# "MANAGEMENT OF POWDERY MILDEW DISEASE (*Erysiphe cruciferarum* Opiz ex. Junell) OF MUSTARD [*Brassica juncea* (L.) Czern. & Coss.]"


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**JUNAGADH–362 001**



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# "MANAGEMENT OF POWDERY MILDEW DISEASE (*Erysiphe cruciferarum* Opiz ex. Junell) OF MUSTARD [*Brassica juncea* (L.) Czern. & Coss.]"

**A THESIS SUBMITTED TO THE JUNAGADH AGRICULTURAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE**

**OF**

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**IN**

**PLANT PATHOLOGY**

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Dedicated
To
My
Beloved
Parents.....

# ABSTRACTS

# MANAGEMENT OF POWDERY MILDEW DISEASE (*Erysiphe cruciferarum* Opiz ex. Junell) OF MUSTARD [*Brassica juncea* (L.) Czern. & Coss.]


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## ABSTRACT


Indian mustard (*Brassica juncea* (L.) Czern. & Coss.) is the most important oilseed crop of India. Like other crops, rapeseed and mustard are attacked by a number of fungal, bacterial and virus diseases, which are considered economically important. Among them, powdery mildew caused by *Erysiphe cruciferarum* Opiz ex. Junell is an important disease particularly in the Saurashtra region of Gujarat. Hence, present investigation was carried out to assess losses due to this disease and to develop feasible management options.

The initial symptoms of powdery mildew disease appeared with minute visible and almost circular fungal colony on upper surface of lower most leaf and progressed towards upper leaves on both the surfaces, stems, branches and siliquaes. Eventually whole plant covered with white powdery fungal growth showing a dusty appearance. In advanced stage, purple blue patches were seen on the stems. Heavily infected leaves turned pale yellow, dried and shedded. Infected siliquae produced shrivelled seeds. Heavily infected plant showed early maturity.

The conidiophores were erect, stout and ellipsoid to cylindrical in shape and measured 67.4 ± 6.2 µm with a moderately straight foot cell bearing 2-3 conidia in chain. Conidia were unicellular, hyaline, elliptical to cylindrical in shape and measured 26.5-39.8 µm x 12.4-16.6 µm in size without fibrosin bodies.

Estimation of seed yield, oil, protein and test weight loss due to *E. cruciferarum* was 22.50, 7.26, 21.74 and 21.52 per cent, respectively when no control measures were adopted. The avoidable yield loss 23.48 per cent and net profit of Rs.9,390 per hectare was achieved by spraying the crop with hexaconazole @ 0.005 per cent.

Screening of 13 entries against powdery mildew *in vivo* showed that the entries GM-2 was highly susceptible, while GM-1 and GM-3 showed susceptible reaction. The entries HNS-0004, ISN-129 and NUDB-26-11 were moderately susceptible and GSL-1 and GSL-861-212 exhibited resistant reaction. DLSC-3, Kiran, NPC-3, NPC-111 and NPJ-87 exhibited highly resistant reaction.

The effect of maximum air temperature on disease development exhibited positive and significant relationship with per cent disease intensity (PDI) while minimum air temperature with PDI was found non significant. The morning relative humidity was significantly negatively correlated with PDI and afternoon relative humidity was highly negatively significant. In multiple regression analysis, maximum temperature (°C) and afternoon relative humidity were highly significant to disease development.

In laboratory screening of systemic fungicides, non systemic fungicides, insecticides and phytoextracts,

hexaconazole, dinocap, methyl-o-demeton and clove extract of garlic (*Allium sativum)* were found better with 84.10, 79.98, 54.97 and 74.08 per cent inhibition of spore germination, respectively.

In field evaluation of different fungicides, the minimum per cent disease intensity (PDI) 28.17 and a maximum yield of 2225 kg/ha was recorded in the treatment of hexaconazole with 54.17 per cent disease control and 30.04 per cent yield increase. The highest incremental cost benefit ratio (ICBR) of 1:4.63 was obtained in four sprays of hexaconazole 0.005 per cent followed by wettable sulphur 0.2 per cent (1:3.36) and penconazole 0.010 per cent (1:1.07).

The maximum oil (34.37%), protein (18.05%) and test weight (5.39 g) was also recorded in the treatment of hexaconazole (0.005%). Similarly, oil, protein and test weight increase were 11.95, 26.05 and 22.78 per cent, respectively.

Neem leaf extract proved to be the most effective biopesticide and recorded 38.35 PDI with 44.20 per cent disease control and 2013 kg/ha seed yield with 21.41 per cent yield increase. The highest ICBR of 1:5.19 was found in four sprays of neem leaf extract and followed by neem seed kernel extract (1:3.72) and azadirachtin (1:1.08).

The maximum per cent oil (33.97), protein (16.69) and test weight (5.38 g) and per cent increase in oil (9.97), protein (15.34) and test weight (23.68) were recorded in neem leaf extract treatment under field conditions.

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## -: CERTIFICATE :-

This is to certify that the thesis entitled **"MANAGEMENT OF POWDERY MILDEW DISEASE (*Erysiphe cruciferarum* Opiz ex. Junell) OF MUSTARD [*Brassica juncea* (L.) Czern. & Coss.]"** submitted by **KANZARIA KESHAVJI KALYANJI** in partial fulfillment of the requirement for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **PLANT PATHOLOGY** of the Junagadh Agricultural University is a record of *bonafide* research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: Junagadh
Date : 17th July, 2012

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# CERTIFICATE – I

This is to certify that **Mr. KANZARIA KESHAVJI KALYANJI** has successfully completed the comprehensive/ preliminary examination held on 30th July, 2009 as required under the regulation for Post-Graduate Studies.

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This is to certify that the thesis entitled **"MANAGEMENT OF POWDERY MILDEW DISEASE (*Erysiphe cruciferarum* Opiz ex. Junell) OF MUSTARD [*Brassica juncea* (L.) Czern. & Coss.]"** submitted for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in the subject of **PLANT PATHOLOGY** embodies bonafide research work carried out by **Mr. KANZARIA KESHAVJI KALYANJI** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged.

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**Date: 24/12/2012**

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This is to certify that **Mr. KANZARIA KESHAVJI KALYANJI** student of **Ph.D.(Agri.),** Department of Plant Pathology, College of Agriculture, J.A.U., Junagadh has made all corrections/modifications in the thesis entitled **"MANAGEMENT OF POWDERY MILDEW DISEASE (*Erysiphe cruciferarum* Opiz ex. Junell) OF MUSTARD [*Brassica juncea* (L.) Czern. & Coss.]"** as suggested by the external examiners and the advisory committee in the oral examination held on 24/12/2012. The final copies of the thesis duly bound and corrected have been submitted on 26/12/2012.

Place: Junagadh
Date : 26/12/2012

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Place: Junagadh
Date : 17th July, 2012 (Kanzaria K. K.)

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# INTRODUCTION

# CHAPTER - I

# INTRODUCTION

The oilseed crops, especially *Brassica* spp., play a pivotal role in the agricultural economy of India. Indian mustard (*Brassica juncea* (L.) Czern. & Coss.) belongs to the family Cruciferae. It is the most important oilseed crop in India next to groundnut grown under a wide range of agroclimatic conditions.

European Union is the leading producer of mustard seed in the world accounting for 34 per cent of the world production followed by China (23%), Canada (19%) and India (14%). European Union, China and Canada together account for 76 per cent of the world mustard seed production (Anon., 2010).

Indian mustard was originally introduced from China into North-eastern India from where it had spread to Afghanistan via Punjab. It is predominantly cultivated in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat (Anon., $2011_d$).

The world area, production and productivity of rapeseed-mustard was 30.74 million hectares, 59.93 million tonnes and 1950 kg/ha, respectively (Anon., $2011_b$). In India, rapeseed and mustard is the second largest oilseed crop after groundnut with 5.59 million hectares, producing about 6.61 million tonnes of seed annually with productivity of 1182 kg/ha (Anon., $2011_a$). Gujarat accounted for an area of 2.16 lakh hectares with production of 3.41 lakh tonnes and a productivity of 1581 kg/ha during the year 2009-10 (Anon., $2011_c$).

Rapeseed and mustard are considered to be of high economic importance in national and international trade with significant implications as they yield the most important edible oil ranging from 30-48 per cent which is used as the main

cooking medium in North India. The seed and oil are used as a condiment in the preparation of pickles and for flavoring the curries and vegetables. The leaves of the young plants are used as a green vegetable. Rapeseed and mustard oil possesses a sizeable amount 38-57 per cent of erucic acid, 4.7 to 13 per cent linolenic acid along with oleic acid having higher nutritive value constituting about 27 per cent.

The mustard crop is affected by various biotic and abiotic stresses causing considerable yield losses. Among biotic stresses, the damage caused by plant diseases is one of the major constraints. The weather conditions during December and January are most congenial for outbreak of powdery mildew, which has become a limiting factor for successful cultivation of mustard. Like other crops, rapeseed and mustard are subjected to attack by a number of fungal, bacterial and viral diseases, which are considered economically important.

More than 20 diseases are known to affect rapeseed and mustard in India but diseases like *Alternaria* blight, white rust, downy mildew, powdery mildew and phyllody are of major consequence because of their global distribution and heavy yield losses (Saharan, 1992).

Powdery mildew, caused by *Erysiphe cruciferarum* Opiz. Ex. Junell., is becoming widespread disease in most mustard growing areas of India including Gujarat. It appears in epidemic form in states like Rajasthan, Haryana and Punjab. *Erysiphe* spp. can infect any above ground plant part and can cause heavy yield losses by reducing plant growth and consequently, the quantity and quality of seeds. Saharan and Sheoran (1985) observed that damage to mustard crop may be severe at the rate of 17.5 per cent when disease appears in early stage of plant

growth. The yield losses were to the tune of 45 per cent at more than 90 per cent severity of powdery mildew. The yield loss due to this disease in mustard was estimated as 16.97 per cent in Gujarat (Dange *et al.*, 2002).

Powdery mildew is an obligate pathogen and may persist on the host plant of *Brassica* spp. The disease is aptly named for infection produces a white lawn of fungal mycelium that covers the all above ground parts of the plant covered with dirty white circular patches, while chains of aerial conidia give the characteristic powdery appearance.

A number of fungicides have been recommended to manage powdery mildew disease, but spray of fungicides in standing crop at full bloom stage is practically difficult, less economical and non-ecofriendly. Genetic approaches such as exploiting disease resistance is considered to be the most effective, stable as well as economical method of protecting the crops for ensuring their productivity. Selection for resistance implies measurement of plant's resistance.

Severity of the diseases on oilseed *Brassicas* differs over seasons and regions as also between individual crops within a region in India. In the absence of stable, desirable and diverse sources of resistance to the mustard diseases with a broad genetic base, fungicides have so long been the only effective means to manage the disease. Despite high consumption of fungicides on rapeseed-mustard crops in India, timing their application has not been optimal while crops requiring treatment have been left unsprayed at appropriate time and others sprayed unnecessarily. Thus, the optimum timing of fungicide application to manage the build-up of the diseases varies.

In recent years, an increasing consciousness about environmental pollution due to pesticides and development of fungicide resistant strains in plant pathogens has challenged to search for eco-friendly tools for disease management (Meena *et al.*, 2011). Earlier workers reported management of oilseed *Brassica* diseases by fungicides. However, limited effort was made to use plant extracts as 'eco-friendly' components for effective management of oilseed *Brassica* diseases.

The information regarding yield loss assessment, epidemiology, management aspects and basic research are lacking especially in Saurashtra region of Gujarat State, where mustard crop is harvested during winter and powdery mildew is occurring in severe form thereby reducing the yield. The other foliar diseases are minor in nature for the mustard crop. Hence, taking into consideration the severity of the disease and yield losses, this research problem was undertaken to study the management strategy through fungicides and biopesticides with following aspects.

1. Symptomatology of the disease
2. Yield loss assessment due to powdery mildew disease
3. Evaluation of different mustard genotypes against powdery mildew disease *in vivo*
4. Epidemiological studies of powdery mildew disease
5. *In vitro* testing of systemic and non systemic fungicides, insecticides and phytoextracts against *E. cruciferarum*
6. Field evaluation of different fungicides and biopesticides against powdery mildew disease of mustard, and
7. Estimation of oil, protein content and test weight of mustard under different fungicidal and biopesticidal treatments.

# REVIEW OF LITERATURE

# CHAPTER – II

# REVIEW OF LITERATURE

Powdery mildew caused by *Erysiphe cruciferarum* Opiz ex. Junell is an economically important disease of mustard. Several researchers have investigated the disease in India and abroad. The brief information on different aspects of disease is narrated herein.

