standard Blotter method (ISTA, 1996)

Fungicide	Concentration (g per Kg of seed)	Per cent infection of <i>Alternaria alternata</i>	Per cent Seed germination
Copper oxy chloride	2.5	0.0	88
Carbendazim	2.0	4.0	80
Mancozeb	2.5	3.0	83
Carboxin + Thiram	2.0	0.0	88
Mancozeb + Carbendazim	2.5	0.0	88
Mancozeb + Thiophenate methyl	1.0	1.0	82
Mancozeb + Thiophenate methyl	1.25	1.0	82
Mancozeb + Thiophenate methyl	1.50	0.0	86
Mancozeb + Thiophenate methyl	1.75	0.0	84
Mancozeb + Thiophenate methyl	2.0	0.0	84
Mancozeb + Thiophenate methyl	2.25	0.0	84
Control	0.0	18.0	85

In untreated seeds, 18.0% infection of *Alternaria alternata* was recorded. In treated seeds the fungus was observed upto 4.0%. In fungicide treated seeds germination range from 86.0-88.0% as compared to 85.0% in untreated seeds (control). In seeds treated with mancozeb + thiophenate methyl (1.75, 2.0 and

2.25 g/kg of seed) phytotoxicity was recorded and it resulted in lower germination (84.0%) (Table 4.14).

Sweet pepper

Colletotrichum dematium

Data presented in Table 4.15 indicate the association of *Colletotrichum dematium* upto 3.0% in fungicide treated seeds as compared to 12.0% in untreated (control) seeds. The fungus was recorded upto 3.0% in seeds treated with carbendazim (0.2%). Complete elimination of *Colletotrichum dematium* was observed in seeds treated with copper oxy chloride, mancozeb, carboxin + thiram and mancozeb + carbendazim. In seeds treated with mancozeb + thiophenate methyl (@ 1.0, 1.75, 2.0 and 2.25 g/kg seed) no association of the fungus was observed.

Table 4.15 : Influence of seed dressing with fungicides on the associated *Colletotrichum dematium* with sweet pepper seeds using the Standard Blotter method (ISTA, 1996)

Fungicide	Concentration (g per Kg of seed)	Per cent infection of <i>Colletotrichum dematium</i>	Per cent seed germination
Copper oxy chloride	2.5	0.0	93
Carbendazim	2.0	3.0	86
Mancozeb	2.5	0.0	94
Carboxin + Thirum	2.0	0.0	92
Mancozeb + Carbendazim	2.5	0.0	93
Mancozeb + Thiophenate methyl	1.0	0.0	92
Mancozeb + Thiophenate methyl	1.25	2.0	88
Mancozeb + Thiophenate methyl	1.50	2.0	88
Mancozeb + Thiophenate methyl	1.75	0.0	91
Mancozeb + Thiophenate methyl	2.0	0.0	89
Mancozeb + Thiophenate methyl	2.25	0.0	89
Control	0.0	12.0	80

Alternaria alternata

The association of *Alternaria alternata* was recorded in the range of 1.0-3.0% in fungicide treated seeds as compared to 12.0% in untreated seeds. Similar trend of effectiveness of fungicide was noticed. Seed treatment with fungicide increased the germination from 85.0 to 88.0%, as compared to 78.0% in untreated seeds. Copper oxy chloride mancozeb, carboxin + thiram eliminated the fungal infection (Table 4.16).

Table 4.16 : Influence of seed dressing with fungicides on the associated *Alternaria alternata* with sweet pepper seeds using the Standard Blotter method (ISTA, 1996)

Fungicide	Concentration (g per Kg of seed)	Per cent infection of <i>Alternaria alternata</i>	Per cent Seed germination
Copper oxy chloride	2.5	0.0	88
Carbendazim	2.0	3.0	81
Mancozeb	2.5	0.0	87
Carboxin + Thirum	2.0	0.0	88
Mancozeb + Carbendazim	2.5	2.0	82
Mancozeb + Thiophenate methyl	1.0	0.0	87
Mancozeb + Thiophenate methyl	1.25	0.0	85
Mancozeb + Thiophenate methyl	1.50	1.0	84
Mancozeb + Thiophenate methyl	1.75	1.0	84
Mancozeb + Thiophenate methyl	2.0	0.0	86
Mancozeb + Thiophenate methyl	2.25	2.0	83
Control	0.0	12.0	78

Influence of fungicidal treatment on seed emergence

The seed lot with known infection of *Colletotrichum dematium* and *Alternaria alternata* was used. One hundred fungicide treated seeds were sown in the well cleaned sterilized sand to determine the effect of fungicide treatment on emergence.

Data presented in Table 4.17, indicate that the seed emergence of hot pepper ranged from 75.0-85.0% in fungicide treated seeds as compared to 65.0% in untreated seeds. In fungicide treated seeds of sweet pepper the emergence ranged from 75-85% as compared to 69% in untreated seeds. Fungicide increased the emergence of seed.

Table 4.17 : Influence of seed dressing with fungicides on the emergence of pepper seedling

Fungicide	Dose (gram per Kg of seed)	Per cent seed emergence		Per cent Reduction	
		Hot Pepper	Sweet Pepper	Hot Pepper	Sweet Pepper
Copper oxy chloride	2.5	85	83	30.76	20.28
Carbendazim	2.0	85	85	30.76	23.18
Mancozeb	2.5	83	83	27.69	20.28
Carboxin+ Thirum	2.0	85	85	30.76	23.18
Mancozeb + Carbendazim	2.5	84	82	29.23	18.84
Mancozeb + Thiophenate methyl	1.0	80	80	23.07	15.94
Mancozeb + Thiophenate methyl	1.25	82	81	26.15	17.39
Mancozeb + Thiophenate methyl	1.50	80	81	29.23	17.39
Mancozeb + Thiophenate methyl	1.75	79	75	21.53	08.69
Mancozeb + Thiophenate methyl	2.0	79	75	21.53	08.69
Mancozeb + Thiophenate methyl	2.25	75	75	15.38	08.69
Control	0.0	65	69	-	-

Through foliar application of fungicide

Attempts were made to manage fruit rot and die-back problem of hot pepper by the foliar application of Difenoconazole, Azoxystrobin, kitazin, Tebuconazole fungicide under field conditions. Possible combinations of these fungicides were also used. The application of fungicides was made on the initiation of disease as usual observed method. In a replicated trial, seedlings of hot pepper variety JM 283 was used. The age of the seedling was about 30 days. The plant to plant and row to row distance was 40 cm. This enabled to accommodate about 30 plants in a plot. The solution of fungicide was sprayed with the help of knapsack sprayer (15 litre capacity). Emulsified and suspension concentrate were used.

