STUDIES ON EPIDEMIOLOGY AND MANAGEMENT OF CUCUMBER POWDERY MILDEW

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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON EPIDEMIOLOGY AND MANAGEMENT OF CUCUMBER POWDERY MILDEW"** submitted by **Mr. PARAMESHWAR NAIK H.,** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **PLANT PATHOLOGY** to the University of Agricultural Sciences, Dharwad is a record of bonafide research work done by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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'Mother' and 'Father'

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1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the oldest cultivated vegetable crops belongs to the family cucurbitaceae with 7 pairs of chromosomes and several distinct morphological features stands apart from other species with 12 pairs of chromosomes which are indigenous to tropical Africa. Cucurbit includes about 118 genera and 825 species. In India, a number of major and minor cucurbits are cultivated, which share about 5.6 per cent of the total vegetable production. In India about 112 open pollinated varieties of several cucurbits have been recommended for cultivation at National and state level. The main goal of research on cucurbitaceous vegetables in India is to improve productivity on sustainable basis through developing biotic and abiotic resistant varieties/hybrids coupled with quality attributes (Rai *et al.*, 2008).

In India it has been suggested that the cultigen, *C, sativus* originated in northern India, wild species *Cucumis hardwiki* royle occurs worldwide although this might be a weedy form of *C. sativus* which has escaped from cultivation. From India, the crop was introduced into Europe and other Asian countries during the last 2000 years and is now widely distributed along the tropical and subtropical regions of Europe and Asia. It was known in France since ninth century and in England from 1327 (Yawalkar, 1985). It is introduced to the new world by Columbus who planted it in Haiti in 1494 A.D. and soon afterwards it was brought to the USA.

Cucumber is an important crop, especially in the hill tracts of northern India where people take it with them as a gift while visiting friends and relatives. The fruit is eaten raw with salt and pepper at immature and mature stage. They are often eaten as a cooked vegetable. The seed which yield edible oil are occasionally eaten, the young ones are eaten as salad or cooked with spinach in Indonesia and Malaya. Size of the fruit is 30 to 45 cm long and 8 to 10 cm thick, the colour of the fruit is green, it changes to yellow and finally to reddish brown when fully mature, the pulp of the fully matured fruit is used in making mash cakes.

The vulnerability of this crop to several biotic and abiotic stresses accounts for its low yield potential and in turn the high cost of production. *Alternaria* blight, powdery mildew, downy mildew and cucumber mosaic diseases are the major foliar

diseases which are responsible for yield loss and quality parameters in cucumber. In India area under cucumber cultivation is 71,000 hectare with a production of 12,02,000 tonnes with an average productivity of 16.92 tonnes (Anon, 2015-16).

Powdery mildew is serious disease of cucumber. Symptoms first appears as white nearly or fluffy somewhat circular patches or spots which appear on the upper surface of the leaves and spreads also to the petiole, stem and fruit. Severely infected leaves become brown, shrivelled and defoliation may occur. Fruit of the affected plants do not develop fully and remain small.

Cucumber powdery mildew disease is attributed to two fungal species, *Sphaerotheca fuliginea* and *Erysiphe cichoracearum*, which belonging to two different genera in the same family Erysiphaceae (Schlosser, 1972).

Yield loss due to powdery and downy mildew diseases was estimated to be 50-70 % (Sitterly, 1972). Though there are many cultural practices employed such as crop rotation and fall ploughing and also the use of fungicides still crop loss was reported up to be 50-70 % (Awad, 2000).

Etiology of powdery mildew of cucumber is identified as *E, cichoracearum* (DC.) and also reported it as *S, fulginia* (Schltdl.) Pollaci. *S. fulginia* causes somewhat brownish coloured fruiting body on the foliage while that of the *Erysiphe cichoracearum* it is flour–white coloured. The *Sphaerotheca fulginia* has branched appendages on dark coloured globular fruiting body (cleistothecia), which usually contain only one ascus. The *E. cichoracearum* has mostly unbranched appendages with more than one ascus in each cleistothecium. The fungus is known to produce the conidial stage as well as the cleistothecial stage and the hypha draws nutrients by sending haustoria into the epidermal cells of the host plant. Pathogens produces conidiophores which are hyaline, thin walled and bear oblong conidia in chains measuring 20-30 × 15-20 µm. Later as the disease advances, the cleistothecial stage is formed. The cleistothecia are scattered over the affected plant parts dark coloured, spherical with thick walled appendages and measure 80-140 µm in diameter. They contain numerous asci which are sub-cylindrical measuring 60-90×30-35 µm, each ascus contains eight ascospores which are hyaline, elliptic and thin walled measuring 20-28 ×12-20 µm.

The mycelium of *S, fulginia* is hyaline, occasionally brown when old usually evanescent but sometime persistent. Conidia are formed in long chains. They often show fibrosin bodies and are ellipsoidal to barrel shaped, 25-37 × 14-25 µm in size. Cleistothecia are scattered to densely gregarious size of 66-98 µm in diameter and usually 85 µm wide. Appendages vary in number, myceloid brown and as long as ascocarp asci are broadly elliptic to subglobose and measure 58 × 27-60 µm. Each ascocarp contains a single ascus. There are eight ascospores in the ascus. They are ellipsoidal to nearly spherical and measure 17-22 × 12-20 µm.

Infection by powdery mildew fungi is greatly influenced by humidity, temperature and the age of the plant. Usually 16-23 days old leaves are highly susceptible while very young leaves are almost immune. The pathogen can infect and sporulate under very dry as well as humid atmosphere because of higher water content in conidia. The minimum and maximum temperature for conidial germination and host penetration ranged from 10º - 32º C whereas, optimum being about 26-28 ^{0}C (Singh, 1987).

There is a need for assessment of disease development in various geographical conditions in northern Karnataka by conducting roving survey for the disease to get information on disease distribution, level of severity, extent of spread and to locate hot spots in cucumber growing areas of northern Karnataka under protected cultivation and open field conditions.

As we all know that cucumber powdery mildew is caused by two causal pathogens and there is need to characterize the pathogen by molecular approach because of similarity in morphological characters of *Erysiphe cichoracearum* and *Sphaerotheca fuliginia.*

The severity and disease development in cucurbits has led to the severe yield losses, hence a detailed study was undertaken to assess the efficacy of systemic fungicides, combi fungicides, bio agents and botanicals under *in vitro* conditions.

Epidemiological studies which gives an idea about the outbreak and disease development in order to confirm that both *in vitro* and *in vivo* experiments were planned. The most cost effective way of combating diseases is the production of cucumber

hybrids with multiple disease resistance. Due to the unfavorable climatic conditions, resistant varieties are becoming susceptible and also not showing consistent resistance. A few commercial cucumber varieties or hybrids resistant to powdery mildew and downy mildew diseases are currently available in India. Primary importance in disease management is host plant resistance. To achieve this screening of cucumber genotypes has been taken in late *kharif* during 2016.

The successive use of systemic fungicides such as fenarimol, triadimefon and bupirimate to control these diseases has led to the development of tolerant strains (Gupta and Shyam 1996). Frequent sprays of copper containing fungicides (Bordeaux mixture and copper oxychloride) and certain other groups of fungicides are required to check the diseases, which has increased the cost of cultivation besides posing residue problem. Cucumber is often consumed as a raw vegetable so it is very important to consider toxic effects of usage of chemicals. Hence, the present investigation was carried out to find out best alternative means of management of powdery mildew with combination of systemic fungicides, combifungicides, bioagents and botanicals with following objectives:

1. To conduct survey the severity of powdery mildew of cucumber in major growing areas of northern Karnataka.
2. To conduct studies on epidemiology and disease development.
3. To conduct *in vitro* studies on bio efficacy of fungicides, botanicals and bio agents.
4. To screen available cucumber genotypes against powdery mildew disease.
5. Integrated management of powdery mildew in cucumber.

2. REVIEW OF LITERATURE

Cucumber is a very important vegetable crop grown throught the year and suffer from many fungal diseases. Among them powdery is severe in winter season mainly from October to late February. The disease is caused by two fungal agents namely *Sphaerotheca fuliginia* and *Erysiphe cichoracearum.* Presently the outbreak of cucurbit powdery mildew is very problematic because of abrupt change in weather parameters and higher level of humidity in greenhouse grown cucumber. The loss is proportional to the disease severity and considerably depends on the stage of the crop growth at which the disease occurs. The disease is gaining more economic importance in cucumber growing areas of the world. The present investigation is undertaken to find out the hotspot of disease occurrence in northern Karnataka and to study role of weather parameters in relation to disease development, *in vitro* evaluation of various fungicides, bio agents and botanicals has been planned. Screening of available sources on finding promising genotype for resistance to powdery mildew was taken up under field condition. In order to reduce the cost of cultivation it is very important to combine different means of managing powdery mildew hence integration of bio agent, botanicals and fungicide was studied. The literature pertaining to present investigations on cucurbitaceous crops and similar studies on related vegetable crops has been reviewed and presented under following headings:

2.1 History and distribution

2.2 Symptomatology

2.3 Etiology

2.4 Survey for incidence and severity of powdery mildew of cucumber in major growing areas of Northern Karnataka

2.5 Molecular characterization of pathogen

2.6 Studies on epidemiological aspects of the disease

2.7 *In vitro* evaluation of powdery mildew through chemicals, botanicals and bioagents

2.8 Screening cucumber genotypes for disease resistance

2.9 Integrated management of powdery mildew in cucumber

2.1 History and distribution

Powdery mildew is known as parasite of plant in all parts of the world and Linnaeus (1767) established the genus *Erysiphe.* De Candolle (1802) described many species of genus *Erysiphe* which causes severe diseases in crop plants.

Clare (1964) reported that the causal fungus of cucurbits powdery mildew did not form cliestothecia in all parts of the world specially under tropical conditions. Usually it had fibrosin bodies inside the conidia of *S. fuliginia* Based on this it was identified as *S. fuliginea.*

Abul-Hayia and Trabulsi (1981) reported that the causal agent of powdery mildew on squash, melon, watermelon and cucumber in Saudi to be the *S. fuliginea*, and also stated that they did not form cleistothecial stage.

El-Kazaz (1981) surveyed the powdery mildew of cucurbits in various localities of Egypt and revealed that no cleistothecia were observed in many localities and finally reported that the disease was caused by *S. fuliginea*, not by *E. cichoracearum.*

Lebeda (1983) surveyed powdery mildew disease of cucumber at 37 localities in Czechoslovakia under open field and greenhouse conditions. Based on type of conidial germination and presence of fibrosin bodies reported two different causal agents, *i.e. E. cichoracearum* and *S. fuliginea* involved in causing the disease.

Castanon *et al.* (1987) identified *S. fuliginea* to be the causal agent of powdery mildew of watermelon and cucumber in Northeast Argentina. They identified it based on the peculiar characteristics such as absence of appressoria and the presence of fibrosin bodies in conidia.

El-mahjoub and Romdhani (1991) reported that the causal agent of powdery mildew on cucumber in Tunisia was *S. fuliginea*. They opined that presence of fibrosin bodies in conidia is most important character, to distinguish them from other species.

2.2 Symptomatology

Sitterly (1972) observed Powdery mildew appearing in most parts of the cucumber plant, but is more common in young tissues on the upper side of the leaves (Agrios, 2005). The first signs of infection are circular white spots, in both the upper and lower surfaces of the leaves which increase in number, until they cover both leaf surfaces and stems. Leaves that are seriously affected turn brown and shrunken. When young leaves are infected it can result in chlorosis. When conditions are ideal, the powdery mildew can cover the whole leaf, causes drying of leaves, which results in premature defoliation. Powdery mildew may also cause reduced yields with failed maturity and small and deformed fruits (Agrios, 2005).

On cultivated cucurbits, the appearance of the disease is favored by humid conditions. The first symptoms are tiny, white to dirty-gray spots (sometimes with reddish brown tinge) on leaves and stems which become powdery as they enlarge. The superficial powdery mass ultimately covers the entire leaf. The ascogenous stage of the fungus appears rarely in late season. It has been found in North India only during winter months. The effect of severe infection may be premature defoliation of the plant and the fruits remain undersized (Singh, 1983).

Anna-Carin Almqvist (2012) reported powdery mildews not often kill their hosts. However, the yield will be reduced, sometimes by as much as 20 to 40 per cent in cucumber due to reduced nutrient utilization, reduced photosynthesis, impaired growth, increased respiration and transpiration caused by the pathogen.

2.3 Etiology

Webster (1964) reported that in addition to the receptive hyphae, the cleistothecia of all members of Erysiphaceae bear thick-walled hyphae (appendages). The cleistothecia, may be branched or unbranched and often have highly distinctive appearance.

Sitterly (1972) described life cycle of the pathogen and reported that it is initiated by germination of conidia or ascospores and process commences within two hours if the light intensity is reduced, the temperature is fair between 22 ^{0}C and 31 ^{0}C in

absence of moisture. When spores of the pathogen come in contact with the host, germ tube formed is normally short and forms a convoluted appressorium. The penetration tube grows into the centre of the cell lumen, haustorium is established and more number of germ tubes are formed which is normally from the single spore. From the primary appressorium hyphae are sent along the leaf surface. Appressoria forms laterally on all hyphae after the first germ tube formation. The mother spore does not collapse after the establishment on the host. Conidiophores begin to form about four days after infection whereas cleistothecia are formed after several weeks after the infection overall normal life cycle takes five to six days.

Narisawa *et al.* (1999) reported two new races of *S. fuliginea*, which could not be identified by the differential genotypes, appeared during late-raising cultivation. These results suggest that the resistance gene to races 1 and 5 of *S. fuliginea* should be introduced into breeding materials in Japan.

2.4 Survey for severity of powdery mildew of cucumber in major growing areas of Northern Karnataka

Ashtaputre (2006) reported average disease severity of powdery mildew of chilli to be maximum in Bellary district (79.12 %) followed by Gulbarga (75.63 %) and least in Belgaum (43.05 %).

Mohith kumar and Sharma (2012) conducted survey in six districts of Haryana and revealed that among various cucurbitaceous crops, bottle gourd and wild cucurbit were severely affected by powdery mildew compared to water melon (*Citrullus lunatus)*, Based on anamorph and telomorph they identified them as *Podosphaera xanthi* and *Golvinomyces cichoracearum.*

Gangwar and Mishra (2014) conducted survey for disease severity in all cucurbits and found that *Lagenaria siceraria* and *Cucurbita moschata* has recorded highest PDI and also the wild cucucrbit *Coccinia cardifolia*. They observed formation of perithecia in *Lagenaria siceraria* and *Cucurbita moschata* whereas *Coccinia cardifolia* had only conidial stage.

Channaveeresh and Kulkarni (2017b) Surveyed and reported that maximum mean per cent disease severity of powdery mildew of blackgram (PDI) was observed in Belgaum district (68.72%) followed by Dharwad district (59.73%), Haveri district (52.10%) and Uttara Kannada district (44.59%). Whereas, minimum per cent disease severity (PDI) was noticed in Gadag district (20.23%)

2.5 Molecular characterization of pathogen

Alvaro *et al.* (2008) attempted identification of powdery mildew in Brazil based on rDNA sequence comparison and analysed internal transcribed sequence (ITS) of the rDNA. They used powdery mildew strains isolated from *Glycine max* and identified them as *E. diffusa*. Strains from *P. vulgaris* were very similar to *E. diffusa* with 4 nt. differences and differed from *Erysiphe poligoni* by 11 nt. Strains from *Helianthus annuus* and *Sonchus oleraceus* grouped with the species *Golovinomyces cichoracearum,* while strains from *Hevea brasiliensis* and *Bidens pilosa* were similar to *Podosphaera fusca* and *Neoerysiphe cumminsiana* respectively.

Keiko *et al.* (2009) studied powdery mildew conidia of cucumber in a greenhouse in Japan. Morphological observations revealed that the fungus belongs to *Oidium* subgenus *Reticuloidium,* anamorph of the genus *Golovinomyces.* Molecular phylogenetic analyses of the nucleotide sequences of the rDNA ITS regions and D1/D2 domains of the 28S rDNA indicated that the fungus belongs to the clade of *G. orontii* with other *Golovinomyces* fungi from a wide range of host plants, suggested that, the fungus was new and arrived from other country.

Reddy (2009) reported A PCR product of 391 bp ampli?ed with *Golvanomyces cichoracearum* with speci?c ITS primer pair while there were no PCR ampli?cation products accountable with *Leveillula taurica* and *Podosphaera xanthii* with speci?c ITS primers. Subsequently, pathogen samples obtained from resistant and susceptible cultivars of Southern India were also subjected to microscopic and molecular analysis, which con?rmed that the pathogen causing powdery mildew in sun?ower in Southern India is *G. cichoracearum.*

Cosme *et al.* (2012) tried to characterize the *Podosphaera xanthii* causal agent of cucumber powdery mildew by molecular approach. The nucleotide sequence

obtained from the region comprising the ITS1, 5.8 S rDNA and the ITS2, amplified by PCR and the assessed physiological races by the using differential melon cultivars grown in greenhouse and growth chamber through morphological characteristic and these sequenced PCR amplified fragments were matched with those described for *Podosphaera xanthii* having the the physiological races 1, 2F, 4 and 5.

Channaveeresh and Kulkarni (2017a) studied molecular identification based on rDNA-ITS sequence of *Erysiphe polygoni* causing powdery mildew in blackgram. There result indicated that Dharwad isolate is having more than 96 per cent homology with reported *Erysiphe polygoni* isolates in NCBI gene bank from different geographical locations such as Mexico (97 %), Berkley (97 % and 96 %) and Iran (96 %). Their results of molecular characterization of Dharwad isolate causing powdery mildew of blackgram are in agreement with characters of *Erysiphe polygoni* thus it is designated as causal agent of blackgram powdery mildew.

2.6 Studies on epidemiological aspects of the disease

Morrison (1964) reported that the light intensity stimulates germination of conidia at a temperature of 14^0 C. The highest percentage of conidial germination was obtained at 18 to 24^0 C and there was a little germination or infection below 10^0 C and none at 32^0 C. Free water on leaf disk surfaces inhibited germination, while high relative humidity favored higher percentage of spore germination of bhendi powdery mildew caused by *E. Cihorcearum.*

Ramakrishanan *et al.* (1976) reported maximum and minimum temperature range for disease development as maximum temperature range of 28.5^0 C to 30.5^0 C and minimum temperature range to be 20.3^0 C to 21.2^0 C along with high relative humidity (91-93 %) and high cold density (8.6-9.4 %) resulted in higher disease development and also observed that the day length did not affect disease intensity and spread, likewise rainfall also had no direct effect but it favored the disease spread, if it was followed by high humidity and cloud density.

Abilko and Kishi (1979) reported that high humidity was most congenial to conidial germination of *S. fulginia*. At later stages of infection low humidity was more favourable.

Lebeda *et al.* (1983) reported presence of cucurbit powdery mildew in the Czech Republic from 1995 to 2007. In 1979–1980 *Galvanomyces cichoracearum* was identified in 86.00 per cent of the samples, *Podosphaera xanthi* in 14 per cent samples. There was no infection since, 1995 and *P. xanthi* was recorded each year on cucurbits usually in mixed infection with *G. cichoracearum.* The average temperature was 8.1 ^{0}C during the period between 1992-2007 and it was higher than corresponding value of 7.4 ^{0}C between 1979–1983. Similarly, average temperature in vegetative season was 16.2 ^{0}C during 1992–2007 and it was higher than corresponding value of 15.7 ^{0}C during 1979–1983. They also reported that higher air temperature has positively influenced the spread of *P. xanthi* in the Czech Republic.

Singh (1987) stated that *E. cichoracearum* and *S.fulginia* can sporulate and cause infection in dry as well as wet atmosphere. Heavy dew deposition favored the penetration by the germ tube. Maximum and minimum temperature for conidial formation and host penetration were 10 ^{0}C and 32 ^{0}C however optimum range was between 26-28 ^{0}C.

Cheah, *et al.* (1996) reported maximum germination of conidia of *S. fuliginea* on glass slides and at 25 ^{0}C coupled with high humidity, although the germination rate was generally low and there was no germination below 15 ^{0}C or above 30 ^{0}C with a relative humidity below 94 %. In field, first symptoms of powdery mildew appeared approximately 1 week after a prolonged period of continuous leaf wetness (about 12 h) and high humidity (about 95 %) in the summer when temperatures frequently rose above 22 ^{0}C. The disease begins in isolated patches on leaves in dense canopies compared to exposed leaves.

Fierrire and Moloto (1998) reported that the screening of melon genotypes for resistance to powdery mildew can be evaluated neither on the cotyledons, which are very susceptible, nor on the first leaf which is resistant, but on the third leaf which is of moderate susceptibility for the genotype. Similarly, accession with late female flowering was more resistant as compared to accession with early pistillate flowering. The ontogenetic stage of plant influences their resistance to the pathogens.

Biju (2000) Maximum conidial germination of *Erysiphe polygoni* (powdery mildew of pea) was recorded at 20^0C and relative humidity of 70 per cent with 73.69 per cent germination.

Gupta *et al.* (2001) revealed the presence of teliomorphic characters like cleistothecia with myceloid appendages, single ascus with eight ascospores, the fungus inciting the disease was identified as *S. fuliginea* (Schlecht.) Pollaci. In epidemiological studies they observed the conidial germination to be maximum at 25 ^{0}C temperature with 100 per cent relative humidity, however moderate temperature of 25 ^{0}C coupled with high relative humidity (> 95 %) and reduced sunshine hours helped significantly in disease development.

Aswathanarayana (2003) has recorded maximum conidial germination of (88.22%) *Uncinula necater* (Powdery mildew of grape) at 20 ^{0}C with relative humidity of 80 per cent.

Mondal *et al.* (2003) observed powdery mildew (*E. polygoni*) incidence in the first and second fortnight of July in tartary buckwheat and common buckwheat, respectively. The disease was favored by dry (mean relative humidity of 14.5 and 30 per cent for day and night, respectively) and cool weather (mean temperature of 25 ^{0}C and 15 ^{0}C for day and night respectively).

Asthaputre (2006) reported that the correlation and multiple linear regression analysis between spores load of *L. taurica* and weather parameters indicated a negative correlation between all-weather parameters, *viz.*, maximum and minimum temperature, morning and evening relative humidity and rainfall during 2004 but significant correlation was observed with minimum temperature and evening relative humidity, except maximum temperature all other weather parameters showed significant negative correlation.

Band *et al.* (2007) studied the role of temperature and relative humidity on spore formation of *E. cichoracearum* causing powdery mildew on okra (*Abelmoschus esculentus* (L.) Moench). During epidemiological studies they observed heavy spore load at minimum and maximum temperature ranges of 10-15^{0}C and 31-33^{0}C respectively, further disease development was restricted below 10^0C and 33^0C.

Minimum and maximum relative humidity values for higher rate of spore load were 45-60 and 95 per cent respectively while the spore load was lower at 37 per cent relative humidity.

Gupta *et al.* (2014) conducted field experiments and revealed that the mid October sown crop despite of having maximum disease severity resulted in minimum apparent infection rate and highest yield of green pods in field pea. However, late November sown crop escaped the disease to a considerable extent but it gave minimum green pod yield. Treatments having plant to plant spacing of 22.5 cm with row to row spacing of 60, 45 and 30 cm resulted in minimum mean disease severity and apparent infection rate; however, there was no significant difference in the pod yield per plot in different plant densities**.**

2.7 *In vitro* evaluation of powdery mildew through chemicals, botanicals and bioagents

2.7.1 Bioagents

Heijwegen (1988) tested nineteen isolates of 17 different fungal species thriving upon other fungi for their ability to control sporulation of cucumber powdery mildew caused by *S. fuliginea*. More than half of the fungi reduced the number of healthy conidiophores to less than 10 % and observed *Tilletiopsis albescens* to be the superior to *Ampelomyces quisqualis.*

Verhaar, *et al.* (1996) tested *Verticillium lecanii* and *Sporothrix rugosa* under glasshouse conditions against cucumber powdery mildew. *Verticillium lecanii* controlled the mildew better than *S. rugosa.* On cv. Flamingo. *V. lecanii* could keep the mildew severity below 15 per cent of the infected leaf area for 9 weeks after inoculation with *S. fuliginea.* In another experiment Weekly and biweekly treatments with *V. lecanii* kept mildew severity at a level below 20 per cent infected leaf area during 10 weeks after inoculation with *S. fuliginea.* They opined that if always with resistant cucumber cultivar, *V. lecanii* is more effective against *S. fuliginea.*

Askary *et al.* (1997) tested the antagonistic effect of three strains of *V. lecanii* against *S. fuliginea* the causal agent of cucumber powdery mildew. They stated that strain 1984 was best in controlling the disease under greenhouse condition.

Elad *et al.* (1998) reported that, among the different bio-control agents tested against *S. fusca* in greenhouse cucumber, *T. harzianum* T39 (TRICHODEX) spray reduced the powdery mildew severity up to 97 per cent but its efficacy declined to 18–55 per cent as the epidemic progressed. Unlike on young leaves, on older leaves the suppression of powdery mildew by *T. harzianum* T39 was poor. Bioagent such as *Ampelomyces quisqualis* (AQ10) was very effective against powdery mildew and effectiveness declined with the progress of the epidemic but unlike the other bio-control agents it retained its efficiency even on older leaves.

Dik *et al.* (1998) used three biological control agents, *A. quisqualis*, *V. lecanii* and *S, flocculosa* and tested them against cucumber powdery mildew (*S. fuliginea*). In the first experiment *A. quisqualis* did not control the disease, whereas, *V. lecanii* had little effect on powdery mildew in the first experiment but not in the second one. *S. flocculosa* gave the best control of powdery mildew in both the experiments. In the first experiment, addition of silicon in the nutrient solution with a concentration of 0.75 mM reduced the disease by 10–16 per cent.

Elad *et al.* (1999) indicated that the application of *T. harzianum* T39 conidia to the root zone of plants resulted in the reduction of foliar grey mould, white mould and powdery mildew. They reported the probable modes of action of *T. harzianum* T39 to be the competition with the pathogen for nutrients and space, suppression of hydrolytic enzymes of the pathogen and induced host resistance.

Elad (2000) reported that the biocontrol agent *T. harzianum* isolate T39 controls the foliar pathogens, *Botrytis cinerea*, *Pseudoperonospora cubensis*, *Sclerotinia sclerotiorum* and *S. fusca* (syn. *S. fuliginea*) in cucumber under commercial greenhouse conditions. They observed involvement of local and systemically induced resistance in the plants. Cells of the bio control agent applied to the roots and dead cells applied to the leaves of cucumber plants induced control of powdery mildew. A combination of several modes of action is responsible for bio control. They found that bio control agent has the potential to degrade cell-wall polymers of pathogen such as chitin.

Seddon *et al.* (2000) Observed *Brevibacillus brevis* (formerly *Bacillus brevis*) inhibiting wide range of fungal plant pathogens under *in vitro* conditons including *Botrytis cinerea.* They reported *suppression of S. fuliginea, Pythium ultimum* by

Bacillus brevis and observed two modes of antagonism: the antifungal metabolite production (gramicidin S) and a bio-surfactant that reduces periods of surface wetness.

Romero *et al.* (2001) studied the bioefficacy of various fungal and bacterial bioagents, ability of mycoparasite-based products AQ10® (*A. quisqualis*) and Mycotal® (*Lecanicillium lecanii*) and bioagent *B. subtilis* found them performing better under high humid condition (90–95 % RH). In greenhouse experiments the effectiveness of the mycoparasites was absolutely dependent on addition of mineral oil. The strains of *B. subtilis* provided disease control similar to that achieved with the mycoparasites with the fungicide azoxystrobin.

Brand *et al.* (2002) studied the interaction between *L. taurica* and the biological control agents *T. harzianum* T39 (TRICHODEX) and *A. quisqualis* (AQ10) and reported biological control agents to be more effective in disease control.

Lima *et al.* (2002) evaluated the antagonistic activity of the yeasts *Rhodotorula glutinis, Cryptococcus laurentii* and *Aureobasidium pullulans* against powdery mildew of cucurbits (*S. fusca; syn. S. fuliginea*). The antagonists significantly reduced the disease incidence on leaves, showing an activity comparable to that of the fungicide penconazole.

Wojdyla (2002) found that under greenhouse conditions, *Bacillus polymyxa* [*Paenibacillus polymyxa*] strongly inhibited the spread of powdery mildew on rose, caused by *S. pannosa var. rosae*. In *in vivo* conditions garlic juice and mineral oil decreased the disease.

El-Desouky (2004) evaluated *Telletiopsis pallescens* as a biocontrol agent against powdery mildew *(S. fuliginea*) on squash and cucumber. The results showed that spore suspension or culture filtrate of *T. pallescens* provided complete control of powdery mildew on both squash and cucumber plants. Both hosts treated with a spore suspension or culture filtrate had a significant reduction in the severity of powdery mildew infection compared with plants treated with distilled water or those untreated. He also reported that significant reduction in density of *S. fuliginea* conidial population was significantly reduced.

Choi *et al.* (2007) used fourteen *B. thuringiensis* isolates having both insecticidal and antifungal activity and tested them against cucumber and Barley powdery mildew. All the isolates gave more than 70 per cent disease control against these two plant diseases. Specifically, under glasshouse conditions, four isolates (50-02, 52-08, 52-16 and 52- 18) displayed potent bio control efficacy against cucumber powdery mildew.

Kim *et al* (2007) applied suspensions of conidia and blastospores of the *Lecanicillium* into 15mm leaf discs dissected from cucumber plants previously inoculated with *S. fuliginea.* Powdery mildew did not develop when the *Lecanicillium* applications were made one and eight days after *S. fuliginea* inoculations. When *Lecanicillium* was applied to highly infected leaf discs 11 and 15 days after *S. fuliginea* inoculation, the application suppressed subsequent production of *S. fuliginea* spores as compared to the controls. These results suggest the potential of a dual role of *Lecanicillium* spp. as microbial control agents against aphids and powdery mildew.

Vimala and Suriachandraselvan (2008) evaluated fourty-five isolates of *Pseudomonas fluorescens* isolated from phylloplane for their antagonistic potential against *E. cichoracearum* infecting bhendi (okra) in *in vitro* condition. Among them isolates, I18, I9 and I36 showed maximum inhibition of conidial germination and germ tube growth.

Hegazi (2010) used culture filtrates of *T. harzianum, Epicoccum* sp., *Streptomyces endus* and an actenomycetal isolate in addition to two plant extracts *i.e.* meswak *(Salvadora persica*) and henna (*Lawsonia inermis*) to control powdery mildew disease of Zinnia plants. The highest disease incidence suppression was noticed when *Epicoccum* sp. and *T. harzianum* were used as 50 % (v/v) sterilized water extract followed by henna and meswak extracts. Sprayed plants recorded best results for most growth characters, peroxidase (POX) and polyphenol oxidase (PPO) enzymes activity compared to unsprayed one. In conclusion, biocontrol agents and some plant extracts can be substituted to fungicides as an alternative and safe method for controlling powdery mildew disease of Zinnia.

Pawar (2010) evaluated seven different bioagents against powdery mildew of bottle gourd and their results revealed that inbition over control was recorded with *A. quisqualis* (87.18 %) followed by *Fusarium pallidoroseum* (75 %) whereas, lowest inhibition was seen with *T. viride* (13.80 %) over the control.