## The causal organism

*Erysiphe cruciferarum* Opiz ex. Junell, a biotrophic causal agent of powdery mildew in crucifers belongs to the Phylum: Ascomycota, Class: Ascomycetes, Order: Erysiphales, Family: Erysiphaceae and Genus: *Erysiphe*. Salmon (1900) used the collective name *Erysiphe polygoni* DC for the fungi causing powdery mildew of many economic crop plants. *Erysiphe communis* (Wall) Link consists of forms whose morphology was insufficienty known, and cleistothecia seldom develop. Junell (1967) divided *E. communis* into seven forms naming the fungi causing powdery mildew of crucifers as *E. cruciferarum* Opiz ex. Junell. Thus, in the literature three species of fungi, *viz.*, *E. polygoni*, *E. communis* and *E. cruciferarum* have been reprted to cause powdery mildew of rapeseed and mustard.

## Occurrence of disease in India

Butler (1918) was probably the first who reported a severe outbreak of the disease in 1907 in the Chenab canal colony of Punjab where large areas were affected. This disease was considered to be of minor importance but in the recent years it has proved to be a very destructive disease of *Brassica juncea* and *Brassica campestris* in some parts of the country particularly Uttar Pradesh, Rajasthan, Jammu & Kashmir,

Haryana and Gujarat (Bhander *et al.*, 1963; Sankhla *et al.*, 1967; Sharma, 1979; Saharan and Kaushik, 1981; Patel *et al.*, 1992).

**Symptoms**

The symptoms of powdery mildew caused by *Erysiphe cruciferarum* have been described earlier are as follows.

Sankhla *et al.* (1967) observed that the powdery mildew attacked the lower leaves first and gradually the entire plant of *Brassica campestris* var. *sarson* and *B. juncea*. Only the conidial stage was found in the beginning, but under dry conditions at plant maturity, perithecia developed around the midribs on the lower side of the leaves, on petioles and stems. Singh and Solanki (1974) have seen the defoliation of the *B. juncea* and *B. campestris* var. *sarson* plants infected by powdery mildew (*E. polygoni)* under natural conditions in Jodhpur region of Rajasthan. Sharma (1979) reported powdery mildew on mustard (*B. campestris* var. *sarson*) from Jammu and its' surrounding areas. He stated that the disease first appeared as white powdery mass on the older basal parts of the plant and by the time, the plant being ready to shed seed. The disease was found to spread all over including the pods giving the plant a dusty appearance. The fungus shows dirty white, hyaline amphigenous mycelium which was mostly rather thin. Saharan and Kaushik (1981) observed dirty white circular flowery patches on both sides of lower leaves of infected plants. The floury patches increased in size with increase in temperature and coalesced to cover stem and leaves. The green pods showed white patches and later they were covered with white mass of mycelium and conidia. In severe diseased condition, pods remained small in size and produced a

few small and shriveled seeds. The cleistothecia appeared on both sides of infected leaves, stems and pods in the form of black scattered and/or concentrated bodies. Singh (2000) also noticed that powdery mildew first appeared on the upper surface in the lower most (oldest) leaves as small (4-5 cm diam), scattered, white almost circular colonies which eventually coalesced as the colonies grew further, eventually covering the entire leaf surface under favorable environmental conditions.

Kaur *et al*. (2008) reported extensive stem colonization by powdery mildew caused by *E. cruciferarum* at the end of the flowering period with whitish patches ranging in size from 3 mm to 3 cm long which coalesced to form a dense, white, powdery layer as they expanded in *B. juncea* genotypes from Australia and China in the spring of 2007 at the University of Western Australia field plots at Crawley.

**Morphology of pathogen**

Brodie (1945) observed that the conidia of *E. polygoni* were formed by the development of a ring of cell wall material that was added inwardly until a transverse disk-like septum was formed, a pore being left in the centre through which the cytoplasm of the young spore was connected with that of the conidiophore. The one conidium was matured and abstracted each day. Sankhla *et al*. (1967) noted that the fungus *E. polygoni* had amphigenous, dirty white, hyaline mycelium with barrel shaped, hyaline, granular conidia, measuring 32.58 x 14.59 µ (42.0-24.5 x 19.5-10.5 µm). Perithecia were scattered, brown to dark brown in colour, globose to subglobose, 102.8 µm (77.0-126.0 µm) in diameter, bearing hypha-like brownish, septate appendages and containing 6 to 7 subglobose to broadly ovate, stalked asci, each

filled with 3 to 5 hyaline, oval to oblong, one celled ascospores. Shabbir and Yadav (2009) found that the conidia of *E. cruciferarum* obtained from infected mustard leaves were ellipsoid to cylindrical in shape, measuring 27.5-35 µm x 12.5-17.5 µm in size without fibrosin bodies. The conidia germinated by the formation of straight but two types of germ tube i.e. short but slightly lobed appressoria and long unlobed appressoria. Simple and forked germ tube emerged apically and basally with or without appressorium.

**Conidial Germination**

Yarwood (1936) stated that conidia of clover mildew (*E. polygoni*) germinated best when removed from diseased plants in the afternoon. With the onset of darkness, the germinability of the conidia gradually decreased; reaching a minimum in the early morning but again rising with the onset of daylight. He also noted that the elongation of the hyphae of clover mildew continued at fairly uniform rate throughout the day and night. The appressoria were formed principally during the light. The generative cell of the conidiophore divided once each day in the late afternoon to form a new proximal generative cell and a distal daughter cell. One conidium matured during the late morning on each conidiophore. Saharan and Sheoran (1988) investigated the effect of temperature (10-35°C), RH (20-70%) and varying light conditions on conidial germination, germ tube elongation and appressorium formation of *E. cruciferarum*. They concluded that maximum spore germination (40%) occurred at 20°C, followed by 25°C (36.1%) temperature but germ tube length remained the same (15 µm). Below 20°C and above 25°C temperature there was a significant reduction in percentage

spore germination. No spore germination was observed below 15ºC and above 30ºC temperature. Temperature had no effect on appressorium formation. Maximum spore germination (36.7%) was recorded at 40 per cent RH. Above 60 and below 30 per cent RH there was no spore germination. There was a slight increase in the percentage spore germination (36.7-40%) and germ tube length when spores were kept in the light for 24 h as compared with dark conditions. Percentage appressorium formation was higher in the light (100%) than in the darkness (87.5%). Conidial germination was not affected by the substrate. Som and Saharan (2000) also reported maximum conidial germination (86.6%) of *E. polygoni* causing powdery mildew of fenugreek after 24 h of incubation at 21ºC temperatures under laboratory condition. Kunkalikar and Padaganur (2001) found increased germination percentage of conidia of *E. polygoni* causing powdery mildew in green gram with increasing temperature up to 20°C, relative humidity up to 80 per cent and decreased thereafter. Shabbir and Yadav (2009) observed that the optimum temperature for the germination of conidia of *E. cruciferarum* was between 20-25°C ± 2°C.

**Yield loss**

Munjal *et al*. (1963) noted that the loss due powdery mildew of pea was proportional to the disease intensity between the limits of 50-100 per cent. The loss in yield of even a 100 per cent infected crop was 21-31 per cent in terms of pod number and 26-47 per cent in terms of pod weight. Gohil *et al*. (1988) assessed 19.1 per cent yield loos due to powdery mildew caused by *E. polygoni* on susceptible cumin variety MC-3 in North Gujarat. Ahmad *et al*. (2006) estimated yield loss in pea cv.

'Meteor' due to powdery mildew under field conditions in Peshawar, Pakistan from 2002 to 2004 using phytobiocide turmeric with 17.9 per cent decrease in disease severity, 23.3, 6.7 and 18.4 per cent less loss in pod number, seed number and seed yield, respectively than that of untreated plots.

The estimation yield losses due to powdery mildew in the mustard were also earlier reported in India. The powdery mildew of mustard disease assumed epidemic form and caused considerable yield loss in Haryana and Rajasthan (Saharan and Kaushik, 1981; Maiti, 1986). Saharan and Sheoran (1985) reported 17.5 per cent loss in total yield and reduction in oil content up to 6.47 per cent. Singh (1986) estimated 17.4 and 6.47 per cent reduction in mustard seed yield and oil content, respectively under epiphytotic condition. An yield loss of 22 per cent was reported in Gujarat (Anon., 1993). Dange *et al.* (2002) observed 16.97 per cent reduction in seed yield due to powdery mildew in mustard cv. 'Varuna' with the per cent disease intensity of 50.75 in control as compared to only 21.71 in treated plots in Gujarat, India during 1994-97. Hingole and Mayee (2004) reported the highest disease incidence and severity in rapeseed mustard cultivars Bio-SYR and lowest in TM-17 with highest loss in yield of 32.91 per cent in Bio-SYR and lowest in Bio-902 which suffered only 6.08 per cent under Maharashtra conditions. Khatri and Gangopadhyay (2008) found that the intensity of powdery mildew and seed yield of mustard crop were significantly influenced by dates of sowing in Bikaner zone. Early sown crop produced higher yield with minimum disease intensity, whereas late sown crop produced lower yield with maximum disease intensity.

**Varietal screening**

Narain and Siddiqui (1965) observed limited form of resistance against powdery mildew in *Brassica napus, Brassica alboglabra, Brassica japonica, Brassica alba* and *Eruca sativa*. Singh (1986) noted that genotypes of *B. campestris* var. brown *sarson* and *Brassica campestris* var. yellow *sarson* were found highly susceptible to powdery mildew of mustard caused by *E. cruciferarum*. However, some genotypes of *B. juncea viz.*, RIK 78-6-1, Pahari rai, DIR 4581, RLM 82, RLM 369, KRB 29, RH 7840, RH 7868, RH 7870, RK 1467, RLM 193 and RK 80-4 were resistant to the disease. *B. napus* and *Brassica carinata* were found immune to the disease. Singh *et al*. (1997) noted that parental lines of *B. juncea* were completely susceptible, whereas, *B. carinata* genotypes were completely free from powdery mildew incidence in Hisar, India.

Dang *et al*. (2000) screened 36 genotypes belonging to different brassicas for resistance to *Alternaria* leaf blight [*Alternaria brassicae* (Berk.) Sacc.]; downy mildew [*Peronospora parasitica* (Pers. ex. Fr.) Fr.]; white rust [*Albugo candida* (Pers.) Kuntze] and powdery mildew (*E. cruciferarum*) diseases during three consecutive crop seasons (1994-96) at Hisar. They concluded that seven varieties/genotypes, *viz.*, (*B. alba* [*Sinapis alba*], *B. carinata* (HC-1), *B. juncea* (DIR-1507 and DIR-1522) and *B. napus* (GS-7027, Midas and Tower) had stable and multiple disease resistance. Also, 13 genotypes belonging to different species possessed fair level of stable multiple disease resistance, but to a lesser extent. Subbalakshmi *et al.* (2001) assessed 25 mustard genotypes for yield and pest and disease reaction in a field trial during *rabi* 1997, in Coimbatore, Tamil

Nadu, India and concluded that the genotypes MCN-68 and 69 recorded lower incidence of leaf blight, white rust and powdery mildew.

Kumar *et al.* (2002) evaluated 13 parents and 10 crosses and found that none of the accessions of *B. juncea* was completely free from powdery mildew infection. The accession of *B. carinata* was resistant to powdery mildew. Kumar and Saharan (2002) reported that none of the cultivars of *Brassica rapa* was resistant to all the three major pathogens (*A. candida*, *A. brassicae* and *E. cruciferarum*). Only three cultivars namely, HC-I, PCC-2 (*B. carinata*) and GSL-1501 (*B. napus*) were resistant to white rust, alternaria blight, and powdery mildew.

Singh and Singh (2003) identified eight resistant donors, namely DIR 621, IJWHJ 001, PCR 10, PCR 9201, RK 8602, RK 8615, RAUD 101 and YSPB 24 including 20 moderately resistant sources, CSTR 610-10-15, DIR 513, DLM 50, NRJ 14, PBR 106, RE 5, RK 9402, RJ 16, RL 91-24, RH 9301, RSK 74, SKM 9328, TM 26, TM 18-8, VMR 1-2, YSBW 871, YSBW 881, NDYS 17, YST 151 and SSK 92-3 against *E. cruciferarum* incited powdery mildew in late sown mustard crops in Uttar Pradesh, India.

Singh *et al.* (2006) tested 54 lines of mustard for reaction to *E. cruciferarum* in Haryana. They found that lines GSL-1, Midas, MNS-9605, YSPb-24 and TH-68 were resistant (10% infection). The moderately resistant (20% infection) lines included Domo-4, BSH-1, TMH-50, TMH-52 and T-27.