Hot pepper

Fruit rot and die back (*Colletotrichum dematium*)

Fruit rot

In untreated-unsprayed plots (control) of JM 283, the incidence of fruit rot was 13.0% whereas, the die back incidence was 15.0%. All the fungicides significantly controlled the disease as observed after 3 applications of fungicide made at 15 day interval. Minimum (4.0%) fruit rot was observed in the plots that received 3 applications of Difenoconazole 25% (EC) applied at 100 ml/100 litre of water as compared to 13.0% in control plot. Among the various concentrations of Difenoconazole (applied at the rate 25-200 ml/100 litre of water) the incidence of fruit rot ranged from 4.0-5.8%. Among the various concentrations of Azoxystrobin (applied at 50, 100, 150, 200 and 400 ml/100 litre of water) least incidence of fruit rot (5.3%) was recorded at the concentration 200 ml/100 litre of water. The incidence of fruit rot ranged from 5.3-6.9%.

The incidence of fruit rot was 9.0, 8.8 and 8.2% was observed in the treatment with kitazin (200 ml), Tebuconazole (400 ml) and kitazin (200 ml) + Tebuconazole (100 ml per 100 litre of water), respectively (Table 4.18).

Table 4.18 : Incidence of die back and fruit rot by *Colletotrichum dematium* after foliar application of fungicides to hot pepper under field conditions (Variety JM 283)

Treatment	Fungicide	Trade Name	Dosage (ml) per 100 Lit of water	Percent disease incidence		Per cent reduction	
				Fruit rot	Die back	Fruit rot	Die back
T1	Difenoconazole 25% (EC)	XL-25	25	5.8	7.3	55.3	51.3
T2	Difenoconazole 25%(EC)	XL-25	50	5.3	7.2	59.2	52.0
T3	Difenoconazole 25%(EC)	XL-25	75	5.3	6.8	59.2	54.6
T4	Difenoconazole 25%(EC)	XL-25	100	4.0	6.0	69.2	60.0
T5	Difenoconazole 25%(EC)	XL-25	200	4.3	7.0	66.9	53.3
T6	Azoxystrobin 23% (SC)	XL-23	50	6.4	8.5	50.7	43.3
T7	Azoxystrobin 23%(SC)	XL-23	100	5.8	7.9	55.3	47.3
T8	Azoxystrobin 23%(SC)	XL-23	150	5.8	7.9	55.3	47.3
T9	Azoxystrobin 23%(SC)	XL-23	200	5.3	7.3	59.2	51.3
T10	Azoxystrobin 23%(SC)	XL-23	400	6.9	7.8	46.9	48.0
T11	Kitazin 48% (EC)	Kitazin	200	9.0	10.0	52.6	33.3
T12	Tebuconazole 23%(EC)	Caviat	400	8.8	9.0	32.3	40.0
T13	Kitazin 48% + Tebuconazole 23%(EC)	Kitazin & Caviat	200 + 100	8.2	9.5	36.9	36.6
T14	Control	-	-	13.0	15.0	-	-
	CD			2.097	1.566	-	-
	SED			1.023	0.764	-	-

EC: Emulsified concentrate ; SC: Suspension concentrate

Die back

Among the various concentrations of Difenoconazole least die back (6.0%) was observed at 100 ml concentration applied with 100 litre of water. The incidence of die back ranged from 6.0-7.3%. Among the various concentrations of Azoxystrobin (50-400 ml/100 litre of water) the incidence of dieback ranged from 7.3-8.5%, being least in the plots received 200 ml fungicide 3 times. The overall die back incidence ranged from 6.0-10.0% among the 13 treatments as compared to 15% in control(T₁₄) (Table 4.18).

It was concluded that minimum fruit rot (4.0%) and minimum die back (6.0%) was observed when Difenoconazol was applied at the rate of 100 ml/100 litre of water (Table 4.18).

Fruit rot and tip drying (*Alternaria alternata*)

Fruit rot

The incidence of fruit rot caused by *Alternaria alternata* ranged from 5.0-10.0% in the plots received the various fungicidal applications as compared to 12.0% in unsprayed and untreated plants. Among the various concentrations of Difenoconazole least (5.0%) fruit rot was observed whereas minimum (6.3%) fruit rot was observed among the 5 concentrations of Azoxystrobin. The fruit rot incidence was 6.0, 8.3 and 7.5% in the plots received the 3 applications of kitazin, Tebuconazole and its combination, respectively (Table 4.19).

Tip drying

Least percent of plants (8.0%) infected with *Alternaria alternata* causing tip drying was observed in T₄ where the fungicide Difenoconazole 25% EC was applied at the rate of 100 ml/100 litre of water. The incidence of tip drying ranged from 8.0-13.0% in different treatments as compared to 19.0% in control. The treatment Azoxystrobin (150 and 200 ml), kitazin and its combination with Tebuconazole were promising where about 9% tip drying was recorded as compared to control (Table 4.19).

Table 4.19 : Incidence of tender tip drying and fruit rot by *Alternaria alternata* after foliar application of fungicides to hot pepper under field conditions (Variety JM283)

Treatment	Fungicide	Trade Name	Dosage (ml) per 100 Lit of water	Percent disease incidence		Per cent reduction	
				Fruit rot	Tip drying	Fruit rot	Tip drying
T1	Difenoconazole 25% (EC)	XL-25	25	7.9	13.0	34.1	31.5
T2	Difenoconazole 25% (EC)	XL-25	50	7.9	12.0	34.1	36.8
T3	Difenoconazole 25% (EC)	XL-25	75	8.0	10.0	33.3	47.3
T4	Difenoconazole 25% (EC)	XL-25	100	5.0	08.0	58.3	57.8
T5	Difenoconazole 25% (EC)	XL-25	200	5.3	11.0	55.8	42.1
T6	Azoxystrobin 23% (SC)	XL-23	50	8.9	12.0	25.8	36.8
T7	Azoxystrobin 23% (SC)	XL-23	100	6.9	10.0	42.5	47.3
T8	Azoxystrobin 23% (SC)	XL-23	150	6.5	09.3	45.8	51.0
T9	Azoxystrobin 23% (SC)	XL-23	200	6.3	09.0	47.5	52.6
T10	Azoxystrobin 23% (SC)	XL-23	400	10.0	11.0	16.6	42.1
T11	Kitazin 48% (EC)	Kitazin	200	6.0	09.9	50.0	47.8
T12	Tebuconazole 23% (EC)	Caviat	400	8.3	12.0	30.8	36.8
T13	Kitazin 48% + Tebuconazole 23%(EC)	Kitazin & Caviat	200 + 100	7.5	09.3	37.5	51.0
T14	Control	-		12.0	19.0	-	-
	CD			1.980	2.184	-	-
	SED			0.966	1.065	-	-

EC: Emulsified concentrate ; SC: Suspension concentrate

DISCUSSION

Capsicum peppers are the foremost preferred condiments in the every household of our country. Peppers are used roasted, fried and raw chopped. These are used to flavour the soups, stews and sauces that increases the palatability of Indian food. Peppers are native to Mexico, Central America and northern South America. The seeds of peppers were carried to Spain during 1493 and later spread over to other parts of the world (Singh, 1989).

