Epidemiology and management of stem gall of coriander (*Coriandrum sativum* L.) caused by *Protomyces macrosporus* Unger

By

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CERTIFICATE-I

This is to certify that this thesis entitled **"Epidemiology and management of stem gall of coriander (*Coriandrum sativum* L.) caused by *Protomyces macrosporus* Unger"** submitted for the degree of **Master of Science** in the subject of **Plant Pathology** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** is a bonafide research work carried out by **Mr.Vijaykumar S, Admin. No. 2017A112M** under my supervision and no part of the thesis has been submitted by him for any other degree.

The assistance and help received during the course of investigations have been duly acknowledged.

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CERTIFICATE- II

This is to certify that this thesis entitled **"Epidemiology and management of stem gall of coriander (*Coriandrum sativum* L.) caused by *Protomyces macrosporus* Unger"** submitted by **Mr. Vijaykumar S, Admin. No. 2017A112M** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** in partial fulfillment of the requirement for the degree of **Master of Science** in the subject of **Plant Pathology** has been approved by the student's advisory committee after an oral examination on the same, in collaboration with an External Examiner.

MAJOR ADVISOR **EXTERNAL EXAMINER**

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Hisar

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ABBREVIATIONS USED

et al.	:	et alia (and others)
%	:	per cent
°C	:	degree Celsius
@	:	At the rate
cm	:	Centimeter
µm	:	Micrometer
cv	:	Cultivar
EC	:	Emulsifiable concentrate
ha	:	hectare
mg	:	Milligram
CRD	:	completely randomized design
RBD	:	randomized block design
viz.,	:	Namely
CD	:	critical difference
g	:	Gram
i.e.	:	that is
mm	:	millimeter
h	:	hour
kg	:	kilogram
m	:	meter
no.	:	Number
ppm	:	parts per million
WP	:	wettable powder
YE	:	Yeast extract
PDA	:	Potato dextrose agar

CHAPTER-I

INTRODUCTION

Spices play an important role not only as condiments but in the Indian agricultural economy owing to medicinal, industrial and processing point of view. India is known as "Home of Spices" and its spices are considered to be best in quality in the world. Coriander (*Coriandrum sativum* L.) an annual herbaceous plant (2n=22), belongs to the family *Apiaceae*, generally grown in winter season as a main crop in India (Singh and Verma, 2015). It is commonly known as dhania or Chinese parsley that originated in Mediterranean region and it is probably one of the first spices used by mankind having been known as early as 5000 BC. Coriander is cultivated in India, UAE, Malaysia, Singapore, South Africa, United Kingdom and Indonesia.

In India coriander is grown mainly in Rajasthan, Madhya Pradesh, Assam, Gujarat, Andhra Pradesh, Orissa, Uttar Pradesh and Haryana. India occupies an area of 664 thousand ha with production of 861 thousand MT and productivity 1.3 MT per ha. In Haryana it is cultivated in 2400 ha with production of 4400 MT and productivity 1.83 MT per ha (https://www.indiastat.com).

Coriander is cultivated all over the world as green leafy vegetable and seeds as a spice for essential oil production (Singh and Singh, 1996). Coriander is rich in Vitamin A, Niacin, Vitamin K, Vitamin C and minerals such as iron, calcium, it also contains fats, carbohydrates, proteins, fibers and provides energy. The fruits of coriander contain 1 per cent of volatile oils which is the active ingredient, the most important constituents of its seeds are fatty oil and essential oils (Coskuner and Karababa, 2007). Seeds also contain malic acid, tannin and some fatty acids, that gives lemony citrus flavour when crushed due to the presence of the pinene and terpenes

Coriander plant is used to cure diseases like disorders of digestive tract, respiratory tract and urinary tract infections and coriander oil has fungicidal and bactericidal properties and also used as a carminative, stomachic and spasmolytic. It is also used for treatment of diarrhea, sub-acid gastritis and dyspepsia of diverse genesis as well as for its stomachic, digestive stimulation and possess antibilious properties (Platel and Srinivasan, 2004).

Coriander is an annual herbaceous aromatic, hairless, soft, plant growing up to 3 feet height with upright stems which are slender and branched. It is a bright green, shining and glabrous plant and green leaves are fan shaped and become feathery towards the top of the plant. The flowers are borne in small, shortly-stalked umbels, with five to ten rays of asymmetrical petals pointing away from the centre of the umbel and longer than those pointing to the middle of the umbel. The seeds clusters are very symmetrical and seeds fall as soon as ripe. The fruit is a globular dry schizocarp brown to yellow colour with diameter of 3-5 mm and consist of two, single-seeded mericarp, which loose its disagreeable scent on drying and the longer they are kept, the more fragrant they become.

Coriander crop is prone to various fungal diseases *viz.*, Powdery Mildew, Wilt and Stem gall. Among the fungal diseases, stem gall is one of important disease causing losses in yield as well as quality. Gupta (1954) reported about 20 per cent mean losses per plant in the field with mean 23 per cent disease intensity. Gupta (1964) and Prasad (1983) in different reports observed that the diseased seeds lose their characteristic smell and condiment values.

The gall appears in the form of tumour like swellings of stems, leaves, peduncles and deformed seeds. The swellings on the veins give a swollen hanging appearance to the leaves. The swellings are initially glossy but later rupture and become rough and their size varies as rule according to the size of the infected plant part. Systemic infection provides greater distortion to different parts of the plant. The inflorescence may show outgrowth on the surface and uniform invasion of the fruit makes it abnormally large but partial invasion may lead to distortion (Gupta, 1962; Rao, 1972). The symptoms appear initially as galls on the lower part of stem which gradually extend upwards to flower and seeds. The diseased seeds are hypertrophied depending upon the stage of infection, ultimately lowering the crop yield and quality (Kumar *et al*., 2014a).

The stem gall of coriander is caused by *Protomyces macrosporus*. The fungus was first described by Unger (1833). The pathogen persists season to season in the chlamydopsore stage and later it germinates and initiates fresh infection to the following season (Pavgi and Mukhopadhyay, 1969c). The stem gall of coriander appears continuously every year when grown in the field having high soil pH and congenial or favourable environment conditions (Verma *et al*., 2017).

In view of the most devastating nature of this problem of coriander and meagre availability of information, it was necessary to investigate further with the following objectives:-

1. To study the effect of weather variables on progression of stem gall of coriander
2. To explore suitable remedial measures for the management of stem gall of coriander
3. To find out the resistant source against stem gall of coriander through screening of different genotypes

CHAPTER-II

REVIEW OF LITERATURE

The stem gall of coriander was first reported from Pusa, (Bihar) in India by Sydow and Butler (1911). In the present chapter the available relevant literature and the status of research related to "Epidemiology and management of stem gall of coriander (*Coriandrum sativum* L.) caused by *Protomyces macrosporus* Unger" is briefly reviewed under the following heads :

2.1 CAUSAL ORGANISM

Stem gall of coriander is one of the economically important disease. Depending upon the symptoms produced by several *Protomyces* spp. Gupta (1958) observed that the mycelium of the fungus is found only in the tumours and causes hypertrophy and hyperplasia. The three layered thick chlamydospores act as resting spores of the fungus. The pathogen survives in soil in the form of chlamydospores and these spores act as primary source of infection. Pavgi and Mukhopadhyay (1969b) reported that the disease is caused by fungus *Protomyces macrosporus* and distinguished morphological characteristics of pathogen are formation of chlamydospores or endospores. The chlamydospores of fungus are yellowish brown, spherical to oval, single-celled with smooth appearance and measuring 40 to 81µm in diameter. A mature chlamydospore is protected externally by a hard thick exospore enclosing a medium thick mesospore and membranous endospore.

Bacigalova *et al*. (2008) examined the association of different species of *Protomyces* causing galls in different families and they found the association of *Protomyces macrosporus* on family Umbelliferae, *P. pachydermus* Thüm on Asteraceae, *P. kriegerianus* Büren on Leontodon, *P. buerenianus* Buhr on Galinsoga and *P. cirsii-oleracei* on Cirsium.

The fungus *Protomyces macrosporus* was first described by Unger (1833) belonging to family Protomycetaceae. This pathogen was previously placed in *Chytridiales* (Heim, 1967). Later this pathogen was placed in class *Ascomycetes* and order *Protomycetales* by Kramer (1973). Preece and Hick (2001) described that *Protomyces macrosporus* was the first member of the *Protomycetaceae* and presently *P. macrosporus* has been placed in Kingdom: Fungi, Division: *Ascomycota* Class: *Taphrinomycetes*, Order: *Taphrinales*, Family: *Protomycetaceae*, Genus: *Protomyces* and Species: *macrosporus* (Krik *et al*., 2008).

2.2 ISOLATION AND IDENTIFICATION

Lodder and Kregervan Rij (1952) obtained salmon red colour and yeast like growth of fungus *P. macrosporus* in young stages after 7 days of inoculation on PDA at room temperature ranging between 22-24°C. Tubaki (1957) studied cultural and biological characteristics of three species of *Protomyces*. Mukhopadhyay and Pavgi (1964) differentiated the pure cultures through colour pigmentation *i.e*. deep salmon red and creamy white, when isolated through spore fall method on malt agar medium. For isolation of pathogen the chlamydospores were dipped in acid or week alkaline distilled water and then transferred to moist filter paper stripes stuck inside the petri plate cover and inverted over media (PDA) at room temperature.

Lakra and Parkash (1993) conducted experiment on isolation of *P. macrosporus* (period of 10-12 days) from one year old coriander infected stem bits and observed appearance of dull creamy white colony on PDA slants after 12 days.

Thirumalachar and Narasimhan (1953) described that mature chlamydospores provoked out of the diseased tissues after 120 and 180 days were adhesive to glass slides by the alternate wetting and drying method. Pavgi and Mukhopadhyay (1969a) isolated *Protomyces macrosporus* from the infected coriander plant parts on different cultural media *viz.*, malt agar, Lilly and Barnett's semi-synthetic medium and potato dextrose agar medium. They found two different pigmented cultures *i.e.* salmon red (SR) and creamy white (CW) on different media. Growth of fungus was slow and pigment was bright salmon red and colony attained a diameter of 4-5.5 mm after 7 days of incubation at 22-24°C and growth resembled with the species of yeast or Taphrina. Texture was sticky and not slimy, smooth on the surface and covered by the zonate rings having smooth and broadly uneven margin. The continuous change in pigmentation occurred after one month and the older central portion became pinkish to dull buff. The new growth of culture was accumulated by successive layer forming a deep mass and further entire colony growth lost its sticky appearance and appeared coarsely granular with after two months.

The mycelium of *Protomyces macrosporus* was septate, hyaline, irregular, branched, 2 to 5 µm thick, 36.50 µm length and 35.00 µm width. Chlamydospores were globose to ellipsoid, thick-walled, three-layered membrane and smooth with brownish colour. The matured Chlamydospores were multinucleate with diameter of 60-70 µm (Mishra *et al*., 2017).

2.3 PATHOGENICITY

Pavgi and Mukhopadhyay (1969b) conducted pathogenicity tests of *Protomyces macrosporus* by collecting the healthy seed lots from disease-free coriander plants and inoculation of one month old seedlings separately by spraying with equal quantity of spore suspension of uniform density from 7 days-old plated colonies of the two culture types. The moisture was retained in moisture chambers up to 48 h and as a check plants were also sprayed separately with sterile distilled water alone. Typical galls developed after two weeks on the stem in the two inoculated sets whereas the control check plant remained free from infection. Chauhan *et al* (1981) observed variable degrees of pollen sterility in artificially inoculated coriander plant. Valverde and Templeton (1984) inoculated seedlings of *Torilis* *japonica* in green house with *Protomyces macrosporus* by spraying suspension of endospores at a concentration of 5×10^6 spores per milliliter. The inoculated plants were maintained for 48 h in a dew chamber at 100 per cent RH at 20±1°C then placed in a greenhouse at 18-24°C temperature and first symptoms appeared within 10-15 days as small white streaks that increased to swelling like galls within 20-30 days.

2.4 EFFECT OF SOWING TIME

Lakra (1999) reported that when coriander was sown on six different dates of sowing *viz.*, 16th Sept, 1st Oct, 16th Oct, 1st Nov, 16th Nov, 1st Dec and 16th Dec, the severity of stem gall was 51, 60, 71, 66, 50, 34 and 26 per cent respectively. Disease intensity was highest when sown on 16th October which also corroborated with maximum yield loss. The stem gall infection was lowest in September and December sown crop with maximum yield.

Lakra (2000) further recorded that intensity of stem gall was less in early and late sown crop with maximum incidence in 16th October sown crop. Seed yield loss was highest in crop when sown on first November and disease intensity was also high (40%). The crop sown on 16th September and 16th December had higher disease incidence and also resulted in drastic reduction in yield. In December sown crop, the disease intensity on seed was more in comparison to early sown crop.

Tripathi (2003) conducted experiment during *rabi* season in the year of 1999-2000 and 2000-01 at Gwaliar and observed that the severity of stem gall diseases was less in early and late sowing (Sept 16 and Dec 1) compared to other sowing dates.

Verma *et al*. (2017) studied the effect of four sowing dates of cv. RCr-436 on stem gall disease incidence and found higher coriander seed yield when sown between 15th Oct to 15th Nov in Zone V of Rajasthan, however in late sown crop the stem gall incidence was less.

2.5 EPIDEMIOLOGY OF THE DISEASE

Weather parameters play a predominant role in the cause and severity of the epidemics however information on this aspect of stem gall disease is limited. Hawker (1950) observed that the germination of chlamydospores was accelerated by exposure to high and low temperature. Gupta (1959) reported that the germination of chlamydospores was high in double distilled water after 7-8 days at 18-20°C temperature.