Singh *et al.* (2010) screened 200 genotypes of rapeseed mustard for their response to powdery mildew during the year 2005-06 and 2006-07 crop seasons in Faizabad, Uttar Pradesh,

out of which 20 genotypes showed consistently resistant reaction in both the years, while nine genotypes were moderately resistant.

Mohitkar *et al.* (2012) screened 15 varieties of mustard against powdery mildew disease under field condition and observed that none of the varieties was immune to the disease. While, Bio-902, PCR-7 and Laxmi were resistant, JD-6 showed moderately resistant reaction to the disease. Highly susceptible reaction was found in Varuna, Vardhan and Kranti with maximum per cent disease incidence and intensity.

**Epidemiology**

Powdery mildew is severe in warm climate. This is because the fungus does not need the presence of water on the leaf surface for the infection to occur. However, the relative humidity of the air need to be high for spore germination. Therefore, the disease is common in crowded plantings where air circulation is poor and in damp, shaded areas.

The influence of climatic factors such as temperature, humidity, rainfall etc on the the development of powdery mildew of mustard caused by *E. cruciferarum* were investigated by several researchers in India.

Saharan and Kaushik (1981) observed that moderate temperature (maximum 25ºC, minimum 7.1ºC with an average of 16ºC), low humidity (65%), minimum rainfall (0.6 mm) and dry weather during February-March were reported to be congenial for powdery mildew development in Haryana, India on October sown mustard crop. The maximum disease progressed under field conditions when the temperature was above 22ºC and relative humidity below 55 per cent (Singh, 1986).

Dang *et al*. (1998) studied the relationship between environmental factors and disease development of *E. cruciferarum* on Indian mustard (*B. juncea*) and revealed that cumulative increase in powdery mildew was positively significant among varieties of mustard and intervals studied. The development was maximum when the average temperature ranged between 17.7 and 21.5°C with average relative humidity between 67 and 77 per cent. Stepwise multiple regression analysis showed that temperature had significant positive relationship with the disease.

Solanki *et al*. (1999) studied the development and progress of powdery mildew (*E. cruciferarum*) disease on Indian mustard in relation to meteorological factors in field conditions for three consecutive *rabi* seasons of 1992-93 to 94-95 at Anand (Gujarat), India. They obtained significantly positive correlation of accumulated growing degree days (GDD) and cumulative number of trapped conidia from flowering to harvesting stage was observed with area under disease progress curve i.e. (Progress of disease). Regression analysis of these factors accounted for 75 per cent of the variation. Excluding the average number of trapped conidia accounted for 69 per cent of the variation (R=0.69).

Gadre *et al*. (2002) investigated simple correlation analysis between various weather factors and diseases like alternaria leaf blight (*A. brassicae*), white rust (*A. candida*) and powdery mildew (*E. cruciferarum*) in mustard (*B. nigra*). There was a significant positive correlation with maximum air temperature, minimum air temperature, mean air temperature, sunshine hours, crop age and plant disease index of this disease except between

minimum air temperature and leaf blight incidence. Multiple regression analysis showed that among the various weather factors which could influence the incidence of diseases, sunshine and crop age were highly significant. Maximum, minimum and mean air temperatures were significant for powdery mildew only.

Desai *et al.* (2004) conducted an experiment to study the relationship of weather parameters with the powdery mildew disease with Indian mustard (*B. juncea*) cultivars 'Varuna' and local ('GM-2' at Sardarkrushinagar and 'PCR-7' at Bharatpur) and concluded that severity of the powdery mildew disease of *B. juncea* was favoured by >5 days of ≥9.1 h of sunshine, >2 days of morning (maximum) relative humidity (RH) of <90 per cent, afternoon (minimum) relative humidity (RH) 24-50 per cent, minimum temperature >5ºC and a maximum temperature of 24-30ºC. Regression analysis showed maximum temperature, minimum (afternoon) RH of the week preceding the date of observation had positive and negative correlation to disease severity both in cvs. 'Varuna' and 'GM-2' within the specified ranges, respectively.

Kohire *et al.* (2008) conducted experiment to determine the suitability of physical factors for disease development by *E. cruciferarum* in mustard (*B. campestris*) grown in Marathwada, Maharashtra, India. They concluded that lower temperatures (5-10ºC) and higher temperatures (35-45ºC) retarded the conidial production as well as germination. A minimum of 7-8 days was required for infection. High conidial production with successful germination was observed at 25-30ºC temperature. The nine day incubation period in the first and second weeks of December was

suitable for pathogen infection. Temperature with relative humidity played an important role in disease development. *E. cruciferarum* did not respond to high humidity. It required dry environment with lower temperature. Ideal humidity (30.2 - 48.8 %) with 12.2-22.8ºC temperature favoured powdery mildew of mustard.

**Effect of fungicides on inhibition of spore germination *in vitro***

Gohokar and Peshney (1981) conducted *in vitro* evaluation of 12 fungicides against *Laveillula taurica* of chilli and concluded that sulphur dust was highly effective in inhibition of spore germination followed by Sultaf, Karathane, Calixin, Benlate, Miltox and Thiovit. In inhibition of germ tube elongation, Karathane ranked first followed by Thiovit, Benlate, Vitavax, Sultaf, Calixin and sulphur dust.

Kunkalikar (1989) evaluated different fungicides *in vitro* condition against *E. polygoni* causing powdery mildew of green gram and found that carbendazim (0.1%) and wettable sulphur (0.3%) were most effective in reducing the germination of conidia. Sataraddi (1994) also noticed that, carbendazim (0.1%) and penconazole (0.1%) were most effective in reducing conidial germination of *Oidium erysiphoides* f. sp. *ziziphi* causing powdery mildew of ber. Sharma and Gupta (1994) found that carbendazim, bitertanol, triadimefon, tridemorph, triforine and thiophanate methyl significantly inhibited spore germination of *Podosphaera leucotricha* and reduced germ tube length. The maximum inhibition (94%) was obtained in triforine and minimum (72%) in thiophanate methyl at 500 ppm. Hiremath (1996) tested six fungicides *in vitro* against *E. cichoracearum*

causing powdery mildew of bhendi. Among them carbendazim (0.1%) was effective in reducing conidial germination.

Thind and Chander (1995) indicated that the test fungicides penconazole and bupirimate proved most effective, exhibiting more than 50 per cent inhibition of germ tube elongation, even at a lower dose of 1 µg/ml which increased to near 80 per cent at 10 µg/ml. Triadimefon and hexaconazole were next best in their efficacy causing more than 50 per cent inhibition of germ tube length at 10 µg/ml. Venkatrao (1997) found that penconazole (0.1%) and difenoconazole (0.1%) were efficient in inhibiting conidial germination of *E. polygoni* causing powdery mildew of green gram. Ravikumar (1998) also reported that penconazole (0.1%) difenoconazole (0.1%), Nimbicidin (0.3%) and Neemark (0.3%) were effective against *Sphaerotheca pannosa* in laboratory conditions using agar plate method. On the contrary, Biju (2000) found out propiconazole (0.1%) as most effective in reducing conidial germination followed by penconazole (0.1%) and carbendazim (0.1%) against powdery mildew of pea. Shivanna *et al.* (2006) tested nine systemic fungicides for inhibition of conidial germination of *E. cichoracearum* of okra in Karnataka. They found that at 0.1 per cent concentration, all fungicides caused complete inhibition of conidial germination. Penconazole (98.6%) was found to be the best and significantly superior to rest of the fungicides followed by hexaconazole (98.2%).

Chovatiya (2010) tested different systemic and non systemic fungicides under laboratory conditions and revealed that difenoconazole as the most effective with 85.50 per cent inhibition of spore germination of powdery mildew (*E. polygoni*

DC.) of fenugreek followed by hexaconazole, penconazole and propiconazole among systemic fungicides, while, among non systemic fungicides wettable sulphur recorded maximum inhibition (80%) of spore germination followed by mancozeb (72.25%) and dinocap (70%).

**Effect of insecticides on spore germination *in vitro***

Ryan and Clare (1972) noted that the use of metasystox and related organo phosphate insecticides to control aphid infestation prevented hyphal growth, sporulation, spore germination and germ tube elongation of *Rhynchosporium secalis*. Gadhiya (1994) reported that methyl parathion had hampered the spore germination of *Helminthosporium sativum*. Solanki (1995) showed toxic effect of triazophos and methyl–o-demeton on conidia of *E. cruciferarum* causing powdery mildew of mustard. Similar type of toxic effect was also found in dimethoate and fenvalerate. Kapadiya (1997) tested 10 insecticides and weedicides on mycelial growth and spore germination of *Cercospora canescens*. Among them, insecticides *viz.*, endosulfan and cypermethrin and weedicides *viz.,* oxyfluorfen and fluzifop-p-butyl were better in inhibition of mycelial growth as well as spore germination. The cypermethrin + profenophos recorded maximum inhibition (71%) of spore germination of powdery mildew of fenugreek followed by carbosulphan (51.75%) *in vitro* (Chovatiya, 2010).

**Effect of phytoextracts on inhibition of spore germination *in vitro***

Sheikh and Agnihotri (1977) found that extract prepared from the leaves of *Lawsonia alba*, roots of *Datura stramonium* and inflorescence of *Mentha piperita* were most effective against

*A. brassicae*, *Colletotrichum papayae* and *Helminthosporium* sp. isolated from the leaves of cauliflower, fruits of papaya and leaves of barley, respectively. Karade and Sawant (1999) tested crude leaf extracts of eight medicinal plants, clove extracts of *Allium sativum* (garlic) and rhizome extracts of *Curcuma aromatica* for their inhibition of spore germination of an onion isolate of *Alternaria alternata* and found that 10 per cent extract of *A. sativum* completely inhibited spore germination of the pathogen. Singh (2000) reported that the rhizome powders of ginger and *Acorus calamuns* significantly reduced the colony growth, number of germ tubes, formation of appressoria and haustoria of powdery mildew fungi. Dhaliwal *et al.* (2002) reported that *A. sativum* exhibited maximum efficacy providing complete inhibition of conidial germination at 100 µg/ml and above followed by *Cyperus scariousus* and *Cuminum cyminum* which gave complete inhibition of conidial germination and germ tube elongation at 100 and 500 µg/ml concentrations, respectively, against *Uncinula necator* causing powdery mildew of grapevine. Alam *et al.* (2002) found that plant extracts of *Tagetes erecta* leaf and *Azadirachta indica* bark extracts were the most effective in inhibiting *Colletotrichum gloeosporioides* after 5-30 minutes of immersion *in vitro* and in 5:1.25 (w/v) concentrations, the causal agent of mango anthracnose. Madhusudhan and Patil (2003) studied the efficacy of leaf and bulb extracts (2.5, 5 and 10%) of 15 plant species against the spore germination of *Colletotrichum truncatum.* They recorded the highest inhibition of spore germination in carrot grass (*Parthenium hysterophous*) extract regardless of the concentration used *in vitro.* Raghavendra (2005) tested various botanicals against powdery midew of chilli caused by *L. taurica* on conidial germination *in*

*vitro*. Among botanicals, Neem Seed Kernel Extract (NSKE) 10 per cent showed least conidial germination of 19.56 per cent and was significantly superior over rest of the treatments. This was followed by nimbicidin (0.5%), which showed 22.50 per cent conidial germination. Next better treatments were Nimibicidin (0.25%) and NSKE (5%) which showed 26.80 and 27.90 per cent conidial germination, respectively. A bulb extract of *A. sativum* was found most effective (even better than mancozeb) in reducing powdery mildew of mustard on leaves over control (Anon., 2007). Chovatiya (2010) evaluated nine plant extracts against *E. polygoni* causing powdery mildew of fenugreek and concluded that garlic as the best for spore germination inhibition (80.00%) followed by ginger (63.75%) and onion (62.00%) under laboratory condition.