The misleading name pepper (*pimiento* in Spanish) was given by Cristopher Columbus upon bringing the plant back to Europe from India. At that time peppercorns the fruit of *Piper nigrum* an unrelated plant originating from India, were a highly prized condiment, the name pepper was at that time applied in Europe to all known spices with a hot and pungent taste and so naturally extended to the newly discovered Capsicum *genus*. The most commonly used alternative name of the plant family. Chilli is of Central American origin (<http://en.wikipedia.org>).

The genus of flowering plant in the nightshade family, Solanaceae. Bell pepper are commonly known as Sweet pepper and Shimla Mirch in Hindi while common chilli used in Indian cuisine is considered as *Hot pepper* (<http://en.wikipedia.org>).

The pungency of chillies is due to an alkaloid capsaicin (C₁₈H₂₇NO₃), the active hot principle which is used in pharmaceuticals, cosmetics, food and drinks (Tiwari, 1990). The red colour in the fruits at the ripening stage is due to the pigment capsanthin (Nath, 1969). The pungent principle of red pepper consist of a mixture of seven closely related methyl vanillyl nonenamide named capsinoides (Govindrajan, 1985). Capsaicin, a lipophilic chemical responsible for strong burning sensation when it comes with contact in mucous membrane. Contrast to hot peppers (chilli), the bell (sweet) pepper has a zero rating on Scoville Heat Scale. The lack of capsaicin is due to a recessive gene that eliminates capsaicin, consequently the hot taste usually associated with the rest

of the *Capsicum* genus (<http://whfoods.com/genpage.php?tname=foodspices&dbid=50>).

The term, bell pepper or pepper or capsicum is often used for any of large bell shaped capsicum fruits, regardless of their colour. In British English, the fruit is simply referred to as a pepper or additionally by colour (as in term green pepper, yellow pepper, for example), whereas in many Commonwealth of Nations countries, Australia, India, Malaysia and New Zealand, they are called capsicum. Across Europe, the term paprika which has its roots in the world for pepper, is used sometimes referred by their colour (e.g. *groene paprika*, *gele paprika* in Dutch which are green and yellow, respectively). Paprika also refers to the powdered spice made from the fruits in the *Capsicum* genus. The colour of the bell pepper can be green, red, yellow, orange and more rarely, white, rainbow (between stages of ripening) and purple.

The crop suffers due to a number of diseases (Mukherji and Bhasin, 1986; Gupta and Thind, 2006; Verma and Sharma, 1999; Mehrotra, 1980). A number of pathogen attack the crop and cause various diseases at various growth stages. Dieback and fruit rot caused by *Colletotrichum dematium* (Pers. ex. Fr.) Grove (= *Colletotrichum capsici* (Syd.) Butler & Bisby) and tender tip drying & fruit rot incited by *Alternaria alternata* are the major problem identified that limit the profitable cultivation of chilli in Madhya Pradesh. The distribution of the diseases, status, development and management aspects were studied in this investigation during 2011-12.

Jabalpur is a semi humid region having subtropical climate with hot dry summer and cold winters. It is situated on 23.9' North latitude 79.58 east longitude and 411.78m above mean sea level.

Investigations on the incidence of diseases of hot pepper were made two times a year, during September-October (2011) and January-February (2012). Observations were made at 15 locations (September-October) and 8 locations (January-February). In all seven diseases were observed during September-October the fruit rot caused by *Colletotrichum dematium* ranged upto 23.0% with

an average incidence 13.2%, the dieback ranged upto 35.0% with an average incidence 17.2%. The *Alternaria* tender tip drying incidence was average 12.0% whereas the fruit rot was 7.4%. The incidence of fruit rot and die back disease has been reported (Chourasia, 1976; Mali and Joi, 1985; Sujatha Bai *et al.*, 1993). The incidence of powdery mildew and Rhizotonia root rot was reported by Gupta *et al.* (2006).

The overall status of fruit rot, die back and tender tip drying was analysed. It was noticed that incidence of fruit rot and dieback due to *Colletotrichum dematium* was greater (13.2% and 17.2%) in September-October as compared to 5.3 and 7.1% in January and February grown. On the other hand the incidence of *Alternaria* fruit rot and tender tip drying was higher (8.1 and 12.5%) in January-February as compared to September-October (7.4 and 12.0%) in grown crop, respectively. The incidence of diseases was recorded on 6 available varieties grown at Research Experimental Field. Maximum die back 40.0% and fruit rot 25.0% caused by the anthracnose fungus was observed in JM 218 while minimum fruit rot and die back 7.0 and 11.0% in Pusa Jwala. Least (5.0%) *Alternaria* fruit rot was recorded in Pant C1 whereas, minimum (6.0%) tender tip drying was observed in Pusa Jyoti. Powdery mildew was not recorded in Pusa Jyoti and Pant C1.

In the present investigation diseases of hot pepper and sweet pepper were recorded under field and ventilated polyhouse conditions, respectively. Under polyhouse conditions powder mildew, anthracnose fruit rot, Rhizoctonia root rot and Phytophthora blight were observed. In hot peppers, major and widespread problem of diseases caused by *Colletotrichum dematium* and *Alternaria alternata* were recorded. Rhizoctonia root rot and Phytophthora blight were of minor prevalence.

Colletotrichum dematium caused variable symptoms that include rot of ripe fruits and downward necrosis of tissues of twigs (dieback). Tender tip drying, fruit & leaf spot are incited by *Alternaria alternata*. The symptomatology of both the diseases was critically analyzed and studied. Progressive downward necrosis

of tender twig was noticed in both the cases. Symptoms incited by *Colletotrichum dematium* and *Alternaria alternata* have been recorded critically on seeds, seedlings, leaves twigs and fruits. Infected seeds were rusty brown with shrunk seed coat. In badly infected fruits seeds were covered with mycelium that become evident by removing the pericarp. On infected and dead seedlings, numerous fungal fruiting bodies were recorded. Symptoms produced by *Colletotrichum dematium* are in close agreement to those described by Thind and Jhooty (1990), Kardale (1990), Dattar and Manale (1989), Dastur (1921). Blazques (1976) described that powdery mildew in chilli appears first on the older leaves and thereafter, progresses to younger leaves. Chlorotic spots were noticed on the upper surface of the leaves, while the corresponding lower surface was covered with white to grey powdery growth of the fungus. Later, the lower surface of the leaves also turned necrotic. Heavy infection of powdery mildew leads to leaf shedding resulting in heavy losses in yield due to reduction in size and also number of fruits, these are closely related to those described by Blazques (1976), Jharia *et al.* (1978), Dixon (1978), Cerkaukas *et al.* (1999) and Damicon (1999).