Mukhopadhyay and Pavgi (1971) observed that primary inoculum of the stem gall of coriander disease was carried to the field with the seed drawn from infected plants, crop debris and uncleaned seed mixed with seed galls. The pathogen survived from season to season in the chlamydospore stage and later spores germinate to initiate fresh infection in the next season. The thick walled chlamydospores resisted the effect of high temperature and desiccation, during the summer months (May-June) and survived under unfavorable environmental conditions over prolonged periods in the absence of the main crop. The chlamydospores overwintering in the crop debris and hypertrophied fruit galls released after monsoon period (July-September) and the chlamydospores from the fruit galls germinated on the soil surface late in January at cool time. Infection of the seedlings took place through the endospores and subsequent blastospores during January-February.

Gupta (1973) observed 37 per cent germination of chlamydospores after one year and 27 per cent after two years, when the infected plant material was stored at room temperature. Lakra (2000) tested and found that the IW: CPE 1.33 resulted in 46 per cent disease incidence, while IW: CPE 0.7 resulted in 22 per cent disease, with 57.2 and 10.4 per cent yield losses respectively.

The stem gall of coriander appeared continuously every year in the field where coriander was grown on high soil temperature, moisture, soil pH and adverse ecological factors (Saxena *et al*., 2002). The temperature and relative humidity play an important role in the development of the stem gall disease incidence. The stem gall appeared on the plants when the average minimum and maximum temperatures were 13.2 and 30.9°C respectively and relative humidity was 57.2 per cent. Maximum disease severity was recorded in the plants when the minimum and maximum temperature was 8.1 and 22.6°C respectively and relative humidity 65.8 per cent. Maximum germination of chlamydospores of *Protomyces macrosporus* was found at 22-24°C (Tripathi *et al*., 2003).

Bacigalova (2004) conducted experiment on occurrence of *Protomyces macrosporus* mainly on the humid places along brooks and streams during whole vegetation season (spring, summer and autumn). The presence of superfluous soil moisture and low sunshine hours due to cloudy weather in winter season helped the spread of stem gall and damaged the crop up to 100 per cent (Malhotra *et al*., 2016).

Leharwan *et al*., (2018) observed that stem gall development was maximum at soil temperature of 25°C and most favorable at 45 per cent of soil moisture level and further reported that Very low and very high soil temperature and moisture levels were not favorable for disease development.

2.6 DISEASE MANAGEMENT

The complete management of stem gall of coriander in the field has still not been achieved. The application of different fungicides reduced the disease incidence but not to appropriate level. Nene *et al*. (1966) reported the partial control of stem gall disease through seed treatment with thiram @0.25 kg per 100 kg of coriander seed and they further indicated that better control of disease is possible by combining seed treatment and soil treatments with thiram @8 kg per acre in the soil.

Pavgi and Mukhopadhyay (1970) reported that seed treatment with ceresan and application of omnamycin to the soil was most effective in reducing galls development on stem as well as invasion of fruits by the pathogen *Protomyces macrosporus* Unger.

Spraying with thiram, captafol or carboxin at periodical intervals from the time of disease appearance were more effective than seed treatment or combined seed and soil treatment in managing stem gall and increasing the coriander yield. Thiram gave maximum fruit yield followed by carboxin and captafol (Bhardwaj and Shrestha 1985). Paul (1992) evaluated eight fungicides and their combinations as a seed treatment against stem gall disease and observed that seed treatment with captafol @2 g/kg seed was most effective in inhibiting the chlamydospores germination of *P. macrosporus.*

Lakra (2000) conducted experiment on different fungicides to manage stem gall of coriander by treating coriander seeds with carbendazim, thiram, vitavax (carboxin) and captan @ 4 g per kg seed before sowing. Carbendazim (0.2%), carboxin (0.1%), copper oxychloride (0.3%), mancozeb (0.25%), tridemorph (0.1%) and streptomycin (500 ppm) were applied to foliage 30, 45, 60 and 75 days after sowing. The disease control by seed treatments with thiram and spraying of streptomycin was 53.5 per cent and 66.6 per cent respectively.

Tripathi (2005) recorded minimum disease incidence in seed treatment with thiram that resultantly reduced 65 per cent disease over control. Minimum disease incidence was recorded in soil treated with neem cake that reduced the disease up to 50% and increased yield up to 36%. Seed treatment with thiram @3g per kg, soil treatment with neem cake @ 1.5 t/ha and two sprays of thiram at 0.2 per cent gave better control of stem gall disease up to 90 per cent. Neem oil also gave a significant reduction in disease up to 27 per cent.

Malhotra *et al*. (2006) studied the influence of nitrogen fertilizer, *Azospirillium* sp. , farmyard manure and their combinations on incidence of stem gall of coriander and observed that application of *Azosprillium* spp., 50 per cent nitrogen and 5 tonnes of FYM was the most efficient treatment in increasing the seed yield and reducing the severity of stem gall disease.

The combination of seed treatment with carbendazim (1g/kg) and foliar spray with Bayleton (0.04%) was found most effective and reduced up to 57.66 per cent disease severity followed by seed treatment with carbendazim + foliar spray with karathane (0.04%) and foliar spray with Bayleton (0.4%) (Shukla *et al*., 2006).

Dabbas *et al*. (2009) studied the effect of IDM and reported that seed treatment with *Trichoderma viride* @ 4 g/kg seed + soil treatment with *Trichoderma viride* @ 2 kg/ha was best for management of stem gall of coriander among different treatments.

Kumar *et al*. (2014 b) evaluated the effect of seed treatment and foliar spray of bioagents *Trichoderma viride, Pseudomonas fluorescens* and fungicides like Carbendazim, Ridomil, Blitox-50, Hexaconazole and Propiconazole on the incidence of stem gall disease of coriander. Hexaconazole as seed treatment (0.2%) and foliar spray after 40, 60 and 75 DAS (0.2%) were more effective for management of stem gall disease of coriander. The seed yield was maximum in treatments with Hexaconazole and Propiconazole and also at par among each other.

2.7 SCREENING OF DIFFERENT CORIANDER GENOTYPES AGAINST STEM GALL

Singh *et al*. (1995) evaluated eight coriander cultivars for yield and disease resistance and reported that Pant Haritama produced highest seed yield (1346 Kg/ha) with lowest stem gall intensity (3.2%) while veldurthy cultivar had maximum disease intensity 92.8% with lowest seed yield

Patel *et al*. (1998) evaluated twenty one genotypes of coriander under different agro climatic conditions of Gwalior and found that G.C. 88-8 was resistant while UD-20, G-5365-91, Pant-1 as moderately resistant against stem gall disease.

Singh *et al*. (2003) screened seventy genotypes of coriander for resistance against stem gall with the goal to select the resistant cultivars. The cultivars PH-7, Pant Haritima, Dhania-8, COR-17, COR-2, COR-2, DH-13, DH-19-M-4 and DH-19-M-11-2 were highly resistant. The highly susceptible genotypes were COR-11, COR-14, COR-18 and R-Swati.

Kumar *et al*. (2016) evaluated 102 germplasms of coriander against stem gall disease under natural field condition and observed that the germplasms did not show disease incidence uniformly and there were variations in date of first appearance of disease and disease severity. Moreover, in one germplasm like NDCor-12 it was observed that symptoms of disease appeared on inflorescence directly without appearing any protuberances or any gall on the stem of the plants. Amongst 102 germplasm of coriander, thirty five entries were moderately susceptible and sixty seven as susceptible.

Khan and Parveen (2016) evaluated Twenty-seven varieties of coriander against stem gall of coriander caused by *Protomyces macrosporus* and out of 27 varieties only four varieties *viz.*, UD-125, UD-317, UD-749 and Rlr480 were graded as resistant and also reported overall yield loss of 27.87 per cent that directly relates to stem gall intensity.

CHAPTER-III

MATERIALS AND METHODS

The present study entitled "Epidemiology and management of stem gall of coriander (*Coriandrum sativum* L.) caused by *Protomyces macrosporus* Unger" was carried out in the Plant Pathology experimental area as well as Vegetable Science experimental area of CCS HAU, Hisar during the year of 2018. The methodologies adopted during the course of study are elaborated as under:

3. 1 MATERIALS

3.1.1 Samples

Samples of stem gall infected stem and seed were collected from experimental research area of Department of Vegetable Sciences CCS HAU Hisar for isolation of the test pathogen and maintenance of inoculum for further study. The samples were stored in polythene bags in refrigerator at 5°C for further use.

3.1.2 Chemicals

Chemicals used in the present study were obtained from Hi-Media laboratories Pvt. Ltd., E. Merck laboratories Pvt. Ltd. and CDH laboratory reagents. Various fungicides were procured from the local market.

3.1.3 Seeds

Seeds of coriander variety seed type (DH-36) and one leaf type (DH-228) were obtained from Department of Vegetable Sciences, College of Agriculture, CCS Haryana Agricultural University, Hisar.

3.2 PREPARATION OF MEDIA

The Potato dextrose agar medium and Potato dextrose agar medium enriched with yeast extract were prepared in distilled water and autoclaved at 15lbs pressure for 20 minutes. The composition of media used in the present investigation is given below:

Potato Dextrose Agar Medium		**Potato Dextrose Agar with Yeast Extract (PDA+YE) Medium**	
Peeled potato	250 g	Peeled potato	250 g
Dextrose	20 g	Dextrose	20 g
Agar	20 g	Agar	20 g
Distilled water	1000 ml	Yeast Extract	20 g
		Distilled water	1000 ml

METHODS

3.3 ISOLATION AND IDENTIFICATION OF PATHOGEN

3.3.1 Isolation

Infected stems and seeds with galls were used for isolation of the test fungus under *in vitro* conditions. Small infected bits of 1 to 2 mm size were taken from infected stem galls with the help of sterilized blade. These bits were sterilized with mercuric chloride at 0.1 per cent for 20 to 50 seconds, washed three times with sterilized water and then placed on sterilized filter paper to remove the excessive moisture and subsequently transferred to potato dextrose agar medium enriched with yeast extract 2 per cent (PDA+YE), under aseptic conditions and incubated for 7-10 days at 21±1°C. The isolated fungus was purified by hyphal tip method and maintained on potato dextrose agar medium (PDA) at 4±1°C and stock culture was maintained by subculturing at every 25-30 days interval.

3.3.2 Identification

The morphological characteristics of pathogen were studied on the host and pieces from diseased portion of infected stems and seeds were examined under microscope in the laboratory. The morphological characteristics were also studied by growing the test fungus *in vitro* on potato dextrose agar medium enriched with yeast extract, and observations on cultural colony were recorded. The identity of test pathogen was confirmed on the basis of morphological characteristics documented in standard reliable descriptions and taxonomic keys as given by (Pavgi and Mukhopadhayay, 1969a).

The diseased parts of coriander plant collected were confirmed for chlamydopsore germination. The method described by Haware and Pavgi (1976) in which infected part of coriander plant bearing mature galls were collected and stored at 10°C. The smears were soaked in acid water at 0.5 per cent H_2SO_4 for 20 minutes and dipped in sterile distilled water and then overturned wet cotton (Thirumalachar and Pavgi, 1950). The developing chlamydospores were fixed at the preferred stage and preserved on slides by lactophenol to study the sequence in the progression of development and variations in the process.

3.4 PATHOGENICITY

Pathogenicity of isolated fungus from infected plant was confirmed on coriander plants by artificially inoculation in pots under screen house conditions with source of inoculum as diseased parts of plant and mycelium of the pathogen.

3.4.1 Raising of plants

The healthy seeds of coriander variety “DH-36” were sown in sterilized pots with 26 cm height which were filled with sterilized soil of 2 kg in screen house by placing at a depth of 2.5 cm in the soil. The crop was irrigated as per necessities and standard recommendations of CCS HAU, Hisar for the raising of crop were followed. Ten plants were maintained in each pot.

3.4.2 Preparation of inoculum

3.4.2.1 Chlamydospore inoculum

For the preparation of chlamydospore inoculum the infected stem and seeds of diseased coriander plants were collected from the field, air dried and powdered with pestle mortar. This crushed material containing 7.5 $\times 10^4$ chlamydospores per g was used for inoculation under screen house conditions.

3.4.2.2 Mycelial suspension

For the preparation of mycelial suspension of test pathogen, the potato-dextrose broth enriched with yeast extract was inoculated with bits (6-8mm) of culture of test fungus *Protomyces macrosporous* and incubated at 21±1°C in BOD incubator. The final mycelial suspension confined nearly 5.9×10^4 spores per ml.

3.4.3 Inoculation methods

The pathogenicity experiments were confirmed on coriander plants in pots by creating the sick soil. Ten coriander plants were maintained in each pot. When the plants were well established they were inoculated with the mycelial suspension or with chlamydospores of the pathogen. The soil was inoculated by adding 10 ml of mycelial suspension and 10 g powder of diseased coriander plant part *i.e.* stem infected with pathogen by one cm deep in soil at the collar region of plant and one cm away from the plant and after inoculation these pots were maintained in screen house condition. The control pots were also maintained at the same time without adding inoculum. Observations on incubation time (days) and disease progress in terms of disease severity was recorded. Koch's postulates were established by re isolating the test pathogen from such infected plants and were confirmed by relating all characters with the original culture and re-inoculation also.