**Use of fungicides for management of powdery mildew *in vivo***

Singh (1986) reported that two foliar sprays of Karathane (0.1%) gave maximum control of powdery mildew disease of mustard, followed by Sulfex (0.3%) and Calixin (0.1%). Kamat *et al.* (1989) observed reduction of mustard powdery mildew in the field by 95 per cent with two foliar spray of Karathane (0.2%) at 10 days interval commencing after appearance of disease. Three sprays of dinocap 0.025 per cent were recommended for effective control of powdery mildew of mustard starting from appearance of disease at 15 days intervals in field trials in Gujarat during 1986-90 (Anon., 1990). Jani *et al.* (1991) conducted experiment in three cropping seasons of 1986-87, 1987-88 and 1989-90 using a susceptible variety 'Varuna' under natural infection condition in Gujarat. They observed that Karathane, Topsin M, sulphur dust, Calixin, Thiovit and Rizolax significantly reduced

powdery mildew severity as compared to control. The lowest disease incidence (36.02%) was obtained with Karathane (0.025%). Patel *et al.* (1992) carried out field trial during the *rabi* season of 1986, 1987 and 1988 with systemic and non systemic fungicides to find out effective and economical control measures of the powdery mildew disease of mustard and reported that the minimum disease intensity was recorded in dinocap (18.7%) followed by tridemorph (30.7%) and wettable sulphur (36.3%) against powdery mildew of mustard. Similarly, foliar spray of Karathane at 0.2 per cent on *E. polygoni* on Indian mustard cv. 'Varuna' was found the most effective in reducing disease and improving mustard yield (Singh and Chauhan, 1996; Singh and Chauhan, 1998). Dang *et al.* (1998) revealed that Punch 0.03 per cent was the most effective, showing 84.7 per cent disease reduction over the control when mustard crop was sprayed just after the appearance of powdery mildew disease. Laxmanrao (1998) found sulphur (0.3%) as the most effective which reduced the disease intensity by 21-98 per cent followed by Karathane (0.1%) and Metalaxyl (0.1%) which reduced the disease intensity by 23.91 and 28.94 per cent, respectively for the control of powdery mildew of mustard. Significantly higher (13.97 q/ha) yield was obtained with sulphur followed by Karathane (13.54 q/ha). Sangwan and Mehta (2001) also noted 95.7 per cent reduction in powdery mildew disease of mustard with two sprays of Karathane 0.1 per cent at an interval of 10 days. Shete *et al.* (2008) evaluated the effect of nutrients and fungicides on incidence of powdery mildew *(E. cruciferarum*) of mustard *(B. juncea)* and revealed that three sprays of dinocap (0.1%) or triademorph (0.1%) significantly reduced the disease severity (14.87 and 14.91%) and thereby increased the yield of mustard

1551 and 1438 kg/ha, respectively in Rahuri, Maharashtra. Patel and Patel (2008) studied the effect of different treatments on intensity of powdery mildew and seed yield of mustard and revealed that tridemorph was significantly the best with PDI of 23.33 followed by hexaconazole (35.00%), tebuconazole (35.33%) and wettable sulphur (38.67%) as against 80.67 PDI recorded in control treatment. They also reported maximum seed yield of mustard in tridemorph (2685.16 kg/ha) with 19.10 per cent increase over control and was at par with hexaconazole (2623.44 kg/ha), tebuconazole (2592.57 kg/ha), wettable sulphur (2530.84 kg/ha) and difenoconazole (2484.55 kg/ha). Shabbir and Yadav (2009) tested different fungicides against *E. cruciferarum* using mustard cultivar 'Varuna' during 2007-08 and 2008-09 and reported that hexaconazole was the most effective fungicide for the management of powdery mildew of mustard. The minimum disease intensity (30.6%) was recorded in hexaconazole treated plants followed by Calixin, wettable sulphur, Bavistin, Blitox-50, Sulphur dust and Topsin-M, respectively.

Som (1997) showed reduction in disease intensity by three sprays of Karathane @ 0.1 per cent against *E. polygoni* causing powdery mildew in fenugreek with increased yield and yield components and found economically superior to CBR of 1:4.45 during 1993-94 and 1:2.37 during 1994-95 followed by Sulfex. Dhruj *et al.* (2000) investigated seven fungicides *viz.*, propiconazole, penconazole, hexaconazole, triadimefon, tridemorph, dinocap and sulphur against powdery mildew (*L. taurica*) of fenugreek. They concluded that all the fungicides significantly reduced the disease as compared to the control. However, penconazole was the most effective fungicide followed

by hexaconazole and propiconazole with highest yield recorded in penconazole followed by propiconazole and hexaconazole. Vikas and Ratnoo (2011) evaluated penconazole, triadimefon, carbendazim, tridemorph, dinocap, sulphur, sulphur dust, azadirachtin and neem oil against *E. polygoni* infecting fenugreek. In the field, all the treatments resulted in the significant reduction of disease severity as compared to the plant extracts, with dinocap as the best treatment, recording the highest yield and minimum per cent disease index. Chovatiya *et al.* (2012) evaluated different fungicides *in vivo* against powdery mildew of fenugreek and revealed that difenoconazole 0.025 per cent as the most effective fungicide in controlling the disease and for higher seed production, followed by penconazole (0.010%). Shivanna *et al.* (2006) evaluated different systemic and nonsystemic fungicides along with botanicals for their efficacy in disease control under field conditions against powdery mildew of okra. They found that penconazole at 0.1 per cent was the best fungicide and recorded least incidence (3.7%) followed by hexaconazole (5.8%) and propiconazole (6.8%). Karathane 0.2 per cent spray showed less incidence (7.3%) followed by wettable sulphur. Dinesh *et al.* (2011) tested 11 fungicides against powdery mildew of sunflower under field condition and revealed that difenoconazole at 0.05 per cent; propiconazole and penconazole at 0.1 per cent were highly superior over other fungicides and recorded the least disease severity 6.77, 7.38 and 7.55 per cent, respectively.

**Use of biopesticides for management of powdery mildew *in vivo***

Singh *et al.* (1991) showed the efficiency of ginger extract (*Zingiber officinale*) against powdery mildew of pea in field condition. Biswas *et al.* (1995) reported that, 10 per cent alcoholic water extracts of fresh plant parts of *Adhatoda zeylanica, Azadirachta indica*, *Launea coromondelica* and *Oxalis corniculates* significantly minimized the powdery mildew (*Phyllactinia corylea*) of mulberry under field condition. Daayf *et al.* (1995) found that an aqueous formulation of concentrated extracts from leaves of giant knot weed (*Reynoutria sachalinensis)* when applied at weekly intervals with a concentration of two per cent showed better control of powdery mildew of cucumber caused by *Sphaerotheca fuliginea*. Singh *et al.* (1995) worked on the effect of ajone, a constituent of garlic on powdery mildew of pea and discussed the possibilities of using this for the complete control of the pathogen under field condition. The spray of fresh neem leaf extract at two per cent or 0.2 per cent wettable sulphur, first at appearance of disease and second and third at 15 days interval were better for the control of powdery mildew of mustard in South Saurashtra (Gujarat) conditions (Anon., 1996). Venkatrao (1997) observed that *Ocimum canum* leaf extract at 10 and Nimbicidin at 0.3 per cent concentration reduced the powdery mildew of green gram caused by *E. polygo*ni up to 21.12 and 45.04 per cent, respectively. Laxmanrao (1998) reported that *behda (Terminalia belerica)* leaves extract (5%) significantly superior over control against powdery mildew of mustard followed by neem leaf extract (5%). Ravikumar (1998) found that neem based products *viz.*, Neemark (0.3%), Nimbicidin (0.3%) and NSKE (5%) were effective

in controlling powdery mildew of rose. Sindhan *et al.* (1999) reported that Neemadol (a neem product) and extracts of *A. indica*, *Allium cepa*, *A. sativum* and *Z. officinale* were highly effective for powdery mildew of pea and at par with Karathane in reducing disease intensity even at 0.25 and one per cent concentration, respectively. The effectiveness also increased with increase in the concentration of extracts. Biju (2000) found that Ovis at 0.15 per cent was most effective against powdery mildew of pea followed by Nimbicidin at 0.4 per cent. Rettinassababady *et al.* (2000) noted that the NSKE (5%) found superior in controlling the powdery mildew disease and increasing the grain yield of blackgram in pot culture experiment. Bulb extracts of *A. sativum* was found most effective (even better than mencozeb) in reducing powdery mildew on mustard leaves over control (Anon., 2007). Patel and Patel (2008) during their investigation on management of powdery mildew of Indian mustard under field conditions, using leaf extracts each at five per cent of neem (*A. indica*), eucalyptus (*Eucalyptus globulens*), *karan* (*Nerium indicum*), *karanj* (*Pongamia pinnata*) and bulb extract of onion (*A. cepa*), found that none of the phytoextracts helped in reducing the disease significantly and all the phytoextracts failed to increase the yield significantly over the control. As the concentration of extracts decreased the effectiveness also decreased. Rajendra *et al.* (2010) observed that garlic bulb extract (2% W/V) was also found most effective against powdery mildew of mustard and recorded 31.05 per cent disease intensity and it was at par with Ridomil MZ 72 (0.2%) and wettable sulphur (0.2%). Dinesh *et al.* (2011) revealed that azadirachtin at five per cent (1500 ppm, 1:10 dilution) was significantly superior with yield of 8 q/ha. It was on par with NSKE and was followed

by *Lantana* and turmeric leaf extracts in controlling sunflower powdery mildew under field condition. Meena *et al.* (2011) revealed that combination of seed treatment and foliar spray by garlic bulb extract resulted in least powdery mildew severity. The combination was at par with chemical fungicides for management of *Sclerotinia sclerotiorum* and was the best for powdery mildew of Indian mustard. Foliar spray of garlic bulb extract increased the seed yield significantly as compared to control. Chovatiya *et al.* (2012) evaluated different biopesticides *in vivo* against powdery mildew of fenugreek and revealed that neem leaf extract (5%) was the most powerful in controlling the disease and also for higher seed production. They also reported neem seed kernel extract as the next best effective treatment.

**Oil, protein content and test weight**

Degenhardt *et al.* (1974) revealed that severe incidence of *Alternaria* leaf spot caused by *A. brassicae* reduced protein and oil content in *B. campestris* in Canada. Ansari *et al.* (1988) reported loss in oil content of the seeds from diseased plants of rape-seed cultivars over the seeds from healthy plants ranged between 14.58 and 35.97 per cent due to Alternaria blight in Kanpur, India. Shivpuri *et al.* (1990) collected 82 Indian mustard seed samples from nine agro-climatic zones of Rajasthan, India and 16 fungal species were isolated to study the effect of these fungi on the quantity and quality of Indian mustard oil. They concluded that fungi *Fusrium oxysporum*, *Phoma lingum*, *Phoma nebulosa* reduced oil content. Singh *et al.* (2001) collected *A. brassicae* and *A. brassicicola* infected seed samples of rai cv. T-59 from different locations of Uttar Pradesh, India. They found that seed oil content decreased due to seed infection and

reduction in seed size. Oil content decreased among the different seed categories in the following order; healthy, discolored, shriveled and shriveled-discolored seeds. Shrestha *et al.* (2005) reported that *Alternaria* leaf blight disease showed a negative effect on oil content causing losses in mustard oil between 4.2 to 4.5 per cent under Nepal conditions. Singh and Singh (2005) recorded the highest avoidable losses due to the combined effect of Alternaria blight, white rust and downy mildew of mustard caused by *A. brassicae*, *A. brassicicola*, *A. candida* and *P. parasitica* diseases in seed yield, seed test weight and oil content as 34.7, 13.1 and 4.2 per cent, respectively. Patel (2006) reported that higher powdery mildew intensity hampered the seed development and thereby lead to poor seed weight, seed germination and seedling growth rate. He also recorded significantly the maximum seed weight of mustard in the treatment of tridemorph (5.82 g) which was at par with hexaconazole (5.77 g), tebuconazole (5.75 g), wettable sulphur (5.72 g) and difenoconazole (5.66 g) for the control of powdery mildew of mustard as compared to 5.39 g in control. Mert-Turk *et al.* (2008) investigated the effect of nitrogen fertilizer and fungicidal treatment against powdery mildew infection caused by *E. cruciferarum* of oilseed rape on seed components, including protein, oil, oleic acid, linolenic acid and undesirable substances such as sinapic acid esters (SAE) and glucosinolates (GSL), using near infrared spectroscopy (NIRS). They concluded that nitrogen fertilization increased the protein, but lowered the oil content of the seeds. Fungicidal treatments significantly increased oil contents in all varieties tested, however reduced protein levels in fertilized and non-fertilized plots.

# MATERIALS AND METHODS

# CHAPTER - III

# MATERIALS AND METHODS

Present investigation on "Management of powdery mildew (*Erysiphe cruciferarum* Opiz ex. Junell) of mustard (*Brassica juncea* (L.) Czern. & Coss.)" was undertaken at the Junagadh Agricultural University (JAU), Junagadh during *rabi* 2007-08 to 2010-11. Field experiments were carried out at Dry Farming Research Station, JAU, Jam-Khambhalia Dist. Jamnagar, whereas *in vitro* studies on various aspects were carried out at the Department of Plant Pathology, College of Agriculture, JAU, Junagadh. Details of the materials and methods followed are described here under.

## General laboratory procedures

### Glassware

All the glassware used throughout the studies was of Schott Duran made. These were cleaned by overnight soaking in six per cent chromic acid solution followed by washing with tap water and rinsing with distilled water followed by drying.