The Rhizoctonia root rot was observed under field and polyhouse condition. Infection was confined to the collar region. The infection resulted in dull green leaves followed by wilting of the plants.

The infection by Phytophthora pathogen have been reported to attack all the aerial plant parts such as leaves, stem, branches, growing shoots, and fruits. The first symptoms appear as water soaked to dull or faded green areas differing slightly from the colour of the normal healthy leaf tissue. The spots on fruits enlarge rapidly, ultimately covering the entire fruit. Completely rotten fruits may fall down on the ground, these symptoms description are closely related to those described by Gupta and Thind (2006).

Identification of the fungi was made on the basis of keys of identification of Sutton (1980), Kulshreshtha *et al.* (1976). After critical examination Kulshreshtha *et al.* (1976) have considered *Colletotrichum capsici* (Sydow) Butler and Bisby as

a synonym *Colletotrichum dematium* based upon the grouping of curved spores. The morphological cultural characteristics of *Alternaria alternata* (Fr.) Keissler have been described by several workers Haware *et al.*, 1986 on other crops.

Alternaria alternata was obtained on potato sucrose agar medium. The colony of *Colletotrichum dematium* was initially pink, later becoming black brown. The colony of *Alternaria alternata* on PSA was grayish white at beginning later darkens and became greenish black to olive brown with a light border. Acervuli were dark brown abundant conidia with numerous setae. Acervuli were round approximately 350 μm in diameter and setae that were 1-5 septate. Acervuli were usually subepidermal and erumptant, Mordue (1971) described the similar characteristics. The setae were larger than conidial mass, conidia were hyaline and single celled, curved at both ends, pointed, pinkish in mass and measured 22.8-27.50x3.5-6.3 μm in size. Conidia of *Alternaria alternata* were formed in long, chains, often with a short beak that was upto but not more than one-third its length. The conidia were 20-63 μm long x 9-18 μm at the widest point and have upto 3-8 transverse and several longitudinal septa. These character are in close agreement with Haware *et al.* (1986), Singh and Suhag (1983), Ellis (1971).

Conidia of *Leveillula taurica* were hyaline, single celled borne singly or in short chains, the range of average conidial measurements was $67.8 \pm 5.3 \times 17.9 \pm 2 \mu\text{m}$ and $62.7 \pm 6.2 \times 15.7 \pm 2 \mu\text{m}$ for pyriform and cylindrical conidia, respectively. These characters match with the discription by Correll *et al.* (1987), Cerkaukas *et al.* (1999), Damicone (1999).

The test of virulence of isolated *Colletotrichum dematium* and *Alternaria alternata* was performed on two varieties of hot pepper under field conditions and on two varieties of sweet pepper under ventilated polyhouse conditions through spore suspension injection, inoculum insertion through pin pricks, inoculum insertion through tooth pick and surface placement of spores and wrapping with moist cotton. It was concluded that tooth pick method was the best for the testing of pathogenecity of *Colletotrichum dematium* and *Alternaria alternata* in ripe intact fruits under natural field and polyhouse conditions. The average

temperature was 25.9 with 80% average relative humidity. Inoculum insertion through tooth pick method was the best, as the symptoms expressed after 6 days in the ripe fruits of JM 218 and JM 283 in field conditions and after 6-7 days in the ripe fruits of Aditi and Gold Carbon of polyhouse conditions. By providing injury on the fruit surface, the expression of symptoms was faster as compared to uninjured fruit.

With a view to determine the correlation between weather parameters and development of diseases of hot pepper under field condition observations were made on the preidentified (tagged) plants at regular period in a fixed plot method. The diseases were identified on the basis of initial symptoms. In the present investigation incidence of fruit rot caused by *Colletotrichum dematium* was maximum (23.0%), that was observed during 38th standard week coincided with 4th week of September 2011. It remained on the peak till 2nd week of October (40th standard week). During this period, average minimum temperature was 20.4°C (18.6-21.9°C), and average maximum temperature was 31.4°C (30.8-32.2°C). The average relative humidity was 89.6% (86.0-93.0%) in the morning and average humidity in the evening was 56.6% (47.0-67.0%). The initiation (1.0%) of fruit rot was recorded in 34th standard week that is coincided with 5th week of August, during the week the maximum temperature was 30.9°C and minimum was 22.9°C. The morning humidity was 93.0% and evening humidity was 70.0% (average 81.5%). The initiation of die back (2.0%) was recorded during 33rd standard week, coincided 4th week of August. Incremental development of dieback was noticed and the two times infection was increased from 15.0 to 32.0% during 35th and 36th standard week and remained upto peak (39.0%) till four weeks (from 37th to 40th week). The die back was initiated in 4th week of August (33rd standard week), at the time temperature ranged from 22.7 to 29.8°C and humidity ranged from 78.0 to 92.0%. The disease was initiated due to the increased humidity which was a result of high rainfall, 140.0 and 118.5 mm received in 2nd and 3rd week of August (31st and 32nd standard week). During the peak infection (39.0%) of die back as observed between 37th to 40th standard week, the average minimum temperature was 20.9°C (18.6-22.4°C) and average

maximum temperature was 31.0°C (29.7-32.2°C). The average relative humidity was 90.5% (86.0-93.0%) in the morning and in the evening 60.7% (47.0-73.0%).

The fruit rot caused by *Alternaria alternata* was initiated in the 5th week of December when the temperature ranged between 7.4-24.9°C (average 16.1°C with morning relative humidity 89.0% and 32.0% in evening (average 60.5%). The fruit rot disease was maximum (12.0%) during 4th week of January 2012 to 2nd week of February 2012 with average maximum temperature 22.9°C (20.8-26.4°C) and average minimum temperature 8.6°C (8.0-9.0°C) with 89% (89.0-91.0%) morning and 44.3% (30.0-57.0%) evening humidity. The tender tip drying was initiated (1.0%) in the 4th week of December 2011 when temperature ranged between 5.3-24.8°C (average 15.05°C) with morning humidity 90.0% and 2.4% in evening. The tender tip drying disease was maximum (19.0%) during 3rd week of January to 2nd week of February with average maximum temperature 23.1°C (ranged from 20.8 to 26.4°C) and average minimum temperature 8.2°C (ranged from 7.1 – 9.0°C) with average morning humidity 89.75% (89.0-91.0%) and average evening humidity was 42.2% (30.0-57.0%) during four weeks of January and February.