3.5 EFFECT OF SOWING TIME

Two coriander cultivars, one seed type (DH-36) and one leaf type (DH-228) were sown under natural condition in Plant Pathology experimental area in randomized block design with three replications on five dates *viz.*, 1st week November, 2nd week November, 3rd week November, 4th week November and 1st week December during year 2018. The size of the plot was 4×2.4 m^2 with row to row distance of 30 cm and plant to plant distance of 20 cm. The layout of the field experiment is elucidated in Figure 3.1. Fertilizers were applied @ recommended level (N=25kg/acre and P=25kg/acre) and other recommended cultural practices were adopted for optimum crop growth and observation on disease severity were recorded at weekly interval as per the 0-4 scale.

3.6 EPIDEMIOLOGY OF THE DISEASE

A field experiment was conducted to study the role of environmental factors (temperature, relative humidity, rainfall and sunshine hours) on the progress of stem gall disease on coriander variety of DH-36 and DH-228. Different metrological parameters recorded at metrological unit of CCS Haryana Agricultural University Hisar research farm are depicted in Table 3.1. The data on the disease progress was recorded at one week interval starting from first appearance of the disease. The disease severity was calculated by using 0-4 scale at weekly interval up to crop maturity (Kumar *et al.*, 2016).

The disease severity (%) was calculated by using formula given by McKinney (1923).

$$\text{Disease severity (\%)} = \frac{\text{Sum of all disease ratings}}{\text{Total no. of disease ratings} \times \text{maximum disease grade}} \times 100$$

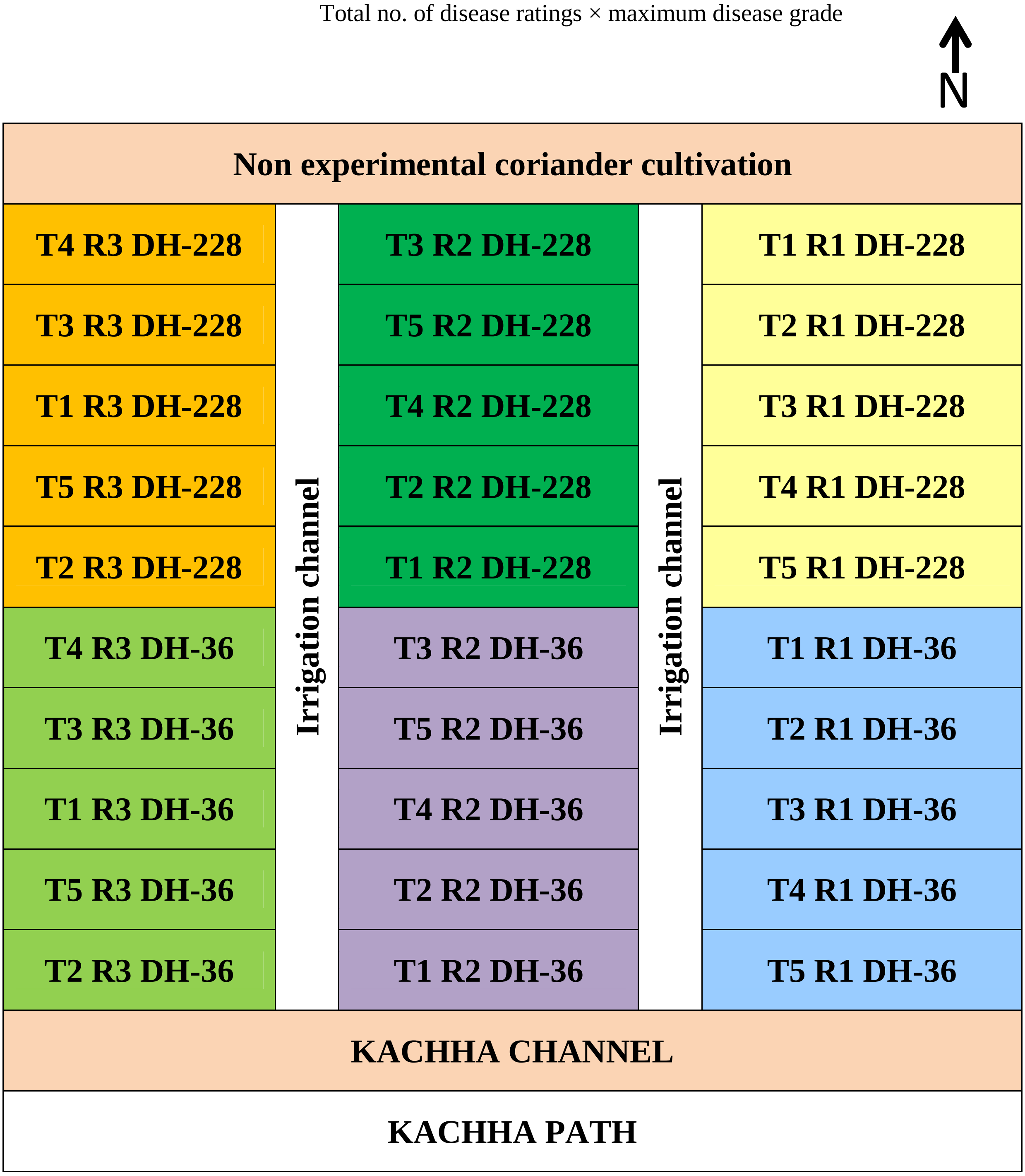


Figure 3.1 Experimental layout of two varieties *viz.*, DH-228 and DH-36 to examine the effect of date of sowing on appearance of stem gall of coriander

Table 3.1: Meteorological Data of different weather parameters (weekly) during the period of coriander crop season (2018-2019)

Standard Meteorological Week	Temperature ^{0}C		Relative Humidity (%)		Sun shine hours	Pan evaporation	Rain fall (mm)
	MAX	MIN	MOR	EVG			
45	27.4	10.1	90	41	3.3	2.1	0.0
46	27.5	12.7	91	53	3.5	1.9	0.0
47	27.4	10.9	87	44	5.8	2.3	0.0
48	27.2	9.4	93	47	5.5	1.7	0.0
49	24.9	7.5	96	45	5.1	1.2	0.0
50	21.0	7.7	90	57	3.6	1.4	0.0
51	20.7	2.0	93	50	6.3	1.2	0.0
52	19.8	1.9	94	49	4.4	0.9	0.0
1	18.9	5.7	95	66	3.3	0.9	7.3
2	19.3	5.6	92	59	4.4	0.9	0.0
3	20.4	4.9	90	55	5.0	1.0	0.0
4	18.2	4.8	99	63	4.6	1.1	6.5
5	17.1	5.3	96	65	3.9	1.1	0.0
6	21.0	6.9	91	56	5.7	1.6	0.0
7	20.0	9.7	94	66	3.1	1.2	0.0
8	22.2	9.0	89	50	5.6	2.1	0.0
9	20.9	8.0	93	53	5.8	1.9	14.8
10	24.2	8.5	88	42	7.2	2.7	0.0
11	24.9	9.1	91	48	6.1	2.6	0.0
12	28.9	11.8	80	42	7.2	4.0	0.0

Table 3.2: Severity Scale of stem gall of coriander

Plant part	Score or Rating
Stem	30 points
Seed	20 points
Leaves	20 points
Pedicel	20 points
Total	100 points

The score of each unit depends on the amount of the disease (on the length for stems and pedicels, area covered for leaves and for seeds number of infected seed).

3.6.1 Calculation of apparent infection rate (r)

The apparent infection rate (unit per week) of the disease for two varieties was calculated by using the formula given by Vander plank (1963) as mentioned below:

$$r = \frac{2.3}{(t_2 - t_1)} \left\{ \log_e \frac{x_2}{1- x_2} - \log_e \frac{x_1}{1- x_1} \right\}$$

Where,

r = Apparent rate of infection at log phase of epidemic development

t_1 and t_2 is time intervals when disease severities are x_1 and x_2 respectively

Accordingly, the data pertaining to above parameters were recorded to finally calculate the apparent infection rate (r).

3.6.2 Calculation of area under disease progress curve (AUDPC)

The area under disease progress curve was calculated for the cultivars by using the formula given by Vander plank (1963).

$$\text{AUDPC} = \sum_{i=1}^{k} \frac{1}{2} (y_i + y_{i+1}) \times (t_{i+1} - t_i)$$

Where

k = number of successive evaluation

y_i = disease severity at time t_i

y_{i+1} = disease severity at time t_{i+1}

t_i = time when disease severity was y_i

t_{i+1} = time when disease severity was y_{i+1}

Accordingly, the data relating to above parameters was recorded to finally calculate the AUDPC.

3.7 DISEASE MANAGEMENT

3.7.1 *In vitro* evaluation of fungicides against *Protomyces macrosporus* incitant of stem gall of coriander

Different fungicides were evaluated under *in vitro* conditions against stem gall of coriander caused by *Protomyces macrosporus* and mentioned as follows.

The effectiveness of five different fungicides with concentrations *viz.*, Hexaconazole, Blitox, Propiconazole, Ridomil MZ and Carbendazim each @ 0.2%, were tested against the test fungus under *in vitro* conditions by using poisoned food technique as described by Vincent (1947).

The double strength potato dextrose agar medium (PDA) was prepared by doubling the amount of ingredients except water. This medium was sterilized for 20 minutes at 15 lbs pressure in an autoclave in 150 ml Erlenmeyer flasks containing 50 ml of double strength medium in each Erlenmeyer flask and equal amount of water was also sterilized separately in 150 ml Erlenmeyer flasks containing 50 ml distilled water. Five test fungicides were dissolved (0.2%) in sterilized water in different sets of Erlenmeyer flasks and then added independently in double strength medium in different sets of flasks, shaken well,

Plate 1. Sowing of coriander in experimental area of Plant Pathology CCS HAU, Hisar (Haryana) during 2018

Plate 2. Evaluation of fungicides, botanicals and bioagents for coriander crop by means of spray technique

Plate 3. Harvesting of coriander crop cultivated in experimental area of Plant Pathology CCS HAU, Hisar (Haryana) during April 2019

Plate 4. Threshing, cleaning of coriander seeds and recording of yield observations

subsequently poured separately in Petri plates and were allowed to solidify. The small bits of 5 mm of 5 to 7 days old culture of test fungus by using sterile cork borer were placed with the help of a sterile inoculation needle into the center of each Petri plate in a laminar air flow under aseptic conditions. Petri plates without test fungicides in the medium served as control and each fungicide were replicated thrice and incubated at 21±1^{0}C for a period of up to 15 days. The radial growth of mycelium was measured and per cent growth inhibition was calculated by using formula given by Vincent (1947) as follows:
Per cent growth inhibition of pathogen by dual culture technique

$$\textbf{Per cent growth inhibition (I)} = \frac{C-T}{C} \times 100$$

Where,

I = Inhibition

C = radial growth in control

T = radial growth in treatment

Table 3.3: Fungicides with their trade, common and chemical names

Trade name	Common name	Formulation	Chemical name
Contaf	Hexaconazole	5 SC	2-(2,4-dichloro phenyl)-1-(1H1,2,4-triazole-1-yl) hexane -2-ol
Blitox	Copper oxychloride	50 WP	Copper oxychloride
Tilt	Propiconazole	25 EC	1-(2-(2,4-dichlorophenyl)-4propyl-1,3-dioxolan-2-yl) methyl1 H-1,2,4-triazole
Ridomil MZ	Metalaxyl+mancozeb	68 EC	Methyl N(2-methoxyacetyl)-N(2,6-xylyl) -DL-alaninate; Manganese ethylenebis (dithiocarbamate) (polymeric) complex with zinc salt
Bavistin	Carbendazim	50 WP	2(Methoxy carbamoyl) benzimidazol

3.7.2 *In vitro* evaluation of botanicals against *Protomyces macrosporus* incitant of stem gall of coriander

Five plant leaves extracts of Neem, *Aloe vera*, Eucalyptus, Parthenium and Datura at 10 % concentration were evaluated for their effectiveness against *Protomyces macrosporus* (Table 3.4). The extracts were prepared by crushing 100 g leaves of each plant species in 100 ml distilled water using mixer. The supernatant was filtered by using muslin cloth followed by Whatman filter paper No.1 and filtrate was then centrifuged at 5000 rpm for 25 min. The clear supernatants obtained were kept in refrigerator and used for further experiments.

Table 3.4: List of botanical evaluated against *Protomyces macrosporus* along with botanical name and family

Common name	Botanical name	Family
Neem	*Azadirachta indica*	Meliaceae
Aloe-vera	*Aloe barbadensis*	Asphodelaceae
Eucalyptus	*Eucalyptus* spp.	Myrtaceae
Parthenium	*Parthenium hysterophorus*	Asteraceae
Datura	*Datura stramonium*	Solanaceae

The efficacy of plant leaves extracts on the growth of *Protomyces macrosporus* was evaluated under *in vitro* condition using poison food technique. The aqueous solution of plant leaves extract was prepared in sterile distilled water and aseptically added to PDA medium to attain a final concentration of 10 per cent before pouring the medium into Petri plates (20 ml PDA for each Petri plate). Three replications were maintained for each plant leaves extract and mixed to the double strength PDA medium, Petri plates were inoculated with *Protomyces macrosporus* under aseptic conditions. These Petri plates were incubated at 21±1˚C and split growth of test pathogen was observed in the Petri plates when the control Petri plates were completely full with test pathogen. Per cent growth inhibition was measured by using the formula given by Vincent (1947).

3.7.3 *In vitro* evaluation of bioagents against *Protomyces macrosporus* incitant of stem gall of coriander

Three bioagents *viz., Pseudomonas fluorescens, Trichoderma viride* and *Trichoderma harzianum* were used to test the efficacy against *Protomyces macrosporus.* The effect of bioagents on the growth of test fungus was evaluated under *in vitro* using per cent growth inhibition of pathogen by dual culture technique with five replications maintained for each bioagent. The PDA medium was poured aseptically in Petri plates and inoculated with test pathogen as well as antagonist. The Petri plates were incubated at 21±1°C and split growth of pathogen was observed when the control Petri plate were completely full with test pathogen. Growth inhibition per cent was calculated as per formula given by Vincent (1947).