### Equipments

The laboratory equipments used were autoclave, oven, incubator, refrigerator, physical balance, electronic balance, NIR spectrometer (Dickey John), compound microscope Leica EC3, Olympus CH-2 attached with camera Olympus C-35AD-4 and stage & ocular micrometer etc.

### Sterilization

All the media were sterilized at 1.036 kg/cm$^2$ [15 lbs psi] steam pressure and 121°C in an autoclave for 20 minutes. The

glassware was sterilized in an electric hot air oven at 180ºC for an hour.

**General climate of the location**

Jam-Khambhalia, where the present investigation was undertaken, is located at an elevation of 38.86 m above the mean sea level and is situated at 22°1' North latitude and 69°43' East longitude and it is 11 km away from the Arabian Sea. The climate of this region is semi-arid and sub-tropical type. Southwesterly current in the summer season brings rains from third week of June to the end of September with an average annual rainfall of 705.3 mm (2001-10). The monsoon is erratic and uncertain a common feature of this region. The unseasonal rains and/or summer storms are normally absent. Excepting sporadic showers in *rabi* season, there is no rainfall during winter and summer. The winter is normal and sets in the month of November and continues till the end of February. December and January are the coldest months of the year. The mean air temperature during the winter varies from 12.3°C to 28.2°C. The summer season usually commences from March and ends by the third week of June. The maximum temperature during summer goes up to 42°C.

**Collection of diseased samples**

The naturally infected leaves of mustard [*Brassica juncea* (L.) Czern. & Coss.] variety 'GM-2' showing typical powdery mildew symptoms were collected during early morning as and when required for present investigation.

**Identification of pathogen**

Powdery mildew pathogen of mustard from freshly infected leaves was critically examined under a compound microscope for preliminary identification of the pathogen.

**Morphology of the pathogen**

Morphological characters of the fungus were studied by observing cotton blue stained slides under compound microscope. After calibrating the microscope, conidia and hyphae were measured with the help of ocular micrometer. On the basis of morphological characters described by Sharma (1979) the causal fungus was identified as an *Erysiphe cruciferarum* Opiz ex. Junell.

**Conidia**

Conidia were collected from the host leaf surface by using a soft, sterilized camel hair brush and mounted in clear lactophenol cotton blue solution over a glass slide. These slides were examined under compound microscope for their length and breadth measurements.

**Germ tube**

From the young colonies, gently fresh conidia were dusted uniformly on glass slide smeared with glycerin to maintain relative humidity and kept in Petri dishes to incubate at room temperature (22° $\pm$ 1°C). After 48 hours of incubation, the slides were examined for respective traits.

**Mycelium**

Powdery mildew infected fresh leaves were immersed immediately in 10 ml of lactophenol containing 1.0 per cent cotton blue and then brought to boiling over a low (Bunsen)

flame and allowed to simmer for three minutes. These leaves were kept in the same solution until cold, and then were removed and gently rinsed in water for the purpose. Gently the mycelial mats were separated from the leaf surface and mounted in clear lactophenol solution on a glass slide to study the types of mycelium.

**Microscopic examination**

The cross-sections of powdery mildew infected leaves of mustard were prepared using lactophenol containing 1.0 per cent cotton blue as mounting medium. Later on photomicrographs of mycelium, conidia and conidiophores were taken using Leica and Olympus CH-2 binocular compound microscope.

**Assessment of yield loss due to powdery mildew *in vivo***

A field trial was conducted during *rabi* season of 2007-2008 to 2009-2010 at Dry Farming Research Station, Junagadh Agricultural University, Jam-Khambhalia. Mustard cv. Gujarat Mustard-2 was used for assessment of yield loss due to *E. cruciferarum*. For this purpose, three strips of 24.0 m x 2.7 m were formed. One strip was sprayed with hexaconazole 0.005 per cent first at the time of initiation of the disease, thereafter four sprays at ten days interval to maintain disease free condition. The remaining two strips were kept as control (with and without water spray).

Eight samples of the size 2.0 m x 1.8 m were drawn from each strip. The incidence of disease was recorded by following the 0-12 scale (Solanki, 1995) as mentioned in the Table 3.1 from 10 randomly selected plants from each sample and five

**Table 3.1: Rating scale with infection/phenotypic class**

| Rating Scale | Infection/phenotypic class |
|---|---|
| 0 | Healthy (i.e. no disease symptoms on the plant) |
| I | Few whitish specks (1 to 5) on leaf |
| II | Up to 25 per cent leaf area covered with whitish specks |
| III | > 25 to 50 per cent leaf area covered with whitish fungal growth |
| IV | More than 50 per cent area of leaf covered with whitish fungal growth and few whitish specks on stem |
| V | More than 50 per cent area of leaf and up to 25 per cent area on stem covered with whitish growth |
| VI | More than 50 per cent area of leaf and stem covered with whitish growth |
| VII | More than 50 per cent area of leaf and stem covered by whitish growth with few whitish specks on branch(es) |
| VIII | More than 50 per cent area of leaf, stem and up to 25 per cent area of branch(es) covered with whitish growth |
| IX | More than 50 per cent area of leaf, stem and branch(es) covered with whitish fungal growth |
| X | More than 50 per cent area of leaf, stem and branch(es) covered with whitish fungal growth with few whitish specks on siliquae |
| XI | More than 50 per cent area of leaf, stem, branch(es) covered with whitish fungal growth and up to 25 per cent area of siliquae covered with whitish growth |
| XII | More than 50 per cent area of leaf, stem, branch(es) and siliquae covered with whitish growth ( i.e. entire plant covered with whitish fungal growth) |

leaves from each plant were selected after seven days of last spray. The seed yield was recorded from each treatment from eight sub plots made in each treatment.

Loss was estimated on the basis of yield obtained in different treatments in terms of percentage according to formula given below (Gupta and Singh, 1981).

$$\text{Percent loss in yield} = \frac{\text{Yield of protected plot} - \text{Yield of unprotected plot}}{\text{Yield of protected plot}} \times 100$$

**Per cent Disease Intensity (PDI)**

The intensity of the disease was recorded by scoring on individual ten plants using 0-12 scale. Further the PDI was calculated with the above scales using the formula given by Wheeler (1969).

$$\text{PDI} = \frac{\text{Sum of total rating}}{\text{Total plants observed}} \times \frac{100}{\text{Maximum disease rating}}$$

**Screening of mustard entries against powdery mildew**

A trial was conducted at Dry Farming Research Station, Junagadh Agricultural University, Jam-Khambhalia to study the response of different entries against powdery mildew disease caused by *E. cruciferarum*. Total 13 entries were screened with two replications under natural conditions during *rabi* 2007-08 to 2009-10. Each of entries was sown with two rows of 6.0 m length spaced at 45 cm apart and single row of susceptible cultivar Gujarat Mustard-2 with same length and spacing intercepted between two rows of test entries. All packages of practices were followed except management of foliar diseases. The details of different entries screened are given in Table 3.2.

**Table 3.2: Screening of mustard entries against powdery mildew *in vivo***

| Sr. No. | Name of entry | Species |
|---|---|---|
| 1 | GM-1 | *Brassica juncea* |
| 2 | GM-2 | " |
| 3 | GM-3 | " |
| 4 | GSL-1 | *Brassica napus* |
| 5 | GSL-861-212 | " |
| 6 | HNS – 0004 | " |
| 7 | ISN – 129 | " |
| 8 | NUDB-26-11 | " |
| 9 | DLSC-3 | *Brassica carinata* |
| 10 | Kiran | " |
| 11 | NPC-3 | " |
| 12 | NPC-111 | " |
| 13 | NPJ-87 | " |

The entries under test were scaled from susceptible to resistant on the basis of PDI. The difference in the percentage of infection was taken into consideration while screening the plants for disease resistance. The general assessment 0-5 scale as described by Haware (1971) was utilized for grouping the entries under different categories as given in Table 3.3.

**Epidemiology of the disease**

The mustard cultivar 'GM-2' was sown in natural condition in the field of 12.0 m x 9.0 m plot size for disease development. The disease severity was recorded from 20-tagged plants on 0-12 scale as mentioned earlier at four days interval.

**Table 3.3: Host reaction to powdery mildew disease on 0-5 scale**

| Infection category | Description | Host reaction |
|---|---|---|
| 0 | No infection | Healthy (H) |
| 1 | 01-20% leaves infected | Highly resistant (HR) |
| 2 | 21-40% leaves infected | Resistant (R) |
| 3 | 41-60% leaves infected | Moderately susceptible (MS) |
| 4 | 61-80% leaves infected | Susceptible (S) |
| 5 | 80-100% leaves infected | Highly susceptible (HS) |

Further, multiple regressions were carried out with weather parameters in relation to PDI. The relationship of disease with weather parameters was established by following multiple linear regression equation.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$$

Where,

Y= PDI

$\alpha$ = Intercept (constant)

$\beta_i$ = Partial regression coefficient associated with each $X_i$

i=1, 2, 3, 4 are the weather variables

$X_1$= Maximum temperature (°C)

$X_2$= Minimum temperature (°C)

$X_3$= Morning relative humidity (%)

$X_4$= Afternoon relative humidity (%)

Indian mustard was sown on 16$^{th}$ October during 2007-08 to 2009-10 and 18$^{th}$ October during 2010-11 adopting common package of practices. Data for first date of appearance of

powdery mildew and gradual progress of the same on the crop was monitored and observations on per cent disease intensity were recorded at regular interval of four days till harvest of the crop. Weather data on maximum and minimum temperatures, morning and afternoon relative humidity at morning (07.48 h) and afternoon (14.48 h) (Local Apparent Time or LAT calculated on the basis of longitude of a location as per standard norms of the World Meteorological Organization) were recorded from nearby installed meteorological instruments. For each assessment date, PDI of 20 tagged plants were averaged to give a single value. Different ranges of weather variables of four days preceding the assessment date were used as independent variables to identify the boundary and favourable conditions that influenced the dependent variables or powdery mildew disease severity on the crops following initial infection, through regression analysis. The important weather indices were selected through stepwise regression.

**Plant protection**

In absence of fungicidal spray, powdery mildew was allowed to develop, over the actual experimental area from natural inoculum. Crop was protected by single spray of each endosulfan @ 0.07 per cent and imidacloprid @ 0.005 per cent against mustard sawfly (*Athelia lugens proxima* Klug) and mustard aphid (*Lipaphis erysimi* Kalt), respectively, during the years of experiment. No protection was taken against any disease.

**Instrumentation**

The instruments *viz*., maximum and minimum thermometer, dry and wet bulb thermometer were used regularly in the study.

**Macroclimate**

Daily maximum and minimum temperature, dry and wet bulb temperature were recorded during the growing season of all the four years.

**Evaluation of different agrochemicals on spore germination**

**Fungicides and insecticides**

All the laboratory experiments were conducted at Post Graduate Laboratory of Department of Plant Pathology, College of Agriculture, Junagadh Agricultural University, Junagadh. The experiment was laid out in quadruplicates adopting Completely Randomized Block Design *in vitro*. Spore germination inhibition activities of different agrochemicals were tested against *E. cruciferarum in vitro* by poisoned food technique using Potato Dextrose Agar (PDA) as a germinating medium (Bagchi and Das, 1968). With micropipette appropriate quantity of each agrochemical required was incorporated into autoclaved PDA medium before solidification and then medium was poured into sterilized Petri dishes (90 mm dia.) in equal quantity (5 ml per Petri dish) to form a thin layer. By using a soft, sterilized, camel hair brush, conidia of *E. cruciferarum* from young colonies were collected and dusted under aseptic conditions over the solidified PDA medium and then Petri dishes were incubated at room temperature (23° $\pm$ 1°C) for 48 hours and observations were recorded at an interval of 12 hours. Inoculated Petri dishes containing PDA medium without agrochemicals served as

control. The conidium having germ tube length of more than its width was considered as germinated conidium. Effect of toxicity on 100 conidia in each treatment and on their germination was observed with the help of compound microscope.

Per cent inhibition of spore germination in each treatment was calculated by using following formula (Bliss, 1934).

$$I = \frac{C - T}{C} \times 100$$

Where,

I= Per cent inhibition

C=Number of germinated spore in control

T= Number of germinated spore in treatment

The agrochemicals *viz*., systemic fungicides, non systemic fungicides and insecticides mentioned in Table 3.4, Table 3.5 and Table 3.6, respectively, were tested using poisoned food technique.

Observations were recorded and per cent spore germination inhibition was calculated as per the formula given earlier.

**Evaluation of antifungal activity of different phytoextracts**

There have been a few investigations on antimicrobial substances being isolated and studied for their antifungal properties against various plant pathogenic microorganisms but still a wide range of plants to be explored. Therefore, the studies were undertaken to ascertain the antifungal properties of extracts of various plant species which are easily available in this area.