Channaveeresh and Kulkarni (2015) conducted *in vitro* evaluation of four bioagents with different concentrations revealed that all the bioagents were significantly superior over the control. Maximum conidial inhibition was recorded with *Bacillus subtilis* (75.47%) at 6 g/L followed by *Pseudomonas fluorescens* (72.19 %) @ 6 g/L.

Sasha *et al.* (2016) conducted field trials for two years on organically managed land in Maryland to evaluate the efficacy of four bio rational products generally, all bio rational treatments resulted in significantly lower downy and powdery mildew severity compared with the non-treated plants, but the level of disease management was not significantly different than that provided by copper alone. However, Actinovate AG, OxiDate and Serenade oil each improved disease management on at least one crop, as compared to copper alone. They concluded that rotational programs with bio pesticides are a viable disease management option for organic production of field grown cucurbits in Maryland.

Basamma and Kulkarni (2017) conducted a pot culture experiment to study the efficacy and growth promoting ability of *Bacillus subtilis* against powdery mildew (*Leveillula taurica*) of tomato. The foliar spray of *B. subtilis* at 10g/l recorded the least per cent disease index of powdery mildew (13.22) and there by recorded highest number of branches (6.90), fruits (16.86), fruit weight per plant (898.76 g). Whereas, untreated check was least effective with highest per cent disease index of powdery mildew (54.89) and early blight (32.22) and recorded less number of branches (3.60), fruits (11.99) and fruit weight (615.00g).

2.7.2 Botanicals

Raghupathi *et al.* (1994) reported that treatment with neem oil and neem seed kernel extracts reduced the incidence of Powdery mildew of okra (*Abelmoschus esculentus*) caused by *E. cichoracearum.*

Raj-Kishore *et al.* (1996) found that ocimum oil (*Ocimum gratissimum*) and lemongrass oil (*Cymbopogon* spp.) gave 100 % inhibition of conidial germination of pathogen causing powdery mildew (*E. polygoni*) of opium poppy (*Papaver somniferum*) using a conidial germination technique at the lowest concentration (250 ppm).

Bettiol *et al.* (1997) studied the Efficacy of fresh cow milk in five greenhouse experiments against powdery mildew (*S. fuliginea*) on zucchini squash (*Cucurbita pepo*). Plants were sprayed with milk at 5, 10, 20, 30, 40 and 50 per cent, either once or twice a week. Additional treatments were fungicides (Fenarimol 0.1 ml/l or Benomyl 0.1 g/l) applied once a week and water as a control treatment. A negative correlation was found between the infected leaf area per infected leaf and milk concentration sprayed on plants. High concentrations of milk were more effective than the conventional fungicides tested.

Doltsinis and Schmitt (1998) studied the efficacy of plant extracts from *Reynoutriu sachalinensis* (Japanese joint weed) with 0.2 per cent concentration against powdery mildew in greenhouse-grown cucumber under high disease pressure in Greece and observed yield enhancement up to 49 % over the control.

Fofana *et al* (2002) reported that plants treated with Milsana (Extracts of *Reynoutriu sachalinensis*) were significantly less infected than controls and this protective effect against powdery mildew was maintained over the time and induced resistance correlated with an increased extractable enzymatic activity and mRNA accumulation of two flavonoid biosynthetic genes, chalcone synthase and chalcone isomerase and the accumulation of flavonoid compounds in treated plants.

Sztejnberg *et al.* (2004) studied the efficacy of *Meira geulakonigii* and they revealed that cucumber leaf coverage by powdery mildew in experiment reached up to 43 per cent after 8 weeks of inoculation whenever *Meira geulakonigii* was applied, as compared to 89.3–91.5 per cent leaf coverage in the three control treatments. Total cucumber yield came down to 98–157 g/plant in all three controls, as compared to 538–886 g/plant after the various applications of *Meira geulakonigii.*

Ferrandino and Smith (2006) studied foliar applications of mixtures of cow's milk and water and reported them to be effective in preventing powdery mildew (*Podosphaera xanthii*) of zucchini plants grown in greenhouse grown plants and they also revealed that on an average effectiveness about 50–70 per cent in reducing foliar symptoms and postharvest fruit rot and 40–50 per cent effectiveness in increasing marketable the yield as the chemical control. However Skim milk was not effective compared whole milk, especially in rainy years.

Zhang *et al.* (2007) reported crude extracts of *Robinia pseudoacacia* Linn. (Black locust) 80 mg/ml had a protective effect with 81.25 per cent reduction in growth of *S. fuliginea* in culture room as well as in greenhouse conditions. The water-soluble extracts had a much higher antifungal efficacy in both the culture room and greenhouse conditions in a dose-dependent manner which was further confirmed by *in vitro* bioassays.

Pawar and Chavan (2010) reported neem leaf extract at 20 per cent concentration resulting in 100 per cent inhibition of conidial germination of cucumber powdery mildew caused by *S. fulginia*, likewise Parthenium leaf extract at (20 %), Ocimum leaf extract (20 %), Citrus leaf extract (25 %), Annona leaf extract (15 %), Ipomea leaf extract (15 %), Jowar leaf extract (20 %), Cow urine (15 %) and Butter milk (25 %) also showed 100 per cent inhibition of conidial germination of *S. fulginia.*

Abbasi *et al.* (2011) conducted experiment by using crude extract of 15 plants using methanol as a solvent, the extract of 50 mg per ml was sprayed 24 hours after seedlings were inoculated with conidial suspension (concentration of 5×10^4 spore per ml). The Severity of powdery mildew was evaluated after 12 days and results indicated that seven plants extracts reduced the infection. The most effective among them were *Syngium aromaticum, Corum captimum* and *Hypericum perforatum* with 99.00, 98.00 and 97.00 per cent disease reduction respectively.

Channaveeresh and Kulkarni (2015) Tested botanicals *in vitro* against *E. polygoni* DC, the effect of neem based products on conidial germination was significantly superior over control. Azadirachtin 1500 ppm showed maximum conidial inhibition of 79.93 per cent followed by NSKE (76.64 %), adusoge (68.25 %) and lantana leaf extract (70.07 %).

Dinesh *et al* (2015) reported management of powdery mildew in sunflower was studied in both in vitro and *in vivo* conditions. Azadirachtin, NSKE, Turmeric (leaf extract), *Lantana camara* (leaf extract) and *Ipomoea carnea* (leaf extract) were effective in inhibiting spore germination of pathogen both under *in vitro* condition at 5 per cent concentration. Similar trend was observed in field condition also with Azadirachtin and NSKE at 5 per cent concentration with least disease incidence of 25.78 and 27.56 per cent disease index, respectively in contrast to 83.33 per cent disease index in control.

2.7.3 Chemicals

Abol-Wafa *et al.* (1976) mentioned that the systemic fungicide Benlate at the rate of 0.05 % was more effective in controlling *E. cichoracearum* on cucumber than the non-systemic fungicide Karathane at the rate of 0.04 per cent.

Mostafa *et al.* (1990) reported that in field trials single applications of Rubigan (fenarimol), Byleton (triadimefon) and Nimrod (bupirimate) at recommended doses gave good control of *E. cichoracearum* the casual organism of cucumber powdery mildew.

Iqbal *et al.* (1994) mentioned that best control of *E. cichoracearum*, in greenhouse grown cucumber was obtained by spraying pyrazophos, while benomyl, carbendazim and bupirimate had moderate effect on the pathogen.

Keinath and DuBose (2004) evaluated the efficacy of contact and systemic fungicides and bio fungicide (*B. subtilis*) for preventing powdery mildew of water melon. They revealed that systemic fungicides myclobutanil, benomyl and azoxystrobin were curatively effective after powdery mildew was detected. Mean weight of individual fruit from non-sprayed plots was significantly lower than mean weight of fruit across all the sprayed plots. Powdery mildew reduced the yields significantly but none of the fungicides consistently increased marketable yield compared with the non-sprayed control.

Ilhe *et al.* (2007) conducted the experiment for the management of powdery mildew of cucumber, among the four fungicides tested, four sprays of amistar 25 SC (0.1 %) at seven days interval from onset of infection followed by four sprays of

carbandazim 50 WP (0.1 %) were best treatment involving amistar 25 SC (0.08 %) and penconazole at 0.05 per cent followed by compared to other treatments.

Anand *et al.* (2008) tested bioefficacy of azoxystrobin (Amistar 25 SC) against cucumber downy mildew and powdery mildew diseases. They sprayed the crop with various doses of azoxystrobin (31.25, 62.50 and 125 gm a.i/ha) and observed that 125 gm a.i. per ha (500 ml/ha) to be the optimum dose for the control of these diseases. Treatment also recorded the highest yield of 13.23 and 14.46 tonnes per ha in the first and second season, respectively. No phytotoxic effect of azoxystrobin was observed in field trials even with four times the recommended dose 500 g a.i. per ha. The persistence of azoxystrobin at 250 and 500 g a.i. per ha was observed up to seven days after last spray. However, the persistence of azoxystrobin at 31.25, 62.50 and 125 a.i. per ha was observed up to three to five days only after last spray.

Yasmin *et al.* (2008) evaluated bio-efficacy of 8 fungicides on sweetgourd at two locations, among the 8 treatments mycosulf 80WP at 0.2 per cent reduced the disease by 84 per cent in Gazipur and 83.49 per cent in Thakurgaon. Insulf at 0.3 per cent gave 83.33 per cent and 81.87 per cent control whereas, thiovit at 0.2 per cent gave 83.33 per cent and 80.94 per cent disease control respectively at above locations.

Khalikar *et al.* (2011) reported powdery mildew disease on okra incited by *Erysiphe cichoracearum* in Marathwada region of Maharashtra state. Studies were carried out to find out disease management strategies against okra powdery mildew using bioagents, plant extracts and chemical fungicides. Dinocap 46 per cent EC (0.1 %) showed significantly the lowest disease incidence (18.51 %) and severity (9.86 PDI) with maximum yield.

Dabbas and Kumar (2015) conducted experiment at vegetable research farm Kalyanpur with nine treatments among them bayleton (0.2 %) and tridemefon (0.1 %) gave good control of powdery mildew and resulted with highest edible fruit yield with 1:2.9 and 1:2.45 cost benefit ratio respectively.

Keinath (2015) tested nine powdery mildew-specific fungicides and applied them three times in alternation with Chlorothalonilin on watermelon. In both the years, four fungicide treatments, chlorothalonil alternated with triflumizole, fluopyram

tebuconazole, quinoxyfen, or both cyflufenamid and quinoxyfen reduced leaf area covered with powdery mildew compared to control treatments. Chlorothalonil alternated with cyflufenamid and quinoxyfen were significantly effective on lower leaf surfaces than all other treatments. Chlorothalonil alternated with tebuconazole did not differ from chlorothalonil applied every other week. All ten fungicide treatments increased the number and weight of marketable-sized fruit in both years compared to the water control treatment.

Channaveeresh and Kulkarni (2015) evaluated fungicides aganst *Erysiphe polygoni* on black gram revealed that maximum inhibition of conidial germination was observed with azoxystrobin 25 % SC @ 0.1 % (94.16 %) followed by hexaconazole 25% EC at 0.1 % (90.51 %). The least per cent inhibition was recorded in dinocap 48 % EC (64.60 %) at 0.2 per cent, wettable sulphur 80 % WP (66.79 %) and carbendazim 50 % WP (68.98 %).

Martins *et al.* (2016) evaluated sulphur-based fungicide, water and cow's milk to control powdery mildew under greenhouse conditions. Four week-old plants naturally infested with powdery mildew were evaluated for disease severity after the spray plants were sprayed weekly with milk (10 % v/v) sulphur (2 g/L) or water. From 7 to 28 days after the onset experiment (DAEO), plants were evaluated weekly for the disease severity milk and fungicide sprayed plants reduction in the disease up to 30 and 10 per cent respectively compared to the water control.

2.8 Screening cucumber genotypes for disease resistance

Lebeda (1983) conducted experiment with a set of 57 accessions belonging to 20 wild species and other varieties of the genus *Cucumis*, originating mainly from the African gene centre and he reported that seedlings were substantially more susceptible than adult plants. Eighty per cent of the accessions were susceptible to *E. cichoracearum* and 40 per cent to *S. fuliginea*. Adult plants of the species *Cucumis ficifolius* (IVT 1801, PI 280231), *C. anguria* (PI 147065), *C. anguria* var. *anguria* (CUC 9/1974), *C. dinteri* (PI 374209) and *C. sagittatus* (PI 282441) were resistant to both pathogens.

Block *et al.* (2005) screened 977 cucumber accessions from US National Plant Germplasms System against powdery mildew, among them seventeen out of 20 most resistant accessions were from Asian countries including China (PIs-418962, 418964 and 432870) India (PIs-197085, 197088 and 695930) Japan (PIs-279465, 288238, 390258 and 390266) Pakistan PIs-330628, Philippines (PIs-426169 and 426170) and Taiwan genotypes (PIs-321006, 321009 and 32101).

Yasmin *et al.* (2008) conducted experiment on screening and management of sweet gourd against powdery mildew caused by *E. cichoracearum.* Their experimental results shown that out of 62 accessions only 4 lines namely BD-4388, 204, 205 and 210 were resistant. 23 lines were moderately resistant, 33 lines were moderately susceptible and 2 lines had shown susceptible reaction.

Sakata *et al.* (2009) reported genotypes Tokiwa Power Z' and White Power are highly resistant to powdery mildew. The accession PPMR-1, Hikari Power Gold' and rootstock 'Shin-tosa' were found to be susceptible. Scions, grafted onto PPMR-1 or Shin-tosa rootstocks, showed increasing powdery-mildew resistance or tolerance. The powdery-mildew-resistant Tokiwa Power Z' and 'White Power' did not impart high levels of resistance to scions, whereas 'Hikari Power Gold', which is used for bloomless cucumber production, reduced the resistance of scions to powdery mildew. These results indicate that rootstock cultivars, including certain pumpkin rootstocks, e.g., PPMR-1, can alter the powdery-mildew resistance or tolerance of cucumber scions at the adult stage.

Tetteh *et al.* (2010) screened totally 1654 plant introduction accessions, cultivars and breeding lines of watermelon in the greenhouse with seven replications and reported 54 cultivers including the 44 most resistant and 10 susceptible checks in greenhouse and field experiments and revealed that eight cultigens had high degree of resistance and 21 had intermediate resistance. Most resistant cultigens were PI 632755, PI 386015, PI 189225, PI 346082, PI 525082, PI 432337, PI 386024 and PI 269365. The most susceptible cultigens were PI 222775 and PI 269677. Many of the resistant cultigens originated from Nigeria and Zimbabwe.

Pitchaimuthu *et al.* (2012) screened cucumber genotypes against cucumber powdery mildew and downy mildew pathogen along with swarna agathi as susuceptible

check, They also screened 42 germplasm accessions of IIHR Bangalore including wild type *cucumis hardwikii* and concluded that wild *cucumis sativus* 14 and 15 and *Cucumis sativus* var. *sativus* and SM12735 showing high level of resistance against powdery mildew. Five accessions namely IIHR-27, 35, 33, 64 and IIHR-82 were moderately resistance with less than 40 % PDI and rest of the accessions were susceptible to both powdery mildew and downy mildew.

Channaveeresha *et al.* (2014) screened 126 blackgram genotypes in field condition against powdery mildew resistance and none of them found was to be immune. However three genotypes were found to be resistant, 14 found to be moderately resistant, 21 found to be moderately susceptible, 85 found to be susceptible but only three genotypes exhibited highly susceptible reaction to the disease. In glasshouse conditions totally 12 genotypes were screened creating artificial disease pressure. However, none of them found to be immune, whereas one genotype LBG-17 found to be resistant. Four genotypes VBN-4, VBN-5, LBG-685 and T-9 were found moderately resistant. Whereas, DBGV-5, DU-1, COBG-653 and PU-31 were found moderately susceptible, two genotypes viz, KUG-216 and GPM-1 were susceptible and genotype TAU-1 was highly susceptible to the powdery mildew.

Gondi (2015) conducted an experiment to evaluate cucumber genotypes against powdery mildew and reported least infection to be with in Mysore local (37.71 %) followed by Sirsi local (37.99 %) and BCMSO-03 whereas, highest infection was seen in GR-3 (46.08 %) followed by Sirsi-1-3 (45.81 %) and BCMSO-02 (45.75 %).

Solmaz *et al.* (2016) screened 85 melon and 15 snake melon genotypes against *Fusarium* wilt, downy mildew and powdery mildew (race 3) as fungal diseases and Cucumber mosaic virus (CMV) and Zucchini yellow mosaic virus (ZYMV) as virus diseases. Among all the genotypes tested, only two genotypes ('Kav 60' and 'Kav 277') were resistant to powdery mildew.

2.9 Integrated management of powdery mildew in cucumber

Mohamed *et al.* (1990) found that Flandor, Sumi-8, Sisthane, Bayfidan, Byleton and Afugan were the most effective fungicides against cucurbit powdery mildew, while Karathane and Sofril were least effective once.

Ohtsuka *et al.* (1991) studied the efficacy of commercial fungicide thiophanate-methyl, dimethirimol, tridemefon, chinomethionate and medicinal oil against 4 isolates of *S. fuliginea*, isolated from diseased cucumber plants. They found that chinomethionate oil was effective against all the tested isolates.

Ahmed (1995) found that Karathane, Bayfidan 48 %, Soril (El-Shalk 98 %) and Sumi-8 were the most effective fungicides against cucurbit powdery mildew, while Kema-Z, Flandor and Benlate were the least effective once.

El-Shami *et al.* (1995) reported that Karathane (dinocap), Anvil (hexaconazol), Alto 100 (cyproconazole), Topaz 100 (penconazole) and Afugan (pyarophos) were the most effective fungicides against powdery mildew of cucumber, while Flowable sulfur, Benlate (benomyl), Dorado (pyrifenox) and Sumi-8 (dinoconazole) were the least effective once.

McGrath and Shishko (1999) screened biocompatible products such as *A. quisqualis*, JMS Stylet-Oil, M-Pede (potassium salts of fatty acids) and Kaligreen (82 % potassium bicarbonate) against powdery mildew of cucurbits and their results indicated that JMS Stylet-Oil was most effective in controlling powdery mildew with increased yield obtained with the conventional fungicide program of Bravo (chlorothalonil) plus Nova (myclobutanil). Powdery mildew severity on upper and lower (under) leaf surfaces was 66 and 80 % for untreated where as it was 3 and 13 % for Bravo plus Nova, 43 and 44 per cent for JMS Stylet-Oil, 38 and 65 per cent for AQ10 and 53 and 65 % for Kaligreen, respectively. Yield (tonnes/ha) obtained was 22.8, 44.2, 36.4, 40.6 and 38.5, respectively. Even sucrose content increased and it was 3.5, 6.6, 4.6, 3.2 and 4.0, per cent respectively.

Manojkumar *et al.* (2008) conducted an experiment with 13 fungicides, 8 biological agents and 13 plants extracts during 2004-05 by using California wonder and Indra varieties of capsicum. The study revealed that fungicides Dinocap 1 ml/Ltr recorded minimum percent diseases index whereas, *A. quisqualis* 20 ml/Ltr and neem oil 20 ml/Ltr were also had better efficacy against powdery mildew among bio-agents and botanicals respectively.

Wyenandt *et al.* (2008) used five fungicides programs and applied them season-long and reported no significant interactions between the fungicide program and cultivar. In each year, area under disease progress curve values were highest when a chlorothalonil + azoxystrobin alternated with azoxystrobin applied weekly compared with a fungicide applied in a weekly rotation with a chlorothalonil + myclobutanil alternated with myclobutanil fungicides.

Loganathan *et al.* (2011) evaluated different fungicides *viz.*, (Tridemorph @ 0.1 per cent, Flusilazole @ 0.1 per cent, Tebuconazole) @ 0.1 per cent, (Sodium bisulphate @ 0.25 per cent, Triadimefon @ 0.25 per cent, Difenconazole) @ 0.05 per cent, Wettable sulphur @ 0.3 per cent, Neem oil 0.25 per cent and Carbendazim 0.1 per cent against powdery mildew disease of pea. The results of field experiments revealed that powdery mildew disease intensity was found to be significantly less in tebuconazole treated plants.

3. MATERIAL AND METHODS

The present investigations on cucumber powdery mildew were carried out at Department of Plant Pathology, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during the year 2016-17. Main Agricultural Research Station Dharwad is situated at 15^0 21' N latitude, 75^0 48' E longitudes and at an altitude of 678 meters above mean sea level (MSL) in the northern transition zone (Zone 8) of Karnataka state. The mean annual rainfall of Dharwad is about 825 mm, distributed over a period of seven to eight months (April to November) with two peaks in July and October.

The details of material and methods used and the methodology followed during the course of investigations are described in this chapter under followings headings:

3.1 General procedure

3.2 Symptomatology

3.3 Morphology of fungus

3.4 Survey for disease severity of powdery mildew of cucumber in northern Karnataka under open field and protected conditions

3.5 Molecular characterization of pathogen

3.6 Epidemiological studies

3.7 Evaluation of fungicides, botanicals and bio agents

3.8 Screening cucumber genotypes against powdery mildew disease

3.9 Integrated management of cucumber powdery mildew

3.1 General procedure

3.1.1 Glassware cleaning

For all laboratory experimental studies, Borosil glassware's were used. The glassware's were immersed in the cleaning solution containing 60 g of potassium dichromate ($K_2Cr_2O_7$) and 60 ml of concentrated sulphuric acid (H_2SO_4) in one litre of

water for a day and were washed with detergent powder followed by tap water washing and finally rinsed with distilled water.

3.1.2 Sterilization

All the glassware's used in the studies were sterilized in autoclave at 1.1 kg/cm^{-2} pressure for 20 minutes in a hot air oven at 55^{0} C for two hours. The cavity slides were surface sterilized with 0.1 per cent mercuric chloride ($HgCl_2$) or 1.0 per cent sodium hypochlorite using cotton swab.

3.2 Symptomatology

To study the symptom development on the plants, test was carried out with infected plant part from susceptible genotype at Department of Plant Pathology, College of Agriculture, Dharwad. Observations on symptom development were recorded at regular intervals after infection started.

3.3 Morphology of fungus

Morphological features of fungus *Erysiphe cichoracearum* and *Sphaerotheca fuliginia* from infected part of susceptible genotype collected and brought to the laboratory. The white powdery mass of mycelium and conidial growth was collected by using camel hair brush. The spore suspension was placed on cavity slides to study shape, size, of conidia and mycelium. Same time leaf is folded and directly observed under microscope to study conidiophores, conidia and their germination under compound microscope at 10 X and 40 X magnifications.

3.4 Survey for disease severity of powdery mildew of cucumber in northern Karnataka under open field and protected conditions

A roving survey for severity of powdery mildew of cucumber was taken up in Belagavi, Haveri, Dharwad and Vijaypura districts of northern Karnataka during late *kharif* 2016-17. The information on cucumber growing areas was collected from state department of horticulture of respective districts. Details of individual fields were visited and necessary information on disease severity was recorded. During survey cucumber fields were observed for powdery mildew severity, stage of crop and other

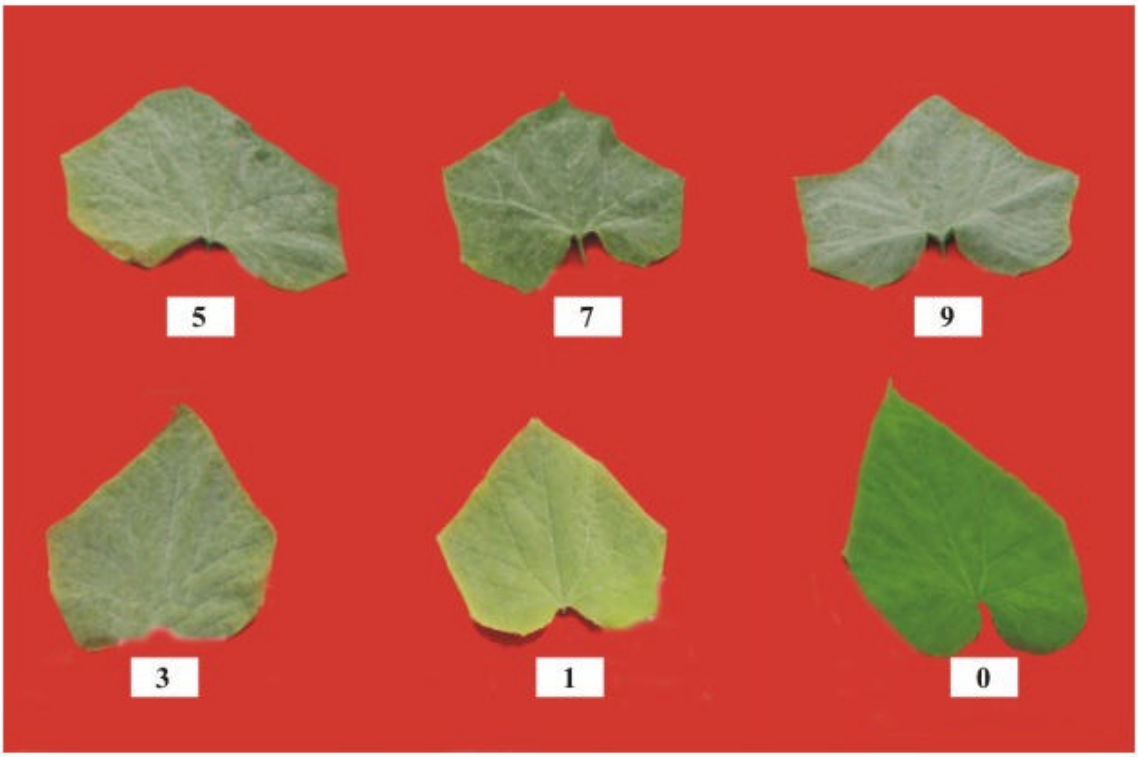


Plate 1: Disease rating scale

details were recorded. From each field, five plants were randomly selected and powdery mildew severity was recorded by following 0-9 scale through visual observation (Mayee and Datar, 1986) as given below.

Disease scoring scale

Score	Description
0	No symptom of powdery mildew on leaves.
1	Small scattered powdery mildew specks covering 1 % or less leaf area.
3	Small powdery lesions covering 1-10 % of leaf area.
5	Powdery lesions enlarged covering 11-25 % of leaf area.
7	Powdery lesions coalesce to form big patches covering 26-50 % leaf area.
9	Big powdery patches covering 51 % or more of leaf area and defoliation occur

Per cent disease index (PDI) has been calculated by using formula given by Wheeler (1969).

$$PDI = \frac{\text{Sum of individual disease ratings}}{\text{Total No. of leaves graded x Maximum disease rating}} \times 100$$

Survey format: for protected cultivation

Name of the farmer:_____ **Village:_____**		**Taluk:_____** **District: _____**
Crop grown under: Protected	Size of protected structure:	Age of polyhouse:_____
Variety/Hybrid:_____	Colour of variety grown: white/Green	
Stage of crop:_____ Date of sowing:_____	Spacing:_____ Date of planting:_____	Planting method: Zig-zag/Normal

Duration of crop _____	Staking practice:_____
Previous crop:_____	Method of irrigation: Drip/Sprinkler/Flood
Method of fertilizer application: Manual/Fertigation	Weed flora:_____
Adoption of cooling system in green house: Fan and Pad / Foggers /Misting	
Major disease/Disorder and time of appearance:_____	
Management practice adopted: Sterilization/Soil solarisation /Fumigation/ Chemical/ Biorational	
Average yield:_____	Annual income:_____

Survey format followed for open field condition:

1	Village, Taluk, District	
2	Season	
3	Crop stage	
4	Soil type	
5	Type of cultivation	
6	Variety or hybrid	
7	GPS	
8	Per cent Disease Index	
9	Other diseases observed	

Per cent disease index (PDI)

The severity of cucumber powdery mildew was recorded by using 0-9 scale developed by Mayee and Datar (1986) as given below:

Score	Description
0	No symptom of powdery mildew on leaves.
1	Small scattered powdery mildew specks covering 1 % or less leaf area.
3	Small powdery lesions covering 1-10 % of leaf area.
5	Powdery lesions enlarged covering 11-25 % of leaf area.
7	Powdery lesions coalesce to form big patches covering 26-50 % leaf area.
9	Big powdery patches covering 51 % or more of leaf area and defoliation occur

Per cent disease index (PDI) was calculated by using formula given by Wheeler (1969).

3.5 Molecular characterization of pathogen

3.5.1 DNA extraction

Procedure: The conidia were collected from the infected cucumber leaves with the help of camel brush. The DNA extraction method was standardized and certain steps were optimized to produce good concentration of DNA using plant DNA isolation kit (CTAB method).

The new colonies were scraped from the leaf surface with a small brush and water and grounded in a Pestle and Mortar with nine ml of CTAB extraction buffer and mixed gently by inversion. Tubes were incubated for 60-90 minutes, with occasional inversion at 65^0 C. The samples were allowed to cool by keeping the tubes in a trough of water at room temperature.

Five ml of chloroform and isoamyl alcohol (24:1) was added, the tubes were rocked gently to mix the content for five min. The samples were subjected to spinning

in a centrifuge for 15 min at 6500 rpm at room temperature. The aqueous layer was transferred to a fresh tube and 25 µl RNase A (20 mg ml-1) was added.

The samples were mixed gently by inversion and incubated for 30 min at room temperature. Six ml of isopropanol was added to each tube and mixed gently by inversion until a white fluffy DNA precipitate appeared. The contents were centrifuged at 6500 rpm for 15min to pellet the DNA. After 2- 3 min, eight ml of cold wash buffer was added and incubated for 20 min at room temperature.

The tubes were centrifuged to pellet the DNA at 6500 rpm for 15 min. The supernatant was discarded and eight ml of cold 70 per cent ethanol was added to the tube containing the DNA pellet. One ml of elution buffer was added and mixed gently to dissolve the pellet and kept at 4^0 C overnight.

The DNA solution appeared to be turbid after standing overnight at 4^0 C and the samples were heated to 65^0 C for 10 min, inverting the tube every 3 min. Insoluble material was removed by centrifugation at 6500 rpm for 15 min and the clear supernatant containing DNA was transferred to a fresh 1.5 ml tube discarding the pellet.

The samples were subjected to spinning in a centrifuge for 15 min at 6500 rpm at room temperature. The aqueous layer was transferred to a fresh tube and 25 µl RNase A (20 mg ml-1) was added. The samples were mixed gently by inversion and incubated for 30 min at room temperature. Six ml of isopropanol was added to each tube and mixed gently by inversion until a white fluffy DNA precipitate appeared.

The contents were centrifuged at 6500 rpm for 15min to pellet the DNA. After 2- 3 min, eight ml of cold wash buffer was added and incubated for 20 min at room temperature. The tubes were centrifuged to pellet the DNA at 6500 rpm for 15 min. The supernatant was discarded and eight ml of cold 70 per cent ethanol was added to the tube containing the DNA pellet.

One ml of elution buffer was added and mixed gently to dissolve the pellet and kept at 4^0 C overnight. The DNA solution appeared to be turbid after standing overnight at 4^0 C and the samples were heated to 65^0 C C for 10 min, inverting the tube every 3 min. Insoluble material was removed by centrifugation at 6500 rpm for 15 min and the

clear supernatant containing DNA was transferred to a fresh 1.5 ml tube discarding the pellet.