The initiation of incidence of powdery mildew was observed in the 2nd week of the October (40th standard week) with average temperature was 25.4°C (18.6-32.2°C) and morning humidity 90.0% and evening 47.0%. Due to increased humidity (because of 5.2 mm rainfall in 40th standard week) the disease increased five times from 2nd week to 3rd week of October coincided from 40th week to 41st week. The maximum incidence of powdery mildew was from 41st standard week (3rd week of October) 43rd standard week (5th week) of October when the average maximum temperature was 32.6°C (31.8-32.6°C) and average minimum temperature was 16.2°C (13.9-19.1°C). The average morning humidity was 89.3% (87.0-92.0%) and the evening humidity 34.6% (30.0-43.0%).

It was concluded that the anthracnose fruit rot caused by *Colletotrichum dematium* was maximum (23.0%) during 38th to 40th standard week, coincided from 4th week of September to 2nd week of October 2011, whereas the fruit rot of

Alternaria alternata was maximum (12.0%) from 4th standard week of January till 6th standard week of February 2012. The dieback caused by *Colletotrichum dematium* was maximum (39.0%) from 37th to 39th standard week, coincided, 3rd week of September to 1st week of October. The tender tip drying caused by *Alternaria alternata* was maximum (19.0%) from 3rd week (3rd standard week) of January to 1st week (5th standard week) of February 2012. Powdery mildew infection was maximum during 3rd week of (41st standard week) to 5th week (43rd standard week) of October 2011.

The incidence of anthracnose fruit rot under polyhouse conditions ranged between 6.0-9.0% in Aditi and 3.0-15.0% in Gold Carbon cultivar from April 2nd week to 3rd week of May and maximum incidence was in 3rd week of May. The incidence of powdery mildew was under protected conditions ranged from 3.0-7.0% in Aditi and 2.0-9.0% in Gold Carbon from 1st week to 2nd week of May and it was maximum during 2nd week of May. The incidence of Phytophthora blight was recorded from 1st week of April to 1st week of May, ranged from 2.0-4.3% in Aditi and 1.5-5.0% in Gold carbon and incidence was maximum during May 1st week.

Management of fruit rot and die back was attempted by seed dressing fungicides and foliar application under field conditions. The efficacy of fungicides using the combination of new molecules was determined at seed, seedling and plant level. The fungicides used as seed dresser were combination of mancozeb plus thiophenate methyl (as Super XL), mancozeb (as Dithane M 45), copper oxy chloride (as Fytolon), carbendazim (as Bavistin), mancozeb plus carbendazim (as Saff) carboxin plus thiram (as Vitavax Power) at different dose level. Untreated seeds (seeds with no fungicides) served as control. The fungicidal treated seeds were placed on top of the blotter as in standard blotter method. Seeds of variety JM 283 (hot pepper) and Aditi (sweet pepper) were used during the investigation. In hot pepper, complete elimination of *Colletotrichum dematium* and *Alternaria alternata* associated with seeds was observed in the seeds treated with copper oxy chloride (0.25%), carboxin + thiram (0.2%), mancozeb plus carbendazim (0.25%), mancozeb plus thiophenate methyl (0.15, 0.175, 0.2 and

0.225%). As compared to control (22.0 and 12.0%) incidence of *Colletotrichum dematium* ranged upto 2.0% in hot pepper and upto 3.0% in sweet pepper seeds treated with fungicides respectively. As compared to control (18.0 and 12.0%) incidence of *Alternaria alternata* ranged upto 4.0% in hot pepper and upto 3.0% in sweet pepper seeds treated with fungicides, respectively.

During last 5 decades, number of chemicals have been evaluated against these pathogens at global level under diverse agroclimatic conditions. The efficacy of ferbam, maneb and captan was reported by Crisam and Mesechu (1970). While seed treatment with thiram plus captan in checking pre and post emergence losses and mortality was recorded by Jharia *et al.* (1978).

Attempts have been made by several workers to find suitable fungicides for the control of *Colletotrichum dematium* (Takano *et al.*, 1985; Thind and Jhooty, 1980; Rathore, 2006; Sharma and Thakre, 2004), and fruit rot and twig drying pathogen by Khare *et al.* (2002), Parwez *et al.* (1968), Singh and Tandon (1967), Miller *et al.* (1984). Efficacy of vitavax, plantavax and ziram (Panigrahi and Narain, 1971) and zineb (Boswell *et al.*, 1952) has been reported. Management of seed associated *Colletotrichum dematium* and *Alternaria alternata* was attempted by Srinivas *et al.* (2006), Thippeswamy (2007), Prasanna *et al.* (2009), Rahman *et al.* (2004). Little work has been done for the management of seed associated mycoflora of sweet pepper (Pathania and Chandel, 2004; Sharma *et al.*, 2006; Verma *et al.*, 2001).

Influence of fungicide treated seeds (having natural infection of *Colletotrichum dematium* and *Alternaria alternata*) was determined in terms of emergence for hot and sweet pepper. The fungicide treated seeds were sown in sterilized sand placed in plastic trays under laboratory conditions. Fungicide treated seeds had better emergence as compared to untreated seeds. The hot pepper seed emergence of treated seeds ranged from 75 to 85% as compared to 65% in untreated seeds (control). Maximum (85%) seed emergence was recorded in seeds treated with copper oxy chloride (0.25%) carbendazim (0.2%) and carboxin plus thiram (0.2%). The sweet pepper seed emergence of treated

seeds ranged from 75 to 85% as compared to 69% in untreated seeds (control). Maximum (85%) seed emergence was recorded in seeds treated with carbendazim (0.2%) and carboxin plus thiram (0.2%).

Foliar application of Difenoconazole, Azoxystrobin, Kitazin and Tebuconazole was made on the initiation of disease symptom under field condition. Seedlings of JM 283 of about 30 days age were transplanted on 14 November 2011. The plant to plant and row to row distance was 40 cm and about 30 plants were accommodated in one plot of 2.4 x 2 m, with 13 treatments and a control. Emulsified and suspension concentrate were used. All the fungicides significantly controlled the disease. Minimum incidence (4.0%) of fruit rot and (6.0%) die back due to *Colletotrichum dematium* was recorded in T₄ where Difenoconazole 25% (EC) was applied 3 times at the rate of 100 ml/100 litre of water. Among the various concentrations of Azoxystrobin 23% (SC) (50, 100, 150, 200, 400 ml/100 litre water) least (5.3%) fruit rot was observed when 200 ml/100 litre water was used. Maximum incidence of fruit rot was 9.0% in kitazin applied at 200 ml. The incidence of die back ranged from 6.0-10.0% in various treatments. Least die back was recorded in T₄, where Difenoconazole was applied at the rate of 100ml. Application of Azoxystrobin applied at 200 ml was also promising that exhibited 7.3% dieback.