3.7.4 Evaluation of fungicides against stem gall of coriander under field conditions

The experiment was conducted at Plant Pathology experimental area of CCS HAU, Hisar to study the effect of two best fungicides (Blitox 50WP and Ridomil MZ EC @ 0.2%) on disease severity and incidence of stem gall of coriander under field conditions. The seeds of coriander cultivar “DH-36” treated with two fungicides were sown by maintaining a spacing of 30 × 20 cm during the month of November 2018 in randomized block design with three replications and routine intercultural operations were followed to raise a healthy crop. The fungicides were sprayed at 50 and 70 DAS (Figure 3.2). Observations on disease severity in ten tagged plants and incidence were recorded and seed yield was also recorded at crop maturity.

3.7.5 Evaluation of botanicals against stem gall of coriander under field conditions

The experiment was conducted to study the effect of two best botanicals (Neem leaves extract and Datura leaves extract @ 10%) on disease severity in ten tagged plants and incidence of stem gall of coriander under *in vivo* conditions. The seeds of coriander cultivar “DH-36” treated with two plant leaves extracts were sown by keeping a spacing of 30 × 20 cm during the month of November 2018 in randomized block design (RBD) with three replications and routine cultural operations were followed to raise a healthy crop. Both the botanicals were also sprayed at 50 and 70 DAS (Figure 3.2). Observations on disease severity and incidence were recorded and seed yield was also recorded at crop maturity.

↑ N

<table>
<tr><td colspan="5">KACHHA PATH</td></tr>
<tr><td>T3 R3</td><td rowspan="7">Irrigation channel</td><td>T7 R2</td><td rowspan="7">Irrigation channel</td><td>T1 R1</td></tr>
<tr><td>T7 R3</td><td>T4 R2</td><td>T2 R1</td></tr>
<tr><td>T2 R3</td><td>T6 R2</td><td>T3 R1</td></tr>
<tr><td>T1 R3</td><td>T5 R2</td><td>T4 R1</td></tr>
<tr><td>T4 R3</td><td>T3 R2</td><td>T5 R1</td></tr>
<tr><td>T5 R3</td><td>T2 R2</td><td>T6 R1</td></tr>
<tr><td>T6 R3</td><td>T1 R2</td><td>T7 R1</td></tr>
<tr><td colspan="5">KACHHA CHANNEL</td></tr>
<tr><td colspan="5">KACHHA PATH</td></tr>
</table>

Figure 3.2: Experimental layout to explore suitable remedial measures for the management of stem gall of coriander (DH-36) in Plant Pathology experimental area during 2018

3.7.6 Evaluation of bioagents against stem gall of coriander under *in vivo* conditions

The experiment was conducted to study the effect of two best bioagents (*Trichoderma viride* and *Pseudomonas fluorescens* @ 0.4%) on disease severity in ten tagged plants and incidence of stem gall of coriander under field conditions. The seeds of coriander cultivar “DH-36” treated with two bioagents were sown by maintaining a spacing of 30 × 20 cm during the month of November 2018 in randomized block design (RBD) with three replications and routine cultural operations were also followed to cultivate crop. Spray application of bioagents was also given at 50 and 70 DAS (Figure 3.2). Observations on disease severity and incidence were recorded and seed yield was also recorded at crop maturity

3.8 Screening of different coriander cultivars against stem gall of coriander caused by *Protomyces macrosporus*

Twenty eight genotypes of coriander were screened for resistance against stem gall of coriander (*Protomyces macrosporus*) under natural conditions in randomized block design (RBD) with three replications in sick plot. The seeds were sown (30x20 cm) on 8th November 2017. Ten plants were selected after germination from each plot and fertilizers were applied as recommended level of N:P:K per plot equivalently before sowing. The disease severity on various plant parts (stem, pedicels and fruits) was recorded in ten selected plants in each plot at the maturity stage. The disease intensity was recorded as per scale proposed by Lakra (1991). The genotypes were grouped into from resistant to susceptible categories by adopting 0-4 scale as follows.

Rating	Per cent Area covered by the disease	Reaction
0	0	Disease Free
1	1-5.0	Resistant
2	5.1-20	Moderately Resistant
3	20.1-50	Moderately Susceptible
4	> 50	Susceptible

Table 3.5: List of coriander genotypes screened for stem gall of coriander

S. No.	Genotypes	S. No.	Genotypes
1	Rcr-728	**15**	LCC 275
2	JD-2	**16**	LCC 276
3	JCR-389	**17**	ACr-4
4	JCR-401	**18**	ACr-5
5	UD-856	**19**	NDCOR-86
6	UD-857	**20**	NDCOR-100
7	WFPS 48.1	**21**	H. Anand
8	WFPS 48.2	**22**	DH-318
9	RKC 17.1	**23**	DH-281
10	RKC-155	**24**	RD-416
11	CS 211	**25**	RD-417
12	CS 228	**26**	ICS-4
13	CS 245	**27**	PD-1
14	LCC 200	**28**	JD(SI)1

3.9 Statistical analysis

Statistical analysis of different experiments was carried out using opstat software at http:// hau.ac.in.

CHAPTER-IV

RESULTS

The results of the study entitled **"Epidemiology and management of stem gall of coriander (*Coriandrum sativum* L.) caused by *Protomyces macrosporus* Unger** " for *Rabi* season 2018 are presented in this chapter under following headings:

4.1 ISOLATION AND IDENTIFICATION OF PATHOGEN

4.1.1 Isolation

The pure culture of pathogen *Protomyces macrosporus* isolated from the diseased coriander stem, seeds on potato dextrose agar medium enriched with yeast extract (PDA+YE). The isolated pathogen *i.e. Protomyces macrosporus* was purified further by using hyphal tip method. The purity and virulence of isolated pathogen was regularly checked by sub-culturing after every 20-25 days and maintained in refrigerator at 4±1°C.

4.1.2 Cultural characteristics of pathogen

The cultural characteristics of test pathogen (*Protomyces macrosporus*) were studied on potato dextrose agar medium enriched with yeast extract (PDA+YE). The growth of test pathogen was observed better with a diameter of 4-5 mm after 7 days of incubation at 21±1°C in potato dextrose agar medium enriched with yeast extract as compared to the simple PDA medium where the growth of culture was slow. The colony colour was creamy white initially that later turned into light brown. The surface of the colony was sticky and surrounded by an uneven margin (Plate 5).

4.1.3 Morphological characteristics of pathogen

The morphological characteristics of the test pathogen (*Protomyces macrosporus*) including size and shape of chlamydospores were studied microscopically. The chlamydospores were yellowish brown, smooth spherical to sub spherical in shape with three different layers (endospore, mesospore and exospore) which were smooth and measured 40-80 µm in diameter and had a thick covering with diameter of 2-5 µm (Plate 5).

4.2 PATHOGENICITY

The pathogenicity of *Protomyces macrosporus* on coriander seedlings was proved by inoculating crushed powder of infected coriander stem and mycelial suspension of pathogen by maintaining uninoculated control also in pots under screen house conditions. Ten seedlings of coriander variety "DH-36" were maintained in each pot, and it was observed that out of two inoculum sources, crushed powder of infected stem added to soil was better in disease development over the mycelial suspension where the symptoms appeared in 63 days in comparison to 75 days in mycelial suspension (Table 4.1).

The pathogen was re-isolated from the diseased part of stem on PDA+YE medium. The cultural and morphological characteristics of re-isolated fungus were identical to the original culture of the test pathogen.

Table 4.1: Pathogenicity test of stem gall of coriander caused by *P. macrosporus* in pots under screen house conditions

Inoculum	Incubation period (days)	Disease severity (%)
Crushed powder of infected coriander stem	63	25.00
Mycelial suspension	75	21.00
Control	-	0.00

4.3 EPIDEMIOLOGY OF THE DISEASE

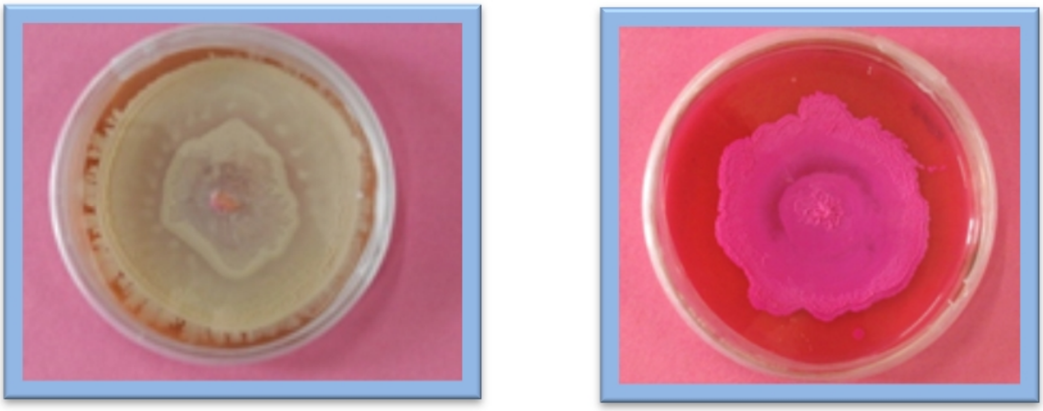
4.3.1 Development of stem gall of coriander in relation to weather parameters

The progression and intensity of stem gall of coriander was observed on two different varieties sown on five different date during *rabi* 2018-2019 and the data is presented in Table 4.2. The disease first appeared in first week of March on both the varieties sown on different dates and the progress of disease intensity was observed up to 29th March 2019, during that period temperature ranged between 22.2-28.9°C (maximum) and 8.0-11.8°C (minimum), while RH ranged between 93.0-80.0% (morning) and 53.0-42.0% (evening) and sunshine hours range and rainfall was 5.8-7.2 h and 14.8-0.0 mm respectively.

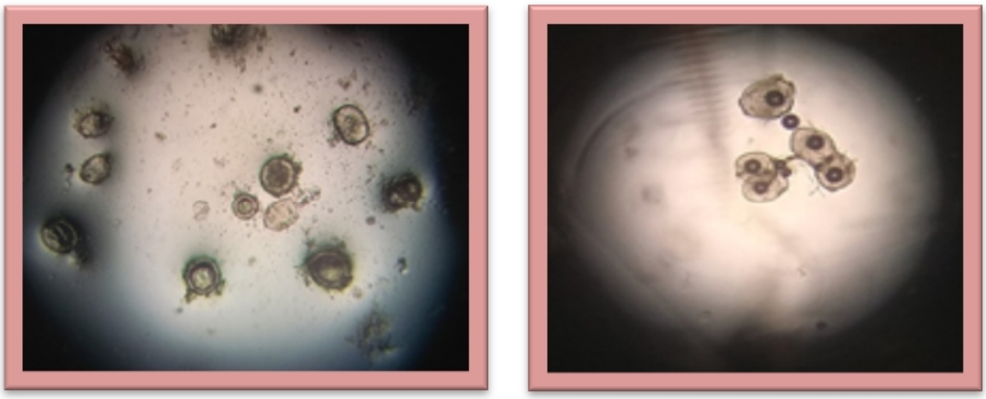
Table 4.2: Progression of Stem gall of coriander on two varieties sown on five different dates

Dates of observations	Disease Intensity (%)									
	Variety DH-228					Variety DH-36				
	1st week Nov	2nd week Nov	3rd week Nov	4th week Nov	1st week Dec	1st week Nov	2nd week Nov	3rd week Nov	4th week Nov	1st week Dec
March 8	6.67	5.83	3.33	6.67	8.33	4.17	3.33	2.50	5.83	8.33
March 15	10.00	8.33	6.67	10.00	10.00	5.83	5.00	4.17	8.33	9.17
March 22	10.83	10.00	8.33	12.50	14.00	8.33	6.67	5.83	9.17	12.50
March 29	11.67	10.83	10.00	15.00	15.17	11.67	10.83	9.17	13.33	16.67

The data on severity of stem gall of coriander and AUDPC is computed in Table 4.3. There was significant difference in disease severity between two varieties over different dates of sowing. The disease first appeared on March 8th on two varieties sown on 1st week of November and the progress of disease was observed up to March 29th at weekly interval with maximum disease progression from March 15th to March 29th. The Figure 4.1 clearly shows that during this period of maximum disease progression the temperature ranged between 24.2-28.9°C (maximum) and 8.5-11.8°C (minimum), while RH ranged between 88.0-80.0%



A) Mycelial growth of *Protomyces macrosporus* on PDA + YE



B) Chlamydospores under microscope with three distinct layers

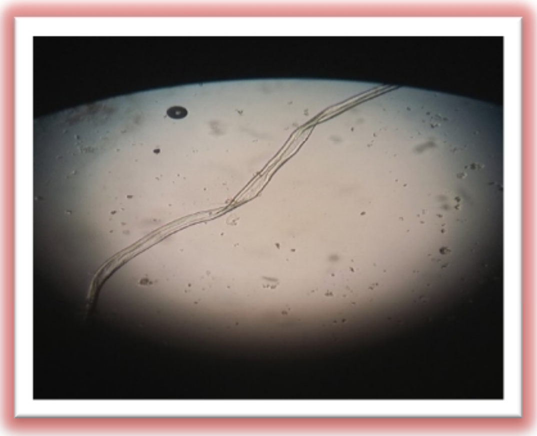


Plate 5 Cultural and morphological characteristics of *Protomyces macrosporus*

A

B

C

Plate 6. Symptoms of stem gall of coriander in experimental area of Plant Pathology CCS HAU, Hisar

(morning) and 42.0-42.0% (evening). Sunshine hours and rainfall during this period was 7.2 h and 0.0 mm, respectively. The disease severity was lower (7.50%) in the variety DH-36 as compared to DH-228 (9.79%).