3.5.2 Polymerase chain reaction

The ribosomal DNA (rDNA) unit contains genetic and non-genetic or spacer region. Each repeat unit consists of a copy of 18S, 5.8S and 28S like rDNA and its spacer like internal transcribed spacers (ITS) and intergenic spacers (IGS). The rDNA have been employed to analyze evolutionary events because it is highly conserved, where as ITS rDNA is more variable. Hence, it has been used to investigate species level relationships. The ITS region was amplified with the universal primers ITS1 (5'TCCGTAGGTGAACCTGCGG-3') and ITS4 (5'-TCCTCCGCTTAT TGATATGC-3') given by White *et al.* (1990). Amplification was performed in 50 µl of reaction mixture containing 50 Pico mol of 1 µl of ITS 1, ITS 4 primers, 0.25 µl *Taq* DNA polymerase, 1 µl (10 mM) of each dNTP, 5 µl of 10 × PCR buffer, 1 µl (40 µg) of template DNA and PCR water 39.75 µl and subjected to PCR in a thermal cycle. The PCR conditions followed were, initial denaturation at 94^0 C for 4 min, denaturation at 94^0 C for 1 min, annealing at temperature 55^0 C for 1min, its extension at 72^0 C for 1.5 min and final extension at 72^0 C for 5 min.

3.5.3 Agarose gel electrophoresis

Agarose gel electrophoresis was performed to resolve the amplified product using 1.4 per cent agarose in 1X TBE (Tris Borate EDTA) buffer, 0.5 µg ml-1 of ethidium bromide and loading buffer (0.25 % Bromophenol blue in 40 % sucrose). Four µl of the loading dye was added to 20 µl of PCR product and loaded to the agarose gel. Electrophoresis was carried out at 80 V for 45 minutes. The gel was observed under UV light and documented using gel documentation unit.

3.5.4 ITS rDNA Sequencing:

The PCR product (50 µl) was sent to Chromus biotech lab Bangalore for the direct sequencing. Sequence analysis: DNA sequence for the internal transcribed spacer region (ITS) of the 28S rDNA was obtained. After collecting the sequence from

Chromus biotech lab, the sequences obtained in this study were submitted to the NCBI (National Centre for Bioinformatics) Gen Bank to check the identity of isolates and previously published sequences used for phylogenetic analyses.

3.6 Epidemiological studies

3.6.1 Effect of time of planting on powdery mildew development on cucumber

A field experiment was conducted during *kharif*, 2016 at Main Agricultural Research Station (MARS), College of Agriculture and Dharwad to assess the progress of powdery mildew at different dates of sowing. The cultural practices like intercultivation and weeding were attended regularly. General sprays of insecticides were given whenever it was necessary to avoid severe damage from insect pests.

The first date of sowing treatment was imposed by sowing seeds of locally cultivated genotype Dharwad green on 1st Fortnight of July and subsequent sowings were done at an interval of 15 days till the last sowing was carried on 1st Fortnight of October. Individual plot size was 5 m × 4 m. Cucumber seeds were sown at 90 cm spacing between rows and 60 cm between plants. Totally seven different dates of sowings were carried out in the experiment. Observations on the age of the crop at which disease appeared and intensity of disease was recorded on five plants in each plot for all the dates of sowing using a disease scoring scale 0-9 and compared to find out the best sowing date. The weather data of MARS, UAS Dharwad was collected from meteorological unit and used for correlating with the disease severity (Appendix I and Appendix II). Correlation matrix was worked out.

3.6.2 Effect of different temperature on conidial germination

The temperature required for conidial germination was studied by cavity slide technique. Two drops of conidial suspension was mixed with two drops of two per cent glucose solution in cavities to achieve the required concentrations of 1.5 per cent. The cavity slides were placed in moist chambers and incubated at 24 hours at different temperature levels *viz.*, 5, 10, 15, 20, 25, 30, 35 and 40^0 C in thermostatically controlled incubators for 24 hours. Three replications were maintained for each treatment. The per cent germination was calculated by counting the number of conidia germinated to the total number of conidia.

3.6.3 Effect of relative humidity on conidial germination

Effect of different levels of relative humidity on conidial germination was studied. Different levels of relative humidity were maintained in desiccators containing various proportion of concentrated sulphuric acid with distilled water. The cavity slides containing conidia were placed in desiccators containing sulphuric acid and distilled water to maintain different levels of relative humidity and presented in appendix III *viz.*, 65, 70, 75, 80, 85, 90, 95 and 100 per centby. The desiccators were incubated at room temperatures of (25 ± 1 ^{0}C) for 24 hours. In each treatment, three replications were maintained. The per cent germination was calculated by counting number of conidia germinated among the total number of conidia observed under microscopic field and expressed in percentage.

3.7 Evaluation of fungicides, botanicals and bio agents

3.7.1 *In vitro* evaluation of systemic fungicides

The efficacy of seven systemic fungicides at three concentrations (0.05, 0.10 and 0.15 %) was tested against *E. cichoracearum* and *S. fuliginia* by spore germination technique. Required concentration of each fungicide was prepared in distilled water. Two drops of fungicide solution was taken on clean cavity slide. Powdery mildew spores were suspended in fungicide solution on the cavity slide. Each concentration was replicated thrice in a separate cavity slide. Control treatment was maintained by putting conidia with distilled water. These cavity slides were kept in the Petridishes lined with moist blotting paper and were incubated at room temperature (28 ± 1 ^{0}C) for 24 hours. After 24 hours, observations were taken at 10 × and 40 × microscopic fields for each cavity and the total number of spores and germinated spores in each microscopic field were recorded and per cent germination was calculated. The fungicides found effective against powdery mildew of cucumber in *in vitro* conditions were selected for *in vivo* studies.

List of systemic fungicides used in *in vitro* evaluation are given below

Sl. No.	Systemic fungicides	Trade names
1	Azoxystrobin 250 % SC	Amistar
2	Carbendazim 50 % WP	Bavistin
3	Difenconazole 25 % EC	Score
4	Hexaconazole 5 % EC	Contaf
5	Myclobutanil 400 WP	Systhane
6	Propiconazole 25 % EC	Tilt
7	Tebuconazole 250 EC	Folicur

List of combi fungicides used in *in vitro* evaluation are given below

Sl. No.	Combi products	Trade names
1	Carbendazim 12 % + Mancozeb 63 %	Saaf 75 % WP
2	Captan 70 % + Hexaconazole 5 %	Taquat 75 % WP
3	Hexaconazole 4 % + Zineb 68 %	Avatar 72 %WP
4	Tebuconazole 50 % + Trifloxystrobin 25 %	Nativo 75 %WG
5	Fenamidone + Mancozeb 60WG (10 % + 50 %)	Sectin 60 % WG

$$\text{Per cent germination (PG)} = \frac{A}{B} \times 100$$

Where,

PG = Per cent germination

A = Number of conidia germinated

B = Number of conidia observed

The average of three cavities (three replications) was found out and the per cent inhibition of spore germination was calculated with the following formula given by Vincent (1927) for each fungicides.

$$\text{Per cent inhibition of spore germination} = \frac{C - T}{C} \times 100$$

Where,

C - Germination of conidia in control

T - Germination of conidia in treatment

3.7.2 *In vitro* evaluation of botanicals and biorationals

Ten grams of leaves of plant material were rinsed in water and cut into small pieces and macerated using pestle and mortar with 50 ml of water. The contents were filtered through a clean double-layered muslin cloth. Then, the volume was made up to 100 ml to get 1.0 per cent concentration. Further, it was diluted with distilled water to get 0.5 per cent concentration. These extracts were centrifuged for 5 min at 3000 rpm to get a clear plant extract and supernatant extract was used for evaluation. Two drops of plant extract solution was taken on clean cavity slide to which powdery mildew spores were suspended by camel hair brush and only sterile water was used as control. Slides were incubated at temperature (25 ± 1^{o}C) for 24 hr.

List of botanicals and biorationals used in *In vitro* studies

Sl. No	Botanicals/ Organics	Plant parts used	Concentrations (%)	
1	*Reynotriu sachalensis* (Giant knot weed)	Leaf	**10**	**20**
2	*Parthenium hysterophoru* (Congress grass)	Leaf	**10**	**15**
3	Annona leaf extract (Custuard apple)	Leaf	**10**	**15**
4	Ipomea leaf extract (Bind weed)	Leaf	**10**	**15**
5	Ocimum leaf extract (Tulsi)	Leaf	**10**	**15**

6	Nimbicidin (Neem oil 90.57%)	Commercial product	**05**	**10**
7	Sorghum leaf extract	Leaf	**15**	**20**
8	Butter milk (Freshly prepared)	Organic product	**15**	**20**

3.7.3 *In vitro* evaluation of bio agents.

Four bio agents at two different concentrations (0.5 and 1%) were tested by spore germination technique. Commercial formulations of these bioagents was collected from institute of organic farming UAS Dharwad and different concentrations were prepared by adding 0.5 gm in 100 ml water (for 0.5%) likewise in 1 gram of bioagent was added in 100 ml water (1%). Three replications were maintained with only distilled water as control. The slides were incubated at (28 ± 1^{o} C) for 24 hours.

Sl. No.	Bio agents	Source
1	*Bacillus subtilis*	Institute of Organic Farming, UAS, Dharwad
2	*Pseudomonas fluorescens*	
3	*Trichoderma harzianum*	
4	*Lecanicillium lecanii*	

3.8 Screening of cucumber genotypes against powdery mildew disease

A field experiment was conducted to find out the resistance source against cucumber powdery mildew. Totally twenty three genotypes were collected and screened against powdery mildew under natural epiphytotic condition. Each genotype was sown in three rows of five meter length during the late *kharif* 2016 at MARS, Dharwad. The disease severity was recorded using 0-9 scale by randomly selecting five plants in each genotype (Mayee and Datar, 1986). Based on their reaction genotypes were categorized into immune, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible.

List of cucumber genotypes used to screen against powdery mildew

Sl. No	Genotypes	Source	Place
1	Swathi	Bioseeds Pvt. Ltd.	Hyderabad
2	BSS-949	Kalash seeds pvt. Ltd	Jalna, Maharashtra
3	JK-special	Agro inputs Pvt. Ltd.	Ahmedabad
4	Mahy sylvia	Mahyco seeds Pvt. Ltd.	Jalna, Maharashtra
5	Chetak	Trusted seeds Pvt. Ltd.	New Delhi
6	Mangalore local	Keyonics seeds Pvt. Ltd.	Bangalore
7	Malini	Monsanto Pvt. Ltd.	Ahmedabad
8	Shirakawa	Sakata seeds Pvt. Ltd.	Gurugram, Haryana
9	Dharwad green	Nadakatti seeds Pvt. Ltd.	Dharwad
10	Yummy	Bioseeds Pvt. Ltd.	Hyderabad
11	Kareena	Nuziveedu seeds Pvt. Ltd.	Hyderabad
12	Green long	Ceres Pvt. Ltd.	Kolkata, West Bengal
13	Ajeeth-99	Ajeeth seeds Pvt. Ltd.	Aurangabad, Maharashtra
14	White long	Keyonic seeds Pvt. Ltd.	Bangalore
15	Gullakai	Mrutyunjaya seeds Pvt. Ltd.	Dharwad
16	Encounter-962	East west seeds India Pvt. Ltd.	Aurangabad, Maharashtra
17	Chitra-	RASI seeds Pvt. Ltd.	Hyderabad
18	Khushi	Dhanvi seeds Pvt. Ltd.	Hyderabad
19	Shalini	Ocean crop science Pvt. Ltd.	New Delhi
20	Sribasava	Tanindo seeds Pvt. Ltd.	Kodigehalli, Bangalore
21	Ranebennur local	Keyonic seeds	Bangalore
22	Harini	Noble seeds Pvt. Ltd.	Bangalore
23	Sarpana hybrid	Sarpan hybrid seeds Pvt. Ltd.	Dharwad

3.9 Integrated management of cucumber powdery mildew

Field experiment was laid-out in a randomized block design with three replications at Main Agricultural Research Station, Dharwad during late *Rabi* 2016-17. The economically viable and effective fungicide, botanicals and bioagents identified under *in vitro* evaluation were tested under field condition using the susceptible genotype (Chitra). Recommended package of practices were followed to raise the crop and necessary insecticides were sprayed at regular intervals to control sucking pests and cucumber beetles. The integration of fungicide, botanicals and bioagents were evaluated by following spraying schedule given below.

Details of experiment:

Design : RBD

Plot size : 3 × 5 m

Treatments : 10

Replications : 3

Fertiliser dose : 60:50:80

Genotype : Chitra

Spray schedule

Treatments	I-Spray	II-Spray
T_1	*Bacillus subtilis* 1 %	*Bacillus subtilis* 1 %
T_2	*Reynoutria sachhalensis* 20 %	*Reynoutria sachhalensis* 20 %
T_3	Amistar 0.15 %	Amistar 0.15 %
T_4	Nativo 0.15 %	Nativo 0.15 %
T_5	Amistar 0.15 %	*Bacillus subtilis 1 %*
T_6	Nativo 0.15 %	*Bacillus subtilis 1 %*
T_7	Amistar 0.15 %	*Reynoutria sachhalensis* 20 %
T_8	Nativo 0.15 %	*Reynoutria sachhalensis* 20 %
T_9	*Bacillus subtilis* 1 %	*Reynoutria sachhalensis* 20 %
T_{10}	Control	

Observation on intensity of disease was recorded using five randomly selected plants from each treatment plot and graded as per 0-9 scale given by Mayee and Datar (1986). Further per cent disease index was calculated as described earlier, average values were taken into consideration for statistical analysis. Yield per plot was recorded for every harvesting and expressed in kg/ha and analysed statistically.

Statistical analysis

The statistical analysis of randomized block design (RBD) was carried out as per the procedure given by Panse and Sukhatme (1985). Per cent data were transformed to arc sine values and analyzed statistically.

4. EXPERIMENTAL RESULTS

The results of the experiment conducted on various aspects of cucumber powdery mildew caused by *Erysiphe cichoracearum* with reference to survey, molecular characterization of pathogen, epidemiological aspects of the disease, *in vitro* evaluation of fungicides, bioagents, plant extracts against pathogen, screening of genotypes for resistance and integrated management of the disease are presented below under following headings:

4.1 Symptamatology

4.2 Survey for severity of powdery mildew of cucumber in open field cultivation

4.3 Molecular characterization of pathogen

4.4 Effect of temperature on conidial germination of *E. cichoracearum*

4.5 *In vitro* evaluation of Chemicals, Botanicals and bio-agents

4.6 Screening cucumber genotypes for disease resistance

4.7 Integrated disease management

4.1 Symptamatology

Symptoms first appears as white nearly or fluffy somewhat circular patches or spots which appear on the upper surface of the leaves sometime lower surface also, spreading to the petiole, stem and fruit. Severely infected leaves turned brown, shrivelled and defoliation occured. Fruit of the affected plants do not develop fully and remained small (Plate 2, 3a, and 3b).

4.2 Survey for severity of powdery mildew of cucumber in open field cultivation

A roving survey was carried out in Dharwad, Haveri, Belagavi and Vijaypura districts of northern Karnataka during late *kharif* 2016 to find out the severity of powdery mildew of cucumber. Twenty seven places in Belagavi, sixteen places in

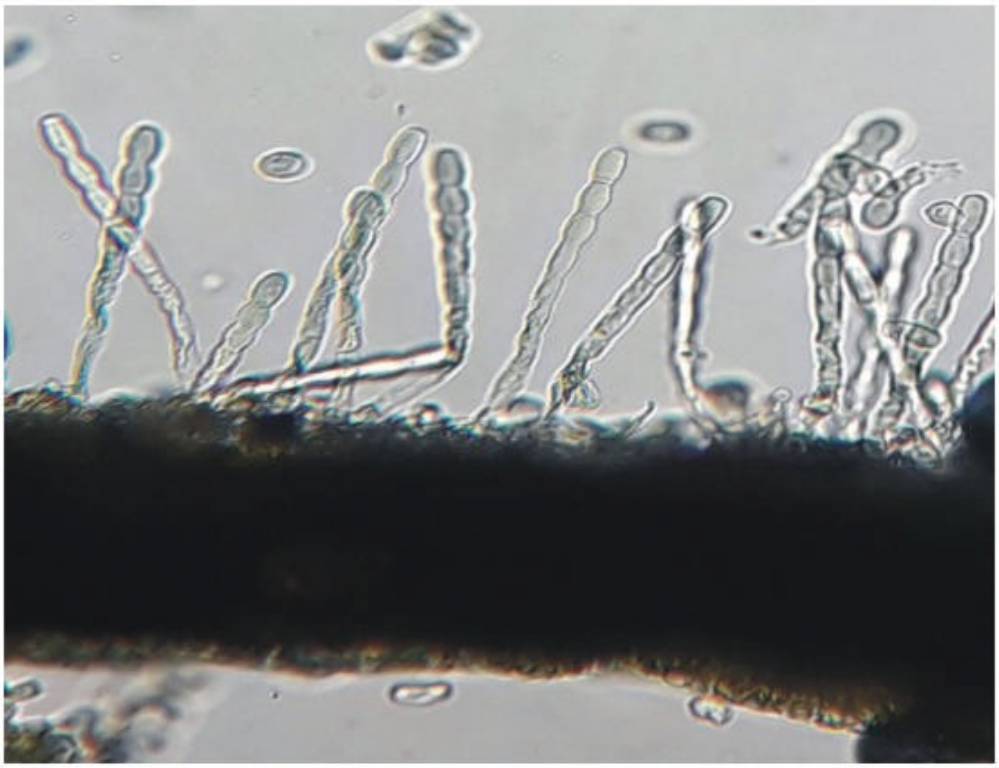
a) Powdery mildew symptoms on leaves

b) Powdery growth on stem

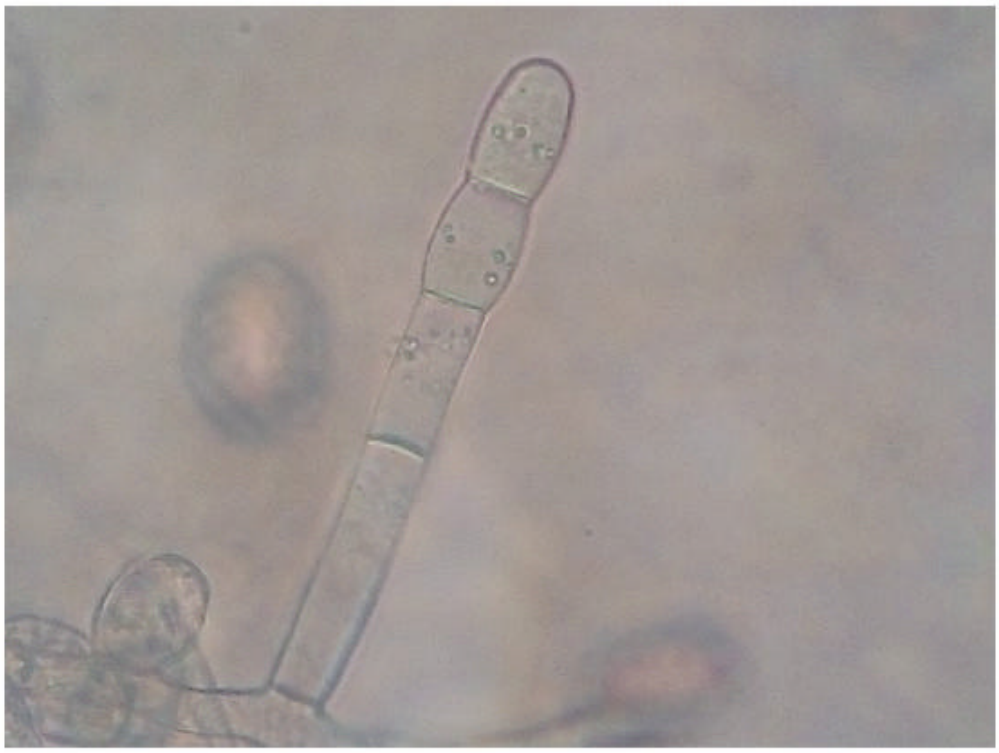
c) Powdery growth on tendrils

d) Conidial sporulation on dried leaves

Plate 2: Powdery mildew symptoms on different plant parts

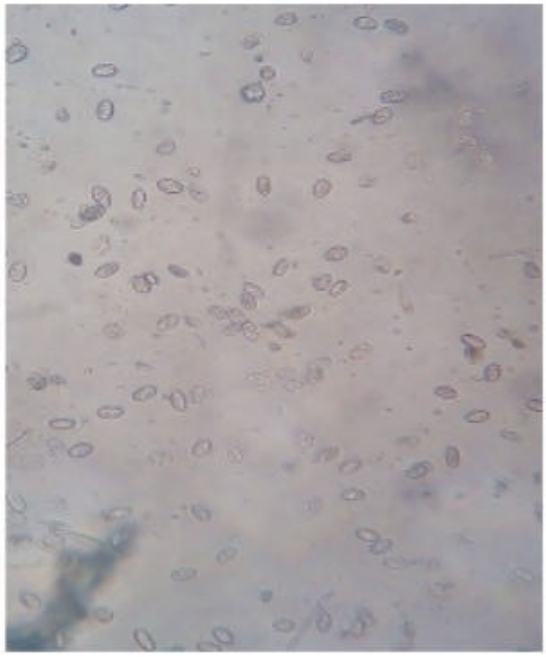


a) Conidia and conidiophores at 100X

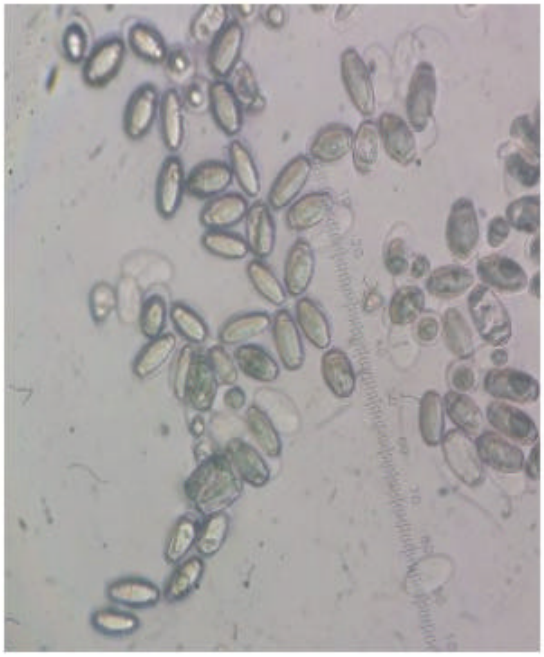


b) Conidia and conidiophores at 400X

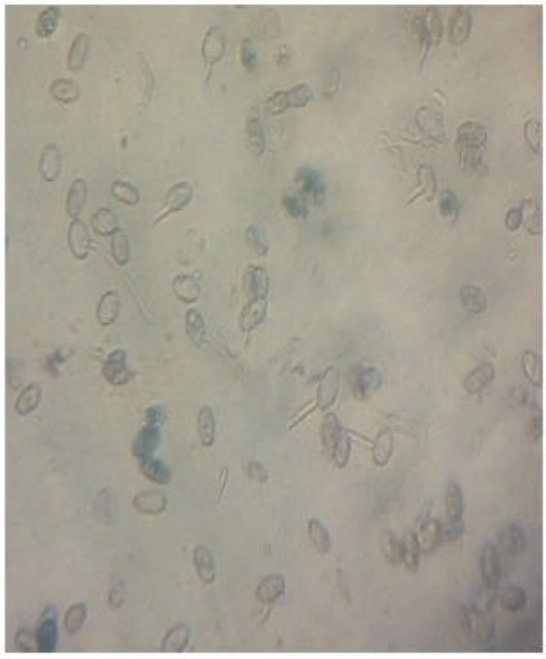
Plate 3a: Microphotographs of conidia and conidiophore of *Erysiphe cichoracearum*



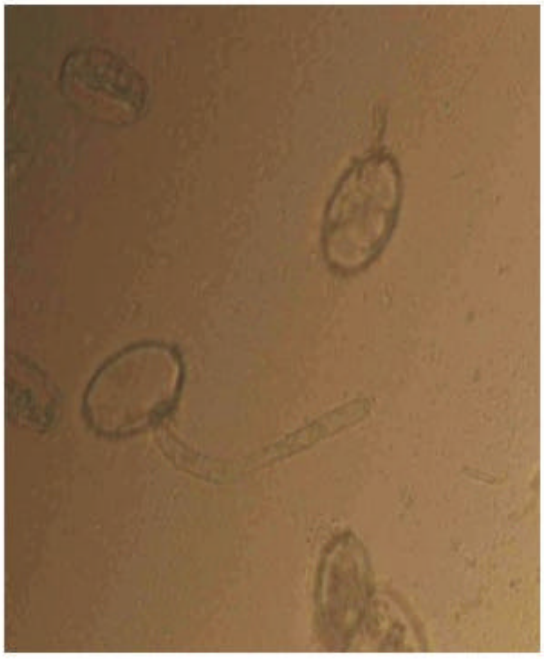
a) Conidia at 100X



b) Conidia at 400X



c) Germinated conidia at 100X



d) Germinated conidia at 400X

Plate 3b: Microphotographs of conidia and germinated conidia of *Erysiphe cichoracearum*

Dharwad, thirty places in Haveri and eleven places in Vijaypura (total eighty four cucumber fields) were surveyed as explained in Material and Methods. The results are presented in Table 1a, 1b, 1c, 1d and 1e; Fig 1a, 1b, 1c, 1d, 1e and Plate 4a.

Maximum mean percent disease severity (PDI) was observed in Dharwad district (33.06 PDI) followed by Haveri district (29.87 PDI) and minimum mean percent disease severity (PDI) was observed in Belagavi (27.21 PDI) district and it is less in Vijaypura district (27.60 PDI).

In Dharwad district, two taluka's were surveyed, *Viz.*, Dharwad and Hubli. In Dharwad taluka the survey was conducted in sixteen villages. Among them, the maximum severity (59.66 %) was recorded at MARS, Dharwad followed by Tadakoda village with an severity of (40.86 %) whereas least severity (12.25 %) was recorded in Mrutyunjay nagar. Similarly in Hubli taluka the maximum severity (43.29 %) was recorded in Samshi followed by Adaragunchi with the severity of 42.78 per cent. The least severity (13.53 %) of powdery mildew was recorded in Ramanakoppa village.

In Haveri district, five taluka's were surveyed, *viz.*, Haveri, Ranebennur, Hirekerur, Shiggaon and Byadgi. In Haveri taluka the survey was conducted in five villages. Among them the maximum severity (29.66 %) was recorded in Vardi cross followed by Motebennur village with a severity of 26.36 per cent. Where as least severity (20.15 %) was recorded in Kerimathihalli village. Similarly in Ranebennur taluka the maximum severity (58.15 %) was recorded in Basirikatti village followed by Medleri with the severity of (40.19 %) whereas, the least severity (18.66 %) was recorded in Chalageri.

In Shiggaon taluka, the maximum severity (36.25 %) was recorded in Gotagodi followed by Shiggaon taluka with the severity of (30.78 %), the least severity (22.18 %) was recorded in Niralgi. In Byadgi taluka, maximum severity (40.18 %) was recorded in Angaragtti whereas the least severity (21.12 %) was recorded in Mallur. Similarly in Hirekurur taluka maximum severity (39.55 %) was recorded in Masur and least severity (20.48 %) was recorded in Bannihatti. Among the talukas surveyed in Haveri district the maximum severity (32.84 %) was recorded in Byadgi and least severity was recorded in Haveri taluka (24.49 %).

Table 1a. Survey for severity of cucumber powdery mildew in different districts of northern Karnataka during *kharif* 2016

Districts	Taluks	Villages	Latitude (°N)	Longitude (°E)	Soil type	Stage of the crop	Type of cultivation	Variety/ Hybrid	PDI	Other diseases observed
Belagavi	Bailhongal	Bailhongal	15.81	74.86	Black	Flowering	Irrigated	Green long	22.16	Downy mildew
		Belavadi	15.76	74.75	Black	Flowering	Irrigated	Dharwad green	29.33	Downy mildew Anthracnose
		Bailawada cross	15.83	74.84	Black	Flowering	Rainfed	Dharwad green	63.08	Downy mildew
		Hire Bagewadi	15.77	74.64	Black	Flowering	Rainfed	Malini	31.18	-
		Badekollimath	-	-	Black	Harvesting	Irrigated	Malini	20.79	Downy mildew
		Ambadagatti	15.63	74.73	Black	Flowering	Rainfed	Malini	24.56	-
		Dasthikoppa	15.69	74.70	Black	Flowering	Rainfed	Malini	36.12	-
		Kadrolli	15.69	74.73	Black	Flowering	Irrigated	Malini	36.17	-
		M.K.hubli	15.72	74.69	Black	Flowering	Irrigated	Malini	30.15	-
								Taluk mean	**32.16**	
	Belagavi	Marihal	15.88	74.67	Black	Harvesting	Irrigated	Malini	16.12	Downy mildew
		Sulebhavi	15.89	74.65	Black	Flowering	Rainfed	Malini	17.88	Downy mildew
		K.K.Koppa	15.85	74.50	Black	Flowering	Rainfed	Malini	10.25	Downy mildew
		Hulikatti	15.78	74.62	Black	Flowering	Rainfed	Malini	24.15	Downy mildew
		Sutagatti	15.86	74.71	Black	Harvesting	Irrigated	Malini	29.18	Downy mildew anthracnose
								Taluk mean	**20.02**	

Contd….

Districts	Taluks	Villages	Latitude (°N)	Longitude (°E)	Soil type	Stage of the crop	Type of cultivation	Variety/ Hybrid	PDI	Other diseases observed
Belagavi	Gokak	Nesargi	15.90	74.77	Black	Flowering	Irrigated	Malini	30.12	-
		Yardal	15.77	74.79	Black	Flowering	Irrigated	Malini	33.59	-
		Murkibhavi	15.63	74.73	Black	Flowering	Irrigated	Malini	29.45	-
		Gokak	15.86	74.84	Black	Flowering	Irrigated	Malini	38.12	Anthracnose
								Taluk mean	**32.82**	
	Savadatti	Kurabetta	16.23	74.59	Black	Flowering	Rainfed	Gullakai	12.45	-
		Munavalli	15.63	74.51	Black	Flowering	Rainfed	Gullakai	18.19	-
		Yaragatti	16.23	74.50	Black	Flowering	Irrigated	Dharwad green	28.27	-
		Inamhongal	15.62	75.07	Black	Flowering	Irrigated	Dharwad green	29.15	-
		Hire ulligeri	15.66	75.09	Black	Harvesting	Irrigated	Green long	27.15	-
		Savadathi	15.75	75.12	Black	Harvesting	Irrigated	Dharwad green	26.15	-
		Kurabetta	16.23	74.59	Black	Flowering	Rainfed	Gullakai	24.13	-
		Munavalli	15.63	74.51	Black	Flowering	Irrigated	Gullakai	28.12	-
		Yaragatti	16.23	74.50	Black	Flowering	Irrigated	Dharwad green	21.10	-
								Taluk mean	**23.85**	
		District mean							**29.61**	

Contd….