**Table 3.4: *In vitro* evaluation of systemic fungicides against *E. cruciferarum***

| **Common Name** | **Chemical Name** | **Trade Name** |
|---|---|---|
| Hexaconazole | (RS)-2-(2,4 dichlorophenyl)-1-(1*H*-1,2, 4 triazol-1-yl) hexan-2-ol | Contaf 5% EC |
| Propiconazole | 1-[[2- (2,4- dichlorophenyl)-4-propyl-1, 3-dioxolan-2yl] methyl]-1*H*-1,2,4-triazole | Tilt 25% EC |
| Difenoconazole | 1-[2-[4-(4-chlorophenoxy)-2-chlorophenyl]-4-methyl-1,3-dioxolan-2-ylmethyl]-1*H*-1,2,4-triazole | Score 25% EC |
| Azoxystrobin | Methyl(E)-2-{2-[6-(2-cyanophenoxy)-4-pyrimidin-4-yloxy]phenyl}-3-methoxyacrylaate | Amistar 25% SC |
| Penconazole | 1-[2-(2-(4-dichlorophenyl)pentyl]-1*H*-1,2,4-triazole | Topas 10% EC |
| Tebuconazole | (±)-α-[2-(4-chlorophenyl) ethyl]-α-(1,1-dimethylethyl)-1*H*-1,2,4-triazole-1-ethanol | Folicur 25% EC |
| Carbendazim | Methyl-1*H*-benzimidazole-2-yl carbamate | Bavistin 50% WP |

**Table 3.5: *In vitro* evaluation of non systemic fungicides *against E. cruciferarum***

| Common Name | Chemical Name | Trade Name |
|---|---|---|
| Mancozeb | Manganese ethylene bis dithiocarbamate (polymeric) complex with zinc salt | Dithane M-45 75% WP |
| Chlorothalonil | Tetrachloroisophthalonitrile | Kavach 75% WP |
| Thiram | Tetramethylthiuram disulfide | Thiram 75% WP |
| Dinocap | 2,6-dinitro-4-octylphenyl crotonates & 2,4-dinitro-6-octylphenyl crotonates | Karathane 48% EC |
| Zineb | Zinc ethylenebis (dithiocarbamate) (polymeric) | Zineb 75% WP |
| Captan | *N*-(trichloromethylthio) cyclohex -4- ene-1,2-dicarboximide | Captaf 75% WP |
| Wet. Sulphur | Sulphur | Sulfex 80% WP |

**Table 3.6: *In vitro* evaluation of insecticides *against E. cruciferarum***

| Common Name | Chemical Name | Trade Name |
|---|---|---|
| Triazophos | O,o-diethyl o-(1-phenyl-1*H*-1,2,4-triazole-3-yl) phosphorothioate | Triazophos 35% EC |
| Triazophos + Deltamethrin | O,o-diethyl o-(1-phenyl-1*H*-1,2,4-triazole-3-yl) phosphorothioate [ 1*R* [ 1 ∞ (S*), 3∞ ]]- cyano (3-phenoxy-phenyl) methyl 3-( 2,2–dibromoethenyl ) -2,2-dimethylcyclopropanecarboxylate | Spark 36% EC |
| Imidacloprid | 1-[(6-chloro-3-pyridinyl) methyl]-*N*-nitro-2-imidazolidinimine | Confidor 17.8% SL |
| Carbosulfan | 2,3-dihydro-2,2-dimethyl-7-benzofuranyl-[(dibutylamino)thio) methylcarbamate | Marshall 25% EC |
| Acephate | O,S-dimethyl acetylphosphoramidothioate | Asataf 75% WP |
| Cypermethrin + Profenofos | Cyano (3-phenoxyphenyl) methyl 3-(2,2-dichloroethenyl)-2,2-dimethyl cyclopropanecarboxylate + O-(4-bromo-2-chlorophenyl) O-ethyl S-propyl phosphorothioate | Polytrin 44% EC |
| Methyl-o-demeton | S-[2-(ethylthio)ethyl] O,O-dimethyl phosphorothioate | Metasystox 25% EC |
| Quinalphos | *O,O*-diethyl *O*-2-quinoxalinyl phosphorothioate | Ekalux 25% EC |
| Azadirachtin | Neemazal | Neemazal 0.15% W/W |

Locally available plant species were tested at two per cent concentration for their efficacy against the spore *E. cruciferarum*. Fresh leaves, cloves or rhizomes of respective plant species as listed in Table 3.7 were first washed with tap water and then with sterilized water. Each sample was then homogenized in sterilized distilled water at the rate of 1 ml/g of tissues with a pestle and mortar and filtered through fine muslin cloth.

**Table 3.7: *In vitro* evaluation of phytoextracts against *E. cruciferarum***

| S.N. | Botanical Name | English/Common Name | Plant parts used |
|---|---|---|---|
| 1 | *Allium sativum* L. | Garlic | Clove |
| 2 | *Allium cepa* L. | Onion | Bulb |
| 3 | *Zingiber officenale* Rose. | Ginger | Rhizome |
| 4 | *Curcuma longa* L. | Turmeric | Rhizome |
| 5 | *Vinca rosea* L. | Periwinkle | Leaves |
| 6 | *Ocimum sanctum* L. | Holy basil | Leaves |
| 7 | *Cassia fistula* L. | Indian Laburnum | Leaves |
| 8 | *Clerodendrum inerme* L. Gaerth. | Bataj | Leaves |
| 9 | *Lawsonia inermis* L. | Henna | Leaves |
| 10 | *Azadirachta indica* A. Juss | Neem | Leaves |
| 11 | *Polyalthia longifolia* (Sonner) Thw. | Pendula | Leaves |
| 12 | *Derris indica* (Lam.) Thw.Bennet. | Karanj | Leaves |
| 13 | Control (without phytoextracts) | - | - |

The filtrate was centrifuged at 5000 rpm for 20 minutes and the supernatant was filtered through sterilized sintered funnel (pore size 1-2 microns), which formed the standard plant extract solution (100%). The clarified extract was stored in refrigerator at 4°C till used. To prevent bacterial contamination, a pinch of streptocycline was added to each dilution. With micropipette appropriate quantity of each phytoextracts required was incorporated into autoclaved PDA medium before solidification and then medium was poured into sterilized Petri dishes in equal quantity (5 ml per Petri dish) to form a thin layer.

Conidia of *E. cruciferarum* from young colonies, by using a soft sterilized camel hair brush were collected and dusted under aseptic conditions over the solidified PDA medium and then Petri dishes were incubated at room temperature (23° $\pm$ 1°C) for 48 hours and observations were recorded at an interval of 12 hours. Inoculated Petri dishes containing PDA without phytoextracts served as control. The conidium having germ tube length of more than its width was considered as germinated conidium. Effect of toxicity on conidia and on their germination was observed with the help of compound microscope. Per cent inhibition of spore germination in each treatment was calculated by using formula as mentioned earlier.

**Evaluation of fungicides for management of powdery mildew *in vivo***

A trial was conducted at Dry Farming Research Station, Junagadh Agricultural University, Jam-Khambhalia to study the efficacy of various fungicides for controlling powdery mildew disease of mustard caused by *E. cruciferarum* under natural conditions. The trial was conducted in randomized block design

with four replications under field conditions during three consecutive *rabi* seasons of 2007-08 to 2009-10.

Certified seeds of mustard variety 'GM-2' were sown @ 3.5 kg seed per hectare on 16th October during all the three years. Seeds were drilled evenly in each of the gross plot size of 6.0 m x 2.7 m having 6 rows manually at a depth of 2-3 cm in fertilized (50:50:00 NPK kg/ha) furrows at 45 cm x 15 cm spacing and the rows were covered by light planking. Each plot was then irrigated carefully. Thereafter, all agronomic practices were followed as and when required.

The spraying of fungicides was carried out at onset of disease and thereafter three sprays at 12 days interval. Control was maintained by water spraying as suggested by Yarwood (1939) that water spray may also control powdery mildew, therefore, one such treatment was also kept as control and without spraying of any fungicide. The details of fungicidal treatments applied are given in Table 3.8.

**Table 3.8: Fungicides tested *in vivo***

| Sr. No. | Fungicides | Trade Name | Concentrations (%) |
|---|---|---|---|
| 1 | Hexaconazole 5% EC | Contaf | 0.005 |
| 2 | Difenoconazole 25% EC | Score | 0.025 |
| 3 | Penconazole 10% EC | Topas | 0.010 |
| 4 | Azoxystrobin 25% SC | Amistar | 0.025 |
| 5 | Dinocap 48% EC | Karathane | 0.048 |
| 6 | Wettable Sulphur 80% WP | Sulfex | 0.2 |
| 7 | Control (Water spray) | - | - |
| 8 | Control (No spray) | - | - |

**Disease assessment**

Observations on disease intensity were recorded from ten plants randomly selected from each treatment after seven days of last spray using 0-12 scale (Solanki, 1995). Each plant was evaluated for its disease reaction by scoring the disease intensity on top, middle and lower leaves following 0-12 scale as given in Table 3.1.

The first date on which powdery mildew symptoms were observed in each treatment was considered as disease onset.

Per cent disease intensity (PDI) in each treatment was worked out as described earlier. The percentage disease control and the percentage deviation in yield were calculated with the help of the following formula (Mathur *et al.,* 1971).

$$\text{Disease control (\%)} = \frac{\text{P.D.I. in check} - \text{P.D.I. in treatment}}{\text{P.D.I. in check}} \times 100$$

$$\text{Yield increase (\%)} = \frac{\text{Yield in treatment} - \text{Yield in check}}{\text{Yield in check}} \times 100$$

**Preparation of fungicide solutions**

Required concentration of fungicidal solution for foliar spray of each fungicide was prepared on the basis of active ingredient available in the formulation. Required quantity of respective fungicide was added to required quantity of water so as to get desired concentration.

Seed yield of net plot area 4.0 m x 1.8 m having four rows of each treatment was recorded after harvest of the crop. Finally, yield in kg per ha was worked out by multiplying yield of net plot area with multiple factor.

**Evaluation of biopesticides for management of powdery mildew *in vivo***

An experiment was conducted at Dry Farming Research Station, JAU, Jam-Khambhalia to study efficacy of various biopesticides for controlling powdery mildew disease of mustard caused by *E. cruciferarum* under natural conditions. The experiment was conducted in randomized block design with four replications under field conditions during *rabi* 2007-08 to 2009-10. Certified seeds of variety 'GM-2' were sown in the experimental plots @ 3.5 kg/ha on 16$^{th}$ October during the period of experimentation. Seeds were drilled evenly in each of the gross plot size of 6.0 m x 2.7 m having six rows manually at a depth of 2-3 cm in fertilized furrows at 45 cm x 15 cm spacing and covered the soil by light planking. Each plot was then irrigated carefully. Thereafter, all agronomic practices were followed as and when required. First spray was given on initiation of disease and thereafter 12 days interval. Control was maintained by water spraying and without any spray.

The details of biopesticidal treatments applied are given in Table 3.9. Observations on disease intensity were recorded as mentioned earlier. Seed yield of net plot area 4.0 m x 1.8 m having four rows of each treatment was recorded after harvest of the crop. Finally, yield in kg per ha was worked out by multiplying yield of net plot area with multiple factor.

**Preparation of phytoextracts**

**Neem seed kernel extract**

Twenty grams of crushed neem seed kernels were soaked overnight in 500 ml of water, crushed with the help of mixture.

The liquid was squeezed through muslin cloth and then the volume made up to 1000 ml to get two per cent concentration.

**Table 3.9: Biopesticides tested *in vivo***

| Sr. No. | Biopesticides | Concentration (%) |
|---|---|---|
| 1 | Neem seed kernel extract | 2 |
| 2 | Neem leaf extract | 2 |
| 3 | Azadirachtin 0.15% W/W (Neemazal) | 0.5 |
| 4 | Wettable Sulphur 80% WP | 0.2 |
| 5 | Control (Water spray) | - |
| 6 | Control (No spray) | - |

**Neem leaf extract**

Fresh and healthy neem leaves were collected and washed thoroughly with running tap water. These leaves were cut into small pieces and macerated in sterilized distilled water (1:1 w/v basis) in blender. Resulting crude extract was filtered through single layer of sterilized muslin cloth. Filtered extracts were considered as standard (100%) solutions. Standard extracts were further diluted to desired concentrations (2%) by adding required quantity of water for foliar spray.