Table 4.3: Effect of different dates of sowing on severity of stem gall of coriander and area under disease progress curve (AUDPC)

Date of sowing	Disease severity (%)		AUDPC	
	DH-228	DH-36	DH-228	DH-36
1st week of November	9.79 (3.27)	7.50 (2.87)	210.00	154.58
2nd week of November	8.75 (3.10)	6.46 (2.68)	186.67	131.25
3rd week of November	7.08 (2.80)	5.42 (2.48)	151.67	110.83
4th week of November	11.04 (3.44)	9.17 (3.16)	233.33	189.58
1st week of December	11.88 (3.54)	11.67 (3.53)	250.26	239.17
CD at 5%	(0.180)	(0.115)		

**Figures in the parentheses are square root transformed values*

The disease first appeared on March 8th on two varieties when sown on 2nd week of November, 4th week of November and 1st week of December and the progress of disease intensity was observed up to March 29th at weekly interval with maximum disease progression from March 22nd to March 29th. The observation so computed have been depicted Figure 4.2, Figure 4.4 and Figure 4.5, clearly exhibit that during this period of maximum disease progression, the temperature ranged between 24.9-28.9°C (maximum) and 9.1-11.8°C (minimum), while RH ranged between 91.0-80.0% (morning) and 48.0-42.0% (evening). Sunshine hours and rainfall during this period was 6.1-7.2 h and 0.0 mm respectively.

The disease severity was minimum in the variety DH-36 (6.46%) and maximum on variety of DH-228 (8.75%) in crop sown during 2nd week of November while DH-36 (5.42%) minimum and DH-228 (7.08%) maximum disease severity on 4th week of November sown crop and minimum severity in the variety of DH-36 (11.36%) and maximum on variety of DH-228 (11.88%) when sown during 1st week of December.

The disease first appeared on March 8th on both varieties *viz.,* DH-228 and DH-36 sown on 3rd week of November and the progress of disease intensity was observed up to March 29th with maximum disease progression from March 9th to March 15th. The computed observation depicted in Figure 4.3 clearly indicate that during this period of maximum disease progression the temperature ranged between 20.9-24.2°C (maximum) and 8.0-8.5°C (minimum), while RH ranged between 93.0-88.0% (morning) and 53.0-42.0% (evening). Sunshine hours and rainfall during this period was 5.8-7.2 h and 14.8-0.0 mm, respectively. The disease severity was minimum on the variety DH-36 (5.42%) followed by DH-228 (7.08%) in crop sown during 3rd week of November and maximum disease severity observed on DH-36 (11.67%) followed by DH-228 (11.88%) in crop sown during 1st week of December.

The quantitative relationship between the disease severity and weather variables for different dates of sowing for two varieties was obtained by performing correlation analysis. The results presented in Table 4.4 showed that temperature (maximum and minimum), and sunshine hours had positive correlation with per cent disease intensity, while relative humidity (morning and evening) and rainfall negatively correlated with the per cent disease intensity.

Significant positive correlation was observed with temperature when sown during 3rd week, 4th week of November and 1st week of December and temperature was non-significant in crop sown during 1st week November and 2nd week of November in variety of DH-228 (Table 4.4). The significant positive correlation was observed with temperature on each sowing date of variety DH-36. Whereas, relative humidity morning and relative humidity evening both had negative correlation on both varieties. Remaining weather parameters had non-significant correlation with each date of sowing but correlated with the disease intensity.

4.3.3 Area Under Disease Progress Curve (AUDPC)

The disease progression over a period was also computed by AUDPC as exhibited in Figure 4.6. Based on the disease progression at different intervals, AUDPC was statistically analyzed and it was found that the value of AUDPC was lowest in 3rd week of November sown crop while it was maximum where crop was sown during 1st week of December. It was observed that, AUDPC was lowest (110.83) in DH-36 which showed less disease intensity and maximum on variety DH-228 (250.26). The AUDPC increased in both varieties when sown early as well as in case of late sown. The trend of AUDPC was more in the variety DH-228 while DH-36 showed less AUDPC under all five dates of sowing.

4.3.4. Apparent infection rate (r)

The disease spread was estimated on the basis of apparent infection rate by using the formula given by Vander plank (1963). The apparent infection rate was high during March 16th to March 22nd on different dates of sowing. However, it was less from 23rd March to 29th March among both the varieties at all dates of sowing. The perusal of the data presented in Table 4.5 showed that, the ‘r’ week^{-1} increased and reached its maximum at initial period of observation on five different dates of sowing.

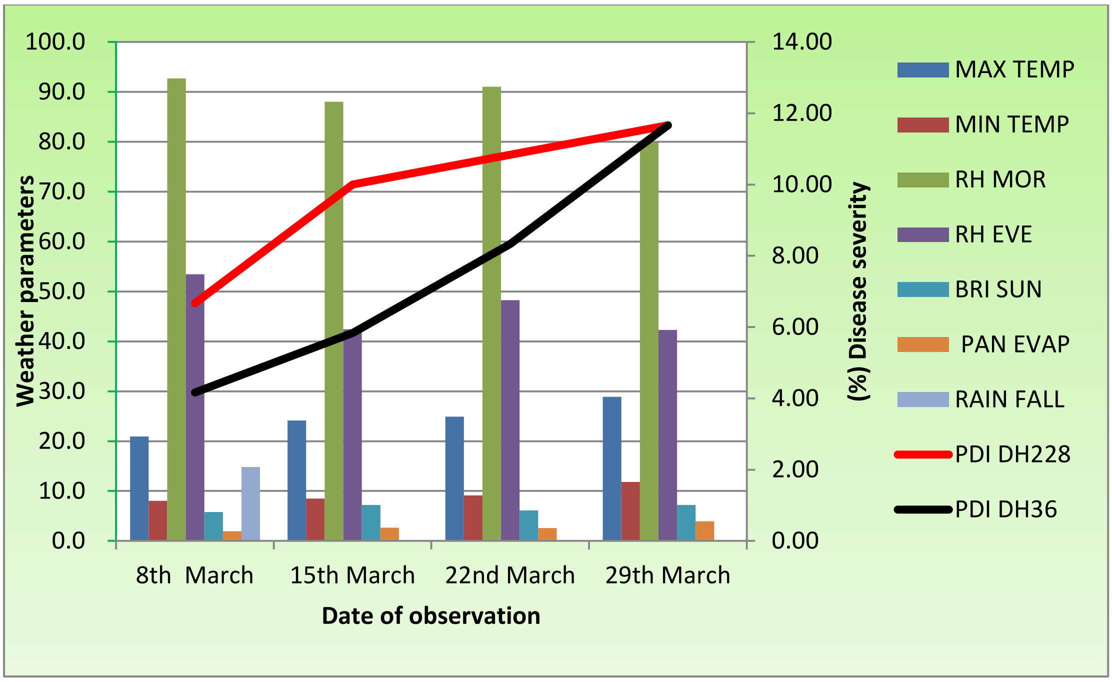


Figure 4.1 Relationship between development of stem gall of coriander and weather variables on two varieties of (DH-228 and DH-36) coriander sown during 1st week of November 2018

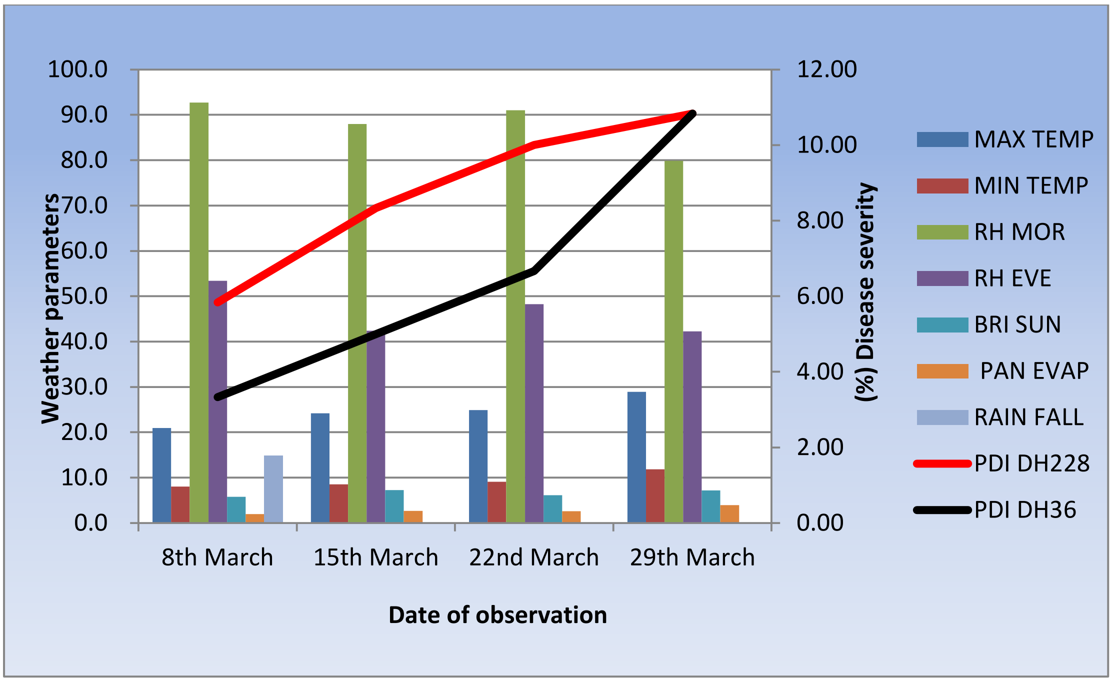


Figure 4.2 Relationship between development of stem gall of coriander and weather variables on two varieties of (DH-228 and DH-36) coriander sown during 2nd week of November 2018

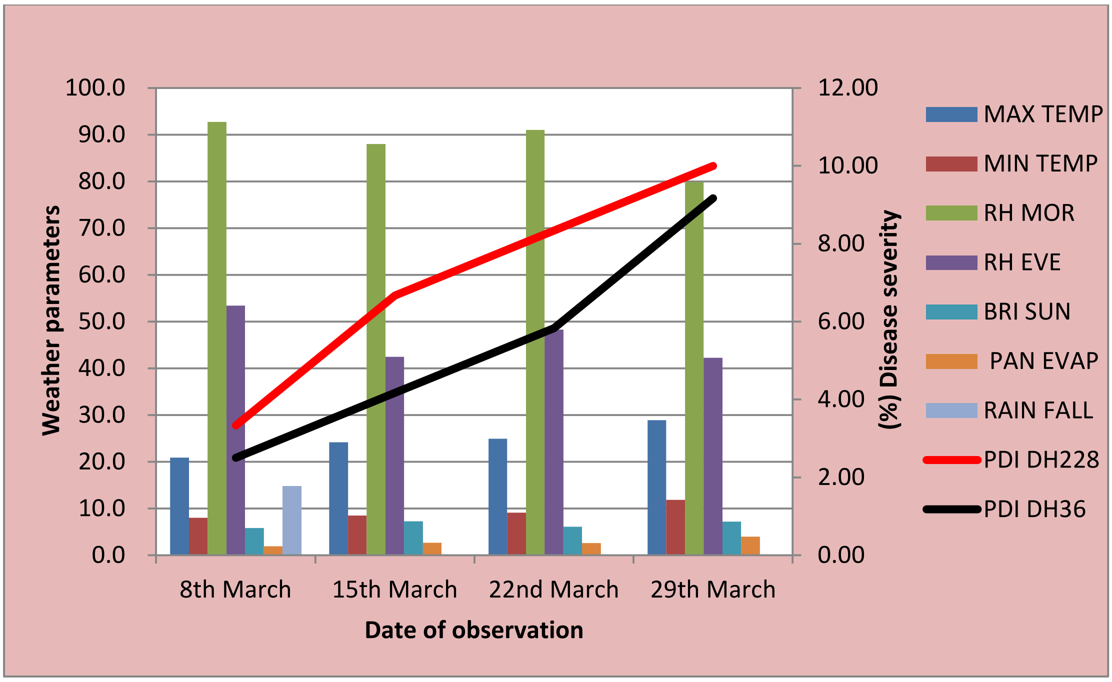


Figure 4.3 Relationship between development of stem gall of coriander and weather variables on two varieties of (DH-228 and DH-36) coriander sown during 3rd week of November 2018