The incidence of Alternaria fruit rot ranged from 5.0% (in Difenoconazole applied at 100 ml) to 10.0% (in Azoxystrobin applied at 400 ml). Among the various concentrations of Difenoconazole least (8.0%) tip drying was recorded when the chemical was applied at the rate 100ml, whereas, Azoxystrobin applied at the rate of 200 ml was the most promising as it resulted in 9.0% tip drying as compared to 19.0% in unsprayed control plants. Kitazin applied at 200 ml resulted in 6.0% and 9.9% fruit rot and tip drying, respectively. The combination of kitazin and Tebuconazole was also promising as it resulted in 7.5% and 9.3% fruit rot and tip drying as compared to 12.0% and 19.0% in unsprayed control. Efficacy of carbendazim was recorded by Mistry *et al.* (2008), Kapgate *et al.*, (2008), Thippeswamy (2007) Udit narain *et al.* (2006) Hegde and Anahosur (2001) observed the efficacy of hexaconazole where Thiophenate methyl had

been used by Kumawat (1997). Significant reduction due to mancozeb plus thiophenate methyl and carbendazim was noticed (Ushakiran *et al.*, 2006). The combination of thiophenate methyl and mancozeb was first attempted at Jabalpur. Extensive studies have been carried out in all the chilli growing areas of the country against diseases incited by *Colletotrichum dematium* and *Alternaria alternata* (Ushakiran *et al.*, 2006; Rathore, 2006; Udit Narain *et al.*, 2006; Hegde and Anahosur, 2001; Hingole and Kurandikar, 2009). Significant reduction due to mancozeb plus thiophenate methyl and carbendazim was noticed (Kumawat, 1997). Efficacy of carbendazim was recorded by Thippeswamy (2007) Hegde and Anahosur (2001) observed the efficacy of Hexaconazole while Nagaraja *et al.* (2004) recorded the efficacy of Kitazin (@ 0.15%).

The induction of systematic resistance was studied to elucidate the role of Azoxystrobin against *Colletotrichum capsici* by Anand *et al.* (2009) and Difenoconazole (Gopinath *et al.*, 2006). The activity of defense enzymes viz., peroxidase, polyphenol oxidase, phenylalanine ammonia lyase, P-1,3 glucanase, chitinase, catalase. Defense. Inducing chemical was found to be increased in treated chilli plants. Efficacy of propioconazole at 0.1% caused a dramatic reduction of disease incidence by 70% when compared to Difenoconazole at 0.05% and carbendazim at 0.1% compared to unsprayed control (Gopinath *et al.*, 2006). When applied two fold doses of recommendation, Difenoconazole showed phytotoxic effect whereas carbendazim and Ridomyl MZ did not show any phytotoxic effect (Kagpate *et al.*, 2008).

Strobilurin compounds have shown activity in suppressing many different fungi. These compounds may be useful in reducing anthracnose. Strobilurins inhibit mitochondrial respiration by blocking quinol oxidation in cytochrome bc₁ complex, thus blocking the production of ATP (Ypema and Gold, 1999). This action is not a lethal effect, but it is inhibitory and may make, the fungus more susceptible to parasitism.

SUMMARY CONCLUSION AND SUGGESTION FOR FUTURE WORK

The native to Mexico, Central America and northern South America, the peppers are used to flavor the sauces, stews and soups that increases palatability of food. Capsicum peppers are the foremost preferred condiments in the every household of our country.

The genus of flowering plant in the nightshade family, Solanaceae, *Capsicum annum* include bell pepper, paprika, Jalapenos and Cayenne. Bell peppers are commonly known as *Sweet pepper* (Shimla Mirch) while common chilli used in Indian cuisine is known as *Hot pepper*. The pungency of chillies is due to an alkaloid capsaicin, the active hot principle which is used in pharmaceuticals, cosmetics, food and drinks. The red colour in the fruit at the ripening stage is due to the pigment capsanthin. Contrast to hot peppers (chilli), the bell pepper has a zero rating on Scoville Heat Scale. The lack of capsaicin a lipophilic chemical responsible for strong burning sensation is due to the recessive gene that eliminates the alkaloid. The crop suffers due to a number of diseases. A number of pathogens have been reported as a limiting factor for profitable cultivation. Investigations were made to determine the status, management of fruit rot and twig die back caused by *Colletotrichum dematium* (Pers. ex Fr.) Grover (= *Colletotrichum capsici* (Sydow) Butler and Bisby and *Alternaria alternata* (Fr.) Keissler. The pathogens are responsible for seed rot, seedling decay, stem blackening, leaf spots and fruit rot and twig drying. Distribution of hot pepper diseases were investigated two times a year (during September and October 2011 and January and February 2012) at 15 and 8 locations, respectively. In all seven diseases were observed that include fruit rot (*Colletotrichum dematium*, *Alternaria alternata*), twig infection (*Colletotrichum dematium*, *Alternaria alternata*) powdery mildew, Phytophthora blight and Rhizotonia root rot. The incidence of twig infection leading to downward necrosis (die back) ranged up to 35.0% (average incidence 17.2%) and fruit infection due to *Colletotrichum dematium* ranged maximum upto 23.0% (average incidence

13.2%) during September-October. The average *Alternaria* tender tip drying incidence was 12.0% (ranged 10 to 17%) while the fruit rot was 7.4%. During January-February the incidence of anthracnose fruit rot was in the range of 2.0-13.0% while die back was 4.0-15.0%. The incidence of *Alternaria* fruit rot ranged from 3.0-12.0% and tender tip drying 6.0-19.0%. It was concluded that the incidence of *Colletotrichum* fruit rot and die back was higher during September and October while the *Alternaria* fruit rot and tender tip drying was higher during January-February.

The status of hot pepper diseases was determined in six commonly available varieties. Maximum die-back (40.0%) and fruit rot (25.0%) was observed in Jawahar Mirch 218 (JM 218) while least fruit rot and die back was in Pusa Jwala. Powdery mildew was not recorded in Pusa Jyoti and Pant C1, however, in JM 283 the incidence was 10.0%. Incidence of *Phytophthora* blight ranged from 2.0 (Pant C1) to 14.0% (Mahyco). The *Rhizoctonia* root rot incidence ranged from 3.0-11.0%, in JM 218 and Pusa Jyoti, respectively.