**Oil and protein content estimation**

Oil and protein content in the seeds were determined directly by using Near Infrared Spectroscope as described by Mandal *et al.* (2005). The mustard seed samples randomly drawn from each treatment were ground in mortar with pestle and screened through fine sieve. Thereafter about five g of each ground seed samples were uniformly placed in a small ring cup (3.8 cm) for scanning on a Monocromator NIR reflectance spectroscopy for the measurement of oil and protein content in

the treatment of different fungicides and biopesticides and also for the study of loss in oil and protein content due to powdery mildew disease of mustard in Food Testing Laboratory, Department of Biotechnology, Junagadh Agricultural University, Junagadh.

**Test weight**

Counting and weighing of 1000-seeds randomly drawn from seed samples of each treatment was done by electronic digital balance. Effect of different treatments of fungicides and biopesticides on test weight was analyzed statistically. For the study of assessment of yield loss same procedure was followed.

**Statistical analysis**

For fungicidal management study the statistical analyses was carried out as per the procedure described by Panse and Sukhatme (1985). An association of various meteorological variables with disease was assessed through correlation analysis and regression equation through multiple linear regression technique (Montgomery *et al.*, 2001). The responsible factors that most influence the disease development were identified. Economics of chemicals used for the disease management was also worked out. Incremental cost benefit ratio was calculated by dividing the increased income over control with total expenditure.

# EXPERIMENTAL RESULTS

# CHAPTER – IV

# EXPERIMENTAL RESULTS

Powdery mildew caused by *Erysiphe cruciferarum* Opiz ex. Junell is the most common disease of mustard [*Brassica juncea* Czern & Coss (L.)] in Saurashtra region of Gujarat state. The disease generally appears at pod formation stage and brings about heavy damage to the crop in terms of yield loss and deteriorates the quality of the seeds. Thus it is becoming an economically important disease of this region. Hence, the present investigation was undertaken to generate basic information on pathogen, yield losses and their economics, weather relationship, effect of pesticides on the pathogen and disease management through fungicides and biopesticides which are narrated here under.

**Identification of the pathogen**

Fungal growth from the infected mustard leaves, stem and siliquae examined under compound microscope revealed the presence of dense, ectophyte, hyaline branched and septate thin mycelial growth. Conidiophores were septate, mostly 2-3 celled, simple and almost straight which beared conidia mostly singly, but rarely in chain of 2-3 conidia. Single celled conidia were cylindrical and occasionally revealed vacuoles. Cleistothecium was not seen. Morphological and cultural characters revealed the pathogen to be *Erysiphe cruciferarum*.

**Disease occurrence**

Powdery mildew of mustard caused by *E. cruciferarum* was observed at Dry Farming Research Station, Junagadh Agricultural University, Jam-Khambhalia during *rabi* season in the second fortnight of December during the year 2007-08 to 2009-10. Naturally infected plants were observed under

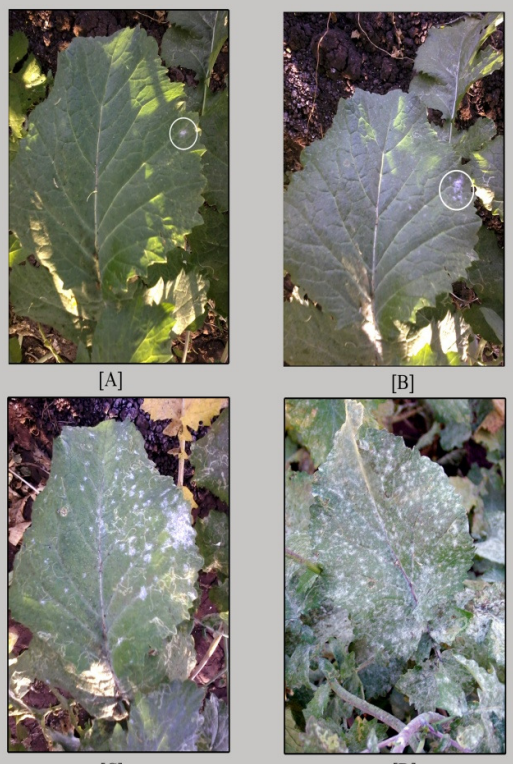
prevailing climatic conditions. The severity of the disease increased with the increase in the age of the plant. The disease was also found in the trials of All India Coordinated Research Project at Main Oilseed Research Station, Junagadh Agricultural University, Junagadh.

**Symptomatology**

The initial symptoms in field were observed during 60-63 days after sowing (DAS) which coincided with completion of flowering period. The symptoms appeared in a few plants as minute visible and almost circular fungal colony of 2-3 mm in size on upper surface of lower most leaf (Plate-1A). The fungal colony gradually expanded in size with whitish visible floury patches (Plate-1B & C). The scattered fungal colony became quite conspicuous within 10-12 days of initial infection and coalesced (Plate-1D). The disease progressed towards upper leaves on both the surfaces (Plate-2A & B), stems & branches (Plate-3A) and on the siliquae (Plate-3B) thereby whole plant was covered with white powdery fungal growth shown within a period of one month after initiation of the symptoms (Plate-3C). On the stems, purple blue patches were seen in advanced stage. Such plants were conspicuous from a distance. Heavily infected leaves turned pale yellow in due course, dried early and shedding of leaves was a common feature (Plate-3D). Infected siliquae produced poor quality shrivelled seeds. The heavily infected plant matured earlier than healthy plants.

**Morphological characters of *E. cruciferarum***

Morphological characters form the primary basis for the identification of pathogen. Measurement of conidia and conidiophores were made by taking fungus directly from the host. These characters of the fungus were studied by observing



[A] [B]

[C] [D]

**Plate 1 : Powdery mildew symptoms on upper surface of leaves [A] initial infection[B] & [C] developing scattered fungal colonies [D] coalesced white powdery patches**

[A] [B]

**Plate 2: Mustard leaves showing powdery mildew infection on upper [A] and lower [B] leaf surface**

[A]

[B]

[C]

[D]

**Plate 3 : Powdery mildew symptoms on stems and branches [A], siliques [B], dusty appearance [C], purple stem and defoliation of infected old leaves [D]**

cotton blue stained slides under compound microscope. The morphological characters of mycelium, conidia and conidiophores are as under.

**Mycelium**

Fungal growth from the infected mustard leaves revealed the presence of dense, ectophyte, hyaline branched and septate thin mycelial growth (Plate-4A).

**Conidia**

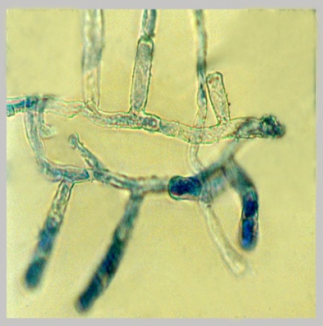
The conidia obtained from infected mustard leaves were ellipsoid to cylindrical in shape measuring 26.5-39.8 µm x 12.4-16.6 µm in size without fibrosin bodies (Plate-4B). The germinated conidium produced germ tube at polar end (Plate-4C).

**Conidiophore**

Microscopic observations revealed that the conidiophores arose from the internal mycelium and emerged through the stomata either singly or in groups and 2-3 celled (Plate-4D). The conidiophores measuring average length of 67.4 $\pm$ 6.2 µm and were more or less erect with moderately straight foot cells with an average length of 19.8 $\pm$ 2.1 µm.

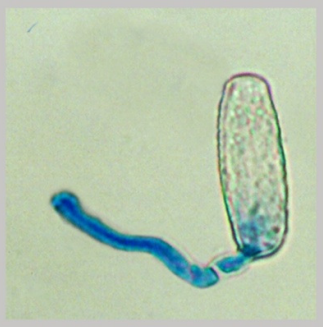
**Assessment of yield loss due to powdery mildew in mustard**

To assess the loss in seed yield of mustard due to infection of powdery mildew**,** an experiment was conducted with three treatments including water spray and no spray control during *rabi* 2007-08 to 2009-10. The spraying of hexaconazole 0.005 per cent was carried out at 10 days interval starting from the initiation of disease to maintain disease free condition. The per cent disease intensity was recorded after seven days of last spray and seed yield was recorded from each treatment after

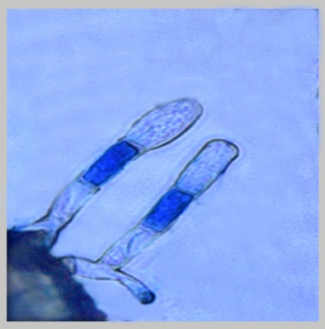


[A] Hyaline, branched & septate mycelium

[B] Conidia



[C] Germinating conidium



[D] Emerged conidiophore from host tissue

**Plate 4: Morphological characters of** *Erysiphe cruciferarum*

harvesting. The data on disease intensity and yield are presented in Table 4.1, Table 4.2 and depicted in Fig.1.

**Per cent disease intensity**

The data presented in Table 4.1 revealed that significantly minimum per cent disease intensity due to powdery mildew disease of mustard was recorded in the treatment of hexaconazole (27.57, 28.13 and 27.35) 0.005 per cent as compared to water spray control (81.95, 84.95 and 82.50) and no spray control (85.13, 89.21 and 85.80) during three consecutive *rabi* seasons of 2007-08 to 2009-10, respectively. The pooled data on per cent disease intensity revealed that lower disease intensity (27.67%) was observed in foliar application of hexaconazole than that of sprayed with water (83.25%) and no spray (86.75%) i.e. unprotected (Plate-5A & B). The maximum disease control 53.77 per cent was recorded with hexaconazole 0.005 per cent.

**Table 4.1: Per cent disease intensity due to powdery mildew in mustard**

| Treatment | Per cent disease intensity | | | Pooled mean | % reduction over control |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Hexaconazole 0.005% | 31.67 (27.57)* | 32.03 (28.13) | 31.53 (27.35) | 31.74 (27.67) | 53.77 |
| Control (Water spray) | 64.86 (81.95) | 67.17 (84.95) | 65.50 (82.50) | 65.84 (83.25) | 4.11 |
| Control (No spray) | 67.31 (85.13) | 70.82 (89.21) | 67.86 (85.80) | 68.66 (86.75) | - |
| S.Em. ± | 0.82 | 0.88 | 0.78 | 0.58 | |
| C.D. at 5% | 2.43 | 2.59 | 2.30 | 1.65 | |
| C.V.% | 4.27 | 4.39 | 4.03 | 4.24 | |

* Data given in parenthesis are retransformed values.

[A]

[B]

**Plate 5: Field view of protected [A] and powdery mildew infected [B] mustard crop**

**Yield loss**

The significantly maximum seed yield (2265, 2186 and 2280 kg/ha) of mustard was obtained in the treatment of hexaconazole 0.005 per cent during 2007-08 to 2009-10 (Table 4.2).

The treatment of unprotected control recorded 1777, 1650 and 1790 kg/ha of mustard seed, but was found at par with water spray control with 1851, 1725 and 1865 kg/ha of mustard seeds during all the three years. The pooled data showed significantly the maximum seed yield 2244 kg/ha in the treatment of crop protected with the fungicide hexaconazole (Fig.1). The minimum yield was recorded in unprotected control 1739 kg/ha, but it was at par with water spray control 1814 kg/ha.

**Table 4.2: Assessment of losses in seed yield of mustard due to powdery mildew**

| Treatment | Seed yield (kg/ha) | | | Pooled mean | Per cent* loss in seed yield |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Hexaconazole 0.005% | 2265 | 2186 | 2280 | 2244 | 22.50 |
| Control (Water spray) | 1851 | 1725 | 1865 | 1814 | 4.13 |
| Control (No spray) | 1777 | 1650 | 1790 | 1739 | - |
| S.Em. ± | 54.57 | 36.92 | 29.96 | 28.36 | |
| C.D. at 5% | 160.53 | 108.60 | 88.11 | 80.79 | |
| C.V.% | 7.86 | 5.63 | 4.28 | 6.12 | |

*Per cent loss in yield as comparison with no spray control

The three years pooled results indicated that there was 22.50 per cent loss in seed yield due to powdery mildew disease in mustard when not followed control measures against the disease.

**Avoidable economic loss**

The avoidable economic loss due to powdery mildew of mustard given in Table 4.3 revealed significant reduction in yield when crop was not protected by hexaconazole 0.005 per cent, which exhibited significant higher net income of Rs.49,512/ha in comparison to corresponding yield of un protected plot (Rs.39,997/ha). The 23.48 per cent avoidable loss and net profit of Rs.9,390/ha was found with spraying of hexaconazole 0.005 per cent.

Results on per cent losses in oil, protein and 1000-seeds weight of mustard due to powdery mildew disease are presented in Table 4.4, 4.5 and 4.6 and illustrated in Fig. 1.