Districts	Taluks	Villages	Latitude (°N)	Longitude (°E)	Soil type	Stage of the crop	Type of cultivation	Variety/ Hybrid	PDI	Other diseases observed
Dharwad	Dharwad	MARS, Dharwad	15.45	75.00	Black	Harvesting	Rainfed	Dharwad green	59.66	Downy mildew, Anthracnose, Wilt.
		Garaga	15.34	74.55	Black	Harvesting	Irrigated	Greenlong	40.16	Downy mildew
		Tadakoda	15. 60	74.99	Black	Harvesting	Irrigated	Dharwad green	40.86	Anthracnose
		Lokur	15.72	74.79	Black	Flowering	Rainfed	Gullakai	35.12	Downy mildew
		Narendra	15.36	75.12	Black	Harvesting	Irrigated	Dharwad green	31.29	-
		Yethinagudda	15.48	74.98	Black	Harvesting	Irrigated	Gullakai	38.15	-
		Maalapur	15.46	75.00	Black	Harvesting	Irrigated	Dharwad green	46.66	-
		Mrityunjayanagar	15.46	75.01	Black	Harvesting	Irrigated	Sarpan seeds	12.25	Downy mildew
		Marewada	15.43	75.05	Black	Harvesting	Irrigated	Dharwad green	14.15	Downy mildew
		Kavalgeri	15.49	75.07	Black	Harvesting	Irrigated	Greenlong	29.16	-
								Taluk mean	**34.74**	
	Hubballi	Varur	15.1	74.97	Black	Harvesting	Irrigated	Dharwad green	28.16	Downy mildew
		Agadi	14.82	75.46	Black	Flowering	Irrigated	Dharwad green	36.66	-
		Adaragunchi	12.97	77.56	Black	Harvesting	Rainfed	Dharwad green	42.78	-
		Samshi	15.21	75.30	Black	Harvesting	Irrigated	Dharwad green	43.29	-
		Betadur	15.22	75.19	Black	Harvesting	Irrigated	Green long	15.17	Downy mildew
		Ramankoppa	15.16	75.14	Black	Harvesting	Irrigated	Gullakai	13.53	Downy mildew
								Taluk mean	**31.39**	
		District Mean							**33.06**	

Contd….

Districts	Taluks	Villages	Latitude (°N)	Longitude (°E)	Soil type	Stage of the crop	Type of cultivation	Variety/ Hybrid	PDI	Other diseases observed
Haveri	Byadgi	Mallur	14.69	75.44	Black	Harvesting	Rainfed	Dharwad green	29.66	Downy mildew
		Angaragtti	14.66	75.44	Red	Harvesting	Rainfed	Ranebennur local	40.18	-
		Kadaramandalgi	14.64	75.51	Red	Harvesting	Rainfed	Dharwad green	35.69	-
		Motebennur	14.71	75.48	Red	Harvesting	Rainfed	Ranebennur local	30.15	-
		Haleshidenur	14.63	75.44	Black	Harvesting	irrigated	Ranebennur local	39.28	-
								Taluk mean	**32.84**	
	Hirekerur	Bannihatti	14.37	75.41	Red	Floweing	Rainfed	Ranebennur local	20.48	Anthracnose
		Hullatti	14.48	75.48	Red	Harvesting	Rainfed	Ranebennur local	32.12	-
		Masur	14.25	75.01	Red	Floweing	Irrigated	Ranebennur local	39.55	-
		Rattihalli	14.42	75.51	Black	Floweing	Rainfed	Ranebennur local	30.36	Anthracnose
								Taluk mean	**30.62**	
	Haveri	Nelogal	14.69	75.40	Red	Harvesting	Rainfed	Ranebennur local	26.12	Downy mildew
		Haveri	14.66	75.43	Red	Harvesting	Irrigated	Ranebennur local	20.16	Downy mildew
		Motebennur	14.63	75.42	Red	Harvesting	Rainfed	Ranebennur local	26.36	Downy mildew
		Kerimattihalli	14.75	75.37	Red	Harvesting	Rainfed	Ranebennur local	20.15	Anthracnose
		Vardi cross	14.32	75.54	Red	Harvesting	Rainfed	Ranebennur local	29.66	Downy mildew
								Taluk mean	**24.49**	

Contd….

Districts	Taluks	Villages	Latitude (°N)	Longitude (°E)	Soil type	Stage of the crop	Type of cultivation	Variety/ Hybrid	PDI	Other diseases observed
Haveri	Shiggaon	Bisalahalli	14.54	75.56	Black	Harvesting	Rainfed	Ranebennur local	23.20	Anthracnose
		Tadasa	13.90	75.70	Black	Harvesting	Irrigated	Ranebennur local	29.26	Anthracnose
		Niralagi	15.31	74.72	Red	Harvesting	Irrigated	Ranebennur local	22.18	Downy mildew
		Kamanhalli	15.01	75.19	Red	Harvesting	Rainfed	Ranebennur local	28.26	Downy mildew
		Gotagodi	15.02	75.18	Red	Harvesting	Rainfed	Ranebennur local	36.25	Downy mildew
		Shiggaon	14.51	75.41	Red	Harvesting	Rainfed	Ranebennur local	30.78	Downy mildew
								Taluk mean	**28.66**	
	Ranebennur	Gangajal tanda	-	-	Red	Harvesting	Rainfed	Ranebennur local	33.26	-
		Asundi	14.61	75.59	Red	Harvesting	Rainfed	Ranebennur local	30.15	-
		Guttal	14.62	75.62	Red	Harvesting	Rainfed	Ranebennur local	39.25	-
		Siddapur	14.34	75.89	Red	Harvesting	Rainfed	Ranebennur local	26.15	Anthracnose
		Halageri	14.61	75.63	Red	Harvesting	Rainfed	Ranebennur local	28.12	Downy mildew
		Ranebennur	14.61	75.62	Red	Harvesting	Rainfed	Ranebennur local	27.15	Downy mildew
		Chalageri	14.56	75.71	Red	Harvesting	Irrigated	Ranebennur local	18.66	-
		Medleri	14.66	75.73	Red	Harvesting	Irrigated	Ranebennur local	40.19	-
		Basirikatti	15.84	74.59	Red	Harvesting	Irrigated	Ranebennur local	58.15	-
		Chikkuruvathi	14.62	75.63	Red	Harvesting	Rainfed	Ranebennur local	26.77	Downy mildew
								Taluk mean	**32.78**	
		District mean							**29.87**	

Contd….

Districts	Taluks	Villages	Latitude (°N)	Longitude (°E)	Soil type	Stage of the crop	Type of cultivation	Variety/ Hybrid	PDI	Other diseases observed
Vijaypur	Basavana bagewadi	Agasabal	16.52	76.05	Black	Harvesting	Rainfed	Dharwad green	28.66	-
		Managuli	16.65	75.81	Black	Harvesting	Rainfed	Malini	40.15	-
		Ronihal	16.52	75.69	Black	Harvesting	Rainfed	Malini	36.69	-
								Taluk mean	**35.16**	
	Vijaypur	Jumanal	16.47	75.52	Black	Harvesting	Irrigated	Dharwad green	29.58	-
		Vijayapur	16.83	75.71	Black	Harvesting	Rainfed	Dharwad green	22.45	-
		Hittinalli	16.31	74.78	Black	Harvesting	Rainfed	Dharwad green	20.18	-
		Bhutanal thanda	16.89	75.71	Black	Harvesting	Irrigated	Dharwad green	22.26	-
		Arakeri	16.90	75.69	Black	Harvesting	Rainfed	Dharwad green	17.29	-
								Taluk mean	**22.35**	
	Indi	Tidagundi	17.21	75.80	Black	Harvesting	Rainfed	Dharwad green	27.69	-
		Horti	17.11	75.78	Black	Harvesting	Rainfed	Dharwad green	23.10	-
		Basanal	17.06	75.78	Black	Harvesting	Rainfed	Dharwad green	25.12	-
								Taluk mean	**25.30**	
		District mean							**27.60**	

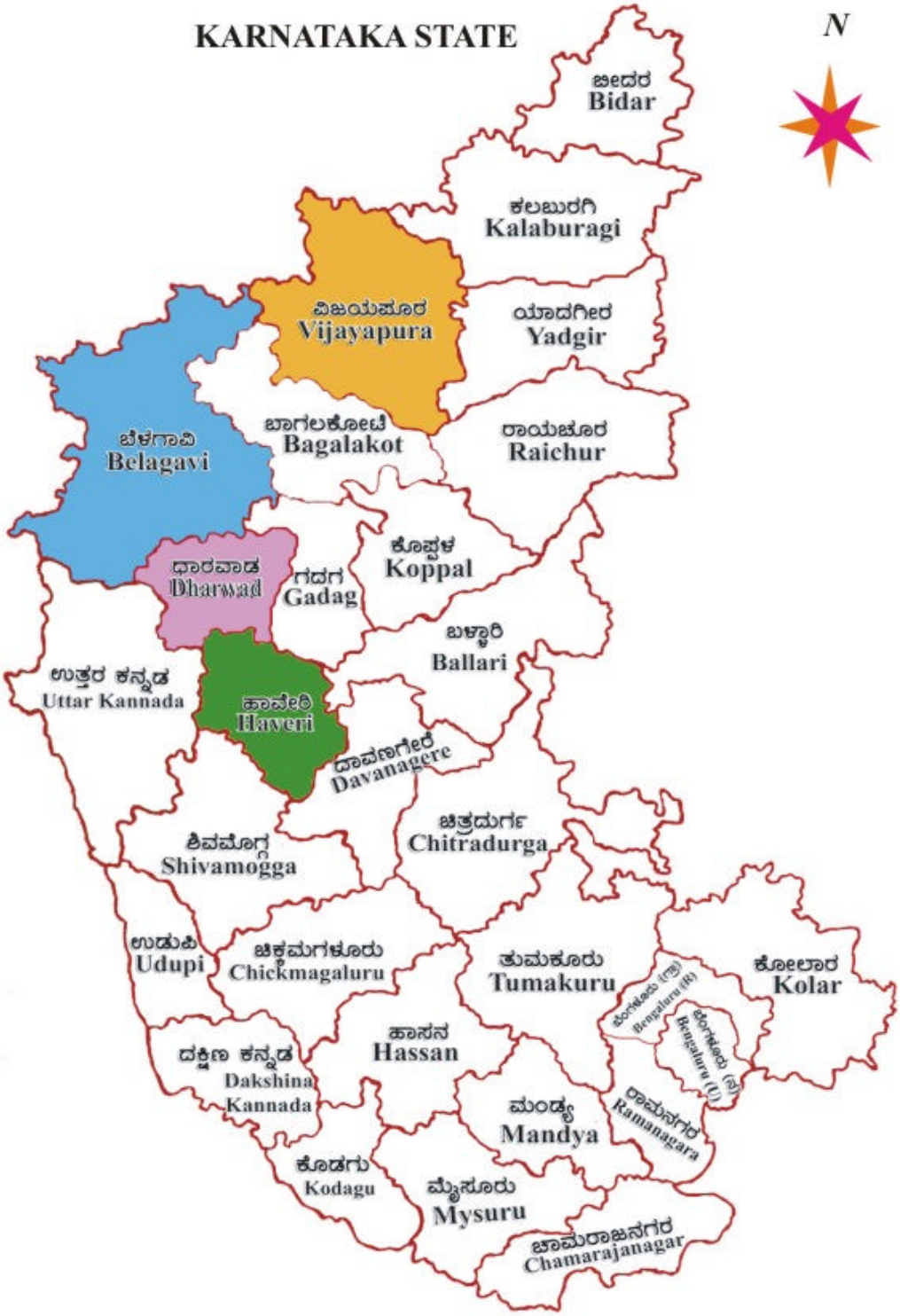


Fig. 1a: Karnataka map showing district-wise distribution of cucumber powdery mildew (open field)

Table 1b: Districts and Talukawise incidence of powdery mildew in cucumber (open field)

Sl No.	District	Taluk	Mean PDI	District mean PDI
1	Belagavi	Bailhongal	32.16	**27.21**
		Belagavi	20.02	
		Gokak	32.82	
		Savadathi	23.85	
2	Dharwad	Dharwad	34.74	**33.06**
		Hubballi	31.39	
3	Haveri	Shiggaon	28.66	**29.87**
		Haveri	24.49	
		Byadgi	32.84	
		Ranebennur	32.78	
		Hirekerur	30.62	
4	Vijaypur	Vijaypur	22.35	**27.60**
		Indi	25.30	
		Basavana bagewadi	35.16	

Table 1c: Influence of type of cultivation on severity of cucumber powdery mildew in northern Karnataka during *kharif* 2016

Sl No.	District	Taluk	Type cultivation		District mean PDI
			Rainfed (PDI)	Irrigated (PDI)	
1	Belagavi	Bailhongal	38.74	27.72	**27.21**
		Belagavi	17.43	22.65	
		Gokak	-	32.82	
		Savadathi	18.26	26.66	
2	Dharwad	Dharwad	47.39	28.61	**33.06**
		Hubballi	42.78	27.36	
3	Haveri	Shiggaon	29.62	25.72	**29.87**
		Haveri	25.57	20.16	
		Byadgi	34.99	39.28	
		Ranebennur	30.12	39.00	
		Hirekerur	27.65	39.55	
4	Vijaypura	Vijaypur	19.97	22.26	**27.60**
		Indi	25.30	-	
		Basavana bagewadi	35.17	-	
Mean per cent disease index			**30.23**	**29.32**	

Table 1d: Influence of variety/hybrids on severity of cucumber powdery in northern Karnataka during *kharif* 2016 (open field)

Sl No.	Variety/hybrid	Per cent disease index (PDI)				Mean PDI
		Belagavi	Dharwad	Haveri	Vijaypura	
1	Malini	27.19	-	-	38.42	**32.80**
2	Dharwad green	32.85	38.17	32.68	24.04	**31.95**
3	Greenlong	24.66	22.17	-	-	**23.41**
4	Gullakai	20.72	28.93	-	-	**24.82**
5	Ranebennur local	-	-	30.44	-	**30.44**
6	Sarpan hybrid	-	12.25	-	-	**12.25**

Table 1e: Influence of stage of crop on severity of cucumber powdery on different varieties/hybrids in northern Karnataka during *khharif* 2016 (open field)

Sl No.	Stage of the crop	Per cent disease index (PDI) in different variety						Mean PDI
		Malini	Dharwad green	Green long	Gullakai	Ranebennur local	Sarpan hybrid	
1.	Flowering stage	28.48	37.46	22.16	23.60	30.13	-	**28.36**
2.	Harvesting stage	18.455	36.075	33.655	32.65	31.705	12.25	**25.42**

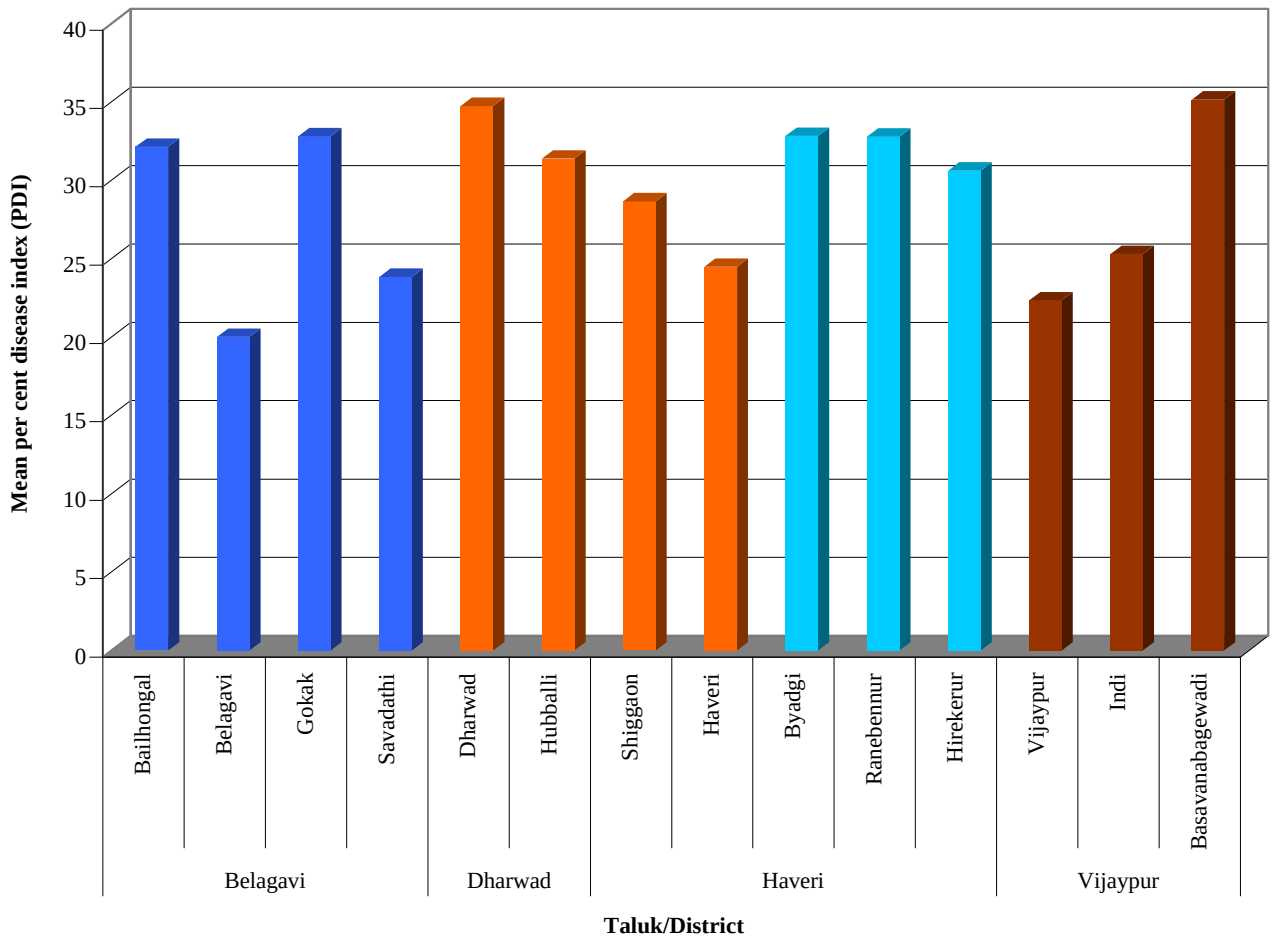


Fig. 1b: Taluka wise incidence of powdery mildew in cucumber (open field)

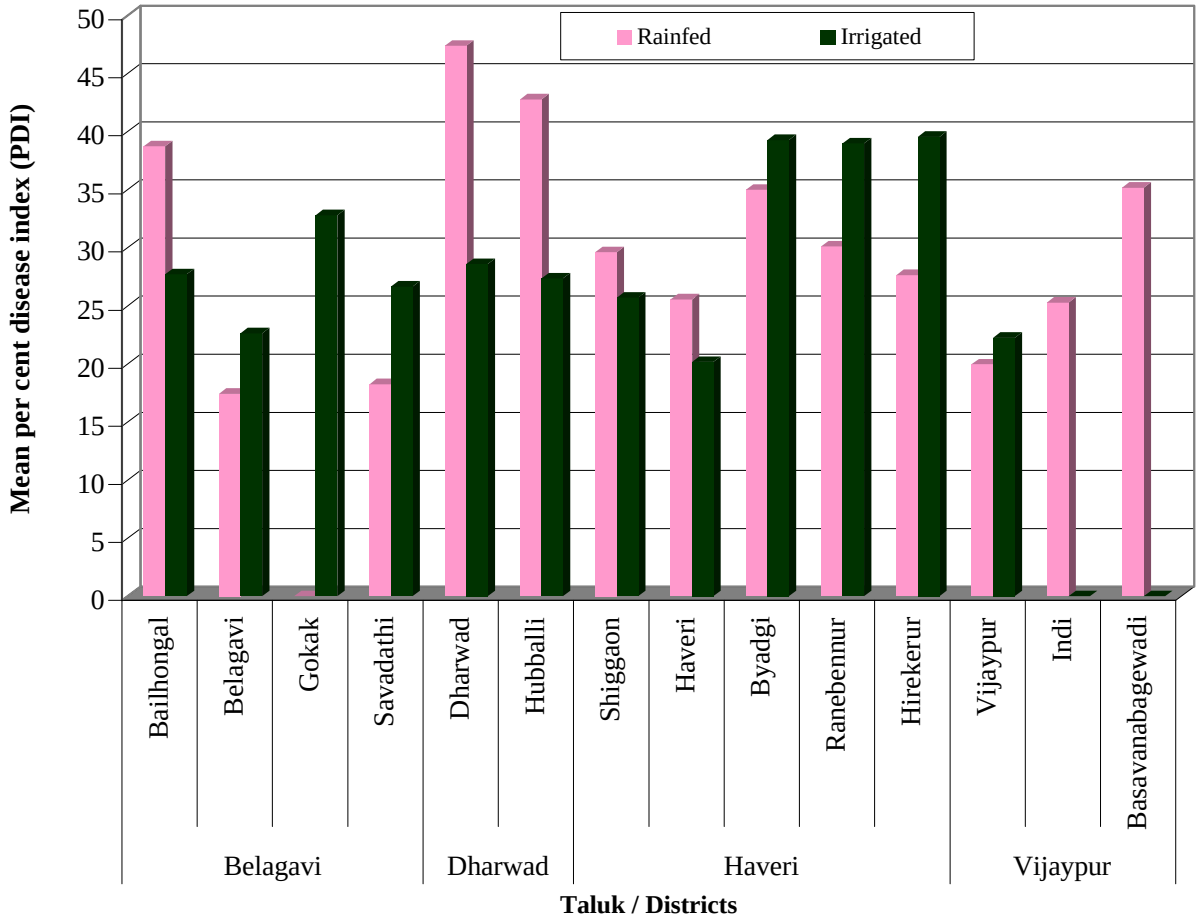


Fig. 1c: Influence of type of cultivation on severity of cucumber powdery mildew in northern Karnataka during *kharif* 2016

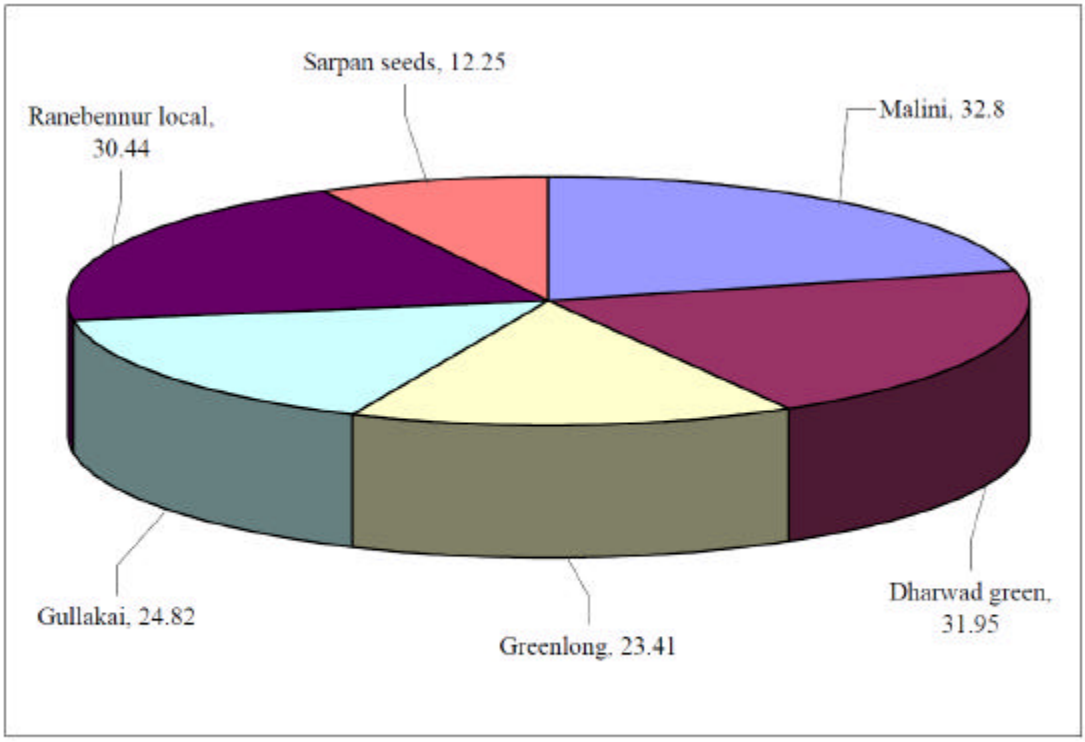


Fig. 1d: Mean disease incidence on various cucumber varieties/hybrids in northern Karnataka during *kharif*- 2016 (open field)

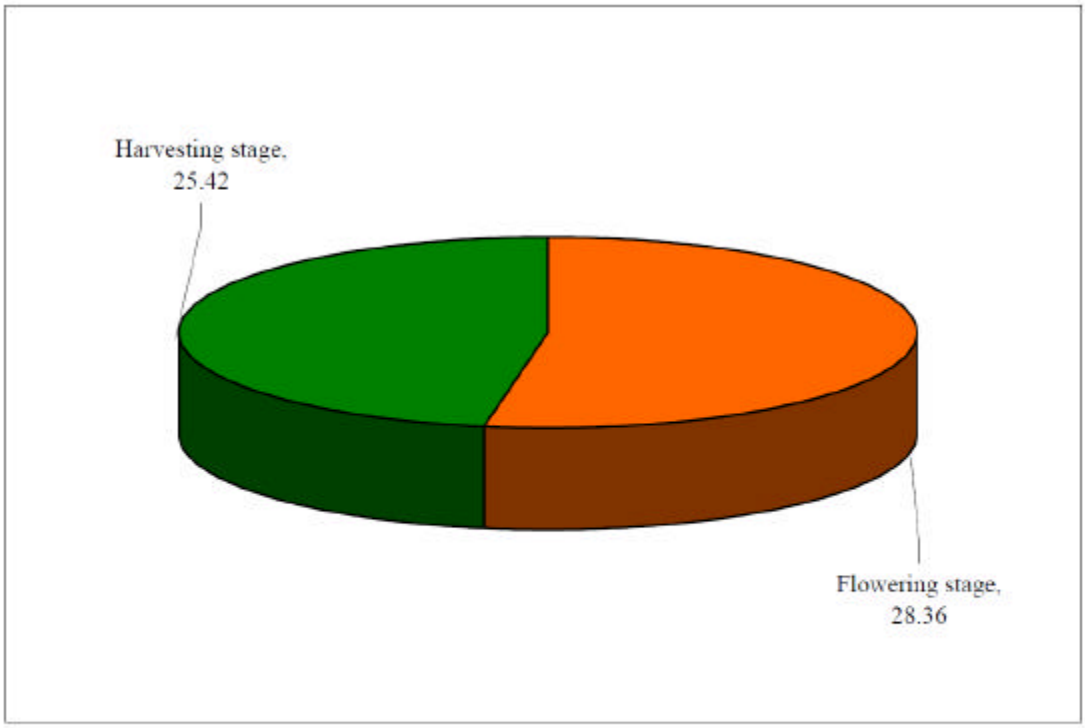


Fig. 1e: Influence of stage of crop on severity of cucumber powdery mildew in northern Karnataka during *kharif* -2016 (open field)

a) Powdery mildew severity at Bailawad cross (Belagavi)

b) Powdery mildew severity at Basirakatti village (Haveri)

c) Powdery mildew severity at MARS (Dharwad)

d) Least disease severity at K.K. Koppa (Belagavi)

Plate 4a: Powdery mildew severity in different farmers field during survey (open field)

In Belagavi district, four taluka's were surveyed, *Viz.,* Belagavi, Bailhongal, Savadathi and Gokak. In Belagavi taluka the survey was conducted in five villages. Among them the maximum severity (29.18 %) was recorded in Sutagatti village followed by Hulikatti village with severity of 24.15 % per cent. Where as least severity (10.25 %) was recorded in K. K Koppa village. Similarly in Bailhongal the survey was conducted in nine villages, among them maximum severity (63.08 %) was recorded in Bailwad cross followed by Kadrohalli village with the severity (36.17 %) whereas the least severity (20.79 %) was recorded in Badekollimath. In Gokak taluka, the maximum severity of 38.12 per cent was recorded in Gokak followed by Yardal with the severity of 33.59 per cent. The least disease incidence (29.45 %) was recorded in Murkibhavi. In Savadathi taluka maximum severity (29.15 %) was recorded in Inamhongal village followed by Yaragatti with a severity of 28.27 per cent and least disease severity was recorded in (18.19 %) Munavalli.

In Vijaypura district, three taluka's were surveyed, *viz.,* Vijaypura, Basavana bagewadi and Indi. In Basavana Bagewadi taluka the survey was conducted in three villages. Among them, the maximum disease severity (40.15 %) was recorded in Managuli followed by Ronihal village (36.69 %) where as least disease severity (28.66 %) was recorded in Agasbal village. In Vijaypura taluka the maximum severity (29.58 %) was recorded in Jumanal village followed by Vijaypura with the severity of 22.45 per cent and least severity (17.29 %) was recorded in Arakeri. In Indi taluka, maximum severity (27.69 %) was recorded in Tidagundi and minimum in (23.10 %) Horti village respectively. Among the talukas surveyed in Vijaypura district the maximum severity (35.16 %) was recorded in Basavana Bagewadi taluka and least severity (22.35 %) was observed in Vijaypura taluka.

During survey it was also observed that disease severity was more during flowering stage rather than harvesting stage. Among the different varieties tested Malini, Dharwad green and Ranebennur local had more disease compared to other varieties and their results also revealed that there is no much difference in rainfed and irrigated type of cultivationson appearance of disease and data presented in table 2c and 2d.

Crops grown in irrigated condition has more disease severity because of luxurious growth and it also observed that flood irrigation will keep moisture for longer duration which builds relative humidity. In case of rainfed condition also disease develops fairly because powdery mildew is disease of rainfed as well as irrigated conditions and this attributes the character of conidia which had ability to germinate under high moisture condition and also dry condition because of higher water content in conidia.

It was also observed that diseases like downy mildew, Alternaria leaf blight and anthracnose.prevailed in some parts of Haveri. Severe downy mildew incidence and less severity of powdery mildew were noticed. In some parts of Dharwad has anthranose and few spots have been found with Alternaria leaf blight.

4.2.1 Protected cultivation

A roving survey was carried out in Dharwad, Haveri, Belagavi and Vijaypura districts of northern Karnataka during late *kharif* 2016 to find out the severity of powdery mildew of cucumber grown under protected cultivation. The results of the survey are presented in Table 2a, 2b, 2c, 2d and Fig 2a, 2b, 2c, 2d and Plate 4b.

In Belagavi district, highest severity of cucumber powdery mildew on cucumber grown under protected condition was recorded at Yardal (69.12 %) followed by Naganur (67.12 %) village of Bailhongal taluka and least disease severity was found at Nesargi (45.66 %) village of Gokak taluka. In Dharwad district, highest disease severity was recorded at Saidapur farm (86.63 %) followed by Tadakoda (55.12 %) village of Dharwad taluka. Least disease severity was recorded at Chikkamalligawada (50.28 %) village of Dharwad taluka. In Haveri district, highest disease severity was recorded at Kamadod village of Ranebennur taluka (52.45 %) followed by Chikka kuruvathi (50.12 %) villages of Ranebennur taluka. Least disease severity was recorded at Gotagodi (34.82 %) village of Shiggaon taluka. Among three districts surveyed, highest disease severity was recorded in Dharwad (64.01 %) and minimum disease severity was recorded in (40.07 %) Haveri district.

Crop raised under protected conditions with normal planting has more severity than zig-zag planting and among the varieties cultivated, Dharwad green has more severity than Malini and Ranebennur local.