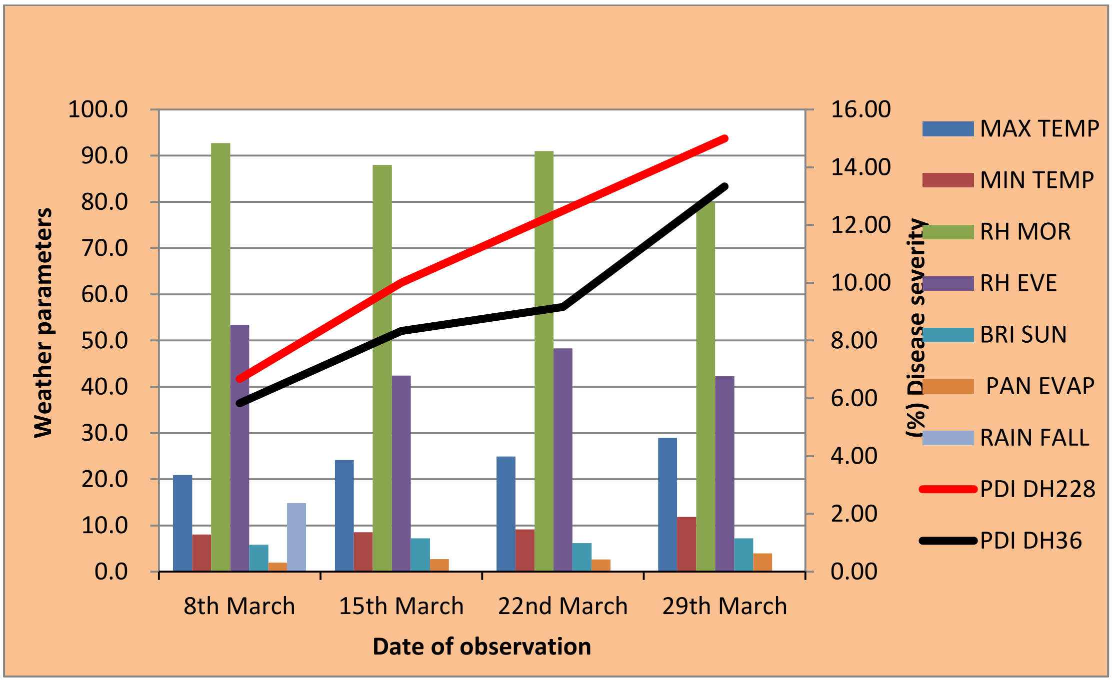


Figure 4.4 Relationship between development of stem gall of coriander and weather variables on two varieties of (DH-228 and DH-36) coriander sown during 4th week of November 2018

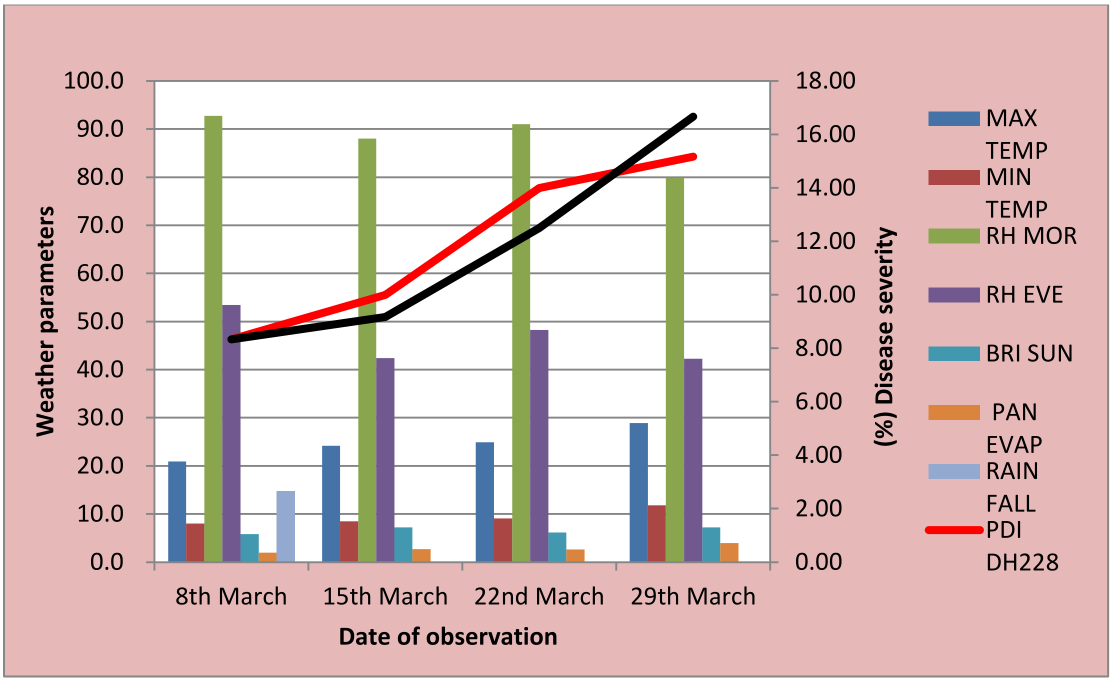


Figure 4.5 Relationship between development of stem gall of coriander and weather variables on two varieties (DH-228 and DH-36) of coriander sown during 1st week of December 2018

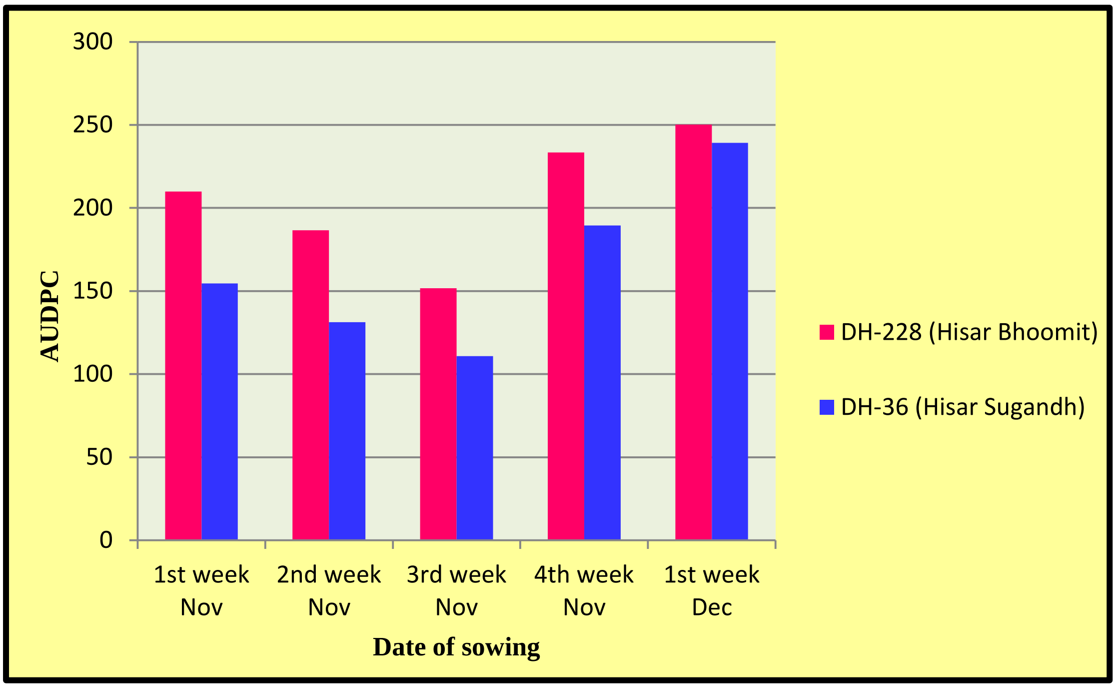


Figure 4.6 AUDPC of stem gall of coriander on two coriander varieties sown on five different dates

Table 4.4: Correlation matrix between weather parameters and per cent disease severity of stem gall in two coriander varieties at different dates of sowing

Weather variables	CORRELATION									
	DH-228					DH-36				
	Nov 1st week	Nov 2nd week	Nov 3rd week	Nov 4th week	Dec 1st week	Nov 1st week	Nov 2nd week	Nov 3rd week	Nov 4th week	Dec 1st week
Temperature Maximum (X1)	0.924	0.927	0.962*	0.971*	0.976*	0.968*	0.979*	0.983*	0.996**	0.998*
Temperature Minimum (X2)	0.76	0.776	0.846	0.898	0.895	0.962*	0.984*	0.975*	0.972*	0.970*
Relative Humidity Morning (X3)	-0.741	-0.729	-0.789	-0.806	-0.803	-0.851	-0.903	-0.893	-0.931	-0.837
Relative Humidity Evening (X4)	-0.808	-0.762	-0.751	-0.692	-0.887	-0.604	-0.647	-0.657	-0.735	-0.53
Sunshine (X5)	0.677	0.624	0.628	0.577	0.782	0.521	0.586	0.587	0.677	0.457
Pan Evaporation (X6)	0.847	0.844	0.893	0.909	0.881	0.934	0.963*	0.962*	0.985*	0.915
Rainfall (X7)	-0.948	-0.927	-0.882	-0.818	-0.948	-0.673	-0.653	-0.683	-0.716	-0.591

*Significance at CD 5%   ** Significance at CD 1%

Table 4.5: Effect of different sowing dates on apparent infection rate (r) of stem gall of coriander

Dates of sowing	Infection rate							
	Variety DH 228				Variety DH36			
	8-03-19 to 15-03-19	16-03-19 to 22-03-19	23-03-19 to 29-03-19	Mean	8-03-19 to 15-03-19	16-03-19 to 22-03-19	23-03-19 to 29-03-19	Mean
1st week of November	0.131	0.141	0.141	0.138	0.130	0.133	0.136	0.133
2nd week of November	0.133	0.140	0.141	0.138	0.125	0.132	0.132	0.130
3rd week of November	0.117	0.137	0.137	0.130	0.112	0.130	0.110	0.117
4th week of November	0.134	0.139	0.142	0.138	0.133	0.140	0.137	0.137
1st week of December	0.136	0.142	0.144	0.141	0.140	0.141	0.139	0.140

4.4 DISEASE MANAGEMENT

4.4.1 *In vitro* evaluation

4.4.1.1 *In vitro* evaluation of fungicides and botanicals

The efficacy of various fungicides *viz.*, hexaconazole, blitox, propiconazole, ridomil and carbendazim as per description in Table 3.3 at 0.2% concentration and botanicals *viz.*, leaves extract of Neem, *Aloe-vera,* Eucalyptus, Parthenium and Datura at 10 % concentration were evaluated against *Protomyces macrosporus* under *in vitro* conditions by poisoned food technique. The data on mycelial growth of fungus in Petri plates was recorded and per cent growth inhibition so calculated and presented in Table 4.6.

It was observed that Ridomil MZ 68 WP, was the most effective in inhibiting the mycelial growth of *P. macrosporus* (100%), followed by Blitox 50 WP (98%), Propiconazole 25 EC (85.93%), Hexaconazole 5 SC (68.84%) and Carbendazim 50 WP (48.06%). The fungicides Ridomil MZ 68 WP and Blitox 50 WP were at par and rest of the fungicides were significantly different from each other in growth inhibition of fungus (Plate 7).

The results presented in Table 4.6 indicated that all the evaluated plant extracts consistently inhibited the fungal growth and found significantly superior over control by inhibiting the growth of test fungus. Highest growth inhibition was observed in datura (89.33%) plant extract followed by neem (74.22%) and lowest growth inhibition was recorded in Parthenium (46.26%) however, difference in comparison to control was significant (Plate 8)

Table 4.6: *In vitro* evaluation of different fungicides and botanicals on the growth inhibition of *P. macrosporus*

S. No.	Dose (%)	Treatments	Growth inhibition (%)
1	0.2	Hexaconazole 5 SC	68.84 (56.58)
2	0.2	Blitox 50 WP	98.00 (85.26)
3	0.2	Propiconazole 25 EC	85.93 (68.00)
4	0.2	Ridomil MZ	100 (90.00)
5	0.2	Carbendazim 50 WP	41.06 (39.70)
6	10	Neem leaves extract	74.22 (59.97)
7	10	*Aloe-vera* leaves extract	68.68 (55.97)
8	10	Eucalyptus leaves extract	64.45 (53.39)
9	10	Parthenium leaves extract	46.26 (42.83)
10	10	Datura leaves extract	89.33 (70.96)
11	-	Control	0.00 (0.00)
CD at 5%			(8.89)

**Figures in the parentheses are arc-sine transformed values*

4.4.1.2 *In vitro* evaluation of bioagents

The efficacy of three bioagents *viz., Pseduomonas fluorescens*, *Trichoderma viride* and *Trichoderma harzianum* was evaluated under *in vitro* condition using dual culture technique against *P. macrosporus.* The results presented in Table 4.7 indicated that *Pseduomonas fluorescens* was most efficacious in inhibition of mycelial growth of the test fungus (41.50%) followed by *Trichoderma viride* (38.86%) and *Trichoderma harzianum* (35.09%) however, significantly different in comparison to control and among each other (Plate 9).