The status of diseases of sweet pepper was determined under ventilated polyhouse at Maharajpur Farm, Jabalpur. Four diseases were observed on two varieties (Aditi and Gold Carbon) during 2012. The incidence of *Phytophthora* stem infection and leaf blight ranged from 1.5-5.0% that appeared maximum during 1st week of May 2012. Incidence of powdery mildew was upto 9.0% during 1st and 2nd week of May. During 2nd week of April, anthracnose fruit rot was noticed and maximum disease incidence 15.0% was observed during 3rd week of May. Among the seven diseases observed, fruit rot & downward necrosis caused by *Colletotrichum dematium* and fruit rot & tender tip drying caused by *Alternaria alternata* were widespread problem, hence, investigations were undertaken. The critical study of symptomatology indicate that tender tip drying and die back could be differentiated due to the presence of silver and white wash symptoms (due to *Alternaria alternata*) and chocolate brown blackening of affected plant due to *Colletotrichum dematium* under field conditions. The test of virulence of *Colletotrichum dematium* and *Alternaria alternata* was verified through injection of spore suspension, inoculum insertion through pin pricks and tooth picks and

surface placement of mycelial bits and spores on semi and ripe intact fruit of two varieties of hot and sweet peppers under field conditions and ventilated polyhouse conditions. Infection and symptoms appeared between 6 to 9 days in tooth pick method. By providing injury on the fruit surface, the expression and development of symptoms was faster as compared to uninjured fruits. Inoculum insertion through tooth pick method was the best for hot and sweet pepper.

The progressive development of diseases of hot peppers was determined under field conditions and periodical observations were made on the tagged pre identified plants using fixed plot method. The diseases were identified on the basis of initial symptoms. Incidence of fruit rot caused by *Colletotrichum dematium* was maximum (23.0%), that was observed during 38th standard week coincided with 4th week of September, 2011. It remained on the peak till 2nd week of October (40th standard week). During this period, average minimum temperature was 20.4°C (18.6-21.9°C), and average maximum temperature was 31.4°C (30.8-32.2°C). The average relative humidity was 89.6% (86-93%) in the morning and 56.6% (47-67%) in the evening. The initiation of fruit rot (1.0%) was recorded in 34th standard week coincided with 4th week of August. Incremental development of die back was noticed and the two times infection was shoot up (from 15.0 to 32.0%) during 35th and 36th standard week and remained upto peak (39.0%) till four weeks (from 37th to 40th week). The die back was initiated in 33rd week (temperature 22.7 to 29.8°, humidity 78.92%) due to the increased humidity which was a result of high rainfall 140 and 118.5 mm received in 31st and 32nd standard week.

The fruit rot caused by *Alternaria alternata* was initiated in the last week of December when the temperature ranged between 7.4-24.9°C (average 16.1°C) with morning 89.0% and 32.0% in the evening (average 60.5%). The fruit rot disease was maximum (12.0%) during 4th week of January. The tender tip drying was initiated in the 4th week of December and was maximum (19.0%) during 3rd week of January to 2nd week of February with average maximum temperature 23.1°C (ranged from 20.8-26.4°C) and average minimum temperature 8.2°C (ranged from 7.1-9.0°C) with average morning humidity 89.7%

(89.0-91.0%) and average evening humidity was 42.2% (30.0-57.0%) during four weeks of January-February, 2012.

It was concluded that fruit rot caused by *Colletotrichum dematium* was maximum (23.0%) during 38th to 40th standard week coincided from 4th week of September to 2nd week of October 2011, whereas, the fruit rot of *Alternaria alternata* was maximum (12.0%) from 4th standard week of January till 6th standard week of February 2012. The die-back caused by *Colletotrichum dematium* was maximum (39.0%) from 37th to 39th standard week, coincided with 3rd week of September to 1st week of October. The incidence of tender tip drying was maximum (19.0%) from 3rd week of January to 1st week of February (5th standard week) 2012. Incidence of powdery mildew was maximum during 3rd week (41st standard week) to 5th week (43rd standard week) of October, 2011.

Management of fruit rot and twig infection of hot pepper caused by *Colletotrichum dematium* and *Alternaria alternata* was attempted by seed treatment and foliar application of fungicides under field conditions. The combination of new molecules was employed to determine the influence on diseases. The fungicides used as seed dresser were combination of mancozeb plus thiophenate methyl (as Super XL), mancozeb (as Dithane M 45), copper oxy chloride (as Fytolon), carbendazim (as Bavistin), mancozeb plus carbendazim (as Saff) and carboxin plus thiram (as Vitavax Power) at different dose level.

Untreated seeds (seeds with no fungicides) served as control. Complete elimination of *Colletotrichum dematium* and *Alternaria alternata* associated with seeds were observed in seeds treated with copper oxy chloride (0.25%), carboxin plus thiram (0.2%), mancozeb plus carbendazim (0.25%), mancozeb plus thiophenate methyl (0.15%, 0.175, 0.2 and 0.225%). As compared to control (22.0 and 12.0%) incidence of *Colletotrichum dematium* ranged upto 2.0% in hot pepper and 3.0% in sweet pepper, respectively. Incidence of *Alternaria alternata* ranged upto 4.0% in hot pepper and 3.0% in sweet pepper was recorded in seeds treated with fungicides, as compared to untreated seeds (18.0 and 12.0%), respectively. Observations on seed associated mycoflora were recorded

on 7 day incubated and fungicide treated seeds, under stereoscopic binocular, microscope. Influence of fungicide treated hot and sweet pepper seeds was also determined in terms of emergence. The fungicide treated seeds were sown in sterilized sand placed in plastic trays under laboratory condition. The emergence of hot pepper seeds treated with fungicides ranged from 75.0-85.0% as compared to 65.0% in untreated seeds. The fungicide treated seeds of sweet pepper the emergence ranged from 75.0-85.0% as compared to 69.0% in control. Fungicide treated seeds exhibited better emergence as compared to untreated seeds (control).

Efficacy of foliar application of new molecules of fungicides viz., Difenoconazole, Azoxystrobin, Kitazin and Tebuconazole was determined against fruit rot and twig infection caused by *Colletotrichum dematium* and *Alternaria alternata* under field condition. All the fungicides significantly controlled the disease. Minimum incidence (4.0%) of fruit rot and dieback (6.0%) due to *Colletotrichum dematium* was observed in T₄ where Difenoconazole 25% (EC) was applied three times at the rate of 100 ml/100 litre of water. Among the various concentrations of Azoxystrobin 23% (SC) (50, 100, 150, 200, 400 ml/100 litre of water) minimum (5.3%) fruit rot was observed when 200 ml/100 litre of water is used. The incidence of die back ranged from 6.0-10.0% in various treatment, least dieback was recorded in T₄, where Difenoconazole applied at the rate of 100 ml. Application of Azoxystrobin applied at 200 ml was promising that exhibited 6.0% incidence of dieback.

The incidence of *Alternaria* fruit rot ranged from 5.0% (in Difenoconazol applied at 100 ml) to 10.0% (in Azoxystrobin applied at 400 ml). Minimum incidence of fruit rot (5.0%) and tip drying (8.0%) caused by *Alternaria alternata* was observed after three applications of Difenoconazole 25% (EC) @ 100 ml/100 litre of water as compared to 12.0 and 19.0% in unsprayed control.