Table 2a: Survey on severity of powdery mildew of cucumber under protected cultivation in northern Karnataka during *kharif* 2016

SI. No.	Belagavi district	Village	Latitude (°N)	Longitude (°E)	Size of polyhouse (gunta)	Age of polyhouse (Months)	Genotype	Planting method	Stage of the crop	Previous crop	Ventilation type	(PDI)	Other Diseases/ pests observed
1	Bailhongal	Bailhongal	15.81	74.86	5	12	Malini F1	Zig-Zag	Fruiting	Capsicum	NV*	66.12	-
		Naganur cross	15.83	74.80	10	8	Malini F1	Zig-Zag	Fruiting	No crop	NV	67.12	Whiteflies
		Hire Bagevadi	15.77	74.64	5	6	Malini F1	Zig-Zag	Fruiting	No crop	NV	33.15	Whitefly and mites
			Taluka mean 55.46										
2	Gokak	Nesargi	15.90	74.77	5	5	Malini F1	Zig-Zag	Fruiting	No crop	NV	45.66	-
		Yardal	15.77	74.79	5	15	Malini F1	Zig-Zag	Fruiting	No crop	NV	69.12	Angular leaf blight
		Gokak	15.86	74.84	5	36	Malini F1	Normal	Vegetative	Gerbera	NV	47.66	Leaf minor, angular leaf blight
		Taluka mean 54.14											
3	Belagavi	K.K. Koppa	15.85	74.50	5	10	Malini F1	Normal	Fruiting	Capsicum	NV	59.12	Leaf minor
		District mean 56.24											

NV*= Natural ventilation

Contd….

SI. No.	Dharwad district	Village	Latitude (°N)	Longitude (°E)	Size of polyhouse (gunta)	Age of polyhouse (Months)	Genotype	Planting method	Stage of the crop	Previous crop	Ventilation type	(PDI)	Diseases and pests observed
4	Dharwad	Saidapur farm	15.47	74.97	5	24	Dharwad green	Normal	Fruiting	Capsicum	NV	86.63	Aphids
		Chikka malligewada	15.48	74.95	5	5	Dharwad green	Normal	Last picking	No crop	NV	50.28	Mites and aphids
		Tadakoda	15.60	74.89	5	3	Dharwad green	Zig-Zag	Fruiting	No crop	NV	55.12	Angular leaf blight
		District mean 64.01											
	Haveri district	**Village**	**Latitude (°N)**	**Longitude (°E)**	**Size of polyhouse (gunta)**	**Age of polyhouse (Months)**	**Genotype**	**Planting method**	**Stage of the crop**	**Previous crop**	**Ventilation type**	**(PDI)**	**Diseases and pests observed**
5	Ranebennur	Chalageri	14.56	75.71	5	24	Ranebennur local	Normal	Flowering	No crop	NV	33.39	-
		Kamadod	14.57	75.68	5	5	Ranebennur local	Normal	Harvesting	No crop	NV	52.45	-
		Chikka kuruvathi	14.62	75.63	5	3	Ranebennur local	Zig-Zag	Fruiting	No crop	NV	50.12	Whiteflies
	Shiggaon	**Taluka mean 45.32**											
		Gotagodi	15.02	75.18	5	10	Ranebennur local	Zig-Zag	Fruiting	Nursery	NV	**34.82**	-
		District mean 40.07											

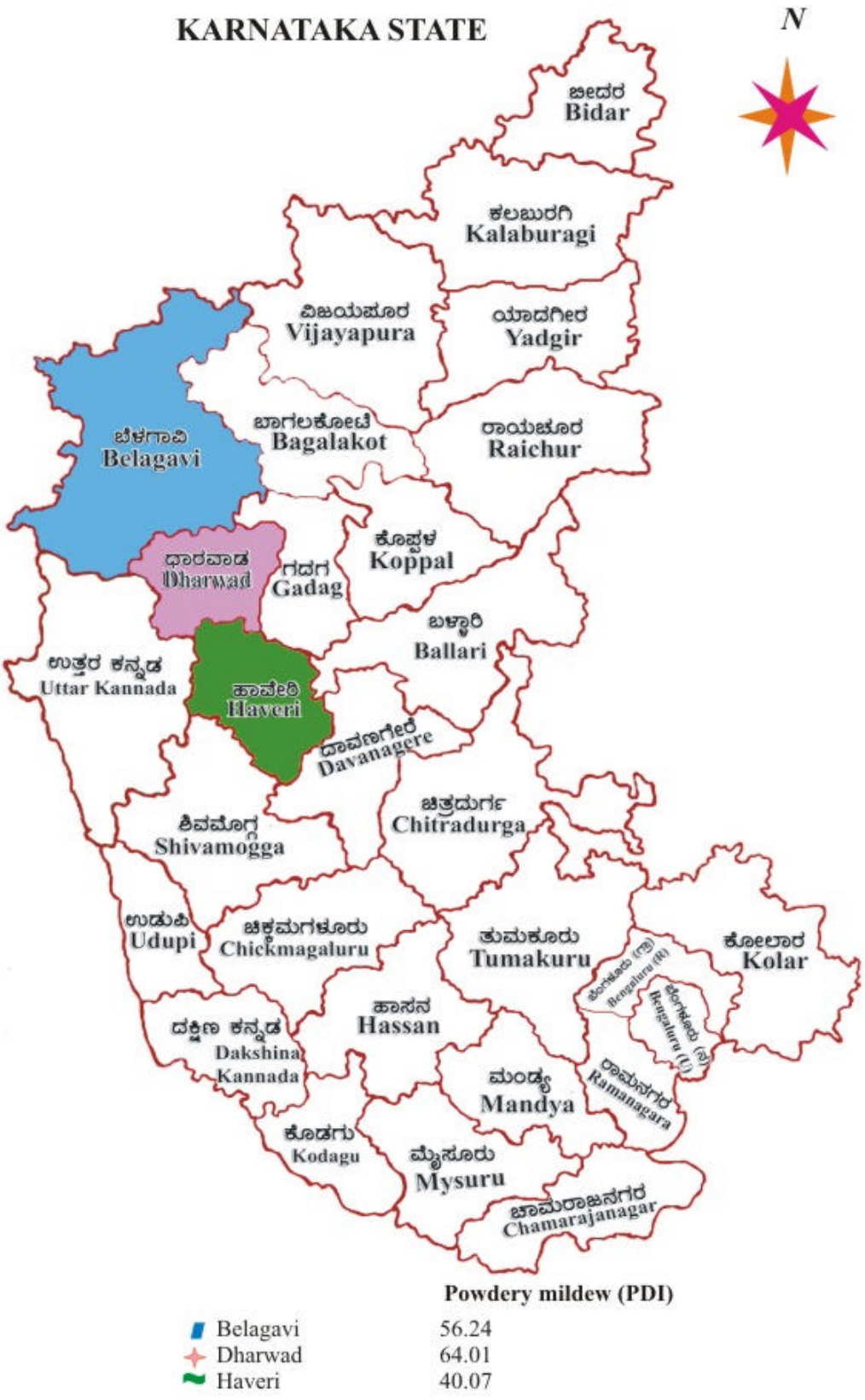


Fig. 2a: Karnataka map showing district-wise distribution of cucumber powdery mildew in protected cultivation

Table 2b: Taluka wise incidence of cucumber powdery mildew in protected cultivation during *kharif* 2016

Sl No.	District	Taluk	Mean PDI taluk	Mean PDI of district
1	Belagavi	Bailhongal	55.46	**56.24**
		Gokak	54.14	
		Belagavi	59.12	
2	Dharwad	Dharwad	64.01	**64.01**
3	Haveri	Ranebennur local	45.32	**40.07**
		Shiggaon	34.82	

Table 2c: Effect of planting method on severity of cucumber powdery mildew under protected cultivation in northern Karnataka during *kharif* 2016

Sl No.	District	Taluk	Zig-zag planting	Normal planting	Mean PDI of district
1	Belagavi	Bailhongal	55.46	-	**56.24**
		Gokak	57.39	47.66	
		Belagavi	-	59.12	
2	Dharwad	Dharwad	55.12	68.46	**64.01**
3	Haveri	Ranebennur	50.12	42.92	**40.07**
		Shiggaon	34.82	-	
	Mean		**50.58**	**54.54**	

Table 2d: Effect of genotype on severity of cucumber powdery mildew under protected cultivation in northern Karnataka during *kharif* 2016

Sl No.	Genotype/variety	Mean per cent disease index (PDI)
1	Malini	55.42
2	Dharwad green	64.01
3	Ranebennur local	42.70

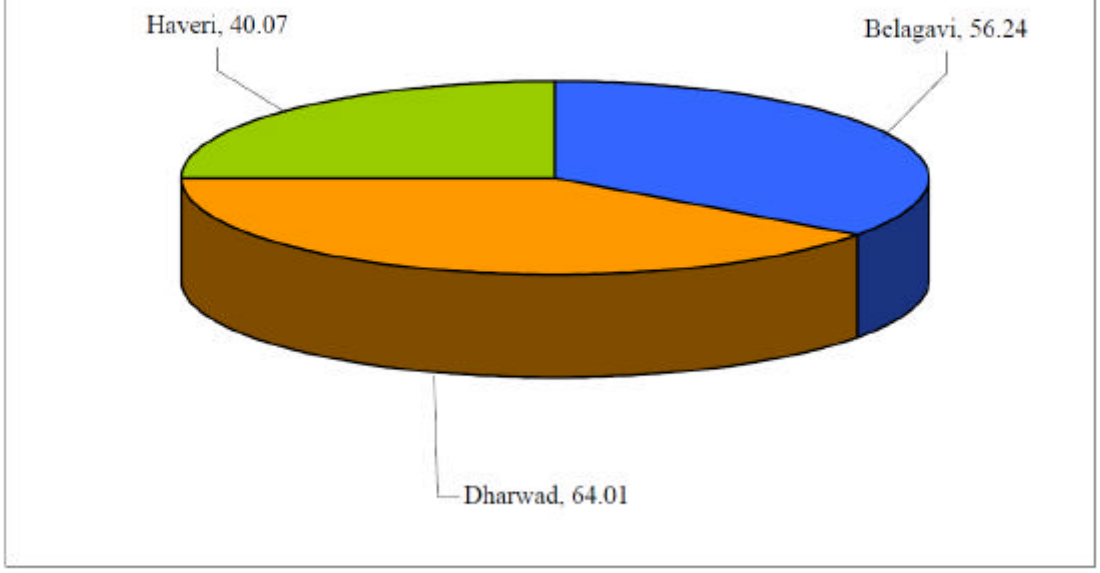


Fig. 2b: District-wise incidence of cucumber powdery in protected cultivation

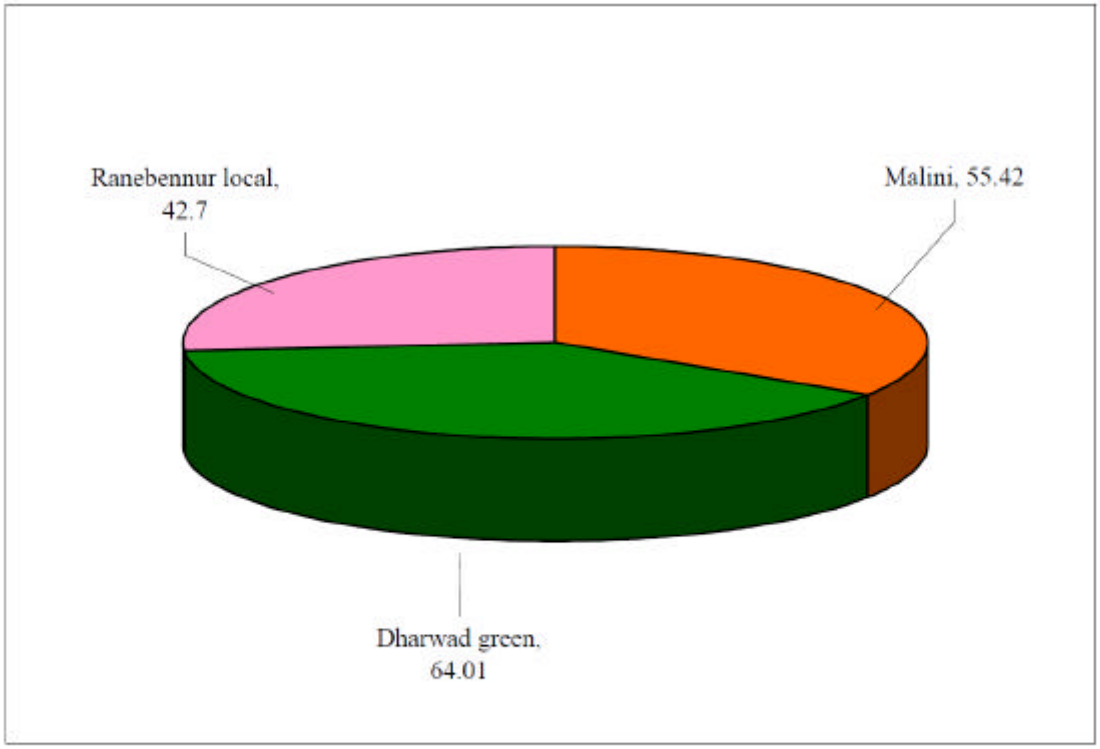


Fig. 2c: Effect of genotype on severity of cucumber powdery mildew under protected cultivation in northern Karnataka during *kharif* -2016

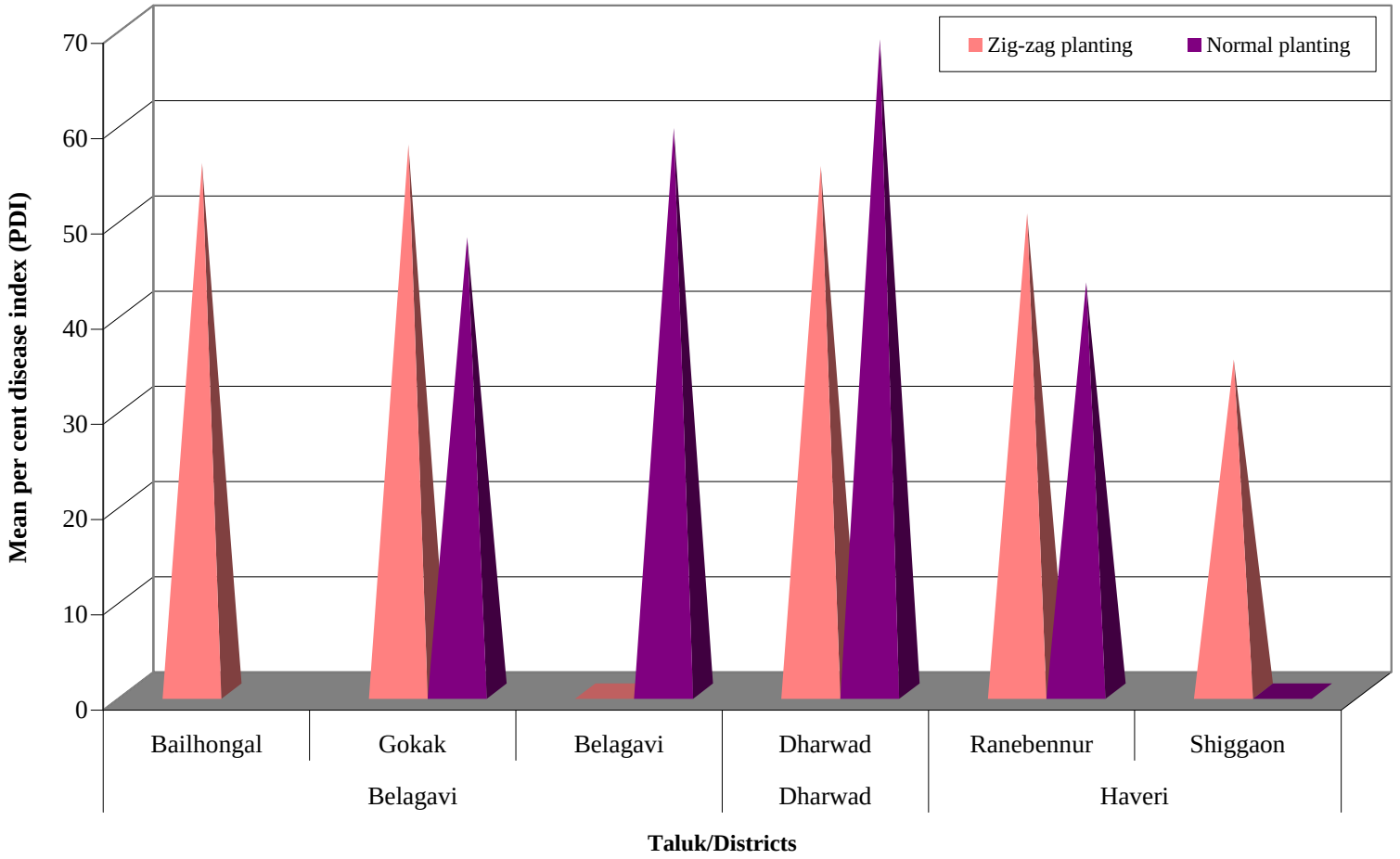


Fig. 2d: Effect of planting method on severity of cucumber powdery mildew under protected cultivation in northern Karnataka during *kharif* - 2016

a) Powdery mildew severity in Challageri village

b) Powdery mildew severity in Saidapur Farm

c) Powdery mildew severity in Yardal village (Gokak, Belagavi)

Plate 4b: Powdery mildew severity in farmers polyhouse during survey

From above survey results revealed that severity was more in protected cultivation. In general it is because of high relative humidity, temperature and luxurious plant growth. Where ever fertigation practiced regular water and nutrient supplement leads to luxurious growth and created microclimate favourable for disease development. Sprinkler irrigation is a practice which keeps leaf surface wetness it is also importanat parameter where inoculom builds, germinate and stable conditions of weather parameter lead to disease progress in polyhouse conditions.

4.3 Molecular characterization of pathogen

4.3.1 Isolation of Genomic DNA

Genomic DNA of the fungus was isolated by C-TAB (Cetyl trimethyl ammonium bromide) method. The obtained DNA was observed by running 1 % Agarose gel electrophoresis and results presented in Table 3.

4.3.2 Amplification of ITS1 and ITS4 region

The full length ITS rDNA region was amplified with ITS1 (5’ TCCGTAGGTGAACCTGCGG-3') and ITS4 (5’-TCCTCCGCTTATTGATATGC-3’) primers and DNA amplicon was observed at the region 529 bp. The amplified products were checked on 1 % Agarose gel electrophoresis (Plate 5a and 5b).

4.3.3 Sequences of *Erysiphe cichoracearum* ITS rDNA

DNA sequencing: The DNA sequences were obtained for ITS rDNA. The sequence of the isolate aminocoding given below.

GTATTTTTCACCCATAGTCTTTTGCGCACTTTTTGTTTCCTGGGCGAGTTCGC
GCCACCAGGACCCAACCATAAACCTTTTTTTATGCAGTTGCAATCAGCGTCA
GTATAATAATTCAATTTATTAAAACTTTCAACAACGGATCTCTTGGTTCTGG
CATCGATGAAGAACGCAGCGAAATGCGATACGTAGTGTGAATTGCAGAATT
CAGTGAATCATCGAATCTTTGAACGCACATTGCGCCCTTTGGTATTCCAAAG
GGCATGCCTGTTCGAGCGTCATTTGTACCCTCAAGCTTTGCTTGGTGTTGGG
CGTCTTTTTGTCTCTCCCCTTGTTGGGGGAGACTCGCCTTAAAACGATTGGC

Table 3: Comparison and identity of *Erysiphe cichoracearum* causal agent of cucumber powdery mildew with referred isolates from NCBI Gen bank

Sl No.	Accession number	Hit results	Sequence homology (%)	Author	Submission
1	AF011297.1	*Erysiphe cichoracearum* internal transcribed spacer, complete sequence	95	Saenz, and Taylor (1997)	Submitted (26-JUN-1997) Department of Plant and Microbial Biology, University of California at Berkeley, 111 Koshland Hall, Berkeley, CA 94720-3102, USA.
2	AF073345.1	*Erysiphe cichoracearum* 18S ribosomal RNA gene, partial sequence, ITS 1, 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence	94	Cunnington, J. H., Takamatsu, S., Lawrie, A. C. and Pascoe, I. G.	Submitted (22-JUN-1998) Applied Biology and Biotechnology, R.M.I.T. University, G.P.O. Box 2476V, Melbourne, Victoria 3001, Australia.
3	AF073345.1	*Erysiphe cichoracearum* 18S ribosomal RNA gene partial sequence internal transcribed spacer 1, 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNAgene, partial sequence.	96	Cunnington,J.H., Takamatsu,S., Lawrie,A.C. and Pascoe,I.G.	Submitted (22-JUN-1998) Applied Biology and Biotechnology, R.M.I.T. University, G.P.O. Box 2476V, Melbourne, Victoria 3001, Australia

AGCCGACCTACTGGTTTTCGGAGCGCAGCACAAATTTGCGCCTTCCAATCCA
CGGGGCGGCATCCAGCAAGCCTTTGTTTTCTATAACAAATCCACATTTTGAC
CTCGGATCAGGTAGGGATACCCGCTGAACTTAAGCATATCAATAAGCCGGA
GGAA and thus obtained sequence was compared with the reference fungus sequence available at NCBI. NCBI BLAST result confirmed that, among total 112 hits available in NCBI accessions were showing maximum 96 per cent sequence similarity with ITS1 and 5.8S-ITS2 region of *E. cichoracearum* and obtained sequence codes for 177 amino acids. Therefore, it is confirmed that causal pathogen of cucumber powdery mildew of Dharwad region is *E. cichoracearum.*