Table 4.7: Evaluation of Bioagents on the growth inhibition of *Protomyces macrosporus* under *in vitro* conditions

S. No.	Dose (%)	Treatments	Growth inhibition (%)
1	0.4	*Pseduomonas fluorescens*	41.50 (40.76)
2	0.4	*Trichoderma viride*	38.86 (38.53)
3	0.4	*Trichoderma harzianum*	35.09 (36.30)
4	-	Control	0.00 (0.00)
CD at 5%			(2.36)

***** *Figures in the parentheses are arc-sine transformed values*

4.4.2 *In vivo* evaluation

4.4.2.1 Evaluation of bioagents, fungicides and botanicals under *in vivo* conditions

The efficacy of various bioagents, fungicides and leaf extracts used for the management of stem gall of coriander caused by *Protomyces macrosporus* has been depicted in Table 4.8. The stem gall severity on tagged plants was 7.50 and 12.50 per cent and over all

Control Hexaconozole 5 SC

Control Blitox 50 WP

Control Propiconazole 25 EC

Control Ridomil 68 EC

Control Carbendazim 50 WP

Plate 7. *In vitro* evaluation of different fungicides against *Protomyces macrosporus*

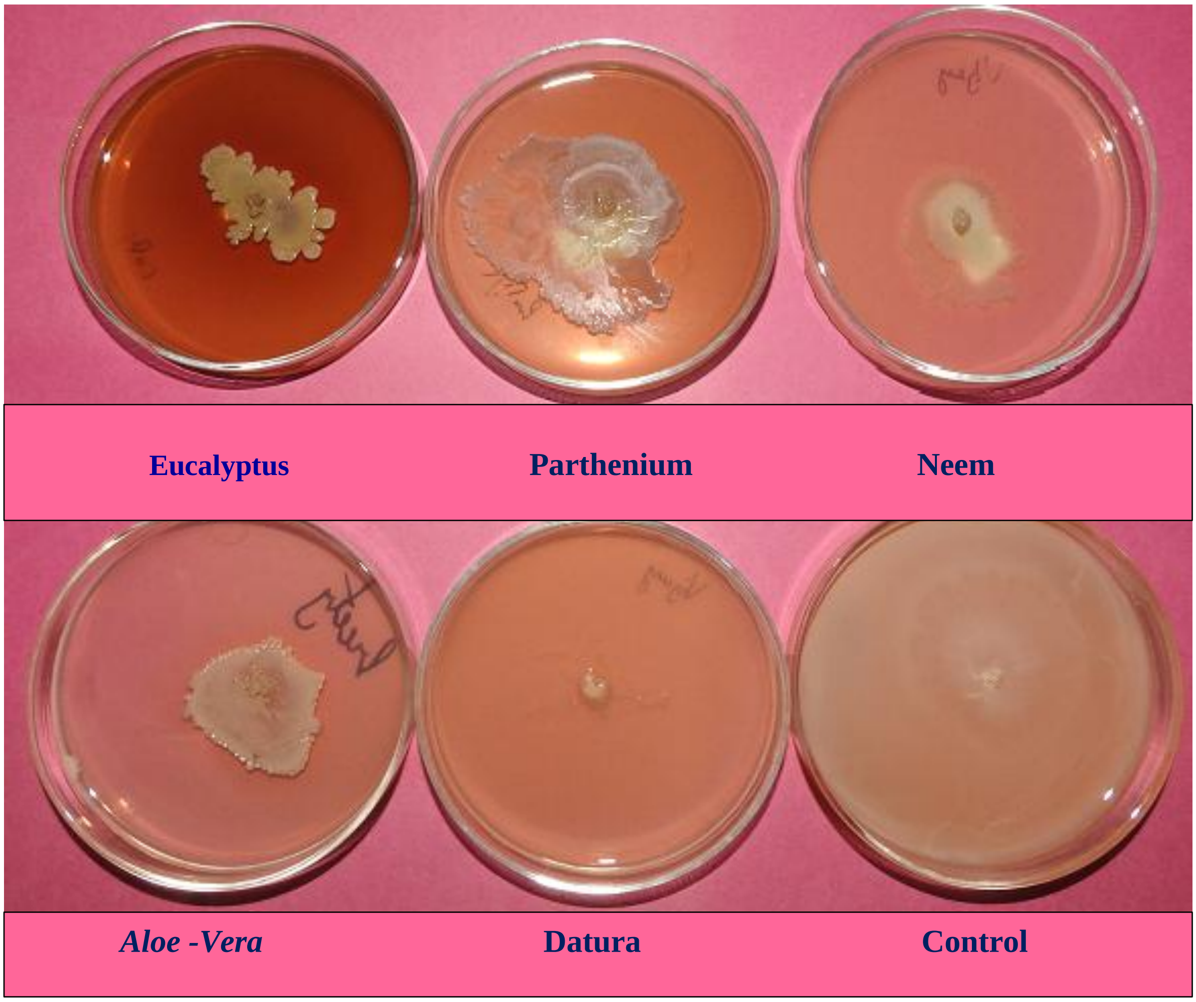


Plate 8. ***In vitro*** **evaluation of different botanicals against** ***Protomyces macrosporus***

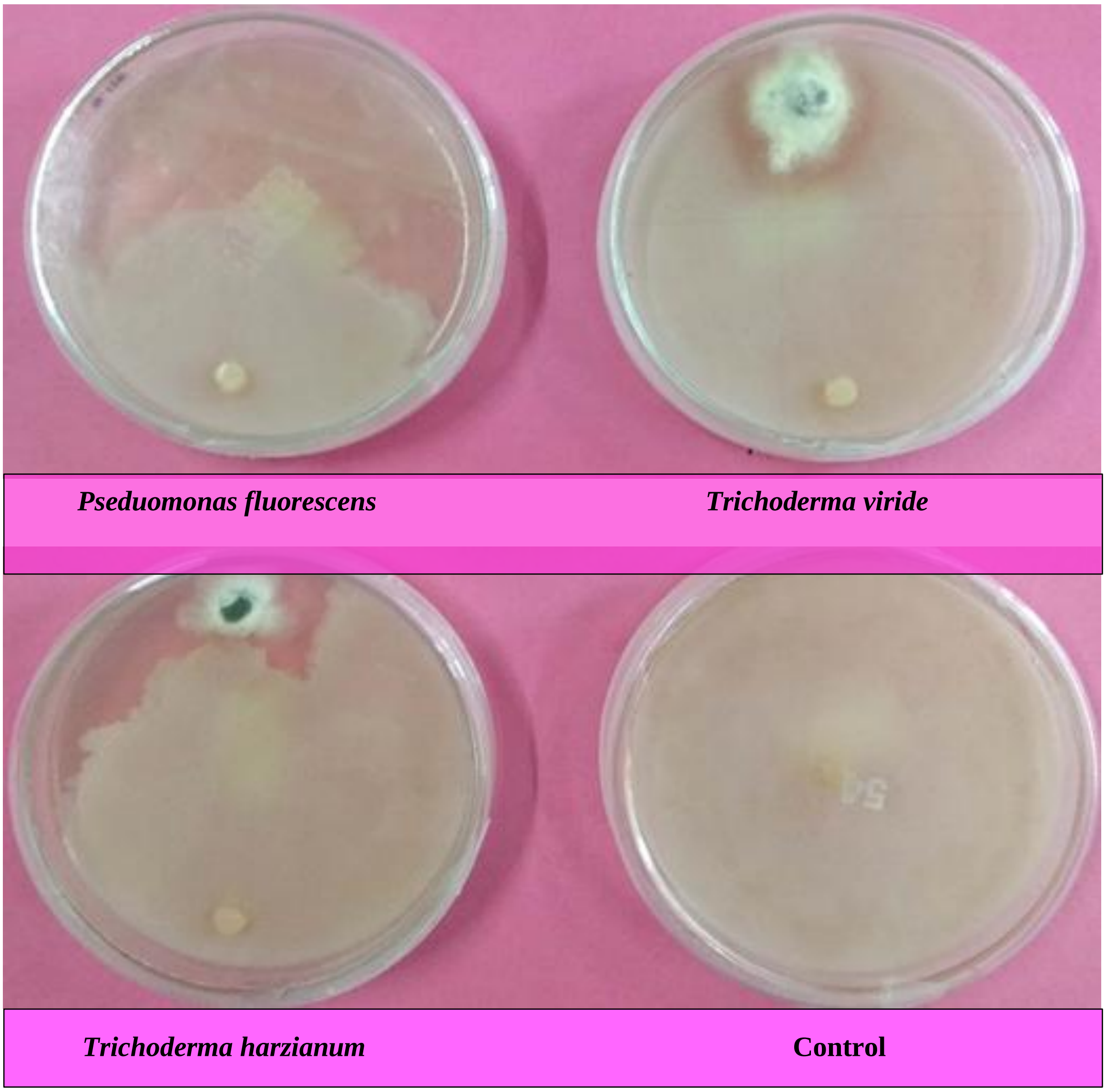


Plate 9. *In vitro* evaluation of different bioagents against *Protomyces macrosporus*

disease incidence 10.05 and 15.61 per cent respectively in spray of bioagents (*Pseduomonas fluorescens*, *Trichoderma viride*), fungicides (Ridomil MZ, Blitox 50 WP). The stem gall severity on tagged plants was 4.16 and 7.50 per cent and disease incidence was 6.91 and 9.67 per cent respectively in spray of Ridomil MZ and blitox respectively whereas stem gall severity on tagged plants was 8.33 and 13.33 and disease incidence was 11.63 and 16.00 per cent respectively in treatment of leaf extracts (Datura and Neem). Stem gall severity (%) on tagged plants in control with sterilized water was 16.66 and disease incidence was 18.44 per cent. Amongst different treatments Ridomil MZ was found superior over other treatments with 6.91 per cent disease incidence followed by Blitox 50 WP 9.67 per cent though statistically different from each other. The seed yield was also maximum (1493.06 Kg/ ha) in case of Ridomil MZ treatment followed by Blitox 50 WP (1284.72 Kg/ha).

Table 4.8: Evaluation of bioagents, fungicides and botanicals against stem gall of coriander under *in vivo* conditions

S. No.	Treatment	Dose (%)	Disease severity (%)	Disease incidence (%)	Yield (kg/ha)
1	*Pseduomonas fluorescens*	0.4	7.50 (2.89)	10.05 (3.21)	1250.00
2	*Trichoderma viride*	0.4	12.50 (3.64)	15.61 (4.03)	1180.56
3	Ridomil MZ	0.2	4.16 (2.25)	6.91 (2.77)	1493.06
4	Blitox 50 WP	0.2	7.50 (2.85)	9.67 (3.26)	1284.72
5	Datura leaves extract	10	8.33 (3.01)	11.63 (3.53)	1232.64
6	Neem leaves extract	10	13.33 (3.78)	16.00 (4.122)	1076.39
7	Control	-	16.66 (4.20)	18.44 (4.39)	729.17
CD at 5%			(0.73)	(0.82)	168.16

**Figures in the parentheses are square root transformed values*

4.5. SCREENING OF DIFFERENT CORIANDER GENOTYPES AGAINST STEM GALL OF CORIANDER

Twenty eight genotypes of coriander were evaluated for their relative resistance to stem gall disease. The results presented in Table 4.9 showed that out of 28 genotypes, none of the genotypes was completely free from stem gall of coriander, while one genotype *viz.*, ICS-4 showed resistant (1-5% disease severity). Eleven genotypes *viz.*, JD-2, JCR-389, JCR-401,

WFPS 48.2, RKC-17.1, CS 211, CS 228, CS 245, LCC 200, LCC 276 and RD-417 showed moderately resistant (5.1-20% disease severity) and sixteen genotypes *viz.*, RCr-728, UD-856, UD-857, WFPS 48.1, RKC-155, LCC 275, ACr-4, ACr-5, NDCOR-86, NDCOR-100, H. Anand, DH-318, DH-281, RD-416, PD-1 and JD(SI)1 were moderately susceptible (20.1-50 % disease severity), while none of the genotypes was susceptible (more than 50% disease severity).

Table 4.9: Screening of different coriander genotypes against stem gall

S. No.	Genotype	Average No. of plants	Disease incidence (%)	*Disease severity (%)
1	Rcr-728	140	7.71	22.50
2	JD-2	145	8.50	16.66
3	JCR-389	130	7.67	14.16
4	JCR-401	120	9.67	14.16
5	UD-856	120	5.55	20.83
6	UD-857	125	17.66	20.83
7	WFPS 48.1	132	10.05	24.16
8	WFPS 48.2	150	4.88	20.00
9	RKC 17.1	132	8.31	17.50
10	RKC-155	164	6.87	21.00
11	CS 211	115	6.91	13.33
12	CS 228	110	8.16	11.66
13	CS 245	150	5.34	15.83
14	LCC 200	126	8.93	15.83
15	LCC 275	104	12.15	24.16
16	LCC 276	135	7.36	20.00
17	ACr-4	130	9.20	21.66
18	ACr-5	150	9.33	25.00
19	NDCOR-86	135	13.03	26.66
20	NDCOR-100	150	15.11	26.66
21	H. Anand	142	9.15	21.66
22	DH-318	140	11.63	26.66
23	DH-281	145	15.61	24.16
24	RD-416	130	18.45	24.10
25	RD-417	145	9.85	18.33
26	ICS-4	130	10.73	5.00
27	PD-1	130	7.16	20.83
28	JD(SI)1	140	10.20	20.83

* **Disease severity for ten tagged plants**

CHAPTER-V

DISCUSSION

The coriander (*Coriandrum sativum* L.) is one of the important spice crops in India. Stem gall of coriander caused by *Protomyces macrosporus* is one of the limiting factors for crop cultivation and seed production. The results obtained on "Epidemiology and management of stem gall of coriander (*Coriandrum sativum* L.) caused by *Protomyces macrosporus* Unger" are discussed as follows:

5.1 Isolation and identification of the pathogen

In the present study, *P. macrosporus* was isolated from the diseased coriander stem and pure culture was obtained on PDA+YE medium with diameter of 4-5 mm after 7 days of incubation at 21±1°C. The colour of colony was creamy white initially which later turned into light brown with sticky colony surface and surrounded by an uneven margin. Pavgi and Mukhopadhyay (1969a) isolated this fungus from the diseased coriander plant parts on different cultural media such as malt agar, Lilly and Barnett's semi-synthetic medium and potato dextrose agar media and found two different pigmented cultures, salmon red (SR) and creamy white (CW) on different media. Lakra and Parkash (1993) also observed appearance of dull creamy white colony of *P. macrosporus* on Potato dextrose agar medium after 12 days. Similarly, Leharwan (2017) isolated the fungus and reported that the colour of colony was creamy white initially which later turned light brown and pasty colony surface surrounded by uneven margins.

5.2 Morphological characteristics of pathogen

The chlamydospores of *P. macrosporus* appeared yellowish brown in colour having smooth spherical to sub spherical in shape with three different layers (endospore, mesospore and exospore) with diameter of 40-80 µm having a thick layer whose diameter was 2-5 µm. Similarly, Pavgi and Mukhopadhyay (1970) reported that mature chlamydospore of *P. macrosporus* were spherical to sub spherical in shape having a thick wall showing three distinct layers. Mishra *et al.* (2017) reported that chlamydospore of *P. macrosporus* were globose to ellipsoid, thick walled with three layered membranes and smooth having brownish colour.