Suggestions for future work

1. Standardization of dosages and time of application of specific chemical molecules and combination of fungicides under varied agro-climatic and farming situations.
2. Influence of foliar application of fungicide on phyllosphere microflora and its implications of subsequent development.
3. Systematic studies on ecofriendly low cost management of bell pepper diseases under polyhouse conditions.

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Abstract

Capsicum peppers are used in many dishes in a variety of ways (roasted, fried, deep fried and raw chopped) (<http://en.wikipedia.org/wiki/Bellpepper>). Purselove (1977) reported that green chillies also contain ascorbic acid and rustin, having specific medicinal value. Bell pepper is commonly known as sweet pepper and in Hindi known as Shimla Mirch. Sweet pepper is the member of the genus *Capsicum*, it is the only *Capsicum* that does not produce capsaicin (<http://www.chilliwonders.com/chilli.scoville.htm>). The pungency of chillies is due to an alkaloid capsaicin ($C_{18}H_{27}NO_3$), the active hot principle which is used in pharmaceuticals, cosmetics, food and drinks (Tiwari, 1990). Capsaicin is a chemical lipophilic that can cause a strong burning sensation when it comes in contact with mucous membrane. While on the other hand, in contrast to hot pepper (chilli), the sweet pepper has a *Capsicum* crop is grown in almost every state of our country. It is commercially cultivated in Andhra Pradesh, Karnataka, Punjab, Bihar, Maharashtra. In Madhya Pradesh, the districts of Khargaoon, Khandwa, Chhindwara, Dhar, Shajapur, Mandsaur and Jabalpur are the major chilli producing areas. In recent years the cultivation of sweet pepper has been adopted by progressive farmers under poly house condition. zero rating on Scoville Heat Scale. The status and epidemiology of hot chilli diseases has been worked out under natural field conditions (Tiwari, 2010; Kumar, 2011), however, no systematic information is available on the prevalence and subsequent development of diseases of bell pepper under cultivation. The major field problems with hot pepper have been identified. It include fruit rot, die back and tender tip drying caused by *Colletotrichum dematium* and *Alternaria alternata*. The incidence of powdery mildew is also recorded. The chilli crop suffers due to a number of fungal, bacterial and viral diseases that renders its production into stake (Gupta and Thind, 2006; Verma and Sharma, 1999). Among the various fungal diseases, anthracnose, dieback and fruit rot incited by *Colletotrichum* spp. is a limiting factor in Madhya Pradesh (Bhale *et al.*, 2000).

Material and methods

Location of the site

The field experimentations were conducted at Research Experimental Area, Department of Horticulture, JNKVV, Jabalpur. The investigation were conducted on the crop grown during 2011-12 at Jabalpur.

Status of the disease

Status of the disease

The prevalence of bell pepper diseases was determined in the ventilated polyhouse at experimental field, Department of Horticulture, JNKVV, Jabalpur.

The status of hot pepper diseases was determined at Jabalpur in the experimental area, nearby backyard gardens/kitchen gardens. The distribution and occurrence by hot pepper diseases was recorded at Maharajpur Farm and Krishi Nagar.

Incidence of disease

The incidence of major diseases was recorded on randomly selected 100 plants in a particular field and polyhouse. The diseases were identified initially on the basis of typical field symptoms. During the study, total and infected plants were counted to calculate the disease incidence as per the formula.

$$\text{PDI} = \frac{\text{TIP}}{\text{TPO}} \times 100$$

Where,

PDI = Percent disease incidence i.e. per cent plant exhibiting symptoms

TIP = Total number of infected plants

TPO = Total number of plants observed

Collection of pepper plant parts

During study infected leaves, fruits and stem were collected in paper envelopes and brought to the laboratory.

Isolation, purification and identification of fungi

Fruits, twigs, leaves and seeds from infected plants/fruits were collected from different locations. Isolations were made to determine the associated mycoflora. The diseased plant parts were cut into small pieces. Surface sterilized with 0.1% NaOCl for 30 seconds followed by three regular washings with sterilized water and thereafter placed in Petri dishes containing 17-20ml of solidified PSA mixed with small quantity of streptopenicillin to avoid bacterial contamination. The Petri dishes were incubated at $25 \pm 2^\circ\text{C}$. After 4 to 7 days incubation, the developing fungi were subcultured on PSA medium and purified by using hyphal tip method.

The isolated fungi were identified with the help of available fungi identification keys and on the basis of morphological characteristics of the colony, mycelium and conidia.

Test of virulence

The pathogenicity test of isolated *Colletotrichum dematium* and *Alternaria alternata* was conducted under field and protected condition. The test was performed by fruit inoculation.

Technique under natural field conditions

Fruit inoculation technique

On semi-ripe and complete red ripe fruits of hot pepper and bell pepper, the cultures of *Colletotrichum dematium* and *Alternaria alternata* were inoculated by pin prick, injection and tooth pick method. Observations on symptom development were recorded. In pin prick and tooth-pick method, the pricks were made with the help of sterile needles and sharpen tooth picks and later the needles and tooth picks were loaded with inoculum. The needles and tooth picks were touched, separately and individually with the fungal culture plates, so that the mycelial bits and spores were stuck / adhered on the surface of the needles/tooth picks, and then inserted into the skin (pericarp) of the fruits. The spore and mycelial bit suspension was prepared in the culture tube and 2 ml of the spore suspension was injected in the fruits with the help of disposable syringe using the needle number 22.

Symptoms

The symptoms of diseases were recorded under field conditions and the progressive development of the diseases, including anthracnose and alternaria fruit rot and twig infection and powdery mildew was recorded.

Management

The fungicides and their combination were employed for the management studies under lab condition. The fungicides included copper oxy chloride, Carbendazim, Mancozeb, Carboxin + Thiram, Mancozeb + Carbendazim, Mancozeb + Thiophenate methyl. Untreated pepper seeds served as control. Pre-determined seed samples with known infection were used.

Treatment of pepper seeds

The required quantity of fungicides was measured and sprinkled over the pepper (both hot and sweet) seeds kept in polythene bags. The fungicide and seeds were gently shaken for uniform coating. The fungicides treated seeds were spread over a butter paper and later air dried capsicum seeds were placed on the top of the blotter (Standard Blotter method) and sown in the sterile sand (Grow Out Test).

Management of seed associated mycoflora

The seeds of pre tested variety Jawahar Mirch 283 (JM 283) having maximum natural infection of *Colletotrichum dematium* and *Alternaria alternata* was used. The seeds were treated with individual fungicides and observations were recorded on the associated mycoflora adopting Standard Blotter method (ISTA, 1996).

Management of fruit and plant diseases

Management of fruit rot & leaf spot, dieback of hot pepper caused by *Colletotrichum dematium* and *Alternaria alternata* was attempted under field conditions at Maharajpur Farm, JNKVV, Jabalpur.