Amino acid coding of obtained nucleotide sequence of *Erysiphe cichorcearum* Dharwad isolate

```
1 ATG GTA TTT TTC ACC CAT AGT CTT TTG CGC ACT TTT TGT TTC CTG 45
1 Met Val Phe Phe Thr His Ser Leu Leu Arg Thr Phe Cys Phe Leu 15

46 GGC GAG TTC GCT CGC CAC CAG GAC CCA ACC ATA AAC CTT TTT TTA 90
16 Gly Glu Phe Ala Arg His Gln Asp Pro Thr Ile Asn Leu Phe Leu 30

91 TGC AGT TGC AAT CAG CGT CAG TAT AAT AAT TCA ATT TAT TAA AAC 135
31 Cys Ser Cys Asn Gln Arg Gln Tyr Asn Asn Ser Ile Tyr End Asn 45

136TTT CAA CAA CGG ATC TCT TGG TTC TGG CAT CGA TGA AGA ACG CAG 180
46 Phe Gln Gln Arg Ile Ser Trp Phe Trp His Arg End Arg Thr Gln 60

181CGA AAT GCG ATA CGT AGT GTG AAT TGC AGA ATT CAG TGA ATC ATC 225
61 Arg Asn Ala Ile Arg Ser Val Asn Cys Arg Ile Gln End Ile Ile 75

226 GAA TCT TTG AAC GCA CAT TGC GCC CTT TGG TAT TCC AAA GGG CAT 270
76 Glu Ser Leu Asn Ala His Cys Ala Leu Trp Tyr Ser Lys Gly His 90

271 GCC TGT TCG AGC GTC ATT TGT ACC CTC AAG CTT TGC TTG GTG TTG 315
91 Ala Cys Ser Ser Val Ile Cys Thr Leu Lys Leu Cys Leu Val Leu 105

316 GGC GTC TTT TTG TCT CTC CCC TTG TTG GGG GAG ACT CGC CTT AAA 360
106 Gly Val Phe Leu Ser Leu Pro Leu Leu Gly Glu Thr Arg Leu Lys 120

361 ACG ATT GGC AGC CGA CCT ACT GGT TTT CGG AGC GCA GCA CAA ATT 405
121 Thr Ile Gly Ser Arg Pro Thr Gly Phe Arg Ser Ala Ala Gln Ile 135

406 TGC GCC TTC CAA TCC ACG GGG CGG CAT CCA GCA AGC CTT TGT TTT 450
136 Cys Ala Phe Gln Ser Thr Gly Arg His Pro Ala Ser Leu Cys Phe 150

451 CTA TAA CAA ATC CAC ATT TTG ACC TCG GAT CAG GTA GGG ATA CCC 495
151 Leu End Gln Ile His Ile Leu Thr Ser Asp Gln Val Gly Ile Pro 165

496 GCT GAA CTT AAG CAT ATC AAT AAG CCG GAG GAA TAA 531
166 Ala Glu Leu Lys His Ile Asn Lys Pro Glu Glu   177
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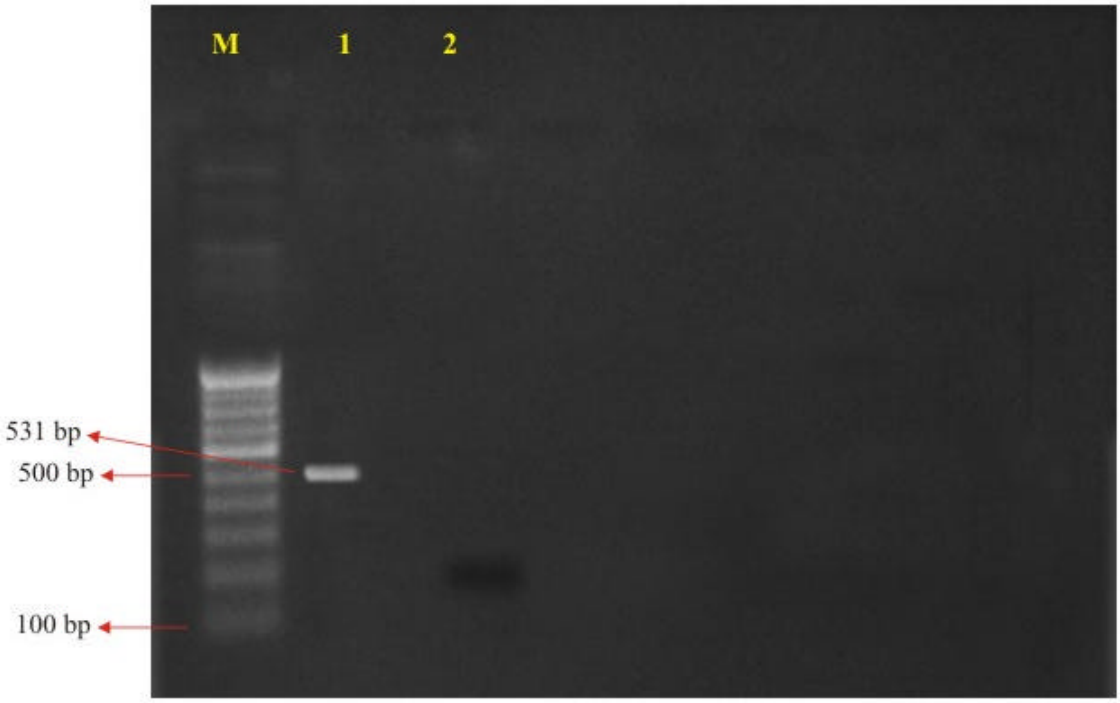


Lane M - 100 bp, 1 - *Erysiphe cichoracearum*, 2 - Water control

Plate 5a: Molecular detection of *Erysiphe cichoracearum* with ITS primers

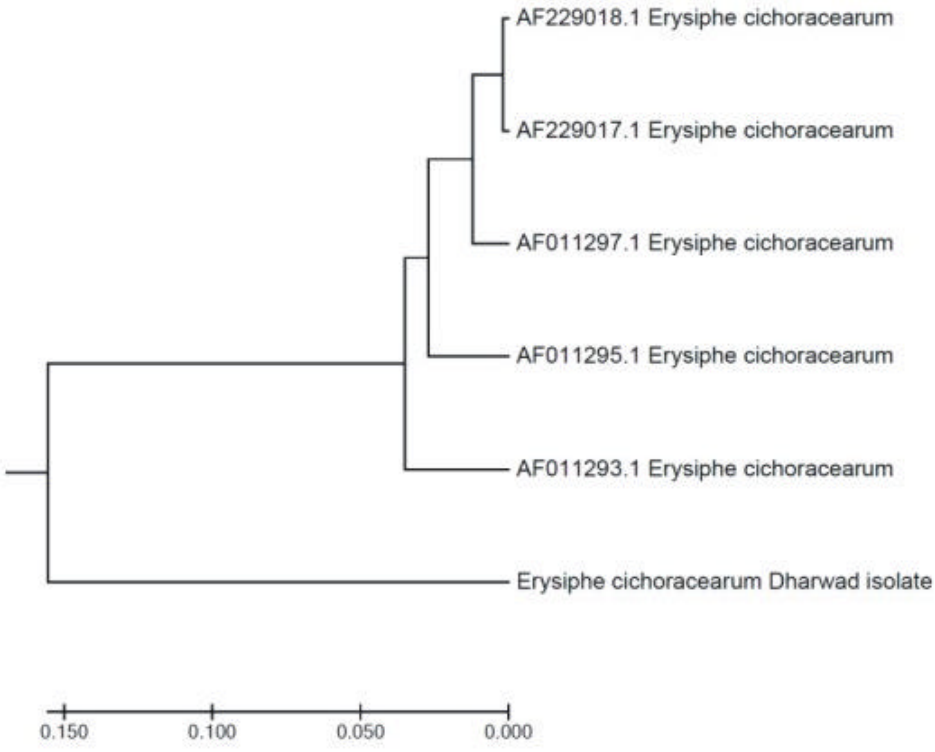


Plate 5b: Phylogenetic tree of *Erysiphe cichoracearum* Dharwad isolate with other *Erysiphe cichoracearum* referred isolates from NCBI GenBank

4.4 Effect of temperature on conidial germination of *E. cichoracearum*

The effect of different temperature levels on spore germination of *E. cichoracearum* was studied as explained in "Material and Methods" and the data are presented in Table 4a and Fig 3a. The effect of different temperature regimes on the conidial germination of fungus was significant. Maximum per cent conidial germination of 48.52 per cent was observed at 25^0 C, and at 30^0 C, 46.12 per cent which are on par with each. This was followed by 35^0 C and 20^0 C at which the conidial germination was 29.30 per cent and 21.15 per cent, respectively.

4.4.1 Effect of different relative humidity levels on conidial germination of *E. cichoracearum*

The effect of different relative humidity levels on spore germination of *E. cichoracearum* was studied as explained in "Material and Methods" and data presented in Table 4b, Fig 3b. The effect of different relative humidity regimes on the conidial germination of fungus was significant. Maximum conidial germination 46.72 per cent was observed at 85 per cent relative humidity, which was significantly superior to other treatments. Relative humidity of 90 percent was the next best treatment with 41.86 per cent conidial germination. The conidial germination of 41.61 per cent and 31.62 per cent was observed at 80 per cent and 95 per cent relative humidity, respectively which varied significantly among the treatments. However conidial germination was least 16.31 per cent was at 65 per cent relative humidity.

4.4.2 Effect of time of planting on powdery mildew development on cucumber

The results on the different dates of sowing of cucumber powdery mildew severity are presented in Table 5a, 5b, 5c, Fig 4 and Plate 6a, 6b. Results of the experiment revealed that sowing of crop in the I fortnight (FN) of July recorded the minimum mean disease severity (7.96 %) followed by crop sown in II FN of July (13.19 %) as against the crop sown in II FN of August (41.44 %) and I FN of September (33.78 %) and the I fortnight of October (33.77 %).

Table 4a: Effect of temperature on conidial germination of *E. cichoracearum*

Temperature (^{0}C)	Conidial germination (%)
5	7.22 (15.58)*
10	18.11 (24.01)
15	19.55 (27.39)
20	21.15 (29.62)
25	48.52 (45.07)
30	46.12 (43.75)
35	29.30 (34.07)
40	13.19 (21.29)
S.Em. ±	0.68
C.D. (P = 0.01)	2.81

* Figures in the parenthesis are arc sine transformed value

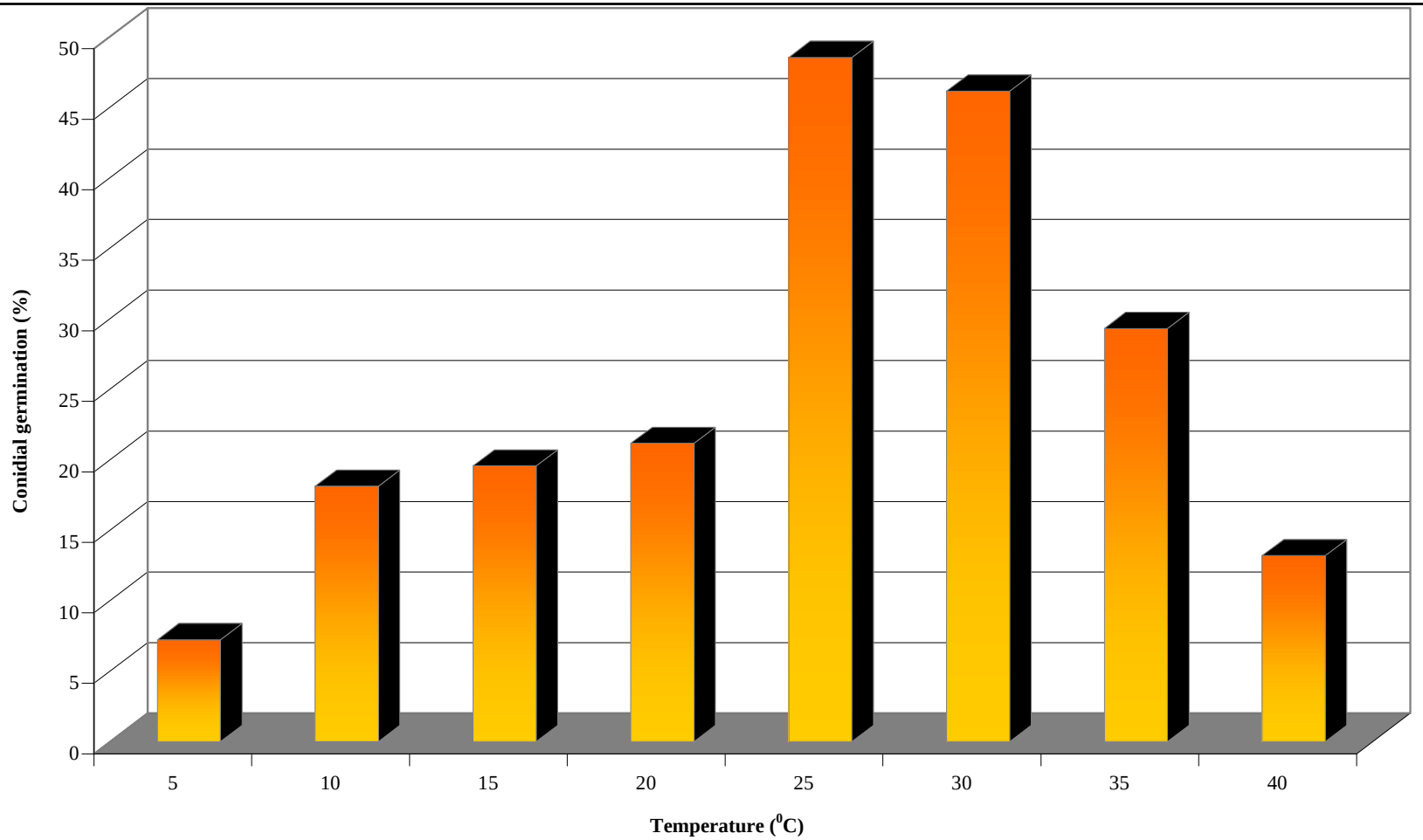


Fig. 3a: Effect of different temperature levels on conidial germination of *E. cichoracearum*

Table 4b: Effect of relative humidity on conidial germination of *E. cichoracearum*

Relative humidity (%)	Conidial germination (%)
65	16.31 (23.81)*
70	26.52 (30.99)
75	30.04 (33.22)
80	41.61 (40.15)
85	46.72 (43.10)
90	41.86 (40.30)
95	31.62 (34.20)
100	26.87 (31.21)
S.Em. ±	0.65
C.D. (P = 0.01)	2.69

* Figures in the parenthesis are arc sine transformed value

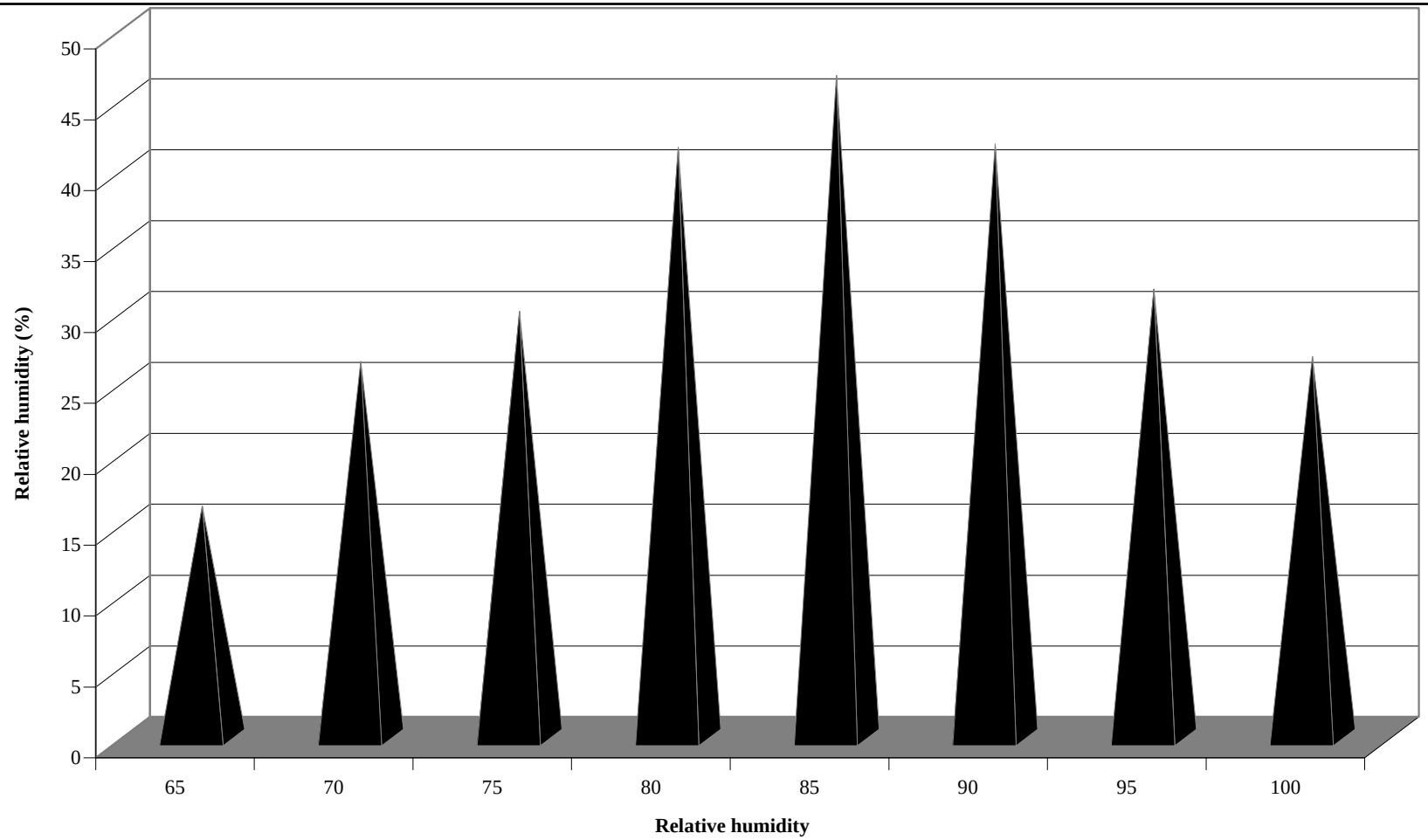


Fig. 3b: Effect of different relative humidity levels of conidial germination of *E. cichoracearum*

Table 5a: Effect of dates of sowing in relation to cucumber powdery mildew severity

Treatments (Date of sowing)	Per cent disease index (PDI)					Mean
	45 DAS	52 DAS	59 DAS	66 DAS	73 DAS	
I Fortnight of July	3.22 (10.33)*	5.28 (13.28)	7.48 (15.87)	9.15 (17.60)	14.66 (22.50)	**7.96 (16.38)***
II Fortnight of July	5.22 (13.20)	7.55 (15.94)	14.97 (22.75)	15.55 (23.22)	22.66 (28.41)	**13.19 (21.29)**
I Fortnight of August	4.15 (11.75)	22.66 (28.41)	36.79 (37.33)	53.26 (46.85)	59.35 (50.37)	**35.24 (36.40)**
II Fortnight of August	16.79 (24.18)	32.77 (34.91)	39.35 (38.84)	52.12 (46.20)	66.15 (54.40)	**41.44 (40.06)**
I Fortnight of September	11.45 (19.77)	28.12 (32.01)	31.11 (33.89)	38.35 (38.25)	59.86 (50.66)	**33.78 (35.52)**
II Fortnight of September	10.79 (19.17)	22.77 (28.49)	36.35 (37.66)	38.12 (38.11)	43.15 (41.05)	**30.24 (33.35)**
I Fortnight of October	11.25 (19.77)	26.66 (32.01)	30.54 (33.89)	38.55 (38.25)	56.45 (50.66)	**32.69 (35.52)**
S.Em. ±						1.87
C.D. (P = 0.05)						5.47

* Figures in the parenthesis are arc sine transformed value

Table 5b: Effect of dates of sowing in relation to weather parameter and severity cucumber powdery mildew

Dates of sowing	Standard meteorological week	Per cent disease index	Temperature (ºC)		Relative humidity (%)				Rainfall (mm)	Number of rainy days
			Max.	Min.	Max.	Min.	Total	Mean		
I Fortnight of July	36	3.22	27.4	19.7	84.7	73.4	158.1	79.1	0.4	00
	37	5.28	27.2	19.9	88.1	81.7	157	84.9	14.8	2
	38	7.48	25.6	20.0	90.4	85.1	159.1	79.6	11.8	3
	39	9.15	27.7	20.5	88.9	81.0	164.1	82.1	44	1
	40	14.66	27.2	19.5	88.6	70.6	98.3	49.1	6.2	1
II Fortnight of July	38	5.22	25.6	20	90.4	85.1	175.6	87.8	11.8	3
	39	7.55	27.7	20.5	88.9	81	157	84.9	44	1
	40	14.97	27.2	19.5	88.6	70.6	159.1	79.6	6.2	1
	41	15.55	28.9	20.2	88.9	75.3	164.1	82.1	38.6	1
	42	22.66	30.8	16.3	59.3	39	98.3	49.1	0	00
I Fortnight of August	39	4.15	27.7	20.5	88.9	81	157	84.9	44	1
	40	22.66	27.2	19.5	88.6	70.6	159.1	79.6	6.2	1
	41	36.79	28.9	20.2	88.9	75.3	164.1	82.1	38.6	1
	42	53.26	30.8	16.3	59.3	39	98.3	49.1	00	00
	43	59.35	31.1	18.5	63.3	39.1	102.4	51.2	00	00

Contd.…..

Dates of sowing	Standard meteorological week	Per cent disease index	Temperature (ºC)		Relative humidity (%)				Rainfall (mm)	Number of rainy days
			Max.	Min.	Max.	Min.	Total	Mean		
II Fortnight of August	42	16.79	30.8	16.3	59.3	39	98.3	49.1	00	0
	43	32.17	31.1	18.5	63.3	39.1	102.4	51.2	00	0
	44	39.35	31.5	18.4	65.3	43	108.3	54.1	0.4	0
	45	52.12	30.3	12.6	43	27.7	70.7	35.4	00	0
	46	66.15	31	17.2	68.9	45	113.9	56.9	5.4	1
I Fortnight of September	45	11.45	30.3	12.6	43.0	27.7	70.7	35.4	0.0	0.0
	46	28.12	31.0	17.2	68.9	45.0	113.9	56.9	5.4	1.0
	47	31.11	30.1	13.2	55.6	35.1	90.7	45.4	0.0	0.0
	48	38.35	31.4	13.1	45.7	29.9	75.6	37.8	0.0	0.0
	49	59.86	29.4	16.2	64.7	44.0	108.7	54.4	0.0	0.0
II Fortnight of September	47	10.79	30.8	16.3	59.3	39.0	98.3	49.1	0.0	0.0
	48	22.77	31.1	18.5	63.3	39.1	102.4	51.2	0.0	0.0
	49	36.35	31.5	18.4	65.3	43.0	108.3	54.1	0.4	0.0
	50	38.12	30.3	12.6	43.0	27.7	70.7	35.4	0.0	0.0
	51	43.15	31.0	17.2	68.9	45.0	113.9	56.9	5.4	1.0
I Fortnight of October	49	11.15	31.5	18.4	65.3	43.0	108.3	54.1	0.4	0
	50	26.66	30.3	12.6	43.0	27.7	70.7	35.4	0.0	0
	51	30.54	31.0	17.2	68.9	45.0	113.9	56.9	5.4	1
	52	38.55	30.1	13.2	55.6	35.1	90.7	45.4	0.0	0
	1 week (2017)	56.45	31.4	13.1	45.7	29.9	75.6	37.8	0.0	0

Table 5c: Correlation coefficient between weather parameters and per cent disease index (PDI) of Powdery mildew of cucumber caused by *Erysiphe cichoracearum*

Sl. No	Weather parameter	Correlation coefficient
1	Max. temperature	0.606
2	Min. temperature	-0.471
3	Max. relative humidity	-0.531
4	Min. relative humidity	-0.608
5	Rainfall	-0.421*
6	No. of rainy days	-0.422*

Significant at 5% level of probabilities

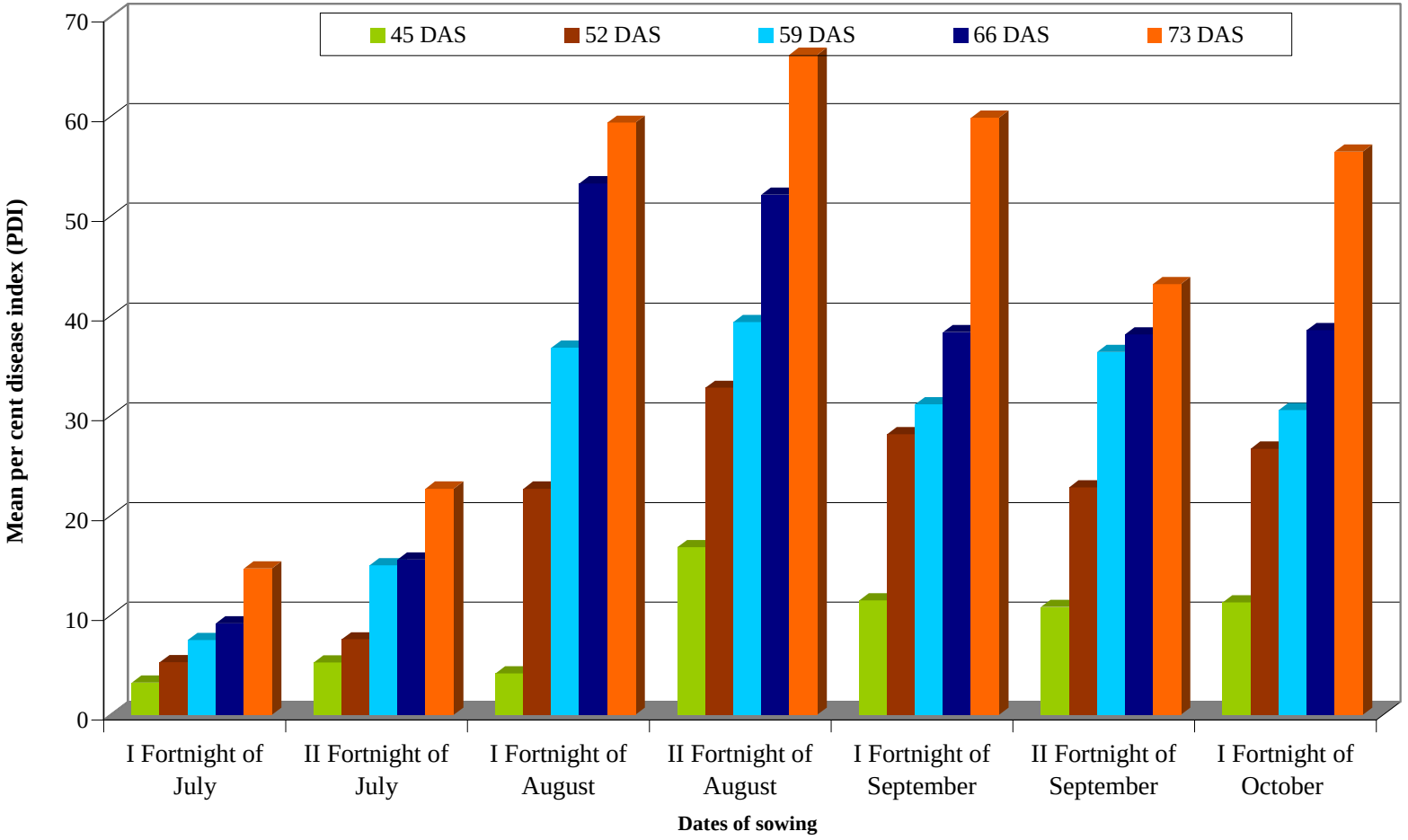


Fig. 4: Effect of dates of sowing in relation to cucumber powdery mildew severity

a) General field view of the sowing experimental block

b) T_1 - I fortnight of July

c) T_2 - II fortnight of July

d) T_3 - I fortnight of August

Plate 6a: Photograph depicts disease incidence on different dates of sowing

a) T_4 - II fortnight of August

b) T_5 - I fortnight of September

c) T_6 - II fortnight of September

d) T_7 - I fortnight of October

Plate 6b: Photograph depicts disease incidence on different dates of sowing

In first date of sowing infection started at 45 DAS and progressed till 73 DAS and it was up to 14.66 Per cent and in second date of sowing disease progressed up to 22.66 per cent and in third date of sowing it was upto 59.35 per cent. Afterwards, disease started earlier and progressed up to 66.15 per cent and in sixth and seventh date of sowing disease progressed up to 43.15 per cent and 59.85 per cent respectively.

Disease progress is very fast after 45 days after sowing and highest disease incidence was noticed at 73 DAS irrespective of dates of sowing. From the results of present study it is very clear that disease development will be very high if crop sown in between 1st fortnight of august and 1st fortnight of September.

4.4.3 Correlation of weather parameter with disease severity

The PDI obtained at different stages of crop growth and different dates of sowing were correlated with weather parameters prevailed during the respective dates of sowing. The correlation coefficients are presented in Table 5a. The results in Table 5a reveals that during 2016, maximum temperature (0.606) was positively correlated with PDI, Minimum temperature (-0.471), Morning relative humidity (-0.531) and evening relative humidity (-0.531) negatively correlated with PDI. While, rainfall (-0.421*) and number of rainy days were (-0.422*) was significantly negatively correlated with PDI at one per cent.

4.5 *In vitro* evaluation of Chemicals, Botanicals and bio-agents

4.5.1 *In vitro* evaluation of Systemic fungicides

Seven systemic fungicides were tested under *in vitro* conditions against *Erysiphe cichoracearum* on inhibition of conidial germination and the results are presented in Table 6, Fig 5 and Plate 7.

Among the tested fungicides, azoxystrobin was found to be significantly superior over all other fungicides tested and showed maximum inhibition of conidial germination upto 94.51 per cent at 0.15 per cent concentration followed by tebuconazole (90.54 %) Difenconazole 88.04 per cent at 0.15 per cent concentration and it was on par with propiconazole (85.41 %) at 0.15 per cent concentration. Minimum inhibition of conidial germination was recorded with myclobutanil (78.83 %) at 0.15 per cent concentration.

Table 6: Efficacy of systemic fungicides on inhibition of conidial germination of *Erysiphe cichoracearum*

Fungicides	Per cent inhibition			Mean
	Concentrations (%)			
	0.05	**0.1**	**0.15**	
Azoxystrobin (Amistar)	89.93 (71.48)*	93.61 (75.43)*	100.00 (89.96)*	**94.51 (78.96)***
Carbendazim (Bavistin)	79.05 (62.75)	81.22 (64.31)	85.29 (67.46)	**81.85 (64.84)**
Hexaconazole (Contaf)	80.87 (64.08)	85.05 (67.32)	86.44 (68.51)	**84.13 (66.64)**
Myclobutanil (Systhane)	72.94 (59.85)	80.41 (63.72)	83.13 (65.76)	**78.83 (63.11)**
Difenconazole (Score)	86.02 (68.07)	88.04 (69.85)	90.05 (71.71)	**88.04 (69.88)**
Propiconazole (Tilt)	82.42 (65.25)	84.25 (66.64)	89.55 (71.14)	**85.41 (67.68)**
Tebuconazole (Folicur)	83.69 (68.90)	91.04 (72.56)	93.60 (75.43)	**90.54 (72.30)**
Mean	**82.13 (65.76)**	**86.22 (68.54)**	**89.72 (72.85)**	**86.18 (69.05)**
		S.Em. ±		C.D. at 1 %
1. Fungicides (F)		0.69		2.64
2. Concentrations (C)		0.45		1.73
3. F × C		1.20		4.57

* Figures in the parenthesis are arc sine transformed value

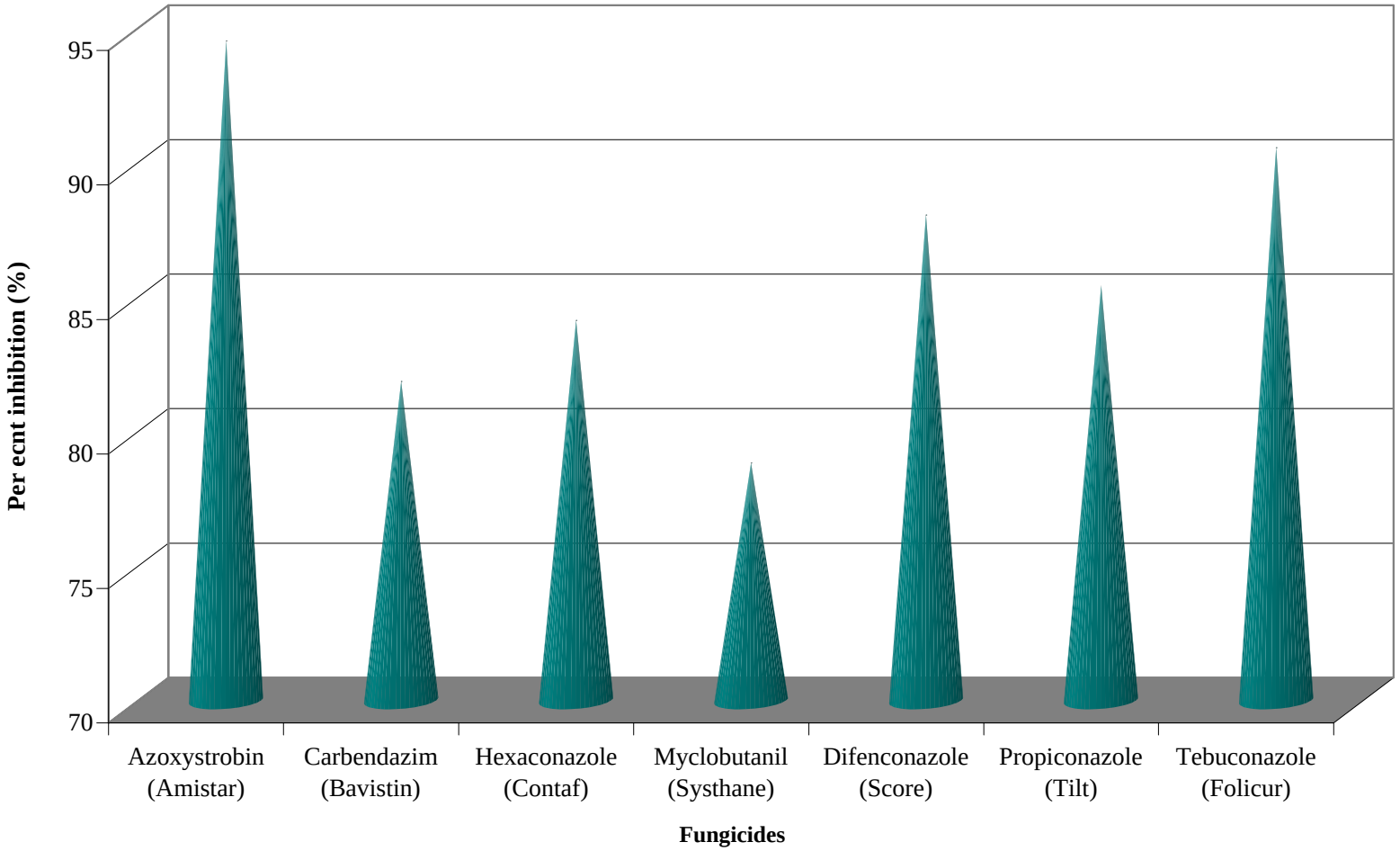
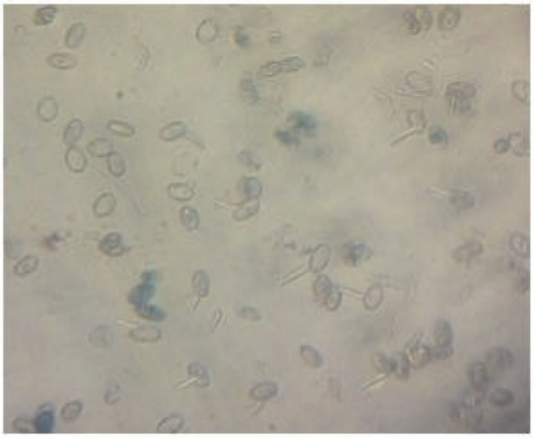
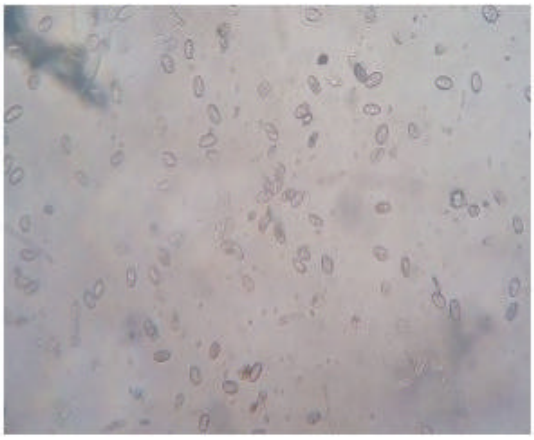


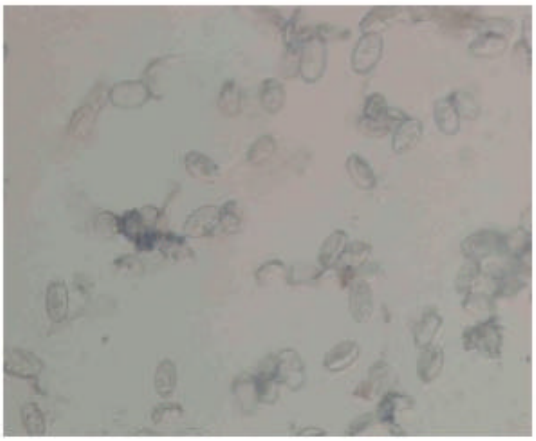
Fig. 5: Efficacy evaluation of systemic fungicides on inhibition of conidial germination of *Erysiphe cichoracearum*



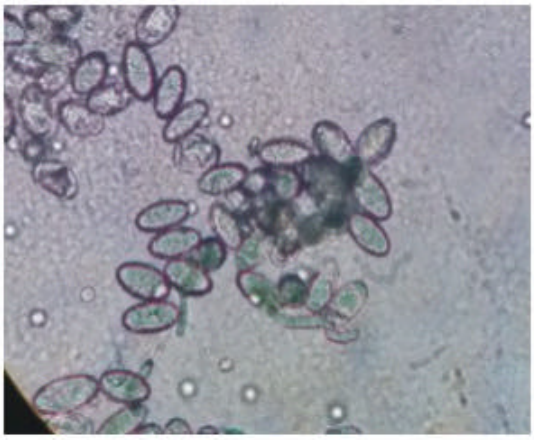
a) Conidial germination in control (sterile distilled water



b) Conidial Germination inhibition in Azoxystrobin @ 0.15%



c) Conidial germination inhibition in Nativo @ 0.15%



d) Conidial germination inhibition in *Reynoutriu sachhalensis* (Giant knot weed)

Plate 7: Inhibition of conidial germination in different chemicals and botanical

4.5.2 *In vitro* evaluation of Combi fungicides

Five combi fungicides were evaluated under *in vitro* conditions for their efficacy on inhibition of conidial germination of *Erysiphe cichoracearum* and the results are presented in Table 7, Fig. 6 and Plate 7.

Among the tested combi fungicides evaluated at different concentrations, tebuconazole 50 % + trifloxystrobin 25 % (Nativo) found to be significantly superior over other treatments and showed maximum inhibition (87.78 %) at 0.15 per cent followed by captan + hexaconazole (Taquat) which has recorded 74.65 per cent at 0.15 per cent concentration and minimum conidial germination inhibition was with combi fungicide found in carbendazim + mancozeb (Saaf) (56.02 %) at 0.05 per cent. In general, it was observed that as concentration increased the inhibition also increased in all the fungicides evaluated**.**

4.5.3 *In vitro* evaluation of bio-agents

Four bio-agents were **e**valuated under *in vitro* conditions for their efficacy on inhibition of conidial germination of *Erysiphe cichoracearum* and the results are presented in Table 8 and Fig 7. Among the various bioagnts evaluated, maximum inhibition of conidial germination was found with *Bacillus subtilis* (55.74 %) at 1.0 per cent concentration which was significantly superior over all treatments followed by *Pseudomonas fluorescens* (51.24 %) at 1.0 per cent concentration. Minimum conidial germination inhibition was found in *Lecanicillium lecanii (*27.33 %) at 0.5 per cent concentration.

4.5.4 *In vitro* evaluation of botanicals

Seven botanicals (Plate 5) and one organic product were **e**valuated under *in vitro* conditions for their efficacy to inhibit of conidial germination of *Erysiphe cichoracearum* and the results presented below Table 9 and Plate 7.

Among the botanicals evaluated, maximum inhibition (100 %) of conidial germination was found in *Reynotriu sachalensis* (Giant knotweed) at 20 per cent concentration which was superior over all other treatments followed by Nimbicidin (64.13 %) at 10 per cent concentration . Minimum conidial germination inhibition was

Table 7: Efficacy of combi fungicides on inhibition of conidial germination of *Erysiphe cichoracearum*

Fungicides	Per cent inhibition			Mean
	Concentrations (%)			
	0.05	**0.1**	**1.5**	
Carbendazim 12 % + Mancozeb 63 % (Saaf)	56.02 (48.44)*	61.54 (51.65)*	68.55 (55.88)*	**62.04 (51.99)***
Hexaconazole 5 % + Captan 70 % WP (Taquat)	69.80 (56.65)	73.66 (59.11)	80.48 (63.79)	**74.65 (59.85)**
Hexaconazole 4 % + Zineb 68 % + (Avatar)	62.23 (52.06)	67.99 (55.53)	73.89 (59.26)	**68.03 (55.62)**
Tebuconazole 50 % + Trifloxystrobin 25 % 5 WG (Nativo)	84.53 (66.82)	87.75 (69.54)	91.06 (72.65)	**87.78 (69.67)**
Fenamidone + Mancozeb 60 WG (10 % + 50 %) (Sectin 60 % WG)	62.23 (52.06)	66.51 (54.62)	71.89 (58.00)	**66.88 (54.89)**
Mean	**66.96 (55.19)**	**71.49 (58.09)**	**77.18 (61.91)**	**71.87 (58.00)**
			S.Em. ±	C.D. at 1 %
1. Fungicides (F)			0.47	1.82
2. Concentrations (C)			0.33	1.29
3. F × C			0.82	3.15

* Figures in the parenthesis are arc sine transformed value

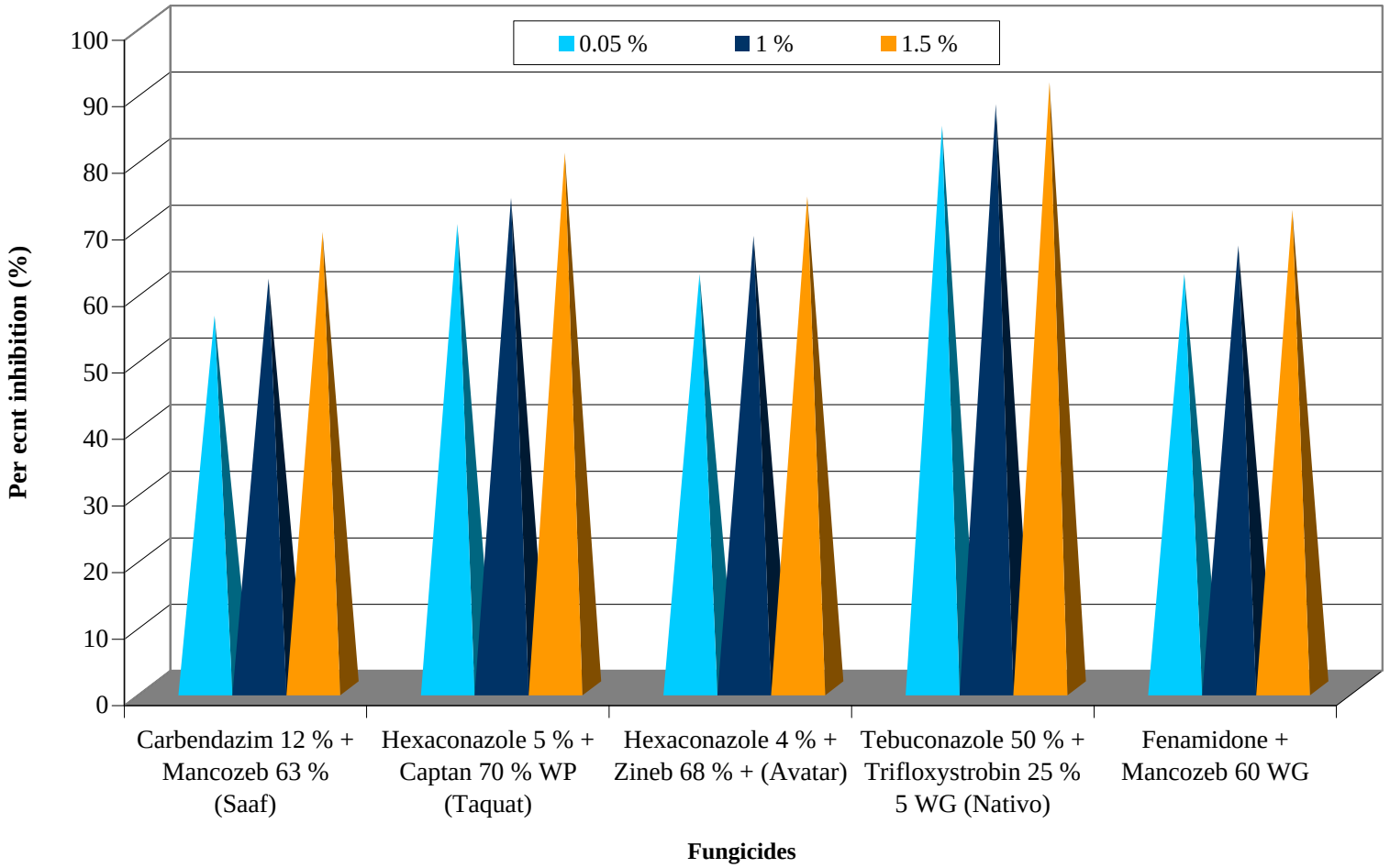


Fig. 6: Efficacy of combi fungicides on inhibition of conidial germination of *Erysiphe cichoracearum*

Table 8: Efficacy of bioagents on inhibition of conidial germination of *Erysiphe cichoracearum*

Bio-agents	Per cent inhibition		Mean
	Concentrations (%)		
	0.5	**1.0**	
Bacillus subtilis	51.70 (45.95)*	55.74 (48.27)*	**53.72 (47.11)***
Pseudomonas fluorescens	48.43 (44.08)	54.05 (47.30)	**51.24 (45.69)**
Trichoderma harzianum	33.32 (35.24)	36.89 (37.38)	**35.11 (36.32)**
Lecanicillium lecanii	27.33 (31.50)	32.52 (34.75)	**29.92 (33.14)**
Mean	**40.19 (39.19)**	**44.80 (41.92)**	**42.49 (40.56)**
		S.Em. ±	C.D. at 1 %
1. bioagents (F)		0.42	1.72
2. Concentrations (C)		0.30	1.22
3. F × C		0.59	2.44

* Figures in the parenthesis are arc sine transformed value

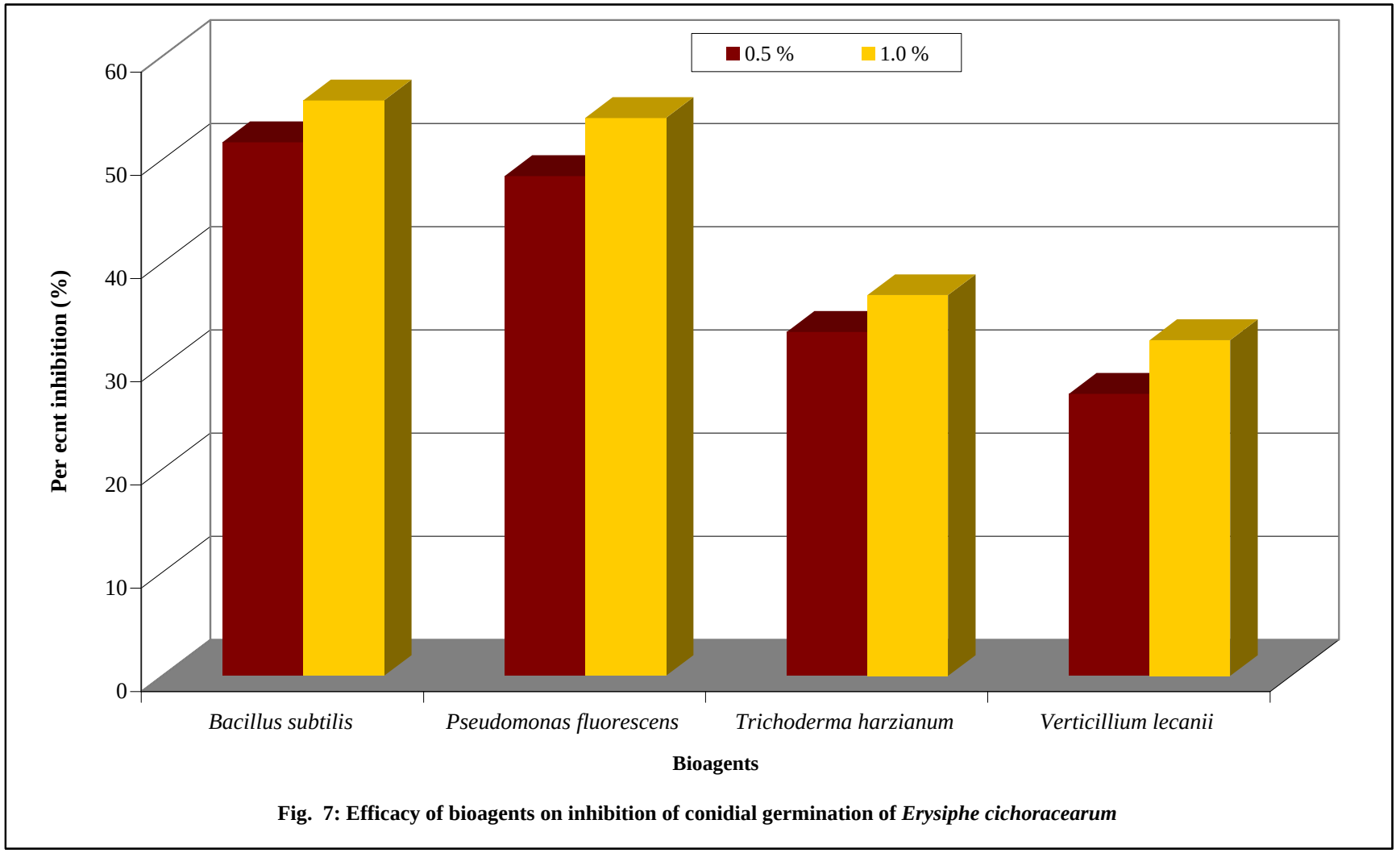


Fig. 7: Efficacy of bioagents on inhibition of conidial germination of *Erysiphe cichoracearum*

Table 9: Efficacy of botanicals on inhibition of conidial germination of *Erysiphe cichoracearum*

Botanicals/organic product	Conc. (%)	Inhibition (%)	Conc. (%)	Inhibition (%)	Mean
Reynotriu sachhalensis (Giant knot weed)	10	82.21	20	100	**91.10**
Parthenium hysterophorus (Congress grass)	10	43.26	15	53.98	**48.62**
Annona leaf extract (Custuard apple)	10	36.58	15	45.61	**41.09**
Ipomea leaf extract (Bind weed)	10	51.36	15	56.39	**53.87**
Ocimum leaf extract (Tulsi)	10	45.51	15	52.30	**48.90**
Nimbicidin (Neem oil 90.57%)	05	60.09	10	64.13	**62.11**
Sorghum leaf extract	15	33.25	20	41.55	**37.40**
Butter milk (Freshly prepared)	15	51.89	20	56.96	**54.42**
Mean	**-**	**50.51**	-	**58.86**	**54.68**

found with Sorghum leaf extract (33.25 %) at 15 per cent. Bio rational such like butter milk showed inhibition of conidial germination 56.96 per cent at 20 per cent concentration and whereas, least inhibition was observed (51.89 %) at 15 per cent butter milk.

4.6 Screening cucumber genotypes for disease resistance

Twenty three genotypes were screened against *E. cichoracearum* under natural epiphytotic conditions in the field to identify the resistance source during late *kharif* 2016 as described in “Material and Methods” and results are presented in Table 10, 11 and Plate 8a, 8b. The results from the experiment revealed that, out of twenty three genotypes screened, none was found to be immune or and resistant. However, fifteen genotypes *viz.*, Swathi, BSS-949, JK-special, Mahy Sylvia, Malini, Shirakawa, Yummy, Kareena, Green long, Ajeeth-99, White long, Encounter-962, Shalini, Ranebennur local and Sarpan hybrid were found to be moderately resistant with five grade and five genotypes *Viz.*, Chetak, Gullakai, Khushi, Sribasava and Harini were found to be moderately susceptible with seven grade and Mangalore local, Dharwad green and chitra showed highly susceptible reaction with maximum reaction of nine grade.

4.7 Integrated disease management

The concept of economically viable and ecofriendly management has encouraged the farmers to take up integrated plant protection especially in vegetables because of their raw consumption most oftenly. Experiment was conducted to evaluate spray schedule involving various fungicides, botanicals and bioagents and their combinations for the management of powdery mildew. Treatments were selected based on results obtained from *in vitro* evaluation and economically viable ones and proper in schedule was prepared for the management of disease and results of the experiment are presented in Table 12, Fig 8 and Plate 09a, 09b. Among the systemic fungicides tested, Azoxystrobin, and among the combi fungicides Nativo (tebuconazole 50 % + trifloxystrobin 25 %) was chosenas treatment similarly *Bacillus subtilis* was selected from bioagents and in botanicals *Reynoutria sachalinensis* (Giant knot weed) extract was selected for field experiment based on *In vitro* studies. In the present investigation, a field experiment was conducted during *Rabi*-2016-17 in MARS, UAS, Dharwad. Two

Table 10: Reaction of cucumber genotypes against powdery mildew caused by *Erysiphe cichoracearum* (0-9 scale)

SL. No.	Genotype	Maximum grade observed	Reaction type
1	Swathi	5	MR
2	BSS-949	5	MR
3	JK-special	5	MR
4	Mahy sylvia	5	MR
5	Chetak	7	MS
6	Mangalore local	9	HS
7	Malini	5	MR
8	Shirakawa	5	MR
9	Dharwad green	9	HS
10	Yummy	5	MR
11	Kareena	5	MR
12	Green long	5	MR
13	Ajeeth	5	MR
14	White long	5	MR
15	Gullakai	7	MS
16	Encounter-962	5	MR
17	Chitra	9	HS
18	Khushi	7	MS
19	Shalini	5	MR
20	Sribasava	7	MS
21	Ranebennur local	5	MR
22	Harini	7	MS
23	Sarpana hybrid	5	MR

MR – Moderately resistant MS – Moderately susceptible
HS – Highly susceptible

Table 11: Grouping of cucumber genotypes based on reaction against powdery mildew caused by *Erysiphe cichoracearum*

Grade	Reaction	Per cent infection	Entries	No. of genotypes
0	I	0	-	0
1	HR	Up to 1	-	0
3	R	1-10	-	0
5	MR	11-25	Swathi, BSS-949, JK-special, Mahy Sylvia, Malini, Shirakawa, Yummy, Kareena, Green long, Ajeeth-99, White long, Encounter-962, Shalini, Ranebennur local, Sarpana hybrid.	15
7	MS	26-50	Chetak, Gullakai, Khushi, Sribasava, Harini.	5
9	HS	More than 51	Chitra, Dharwad green, Mangalore local	3

a) General view of screening experimental plot

b) Highly susceptible : Mangalore local