5.3 Pathogenicity

To prove the pathogenicity of *Protomyces macrosporus* on coriander seedlings inoculum was used as crushed powder of infected coriander stem and mycelial suspension along with a control under pot culture conditions. The crushed powder of infected stem added to soil was better in disease development over the mycelial suspension and the symptoms appeared in 63 days in comparison to 75 days in mycelial suspension. Similarly, Khan and Parveen (2016) used crushed powder of stem gall infected plant parts and seeds of coriander for pathogenicity test and observed tumour like swellings on different parts of plants as well as on fruits.

5.4 Epidemiology of the disease

The severity of stem gall of coriander was influenced with different date of sowing. The stem gall of coriander appeared in first week of March 2019 on both varieties (DH-228 and DH-36) sown on five different dates. The temperature during this period was 24.2°C (maximum) and 8.0°C (minimum), while relative humidity (RH) was 93.0% (morning) and 53% (evening) and sunshine hours and rainfall was 5.8 and 14.8 mm respectively. The disease severity was lower (5.42%) on the variety DH-36 followed by DH-228 (7.08%) in crop sown on 3rd week of November and maximum disease severity observed on DH-36 (11.67%) followed by DH-228 (11.88%) in crop sown by 1st week of December.

Tripathi (2003) indicated that early and late sowing exhibited significantly less mean disease severity as compared to other dates. The disease appeared on the plant sown in third week of October when the min. and max. temperature were 13.2 and 30.9°C respectively and relative humidity was 57.2%. Verma *et al*. (2017) reported that the crop sown on 15th October at ATC Nanta had maximum Plant Disease Intensity whereas maximum disease incidence was recorded at KVK Anta in 30th October sown crop.

In the present study the significant positive correlation was observed with temperature on 3rd week, 4th week of November and 1st week of December sown crop and effect temperature was non-significant in 1st and 2nd week of November sown crop in the variety of DH-228. Significant positive correlation was observed with both temperatures *i.e.* maximum and minimum in all the dates of sowing of crop variety DH-36 whereas, relative humidity morning and relative humidity evening both were negatively non-significant on both varieties. Area under disease progress curve (AUDPC) was lowest in 3rd week of November sown crop while it was maximum where crop was sown on 1st week of December. The apparent infection rate was high during March 16th to March 22nd at all dates of sowing, however, it was less from 23rd March to 29th March in both the varieties at all dates of sowing.

Tripathi (2003) also found that the relationship of disease severity with minimum temperature was negative and highly significant in early sown crop whereas maximum temperature exhibited negative and significant correlation with early as well as late sown crop. The relative humidity showed significant positive association with the disease intensity revealing that disease intensity increased with corresponding increase in relative humidity. Rainfall had positive but non-significant correlation with disease intensity in various dates of sowing.

5.5 Evaluation of fungicides, bioagents and botanicals against *P. macrosporus* under *in vitro* conditions

The antifungal activity of fungicides was evaluated to study their effect on growth of *Protomyces macrosporus* using poison food technique. The results indicated that Ridomil and

Blitox at 0.2 per cent concentration were most effective in inhibition of the mycelial growth followed by Propiconazole and Hexaconazole whereas Carbendazim was least effective. These results support the findings of Mathur and Narula (1963) that copper oxychloride inhibited the chlamydospore germination by 50 per cent under laboratory conditions. Piperkova (2014) tested different fungicides under laboratory conditions and found mancozeb and copper oxychloride, highly effective giving 79.2 and 50.2 per cent growth inhibition of *P. macrosporus*.

In present study the effectiveness of five plant extracts (Neem, Aloe vera, Eucalyptus, Parthenium and Datura at 10 % concentration) was evaluated under *in vitro* condition using poison food technique against *P. macrosporus.* Highest growth inhibition was observed in datura followed by neem and lowest growth inhibition was recorded in Parthenium, however difference in comparison to control was significant with each other. Mima *et al*. (2009) also reported the inhibitory effect of *Azadirchta indica* on the mycelial growth of *Taphrina maculans* causing leaf blotch of turmeric. The extracts from neem leaves have been used to manage several fungal plant pathogens (Wang *et al*., 2010; Meena, 2012).

The three bioagents (*Pseudomonas fluorescens*, *Trichoderma viride* and *Trichoderma harzianum*) was evaluated under *in vitro* condition using dual culture technique against *P. macrosporus.* The results indicated that *Pseduomonas fluorescens* was effective inhibitor of the mycelial growth followed by *Trichoderma viride* and *Trichoderma harzianum*. In corroboration our studies, Khan and Parveen (2018) reported that the application of biocontrol agents / botanicals both alone and in combination caused significant reduction in stem gall intensity (20.33-84.82%) as compared to control and they found that *T. viride* as superior in reduction in stem gall intensity (44.37%) and in enhancing the growth and yield of the crop.

5.6 Evaluation of fungicides, bioagents and botanicals against stem gall of coriander under *in vivo* conditions

The efficiency of best two bioagents, fungicides and leaf extracts was checked for the management of stem gall of coriander caused by *Protomyces macrosporus* under field condition. Among all treatments Ridomil MZ was found most effective lowering disease incidence (6.91%) followed by Blitox 50 WP (9.67%) though statistically different from each other and minimum disease severity was recorded with foliar sprays of Ridomil MZ (4.16%) followed by Blitox 50 WP and *Pseduomonas fluorescens* (7.50%) statistically at par with each other. The maximum seed yield obtained in treatment of Ridomil MZ (1493.06 kg/ha) followed by Blitox 50 WP (1284.72 kg/ha). Lakra (2000) reported the disease control by seed treatments with thiram and spraying of streptomycin to the extent of 53.5 per cent and 66.6 per cent respectively whereas Singh (2010) observed that foliar sprays of carbendazim (Bavistin 0.1%) at 60 DAS were effective in reducing the disease intensity of stem gall of coriander and in improving the yield. Kumar *et al*. (2014 b) found hexaconazole as seed treatment (0.2%) and foliar spray after 40, 60 and 75 DAS (0.2%) was more effective for management of stem gall disease of coriander than the seed treatment of bioagents *viz.*, *Trichoderma viride* (0.4%) and foliar spray of *Trichoderma* species (0.4%) after 40, 60 and 75 days of sowing.

5.7 Screening of different coriander genotypes against stem gall

In the present study, Twenty eight genotypes of coriander were evaluated for their relative resistance to stem gall disease under natural conditions in field. Amongst 28 genotypes, none of the genotypes was completely free from stem gall, while one genotype showed resistance, eleven genotypes showed moderately resistance and sixteen genotypes were moderately susceptible.

In corroboration to the present study, Singh *et al*. (2003) also screened seventy genotypes of coriander for resistance against stem gall with the aim to select the resistant cultivars and found PH-7, Pant Haritima, Dhania-8, COR-17, COR-2, COR-2, DH-13, DH-19-M-4 and DH-19-M-11-2 were highly resistant. Kumar *et al*. (2016) evaluated 102 germplasm of coriander against stem gall under natural condition and found thirty five genotypes as moderately susceptible and sixty seven susceptible. Similarly Khan and Parveen (2016) screened twenty seven varieties of coriander and found four resistant varieties as resistant against stem gall and also observed overall yield loss as 27.87 per cent directly related to stem gall intensity.

CHAPTER-VI

SUMMARY AND CONCLUSION

Coriander (*Coriandrum sativum* L.), commonly known as dhania or Chinese parsley is an important spice vegetable crop grown in world for its fresh leaves and seeds which are used as flavouring agent in cooking. Seed production of coriander is affected by many biotic and abiotic factors and amongst them, diseases has been identified as a major limiting factor which are caused by fungi, bacteria and viruses. Stem gall disease caused by fungus *Protomyces macrosporus* is the most prevalent and damaging. This pathogen is soil and seed borne and difficult to manage due to complex soil ecosystem. Therefore, the present investigation was undertaken to study the isolation, identification of pathogen, pathogenicity, effect of environmental factors on the disease development, to evolve an effective management strategy through fungicides, botanicals, bioagents and screening of different coriander genotypes. The results of the present study and conclusion drawn below:

The pathogen was isolated from the diseased coriander stem and seeds and pure culture of *Protomyces macrosporus* was identified on the basis of morphological and cultural characteristics, size and shape of chlamydospores of the fungus. The colony colour was creamy white initially which later turned into light brown. The surface of the colony was sticky and surrounded by an uneven margin. The chlamydospores were yellowish brown, smooth spherical to sub spherical in shape with three distinct layers (endospore, mesospore and exospore).

Pathogenicity of the *Protomyces macrosporus* was proved by using two inoculum sources. The crushed powder of infected stem added to soil was better over the mycelial suspension for disease development and the symptoms appeared in 63 days in comparison to 75 days in mycelial suspension.

The disease severity was minimum (5.42%) on variety DH-36 and (7.08%) on variety DH-228 in crop sown during 3rd week of November and maximum disease severity (11.67%) was observed on DH-36 and (11.88%) on variety DH-228 in crop sown during 1st week of December.

Significant positive correlation was observed between disease appearance and temperature on 3rd week, 4th week of November and 1st week of December sown crop and effect temperature was non-significant in case the coriander variety DH-228 sown during 1st week November and 2nd week of November. The significant positive correlation was observed with both temperatures at each date of sowing of coriander variety DH-36. Whereas, relative humidity morning and relative humidity evening both were non-significant on both varieties. The effect of remaining weather parameters was non-significant at each dates of sowing but correlated with the disease intensity.

Area under disease progress curve (AUDPC) was statistically analyzed and it was found that the value of AUDPC was lowest in crop sown during 3rd week of November while it was maximum where crop was sown on 1st week of December.

The apparent infection rate was high during March 16th to March 22nd at each date of sowing, however, it was less from 23rd March to 29th March in both the varieties at each date of sowing.

The antifungal activity of five different fungicides at 0.2 per cent concentration evaluated to study their effect on growth of *Protomyces macrosporus* using poison food technique. The Ridomil MZ, was the most effective in growth inhibition and the fungicides Ridomil MZ and Blitox 50 WP were at par with each other.

The effectiveness of five plant extracts at 10 per cent concentration evaluated *in vitro* using poison food technique against *P. macrosporus,* revealed highest growth inhibition in datura leaves extract and lowest growth inhibition in Parthenium.

Among three bioagents evaluated under *in vitro* condition using dual culture technique against *P. macrosporus. Pseduomonas fluorescens* was found highly effective in inhibiting the growth of test fungus.

The efficacy of various bioagents, fungicides and leaf extracts used for the management of stem gall of coriander under field conditions indicated that among all treatments, Ridomil MZ was found superior over other treatments with comparatively higher seed yield.

Out of twenty eight coriander genotypes screened for their relative resistance to stem gall under natural conditions, none of the genotypes was found completely free from stem gall, while one genotype *viz.,* ICS-4 showed resistant reaction. Eleven genotypes exhibited moderately resistant reaction and sixteen genotypes were found moderately susceptible.

The results of the present study can be concluded as under:

- The chances of stem gall development in coriander will be minimum if sown during 3rd week of November.
- Seed treatment and protective sprays of Ridomil MZ and Blitox @0.2% are suitable to mitigate the disease effectively under field conditions.

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ABSTRACT

Title of thesis	:	**Epidemiology and management of stem gall of coriander (*Coriandrum sativum* L.) caused by *Protomyces macrosporus* Unger**
Name of the degree holder	:	**Vijaykumar S.**
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Keywords: Coriander, epidemiology, management, *Protomyces macrosporus,* stem gall,

The present investigation entitled "Epidemiology and management of stem gall of coriander (*Coriandrum sativum* L.) caused by *Protomyces macrosporus* Unger" was conducted in the Department of Plant Pathology, CCS HAU Hisar laboratories and research farm during year 2018-2019. Typical symptoms in infected plants were observed on all above ground parts of coriander. Symptoms appeared in the form of tumour-like swellings (galls) on stem and fruits. These tumours were smooth initially but later ruptured and turned to be rough. The pathogen *Protomyces macrosporus* was isolated as pure culture on PDA medium enriched with yeast extract (PDA+YE). The colony colour was creamy white and chlamydopsores were yellowish brown and spherical in shape with three distinct layers & diameter 40-80 µm. The pathogenicity was confirmed as the symptoms developed after 63 and 75 days of incubation with the application of two different source of inoculum. Epidemiology of pathogen was studied under field condition by sowing the crop at five different dates and disease severity on tagged plants and over all incidence was maximum in December 1st week sown crop with average temperature of 28.9°C and 80 per cent of relative humidity. Out of five fungicides evaluated against *Protomyces macrosporus*, Ridomil MZ and Blitox 50 WP were found most effective and significantly superior among the treatments with 100 per cent growth inhibition of the pathogen at 0.2 per cent concentration under *in vitro* conditions. Out of five plant extracts evaluated under *in vitro* conditions against the pathogen, datura extract at 10 per cent was found most effective in mycelial growth inhibition. Among three bioagents evaluated under *in vitro* conditions against the pathogen, *Pseduomanas fluorescens* was found most effective to inhibit the growth of pathogen. Seed treatment and foliar spray of Ridomil MZ and Blitox 50 WP at 0.2 per cent was found most effective to manage the disease severity and incidence, resulting in comparative higher yield under field conditions. Amongst 28 genotypes screened against stem gall of coriander, one genotype *viz.,* ICS-4 was found resistant, eleven genotypes as moderately resistant and sixteen genotypes were moderately susceptible.

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