c) Moderately susceptible : Malini

Plate 8a: General view of the screening experiment and grade observed

a) Highly susceptible : Chitra

b) Moderately resistant : Green long

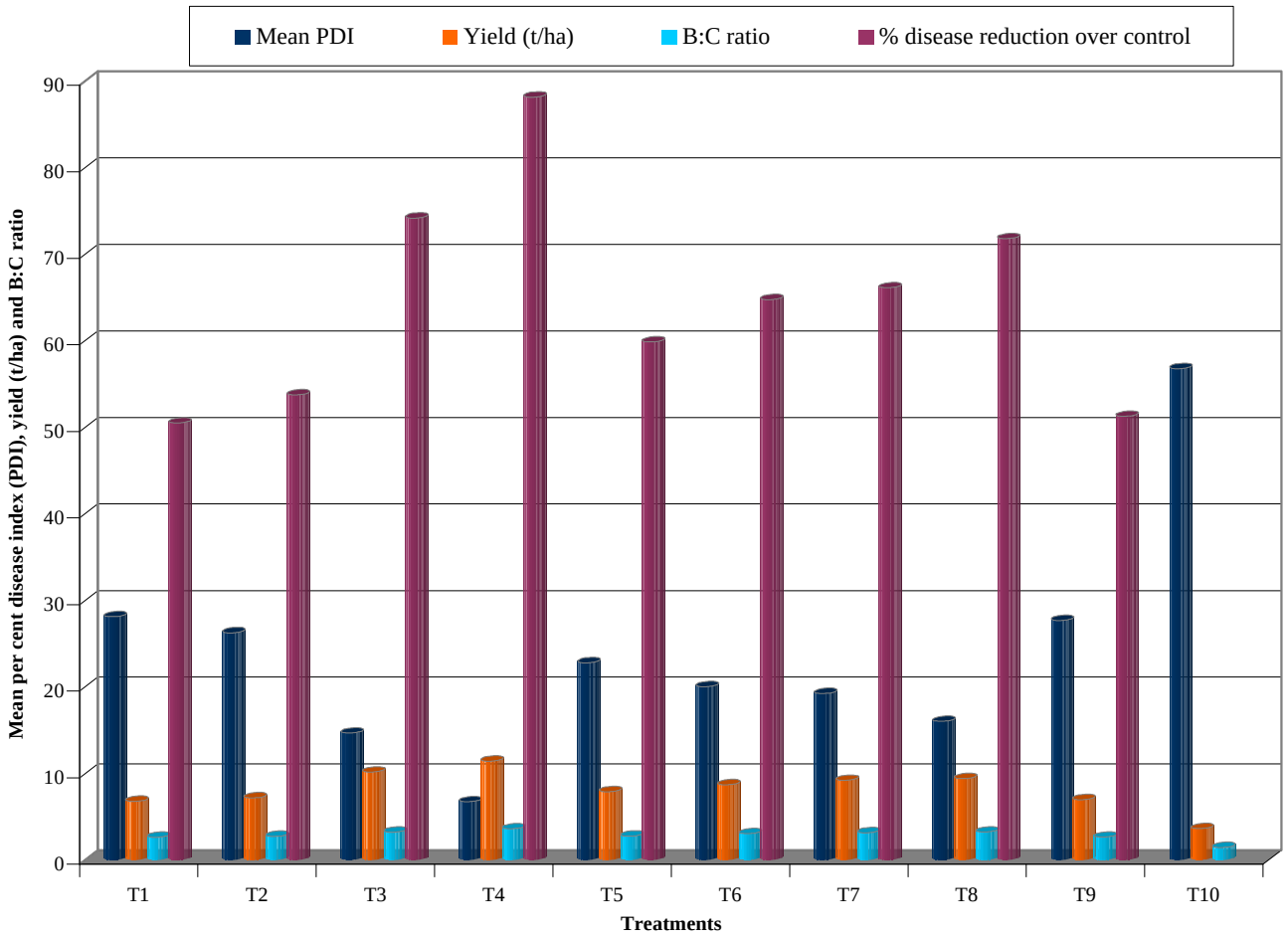
Plate 8b: Grade observed in screening experiment

Table 12: Field evaluation of spray schedule involving fungicides, botanicals and Bio agents for the management of powdery mildew of cucumber

Treatments	Spray schedule		Mean PDI	Disease reduction over control (%)	Yield tonne's/ha	Increase in yield over control (%)	B:C ratio
	First spray	Second spray					
T_1	*Bacillus subtilis* 1 %	*Bacillus subtilis* 1 %	28.11 (32.00)*	50.48	6.77	86.50	2.62
T_2	*Reynoutria sachalinensis* 20 % (Giant knot weed)	*Reynoutria sachalinensis* 20 % (Giant knot weed)	26.26 (30.81)	53.74	7.18	97.77	2.73
T_3	Amistar 0.15 %	Amistar 0.15 %	14.66 (22.45)	74.17	10.16	179.88	3.22
T_4	Nativo 0.15 %	Nativo 0.15 %	6.73 (15.02)	88.14	11.42	214.60	3.60
T_5	Amistar 0.15 %	*Bacillus subtilis* 1 %	22.79 (28.50)	59.85	7.90	117.00	2.76
T_6	Nativo 0.15 %	*Bacillus subtilis* 1 %	20.02 (26.57)	64.73	8.69	139.00	3.03
T_7	Amistar 0.15 %	*Reynoutria sachalinensis* 20 % (Giant knot weed)	19.24 (26.00)	66.10	9.20	153.00	3.16
T_8	Nativo 0.15 %	*Reynoutria sachalinensis* 20 % (Giant knot weed)	16.02 (23.56)	71.78	9.40	158.00	3.23
T_9	*Bacillus subtilis* 1 %	*Reynoutria sachalinensis* 20 % (Giant knot weed)	27.67 (31.72)	51.25	6.98	92.28	2.64
T_{10}	Unsprayed Control		56.77 (48.87)	-	3.63	-	1.44
S.Em. ±			0.62	-	0.54	-	-
C.D. (P = 0.05)			1.87	-	1.63	-	-

* Figures in the parenthesis are arc sine transformed value

Nativo (Tebuconazole 50 % + Trifloxystrobin 25 %) Amistar (Azoxystrobin 25 SC)



LEGEND

	First spray	Second spray
T_1	*Bacillus subtilis* 1 %	*Bacillus subtilis* 1 %
T_2	*Reynoutria sachalinensis* 20 % (Giant knot weed)	*Reynoutria sachalinensis* 20 % (Giant knot weed)
T_3	Amistar 0.15 %	Amistar 0.15 %
T_4	Nativo 0.15 %	Nativo 0.15 %
T_5	Amistar 0.15 %	*Bacillus subtilis* 1 %
T_6	Nativo 0.15 %	*Bacillus subtilis* 1 %
T_7	Amistar 0.15 %	*Reynoutria sachalinensis* 20 % (Giant knot weed)
T_8	Nativo 0.15 %	*Reynoutria sachalinensis* 20 % (Giant knot weed)
T_9	*Bacillus subtilis* 1 %	*Reynoutria sachalinensis* 20 % (Giant knot weed)
T_{10}	Unsprayed Control	

Fig. 8: Field evaluation of spray schedule involving fungicides, botanicals and Bioagents for the management of powdery mildew of cucumber

a) General view of the experimental plot

b) *Reynoutriu sachhalensis* (giant knot weed)

c) 20 % leaf extract of *Reynoutriu sachhalensis*

d) Inoculation in experimental plot

Plate 9a: Photograph depicting conduct of IDM experiment

a) Powdery mildew incidence in unsprayed plot

b) Least incidence in T_3 (2 sprays of Amistar)

c) Least incidence in T_4 (2 sprays of Nativo)

Plate 9b: Disease incidence in different treatments under Integrated Disease Management experiment

sprays were applied as per the combination and schedule along with unsprayed control to know their efficacy in managing powdery mildew under natural epiphytotic condition. Percent Disease Index (PDI), per cent reduction of disease over control, per cent increase yield over control, yield in q/ha were recorded and cost benefit ratio were computed and the data are presented in table 12 and Appendix IV.

4.7.1 Effect of spray schedule on disease severity

From the experimental results it was very clear that all the treatments reduced the disease development compared to the unsprayed plot after two sprays in combination. Among the ten combinations two sprays of Nativo (T_4) recorded the least PDI (6.73 %) with highest yield of 11.42 t/ha which was significantly superior compared to other spray schedulesand their combinations followed by two sprays of Azoxystrobin (T_3) (14.66 PDI) with an yield of 10.16 t/ha, Least disease control was recorded with two sprays *Bacillus subtilis* (T_1) (28.11 PDI) which yielded 6.77 t/ha as compared to unsprayed control 3.63 t/ha.

4.7.2 Benefit cost ratio

The cost benefit ratio has been worked out for different spray schedule and the highest B:C ratio was obtained with spray schedule involving two sprays of Nativo (1:3.60) followed by one spray of Nativo and one spray of *Reynoutria sachalinensis* (1:3.23) and it was on par with two sprays of Azoxystrobin (1:3.22). However, lowest B:C ratio was observed in unsprayed control (1: 1.44).

Table 13: Economic analysis of different powdery mildew management practices in cucumber cultivation

Treatments	Yield (kg/ha)	Gross returns (Rs./ha)	Cost of cultivation (Rs./ha)	Net returns (Rs.)	B:C Ratio
T_1	6,777	1,35,540	51,751	83,789	2.62
T_2	7,180	1,43,600	52,691	9,09,09	2.73
T_3	10,160	2,03,200	63,136	1,40,064	3.22
T_4	11,420	2,28,400	63,431	1,64,969	3.60
T_5	7,900	1,58,000	57,243	1,00,757	2.76
T_6	8,690	1,73,800	57,411	1,16,389	3.03
T_7	9,200	1,84,000	58,153	1,25,847	3.16
T_8	9,400	1,88,000	58,121	1,29,879	3.23
T_9	6,900	1,38,000	52,221	85,779	2.64
T_{10}	3,630	72,600	50,423	22,177	1.44

5. DISCUSSION

Cucumber (*Cucumis sativus* L.) is a widely cultivated plant in the gourd family Cucurbitaceae and belongs to Kingdom: Plantae, Order: Cucurbitales, Genus: *Cucumis*, Species: *Sativus.* The origin of cucumber is India. Cucurbits are of great economic importance and are excellent source of vitamins, minerals and carbohydrates. Many of them form the staple food, both in fresh and preserved form. Powdery mildew of cucurbits caused by *Erysiphe cichoracearum* DC, is the major limiting factor for cucurbits cultivation in India. These are biotrophic parasites growing principally on the foliage of angiosperms and cause damage to a variety of crop plants. Maximum reports of their occurrence are from the temperate regions of northern hemisphere whereas, in subtropics and tropics they are sparsely represented.

The losses caused by powdery mildews in India are tremendous particularly in peas, grapes, cereals and cucurbits. Powdery mildew caused by *Erysiphe cichoracearum* DC, is one among the serious fungal disease that affects cucumber causing considerable yield loss under open field as well as in protected cultivation. Hence, the present study on survey for the disease in Belagavi, Dharwad, Haveri and Vijaypura districts, molecular characterization of pathogen, epidemiological aspects of the disease, *in vitro* and *in vivo* evaluation of fungicides, bio-agents and botanicals and screening of genotypes against cucumber powdery mildew was undertaken at Department of Plant Pathology, College of Agriculture, MARS Dharwad, University of Agricultural Sciences, Dharwad during 2016-17. The results obtained from the above aspects are discussed here under the following headings:

5.1 Survey for severity of powdery mildew of cucumber under open field condition in major growing areas of northern Karnataka

5.2 Molecular characterization of pathogen

5.3 Studies on epidemiological aspects of the disease

5.4 *In vitro* evaluation of chemicals, botanicals and bio agents

5.5 Screening cucumber genotypes against powdery mildew

5.6 Integrated management of powdery mildew in cucumber

5.1 Survey for disease severity of powdery mildew of cucumber in northern Karnataka under open field and protected conditions

In the present investigation roving survey was conducted in Belagavi, Dharwad, Haveri and Vijaypura districts during late *kharif*, 2016 to know the distribution and severity of powdery mildew of cucumber.

The severity of powdery mildew ranged from 10.25 to 63.08 Per cent Disease Index (PDI) in northern Karnataka during late *kharif*, 2016. The highest mean disease severity was recorded in Dharwad district (33.06 PDI) followed by Haveri district (29.87 PDI) and least disease severity was recorded in Belagavi district (27.21 PDI) and severity in Vijaypura district and Belagavi district with less difference. This clearly indicates that the disease severity and development depends on factor like location, stage of the crop, cultural practices adopted and susceptibility of the cultivars grown. Apart from this it also depends on congenial conditions prevailing in that area for disease development.

The highest severity of powdery mildew was attributed to the temperature, relative humidity, leaf wetness period, morning dew and sunshine hours prevailed during the crop period, which was favorable for the powdery mildew development and spread. Similar types of observations were made by Cheah *et al.* (1996) while working with pea.

Prevalence of higher disease intensity in these areas may be due to congenial climatic conditions like relative humidity, cool temperature and susceptible genotypes which might have influenced inoculum multiplication, varied temperature regimes and water content of conidia supported spore germination and infection process of the fungus *E. cichoracearum.*

The results are in confirmation with observation of several investigators (Sharmila *et al,* 2005, Raghavendar, 2005 and Ashtaputre, 2006). Results are also in line with Chaudhary *et al.,* 2014 who reported that capsicum powdery mildew disease severity was differ between the locations of Himachal Pradesh.

If the age of the crop coincides with favourable weather parameters, development of the disease with very fast and cause a severe loss. Minimum rainfall, cooler nights and high day temperatures were enough for disease development. Wide variation (13-15^0 C) in the maximum and minimum temperature and day and night relative humidity (39.9-51.7 %) increases powdery mildew intensity as it was noticed in black gram (Singh and Sirohi, 2003).

The highest severity of powdery mildew was attributed to the temperature and relative humidity prevailed during the crop periods which were favourable for the powdery mildew development and spread. Similar type of observations was made in chilli powdery mildew by Ashtaputre *et al.* (2006).

Among the varieties/ hybrids cultivated Malini a hybrid from Seminis Company has covered more area in Belagvi district. Because of high plant population and heavy fertilizer application by farmers which is resulting in succulency in plant and favourable microclimate for disease development and host susceptibility. Similar observation were also made by Koren (1978) and Palti (1971). Intensive cultivation resulting from continuous cropping, where in proximity of infected crops and amount of inoculum present undoubtedly affect the incidence of infection besides creating the favourable environmental conditions. (Giladi, 1983, Palti, 1971, Friedrich *et al*., 1998, Reuveni and Rotem, 1973, Clerk and Ayesu offei, 1967).

Crops grown in irrigated condition has more disease severity because of luxurious growth and it was also observed that flood irrigation keep, moisture for longer duration which builds relative humidity. In case of rainfed condition also disease develops fairly because powdery mildew is disease of rainfed as well as irrigated conditions and this attributes the character of conidia which had ability to germinate under high moisture condition and also dry condition because of higher water content in conidia. These results with respect to irrigated conditon are agree with Asthaputre *et al.* 2006 while working with chilli powdery mildew and disease development in rainfed condition is also more. These results agree with Sanjeevreddy *et al.* 2012. It is very clear that disease development is more in both irrigated as well as rainfed condition and with mere difference in infection in regions of nothern karnataka.

From above survey results it is revealed that severity is more in protected cultivation. In general, it is because of high relative humidity, temperature and luxurious plant growth. Where ever fertigation practiced, regular water and nutrient supplement will lead to luxurious growth and creates microclimate favourable for disease development. Sprinkler irrigation is a practice which keeps leaf surface wetness it is also importanat parameter where inoculom builds, germinate and stable conditions of weather parameter will leads to disease progress in polyhouse conditions. From above survey results it is very clear that severity was more in protected condition and these results are agree with Mitchell *et al.* 2007. Powdery mildew thrives in moderate/high temperatures (25 to 35 ^{0}C) and high humidity (90 %) without rainfall or overhead irrigation. Consequently, the dense plant growth and high temperatures of a greenhouse muskmelon crop provide the optimal conditions for severe powdery mildew outbreaks (Elad *et al.*, 1996; Jett, 2005, Pottorff, 2005). Powdery mildew can be a persistent and devastating disease since a severe epidemic will decrease photosynthesis, increase respiration and transpiration, impair vegetative and fruit growth, and ultimately reduce yields and fruit quality (Agrios, 2005).

5.2 Molecular characterization of pathogen

The molecular detection methods for identi?cation of the pathogens based on ITS sequences were found to be more accurate over microscopic observations (Reddy 2009). To confirm the pathogen and accurately, molecular characterization of pathogen was carried out by extracting the DNA from the powdery mildew leaf samples followed by PCR amplification of ITS region of ribosomal DNA product of pathogen by using speci?c ITS universal primer and resulted in the amplified product size of 529 bp DNA fragment length against 100 bp DNA ladder. Further amplified PCR product was sequenced. The sequence was used to blast using BLAST algorithm available at http//ww.ncbi.nlm.nih.gov. Among total 112 hits available in NCBI accessions were showing 94-96 per cent sequence homology with ITS1 and 5.8S-ITS2 region of *E. cichoracearum.* Based on above results it has been con?rmed that *E. cichoracearum* is the causal pathogen for cucumber powdery mildew. Similar studies were conducted by Keiko *et al.* (2009), Cosme *et al.* (2012), Reddy (2009) and Channaveeresh and kulkarni (2017).

5.3 Studies on epidemiological aspects of the disease

5.3.1 Effect of temperature on inhibition of conidial germination of *E. cichoracearum*.

Conidia of Erysiphe cichoracearum germinated at all the temperatures tested ranging from 5 to 40 ^{0} C but the maximum germination was observed at temperature ranging from 25 ^{0}C -30 ^{0}C and conidial germinated was maximum at 25^{0} C at a wide range of relative humidity. Similarly, Cheah *et al.* (1996) Gupta *et al.* (2001) Singh (1987) also reported maximum germination of conidia at 25^{0} C while working with pea, cucumber and pea powdery mildew.

5.3.2 Effect of relative humidity on conidial germination of *E. cichoracearum.*

Conidial germination was maximum when the relative humidity was adjusted to 85 per cent however, conidia germinated even from 65 per cent and 100 per cent humidity, indicating the ability of the fungus to infect both under dry and humid conditions in presence of higher water content. This indicates that if the temperature and humidity are optimal then conidia germinate within 24hr. and these results are in conformity with Gupta, *et al.* (2001), Cheah *et al.* (1996), Singh (1987) working with cucumber and pea powdery mildew respectively.

5.3.3 Effect of time of planting on powdery mildew development on cucumber.

Environmental factors decide the epidemic of powdery mildew of various crops. The environmental factors like temperature, relative humidity, rainfall and wind speed are important for disease development and these environmental factors are being used to forecast the disease severity. Further, the knowledge of weather conditions for the development and spread of disease are important to organize agro advisory services to the farmers to take up timely management practices.

The role of temperature, relative humidity (RH) and rainfall on powdery mildew development in cucumber was studied under field conditions during late *kharif* and *rabi* 2016. The rate of disease development was positively correlated with Maximum temperature (0.606) and Minimum temperature was found to be negatively correlated (-0.471), morning relative humidity was found to be negatively correlated (-0.531)

Evening relative humidity (-0.608) is negatively correlated at one per cent significant and rainfall was also negatively correlated (-0.421) significantly. Number of rainy days were (-0.422) negatively correlated. Similar studies were conducted by Guzman Plazola *et al.* (2003) and their observations revealed that temperature 32^0 C and above coupled with very low RH reduces the spore germination of *L. taurica* and progress of powdery mildew in tomato. Ashtaputre (2006) while working with chilli powdery mildew observed maximum temperature had positive correlation and minnimum temperature, maximum and minimum relative humidity and rainfall were negatively correlated with disease development. In general, if low relative humidity is associated with warm weather, then the powdery mildew development is most rapid. The ability of the powdery mildew to spread under dry climatic conditions is largely due to the capacity of their conidia to dissemination of these spores and their germination at lower humidity than moist condition. The findings are in conformation with the reports of Reuveni and Rotem (1973) and Clerk and Ayesu–Offei (1967) while working with sunflower powder mildew reported that the incidence of powdery mildews decreases as the rainfall increases and vice-versa.

5.4 *In vitro* evaluation of chemicals, botanicals and bio agents

5.4.1 *In vitro* evaluation of systemic fungicides

Fungicides still constitute the predominate part of the control measures used against powdery mildew. Use of newer chemicals has become more popular in recent years because of their quick results, especially in absence of resistant varieties. Now a days, people are more concentrating on their health and are showing more interest towards organic products with this background plant extracts and bio-agents screened in the present investigation.

Among the various fungicides tested azoxystrobin found significantly superior over all the fungicides tested and shown maximum conidial germination inhibition (94.51 %) at 0.15 per cent concentration followed by tebuconazole (90.54 %) and difenconazole (88.04 %) at 0.15 per cent concentration and they were on par with propiconazole (85.41 %) at 0.15 per cent concentration.

The strobilurin fungicides, azoxystrobin (Amistar) have recently been labelled for the management of powdery mildew and downy mildew diseases in cucurbits, but only few reports are available on the efficacy of these fungicides against the severe form of the disease. The Strobilurin fungicides represent important class of chemicals for the management of a broad range of fungal diseases in agricultural production systems Ajithkumar *et al.* (2014).

Many researchers observed excellent control of powdery mildew with curative, translaminar action and systemic properties like inhibition of ergosterol synthesis with azoxystrobin and it enables to use efficiently against both powdery mildew and downy mildew of grapevine and leaf blight of tomato at very low concentrations (Hewitt 1998; Mejia Arreaza and Hernandez 2001; Ranganathan 2001).

Among the combi fungicides evaluated with different concentrations, tebuconazole 50 % + trifloxystrobin 25 % (Nativo) was found to be significantly superior over other treatments tested and showed maximum inhibition of 87.78 per cent at 0.15 per cent followed by captan + hexaconazole (Taquat) which recorded 74.65 per cent inhibition at 0.15 per cent concentration. Minimum conidial germination inhibition found with carbendazim + mancozeb (Saaf) (56.02 %) at 0.05 per cent. In general, it was observed that as concentration increased the inhibition of conidial germination also increased in all the fungicides evaluated and these results are in confirmation with Marthand (2016).

5.4.2 *In vitro* evaluation of botanicals and bio-agents

Continuous use of chemical fungicides in the management of diseases also brought new problems along with them and alarming among them are the pollution of air, water, soil residual toxicity and development of resistance of pathogen against fungicides, which has necessitated apply them repeatedly with their escalating prices along with harmful effects on non-target organisms. Botanicals are ecofriendly renewable, inexhaustible, indigenously available, easily assessable largely non phytotoxic, redially biodegradable and relatively cost effective hence they easily accomdated in plant protection in the strategy of integrated disease management.

Screening of plant products for their effectiveness and antifungal activity against the pathogen is essentially required to minimize the use of fungicides and to consider them as one of the component in the integrated disease management (Khadar, 1999). The present investigation was carried out to evaluate the different plant species for the possible presence of fungitoxic substances against conidial germination of *E. cichoracearum.* Among bio-agents and botanicals tested maximum inhibition of conidial germination was found with *Bacillus subtilis* (55.74 %) at 1.0 per cent followed by *Pseudomonas fluorescens* and least inhibition was observed in *Verticillium lecanii* and these results are in line with Seddon *et al.* (2000), Choi, *et al.* (2007) and Romero *et al.* (2001) studied *in vitro* bio efficacy of *Bacillus subtilis* strains, and found that strains such as, UMAF6614, UMAF6619, UMAF6639, and UMAF8561, having ability to suppress the conidial germination on melon in detached leaf assay. Mycoparasites used here were found to be more effective when relative humidity values were above 80% and most likely influenced by a combination of different factors, but mainly, the higher germination rate of mycoparasitic spores in high humidity and secondly, the lower growth rate of *P. fusca* under these conditions (Verhaar *et al*., 1996). Similarly, bacterial strains performed better at high relative humidity, probably because these environmental conditions favour a more efficient colonization of leaves, which could support the effective production and secretion of antifungal compounds

Among the various botanicals tested *Reynoutria sachhalensis* 20 % gave maximum inhibition followed by nimbicidin 10 per cent and similar results were obtained by Gangwar *et al*. 2000, Ravikumar (1998), and Doltsinis and Schmitt (1998). Giant knot weed extract acts by boosting a plant's immune system and inducing resistance to pathogens. It works through a combination of enzyme induction, production of antibiotics called phytoalexins and direct suppression of spore germination. Sprays of giant knotweed extract because increased production of hydrolytic enzymes, such as chitinase and beta-1, 3-glucanase, and oxidative enzymes such as peroxidase and polyphenoloxidase. The hydrolytic enzymes attack chitin in the cell walls of fungi. The oxidative enzymes protect plant cells through increased lignification, forming barriers against pathogen penetration. The antimicrobial hydrogen peroxide also accumulates in tissues near where pathogens are attacking. Induced changes are not systemic, but occur only on treated leaves, although there is some

translaminar action, so treatment of only one side of a leaf can protect both sides (Herger and Klingauf 1990; Schneider and Ullrich 1994; Nicholson and Hammerschmidt 1992; Randoux *et al.* 2006). Induced enzyme levels reach a maximum 1-2 days after treatment, then levels drop back to normal over the course of 1-3 weeks (Fofana *et al.* 2002; Schneider and Ullrich 1994).

5.5 Screening cucumber genotypes against powdery mildew

The management of the disease through host plants resistance has been the best choice in all the disease management programmes. Utilization of resistant cultivars in farming system is the most simple, effective and economical method in the management of disease. Besides this, these resistant cultivars conserve natural resources and reduce the cost, time and energy compared to the other methods of disease management.

Experiment on screening of cucumber genotypes was conducted during late *kharif* 2016. Twenty three genotypes were screened against *E. cichoracearum* under artificial epiphytotic conditions among them none of the genotypes shown immune or resistant, however, fifteen genotypes *Viz.*, Swathi, BSS-949, JK-special, Mahy Sylvia, Malini, Shirakawa, Yummy, Kareena, Green long, Ajeeth-99, White long, Encounter-962, Shalini, Ranebennur local and Sarpan hybrid were found moderately resistant and five genotypes *viz.*, Chetak, Gullakai, Khushi, Sribasava and Harini were moderately susceptible genotypes such as Mangalore local, Dharwad green and Chitra, showed highly susceptible reaction and these work are lined with Gondi (2015).

5.6 Integrated management of powdery mildew in cucumber

One bio-agent, one botanical, one systemic and one combi fungicides which shown maximum inhibition at lower concentration under *in vitro* studies were selected for further evaluation under *in vivo* cultivation against powdery mildew of cucumber susuceptible cultivar chitra was used to study under field condition during *Rabi*-2016-17.

The results indicated that, among treatments tested two sprays of Nativo (T4) recorded the least PDI (6.73 %) along with maximum yield of 11.42 tonnes/ha which was significantly superior to other spray schedule combinations followed by two sprays

of Azoxystrobin (T3) (14.66 %) with cucumber yield of 10.16 tonnes/ha. Least disease control was recorded with two sprays *Bacillus subtilis* (T1) (28.11 PDI) which yielded 6.77 tonnes/ha as compared to unsprayed control 3.63 tonnes/ha. And this work is line up with (two sprays of Nativo) Marthand 2016.

Venancio *et al.* 2003, reported strobilurins fungicides acts by inhibiting mitochondrial respiration by blocking the transfer of electrons in the III complex (bc1 complex) of the transporting current for mitochondrial electrons (Ammermann *et al*., 2000). Transitory influence in the plant mitochondria does not necessarily result in phytotoxicity because the toxicity at the organism level is determined by the importance of mitochondrial respiration for the supply of energy, which varies with environmental conditions and the life stage of the organism (Sauter *et al*., 1995). Strobilurins cause a greater level of cellular damage measured by leakage of the electrolytes, and it aslo interfere in ATP production also site specific action (Koehle *et al*., 2003) and effects of triazoles like inhibition of ergosterol synthesis will coupled with stroubularin group in mode of action when Nativo combi fungicide used for spray.

Azoxystrobin and Tebuconazole at 0.05 per cent were reported to be effective against powdery mildew of cucumber under protected cultivation and similar results were recorded by Banyal *et al.* (2011). They opined that this effect was mainly due to translaminar and systemic movement of Azoxystrobin inside the tissues. Azoxystrobin is widely distributed from the application side by diffusion. Results of the present study supported by many researchers for effective management of powdery mildew and anthracnose diseases of chilli by using Azoxystrobin (Ahila and Prakasam, 2013. Ahila and Prakasam, 2014). Strobilurins inhibit mitochondrial respiration by blocking the electron transfer in cytochromes b and c. It inhibits spore germination, mycelial growth and spore production of fungi. Anke (1995) also reported that Azoxystrobin to be very active at very low doses against a wide range of fungal pathogens.

Yardwood (1957) controlled the powdery mildews using hyper parasites as unlikely to be successful because of the host fungus and parasite are favored by different weather conditions. The present study indicated the inefficacy of bio-agents in field conditions may be attributed to the above quoted reasons and was in agreement with the reports.

Future line of work

For better understanding of the powdery mildew and its management, it is necessary to focus attention on the following future line of work.

1. Studies on biochemical changes in cucurbit plants due to powdery mildew infection.

2. Cross inoculation studies may be carried to know the other hosts of *E. cichoracearum.*

3. Studies on compatibility between fungicides, bioagnts and botanicals to develop suitable spray schedule.

4. Utilization of resistant genotypes in breeding programme to develop high yielding resistant varieties.

6. SUMMARY AND CONCLUSIONS

Cucurbits are of great economic importance and are excellent source of vitamins, minerals and carbohydrates. Many of them form the staple food, both in fresh and preserved form. Cucumber is a very important vegetable crop grown throught the year and it suffering from many fungal diseases. Among them powdery mildew caused by *Erysiphe cichoracearum* is severe in winter season mainly from October to late February. Under north Karnataka conditions presently the outbreak of cucurbit powdery mildew is very problematic because of abrupt change climatic conditions and its severity is more due to higher level of humidity in greenhouse grown cucumber. The yield loss is very much proportional to the disease severity and considerably depends on the stage of the crop growth at which the disease occurs.

Availability of few reviews indicated that survey on the disease pressure, severity in different locations and spread of the disease has not been studied in depth. Until now much work has not been carried out on different aspects of powdery mildew of cucumber such as identification of resistant source, epidemiological aspects and integrated management of disease. Hence, the present study was carried out to address the above mentioned aspects of powdery mildew of cucumber at Main Agriculture Research Station, Agriculture College, Dharwad, during 2016-17 and the results obtained are summarized below.

From the survey during 2016-17 it is very clear that, the disease was noticed in varying intensities in four different districts surveyed. The mean severity was more in Dharwad district (33.06 PDI) followed by Haveri district (29.87 PDI) and average mean percent disease severity (PDI) was observed in Belagavi (27.21 PDI) district followed by Vijaypura (27.60 PDI). The maximum disease severity of 63.08 per cent was observed in Bailwad cross village of Bailhongal taluka, Belagavi district in where prevailing fertile black soils resultsin luxurious growth of the crop and prevailing dry condition helped the pathogen to build up the inoculum hence the disease was made severe there.

The PCR amplification and sequencing of ITS rDNA region of causal fungus obtained from cucumber indicated that Dharwad isolate was proved to be *Erysiphe*

cichoracearum after blasting the gene sequences in NCBI BLAST programme. The amplification and sequencing of ITS rDNA region of fungus seemed to be best molecular tool for identification. Results indicate that Dharwad sequence had 96 per cent homology with Berkeley isolate USA, whereas, it was similar up to 94 per cent with Australian isolate.

Highest germination of conidia (48.52 %) was found at 25^0 C temperature and 85 per cent relative humidity. However, the optimum temperature range of 25 to 30^0 C and 80 to 90 per cent of RH was good for conidial germination of *E. cichoracearum.*

Among different dates of sowing, second fortnight of August recorded maximum disease severity and first fortnight of July resulted in least severity and all the dates of sowing are significantly correlated negatively with weather. Relative humidity and temperature were positively correlated whereas rainfall and number of rainy days are negatively correlations.

In vitro efficacy of fungicides revealed that maximum inhibition of conidial germination was observed with azoxystrobin and it was found significantly superior over all the other fungicides tested with maximum conidial germination inhibition (94.51 %) followed by tebuconazole (90.54 %). Minimum inhibition of conidial germination was recorded in myclobutanil (78.83 %) at 0.15 per cent concentration

In vitro efficacy of combi fungicides revealed that tebuconazole 50 % + trifloxystrobin 25 % (Nativo) found to be significantly superior over other treatments and showed maximum inhibition (87.78 %) at 0.15 per cent followed by captan + hexaconazole (Taquat) which recorded 74.65 per cent inhibition at 0.15 per cent. Minimum conidial germination inhibition was observed with carbendazim + mancozeb (Saaf) (56.02 %) at 0.05 per cent.

In vitro efficacy of four bioagents with different concentrations revealed that all the bioagents were significantly superior over the control. Maximum conidial inhibition was recorded with *Bacillus subtilis* (55.74 %) at 6 g/L followed by *Pseudomonas fluorescens* (51.24 %) @ 6 g/L.

Out of seven botanicals tested *in vitro* against *E. cichoracarum*, the effect of *Reynotriu sachalensis* on conidial germination was significantly superior over control and 20 per cent extract showed maximum conidial inhibition of 100 per cent followed by nimbicidin (64.13 %) minimum conidial germination inhibition was found with Sorghum leaf extract (33.25 %) at 15 per cent.

Out of twenty three genotypes screened under artificial epiphytotic condition, none of them were found immune and resistant, however, fifteen genotypes *viz.*, Swathi, BSS-949, JK-special, Mahy Sylvia, Malini, Shirakawa, Yummy, Kareena, Green long, Ajeeth-99, White long, Encounter-962, Shalini, Ranebennur local and Sarpan hybrid were found to be moderately resistant and five genotypes *viz.*, Chetak, Gullakai, Khushi, Sribasava and Harini were found to be moderately susceptible. With 9 grades in 0-9 scale genotypes such as Mangalore local, Dharwad green and chitra showed highly susceptible reaction.

The results of the field evaluation of fungicides against powdery mildew revealed that among the ten combinations two sprays of Nativo (T4) recorded the least PDI (6.73) with yield enhancement up to 11.42 t/ha with B: C ratio of 1:3.60 which was significantly superior to other spray schedule combinations followed by two sprays of azoxystrobin (T3) (14.66 PDI) with yield of 10.16 t/ha and 1:3.22 B:C ratio. Least disease control was recorded with two spraysod bioagent *Bacillus subtilis* (T1) (28.11 PDI) which yielded 6.77 t/ha as compared to unsprayed control with a yield of 3.63 tonnes/ha.

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Appendix I: Standardization of relative humidity through H_2SO_4

H_2SO_4 (%)	Relative humidity (%)
0	100
5	98.5
10	96.1
15	92.9
20	88.5
25	82.9
30	75.6
35	66.8
40	56.8
45	46.8
50	36.8
55	26.8
60	17.2
65	9.8
70	5.2
75	2.3
80	0.8

Source : Plant pathologists Pocket Book, Third Edition (Edt. by J. M. Waller, J. M. Leenë and S. J. Waller). CABI Publishing.

Appendix II: Weekly meteorological data of MARS Dharawd during 2016

Week	Week days	Temparature (^{0}C)		Relative humidity (%)				Rainfall	Number of rainy days
		Max.	Min.	Max.	Min.	Total	Mean		
1	1st – 7th Jan	30.3	13.6	51.6	23.0	74.6	37.3	0.0	0
2	8th – 14th Jan	29.7	12.0	49.3	20.6	69.9	34.9	0.0	0
3	15th – 21st Jan	28.2	14.5	71.6	41.4	113.0	56.5	0.4	0
4	22nd – 28th Jan	30.7	16.0	63.3	36.0	99.3	49.6	0.0	0
5	29th Jan – 4th Feb	33.7	14.8	43.6	19.7	63.3	31.6	0.0	0
6	5th – 11th Feb	32.6	17.0	74.6	34.3	108.9	54.4	0.0	0
7	12th - 18th Feb	32.0	17.0	59.9	35.3	95.1	47.6	0.0	0
8	19 th - 25th Feb	35.0	20.3	57.4	32.3	73.7	53.9	0.0	0
9	26th Feb - 4th Mar	34.5	20.2	57.6	27.4	85.0	42.5	0.2	0
10	5th - 11th Mar	35.7	20.4	51.4	24.1	75.6	37.8	0.0	0
11	12th - 18th Mar	34.9	19.3	53.0	23.8	70.0	44.7	0.0	0
12	19th - 25th Mar	38.0	21.4	42.4	20.3	62.7	31.4	0.0	0
13	26th Mar – 1st Apr	36.7	21.1	75.9	44.1	120.0	60.0	2.4	0
14	2nd – 8th Apr	36.7	21.3	73.4	45.4	118.9	59.4	8.6	1
15	9 th - 15 th Apr	38.1	21.7	67.1	33.7	100.9	50.4	0.0	0
16	16 th - 22 th Apr	38.8	22.1	71.0	42.0	113.0	56.5	4.8	1
17	23rd - 29 th Apr	38.6	21.2	56.7	32.3	89.0	44.5	6.8	1
18	30 th Apr - 6 th May	38.7	22.1	75.6	35.7	111.3	55.6	0.2	0
19	7 th - 13 th May	38.2	21.4	65.4	35.1	100.6	50.3	34.0	1

Contd.....

Week	Week days	Temparature (^{0}C)		Relative humidity (%)				Rainfall	Number of rainy days
		Max.	Min.	Max.	Min.	Total	Mean		
20	14th – 20th May	35.0	21.8	81.3	58.7	98.0	70.8	48.8	3
21	21 th - 27 th May	33.3	23.0	80.6	56.7	137.3	68.6	0.0	0
22	28 th May – 3rd Jun	34.2	22.2	75.7	50.7	126.4	63.2	7.0	1
23	4 th - 10 th Jun	30.2	21.6	87.6	75.0	162.6	81.3	34.2	4
24	11 th - 17 th Jun	28.4	21.3	85.7	63.9	149.6	74.8	5.8	1
25	18 th - 24 th Jun	28.9	20.8	86.9	75.7	162.6	81.3	6.6	1
26	25 th Jun – 1st Jul	26.4	21.4	88.3	81.9	170.1	85.1	23.4	3
27	2nd - 8 th Jul	26.4	21.5	91.3	84.1	175.4	87.7	36.4	6
28	9 th - 15 th Jul	25.9	21.1	90.3	83.6	173.9	86.9	61.0	5
29	16 th - 22 th Jul	26.7	20.6	91.1	80.9	174.8	82.5	27.2	4
30	23rd - 29 th Jul	26.6	20.8	93.1	85.1	184.2	82.8	21.6	3
31	30 th Jul - 5 th Aug	24.7	20.4	92.1	83.7	175.9	87.9	37.4	3
32	6 th - 12 th Aug	26.1	20.9	92.4	85.0	177.4	88.7	26.0	4
33	13 th - 19 th Aug	26.6	20.7	88.7	78.4	167.1	83.6	15.8	2
34	20 th - 26 th Aug	27.1	20.3	88.7	75.4	164.1	82.1	9.2	1
35	27 th Aug – 2nd Sep	27.3	20.4	91.3	78.7	170.0	85.0	28.8	1
36	3rd - 9 th Sep	27.4	19.7	84.7	73.4	158.1	79.1	0.4	0
37	10 th - 16 th Sep	27.2	19.9	88.1	81.7	169.9	84.9	14.8	2
38	17 th - 23 th Sep	25.6	20.0	90.4	85.1	175.6	87.8	11.8	3
39	24 th - 30 th Sep	27.7	20.5	88.9	81.0	157.0	84.9	44.0	1
40	1 - 7 Oct	27.2	19.5	88.6	70.6	159.1	79.6	6.2	1

Contd.....

Week	Week days	Temparature (^{0}C)		Relative humidity (%)				Rainfall	Number of rainy days
		Max.	Min.	Max	Min	Total	mean		
41	8 th - 14 th Oct	28.9	20.2	88.9	75.3	164.1	82.1	38.6	1
42	15 th - 21st Oct	30.8	16.3	59.3	39.0	98.3	49.1	0.0	0
43	22nd - 28 th Oct	31.1	18.5	63.3	39.1	102.4	51.2	0.0	0
44	29 th Oct - 4 th Nov	31.5	18.4	65.3	43.0	108.3	54.1	0.4	0
45	5 th - 11 th Nov	30.3	12.6	43.0	27.7	70.7	35.4	0.0	0
46	12 th - 18 th Nov	31.0	17.2	68.9	45.0	113.9	56.9	5.4	1
47	19 th - 25 th Nov	30.1	13.2	55.6	35.1	90.7	45.4	0.0	0
48	26 th Nov - 2 th Dec	31.4	13.1	45.7	29.9	75.6	37.8	0.0	0
49	3rd Dec - 9 th Dec	29.4	16.2	64.7	44.0	108.7	54.4	0.0	0
50	10 th - 16 th Dec	29.0	15.1	61.6	43.6	105.1	52.6	0.0	0
51	17 th - 23rd Dec	30.6	13.4	54.3	35.0	89.3	44.6	0.0	0
52	24 th - 31 th Dec	30.5	11.8	52.6	25.9	78.4	39.2	0.0	0

Total rainfall = 568.2 mm
Total number of rainy days = 55
Highest Rain fall received on 28th week (09**th** - 15th July) = 61.0 mm
Winter season (1st to 9th week) rainfal = 0.6 mm
South west monsoon (monsoon season) (23rd to 39th week) rainfall = 404.4 mm
North east monson (post monson season) (41st to 52th week) rainfall = 44.4 mm

Appendix III: Weekly meteorological data of MARS, UAS Dharawd during 2017

Week	Week days	Temparature (^{0}C)		Relative humidity (%)				Rainfall	Number of rainy days
		Max.	Min.	Max	Min	Total	Mean		
1	1st Jan– 7th Jan	30.0	12.1	48.6	33.1	81.7	40.9	0.0	0
2	8 th Jan - 14 th Jan	29.6	13.6	63.9	43.1	107.0	53.5	0.0	0
3	15thJan – 21st Jan	29.2	13.4	56.7	35.0	86.7	47.9	0.0	0
4	22ndJan - 28 th Jan	31.3	15.4	63.4	39.0	102.4	51.2	0.0	0
5	29 th Jan - 4 th Feb	32.3	15.6	50.6	30.7	81.3	40.6	0.0	0
6	5 th Feb - 11 th Feb	32.8	16.1	66.4	24.6	91.0	45.5	0.0	0
7	12 thFeb - 18 th Feb	32.3	15.5	45.7	21.6	67.3	33.6	0.0	0
8	19th Feb – 25th Feb	35.1	17.6	42.4	13.3	48.7	37.6	0.0	0
9	26th Feb – 4th Mar	35.0	16.9	39.6	15.0	54.6	27.3	0.0	0
10	5th Mar – 11th Mar	33.9	16.9	39.7	22.4	62.1	31.1	0.0	0
11	12th Mar – 18th Mar	34.0	17.8	53.4	24.7	78.1	39.1	0.0	0
12	19th Mar – 25th Mar	36.3	18.4	50.7	22.1	72.9	36.4	0.0	0
13	26th Mar – 1st Apr	37.0	21.8	77.6	32.0	109.6	54.8	0.0	0
14	2nd Apr – 8th Apr	36.7	21.0	73.3	20.0	93.3	46.6	0.2	0
15	9th Apr – 15th Apr	38.1	21.6	74.7	19.7	94.4	47.2	5.8	1

Appendix IV: Calculation of cost of cultivation including plant protection

Inputs	Items	Treatments	Total (Rs)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
1	Ploughing	Bullock drawn @ Rs.1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
2	Harrowing (Bullock drawn)	Bullock drawn @ Rs.1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
3	Intercultivation with bullock	(@ Rs 500)	500	500	500	500	500	500	500	500	500	500	500
4	Seeds	2.5 kg (@Rs.1,500/kg)	3,750	3,750	3,750	3,750	3,750	3,750	3,750	3,750	3,750	3,750	3,750
5	Manure and Fertilizer												
6	FYM	25 t (@ Rs. 1000/t)	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
7	DAP	110 kg (@ Rs. 12.8/kg)	1,408	1,408	1,408	1,408	1,408	1,408	1,408	1,408	1,408	1,408	1,408
8	MOP	134kg (@ Rs. 17.2/kg)	2,305	2,305	2,305	2,305	2,305	2,305	2,305	2,305	2,305	2,305	2,305
9	Urea	110 kg (@ Rs. 7.2/kg)	792	792	792	792	792	792	792	792	792	792	792
10	Labour charges												
11	Spraying	4 (@ Rs. 220/labour)	880	880	880	880	880	880	880	880	880	880	880
12	FYM appn	10 (@ Rs. 220/labour)	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200

Contd.....

Inputs	Items	Treatments	Total (Rs)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
13	Fert appn and irrigation	10 (@ Rs. 220/labour)	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
14	Sowing	8 (@ Rs. 157/labour)	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256
15	Harvesting	40 (@ Rs. 157/labour)	6,280	6,280	6,280	6,280	6,280	6,280	6,280	6,280	6,280	6,280	6,280
16	Transportation	(@ Rs. 400/t)		2,680	2,840	4,040	4,560	3,160	3,440	3,680	3,760	2,760	1,452
17	Chemicals												
18	Nativo								5,000				
19	Amistar					10,125	9,900	5,112		5,502	5,390		
20	*B. subtilis*	1g/ ltr	500*2 = 1,000 g	100								490	
21	Giantknot weed				880								
	Total			**51,751**	**52,691**	**63,136**	**63,431**	**57,243**	**57,411**	**58,153**	**58,121**	**52,221**	**50,423**

STUDIES ON EPIDEMIOLOGY AND MANAGEMENT OF CUCUMBER POWDERY MILDEW

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ABSTRACT

The present investigation involving roving survey in 4 districts, epidemiological studies, *in vitro* evaluations, field screening of 23 genotypes, molecular characterization of pathogen and management was carried out at the University of Agricultural Sciences Dharwad during the year 2016-17.

In survey maximum disease severity was recorded in Dharwad (33.06 PDI) and least in Haveri (27.21 PDI). Under protected cultivation maximum disease severity (64.01 PDI) was recorded in Dharwad and least was recorded in Haveri (40.07 PDI).

The rDNA-ITS sequencing of *E. cichoracearum* indicated that Dharwad isolate had 96 and 94 per cent homology with Berkely isolate and Australian isolate. Highest conidial germination (48.52 %) was observed at 25^0 C and 85 per cent relative humidity. Sowing during second fortnight of August recorded maximum severity and maximum temperature showed positive correlation whereas, rainfall and number of rainy days were significantly negatively correlated.

Azoxystrobin showed maximum conidial germination inhibition (94.51 %) among the combiproducts, tebuconazole 50 % + trifloxystrobin 25 % resulted in maximum inhibition (87.78 %). In bioagents tested maximum inhibition observed with *Bacillus subtilis* (55.74 %), Leaf extract of *Reynotriu sachalensis* resulted in 100 per cent inhibition. 15, five and three genotypes were found to be moderately resistant, moderately susceptible and highly susceptible respectively. Field evaluation of fungicides revealed that two sprays of tebuconazole 50% + trifloxystrobin 25% with least PDI (6.73) and yield up to 11.42 t/ha with B:C ratio of 1:3.60 which was significantly superior followed by two sprays of Azoxystrobin (14.66 PDI) with an yield of 10.16 t/ha.