**Table 4.3: Avoidable economic loss due to powdery mildew of mustard**

| Treatment/ Concentr-ation | Seed Yield kg/ha | Total income (Rs.ha) | Increased income due to plant protection (Rs.ha) | Net profit due to protection (Rs.ha) | % Avoidable loss |
|---|---|---|---|---|---|
| Hexaconazole 0.005% | 2244 | 51612 | 11615 | 9390 | 23.48 |
| Control (Water spray) | 1814 | 41722 | - | - | - |
| Control (No spray) | 1739 | 39997 | - | - | - |

Cost of fungicide Rs.2100/five sprays.

**Loss in oil**

The Table 4.4 and Fig.1 showed that the protected mustard crop with hexaconazole recorded significantly the higher amount of oil content (35.33, 33.31 and 35.52%) as compared to water spray control (33.10, 31.74 and 33.40%) and no spray control (32.25, 31.31 and 33.05%) respectively, during the three consecutive *rabi* seasons of 2007-08 to 2009-10. They were found at par except during the year 2007-08. The pooled results revealed the similar trend and recorded significantly the maximum amount of oil (34.72%) in the treatment of hexaconazole as compared to water spray control (32.75%) and unprotected control (32.20%). The three years pooled results indicated 7.26 per cent loss in oil due to powdery mildew disease in mustard.

**Table 4.4: Assessment of losses in oil content of mustard due to powdery mildew**

| Treatment | Oil content (%) | | | Pooled mean | Per cent* loss in oil |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Hexaconazole 0.005% | 35.33 | 33.31 | 35.52 | 34.72 | 7.26 |
| Control (Water spray) | 33.10 | 31.74 | 33.40 | 32.75 | 1.68 |
| Control (No spray) | 32.25 | 31.31 | 33.05 | 32.20 | - |
| S.Em ± | 0.22 | 0.37 | 0.42 | 0.24 | |
| C.D. at 5% | 0.65 | 1.09 | 1.24 | 0.68 | |
| C.V.% | 1.86 | 3.25 | 3.50 | 2.96 | |

*Per cent loss in oil as comparison with no spray control

**Protein loss**

It is revealed from the Table 4.5 and Fig.1 that the protected mustard crop with hexaconazole recorded significantly higher amount of protein content (16.69, 15.71 and 13.83%) as compared to water spray control (14.40, 13.47 and 11.79%) and no spray control (12.93, 12.14 and 11.12%) respectively, during the three consecutive *rabi* seasons of 2007-08 to 2009-10 and was at par during the year 2009-10.

The pooled results recorded significantly the maximum amount of protein (15.41%) in the treatment of hexaconazole as compared to water spray control (13.22%) and no spray control (12.06%). The three years pooled results indicated 21.74 per cent loss in protein due to powdery mildew disease in mustard.

**Table 4.5: Assessment of losses in protein content of mustard due to powdery mildew**

| Treatment | Protein content (%) | | | Pooled mean | Per cent* loss in protein |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Hexaconazole 0.005% | 16.69 | 15.71 | 13.83 | 15.41 | 21.74 |
| Control (Water spray) | 14.40 | 13.47 | 11.79 | 13.22 | 8.77 |
| Control (No spray) | 12.93 | 12.14 | 11.12 | 12.06 | - |
| S.Em. ± | 0.21 | 0.21 | 0.28 | 0.17 | |
| C.D. at 5% | 0.61 | 0.61 | 0.82 | 0.47 | |
| C.V.% | 4.02 | 4.25 | 6.41 | 4.87 | |

*Per cent loss in protein as comparison with no spray control

**Test weight loss**

It is observed from the data presented in Table 4.6 that the protected mustard crop with hexaconazole recorded significantly higher test weight of 1000-seeds (5.70, 5.63, 5.69 and 5.67 g) as compared to water spray control (4.62, 4.50, 4.51 and 4.55 g) and no spray control (4.54, 4.41, 4.41 and 4.45 g) during the three consecutive *rabi* seasons of 2007-08 to 2009-10 and in pooled.

The treatment water spray and no spray control found at par during all the three year and also in pooled analysis (Fig 1). The three years pooled results indicated 21.52 per cent loss in test weight of 1000-seeds due to powdery mildew disease in mustard.

**Table 4.6: Assessment of losses in 1000-seeds weight of mustard due to powdery mildew**

| Treatment | 1000-seeds weight(g) | | | Pooled mean | Per cent* loss in 1000-seeds wt.(g) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Hexaconazole 0.005% | 5.70 | 5.63 | 5.69 | 5.67 | 21.52 |
| Control (Water spray) | 4.62 | 4.50 | 4.51 | 4.54 | 2.20 |
| Control (No spray) | 4.54 | 4.41 | 4.41 | 4.45 | - |
| S.Em ± | 0.06 | 0.07 | 0.09 | 0.05 | |
| C.D. at 5% | 0.19 | 0.21 | 0.26 | 0.15 | |
| C.V.% | 3.59 | 4.21 | 5.11 | 4.34 | |

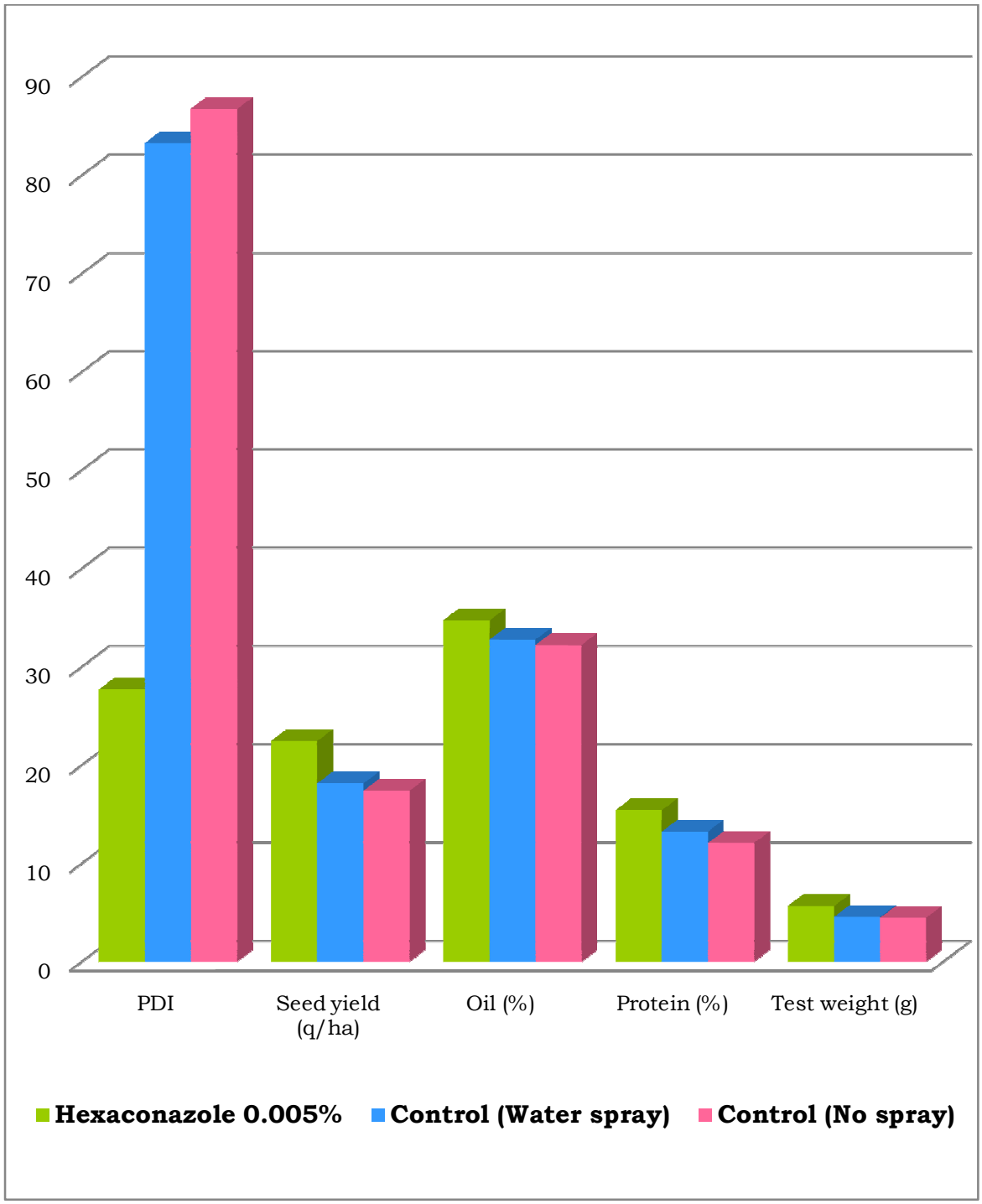



**Fig.1: Per cent disease intensity, seed yield (q/ha), oil, protein content (%) and test weight (g) of mustard in treated and untreated plots**

*Per cent loss in 1000-seeds weight as comparison with no spray control

**Screening of mustard entries against powdery mildew disease *in vivo***

For identifying resistance source in mustard entries to powdery mildew disease, 13 entries of three species i.e., *Brassica juncea* (3), *Brassica napus* (5) and *Brassica carinata* (5) were screened under field conditions at Dry Farming Research Station, JAU., Jam-Khambhalia with two rows of 6.0 m length spaced at 45 cm apart and single row of susceptible cultivar Gujarat Mustard-2 with same length and spacing intercepted between two rows of test entries for three consecutive *rabi* seasons of 2007-08 to 2009-10. Disease intensity of each entry was recorded at fifteen days before harvesting. The disease was scored using 0-5 point scale and entries were grouped into different categories i.e. healthy (score 0), highly resistant (score 1), resistant (score 2), moderately susceptible (score 3), susceptible (score 4) and highly susceptible (score 5). Data on disease intensity, disease score and disease reactions are presented in Table 4.7 and Table 4.8.

Perusal of the data in Table 4.7 and Fig. 2 revealed that during all the three years none of the entries tested was free from the disease. Disease reaction to powdery mildew during all the three consecutive years showed consistent results under screening trial. The mean data on per cent disease intensity (PDI) indicated that entries GM-1, GM-2 and GM-3 of *B. juncea* species recorded the highest PDI of 85.56, 91.94 and 86.11 per cent. Whereas, the moderate 46.95, 46.95, 67.78, 67.50 and 65.00 PDI was observed in entries belong to *B. napus* species GSL-1, GSL-861-212, HNS – 0004, ISN – 129 and NUDB-26-11,

respectively. The entries DLSC-3, Kiran, NPC-3, NPC-111 and NPJ-87 belong to *B. carinata* species recorded the lowest mean PDI 23.61, 24.44, 24.17, 26.67 and 25.28 against powdery mildew disease. Similar trend was also observed in individual year.

**Table 4.7: Per cent disease intensity in different species of mustard against powdery mildew**

| Sr. No. | Entries | Species | Per cent disease intensity* | | | |
|---|---|---|---|---|---|---|
| | | | 07-08 | 08-09 | 09-10 | Av. |
| 1 | GM-1 | *B. juncea* | 81.67 | 89.17 | 85.83 | 85.56 |
| 2 | GM-2 | " | 90.83 | 93.33 | 91.67 | 91.94 |
| 3 | GM-3 | " | 84.17 | 87.50 | 86.67 | 86.11 |
| 4 | GSL-1 | *B. napus* | 45.00 | 49.17 | 46.67 | 46.95 |
| 5 | GSL-861-212 | " | 44.17 | 47.50 | 49.17 | 46.95 |
| 6 | HNS - 0004 | " | 65.83 | 70.00 | 67.50 | 67.78 |
| 7 | ISN - 129 | " | 63.33 | 68.33 | 70.83 | 67.50 |
| 8 | NUDB-26-11 | " | 65.00 | 65.83 | 64.17 | 65.00 |
| 9 | DLSC-3 | *B. carinata* | 24.17 | 25.83 | 20.83 | 23.61 |
| 10 | Kiran | " | 23.33 | 24.17 | 25.83 | 24.44 |
| 11 | NPC-3 | " | 25.83 | 25.00 | 21.67 | 24.17 |
| 12 | NPC-111 | " | 27.50 | 25.83 | 26.67 | 26.67 |
| 13 | NPJ-87 | " | 25.00 | 27.50 | 23.33 | 25.28 |

*On the basis of three observations.

Among 13 accessions screened, entries of *B. juncea* species GM-2 exhibited highly susceptible reaction followed by GM-1 and GM-3 exhibited susceptible reaction with mean disease score of 4.58, 4.25 and 4.28, respectively (Table 4.8 and Fig. 2). The entries of *B. napus* species HNS-0004, ISN-129 and NUDB-26-11 exhibited moderately susceptible reaction with 3.37, 3.35

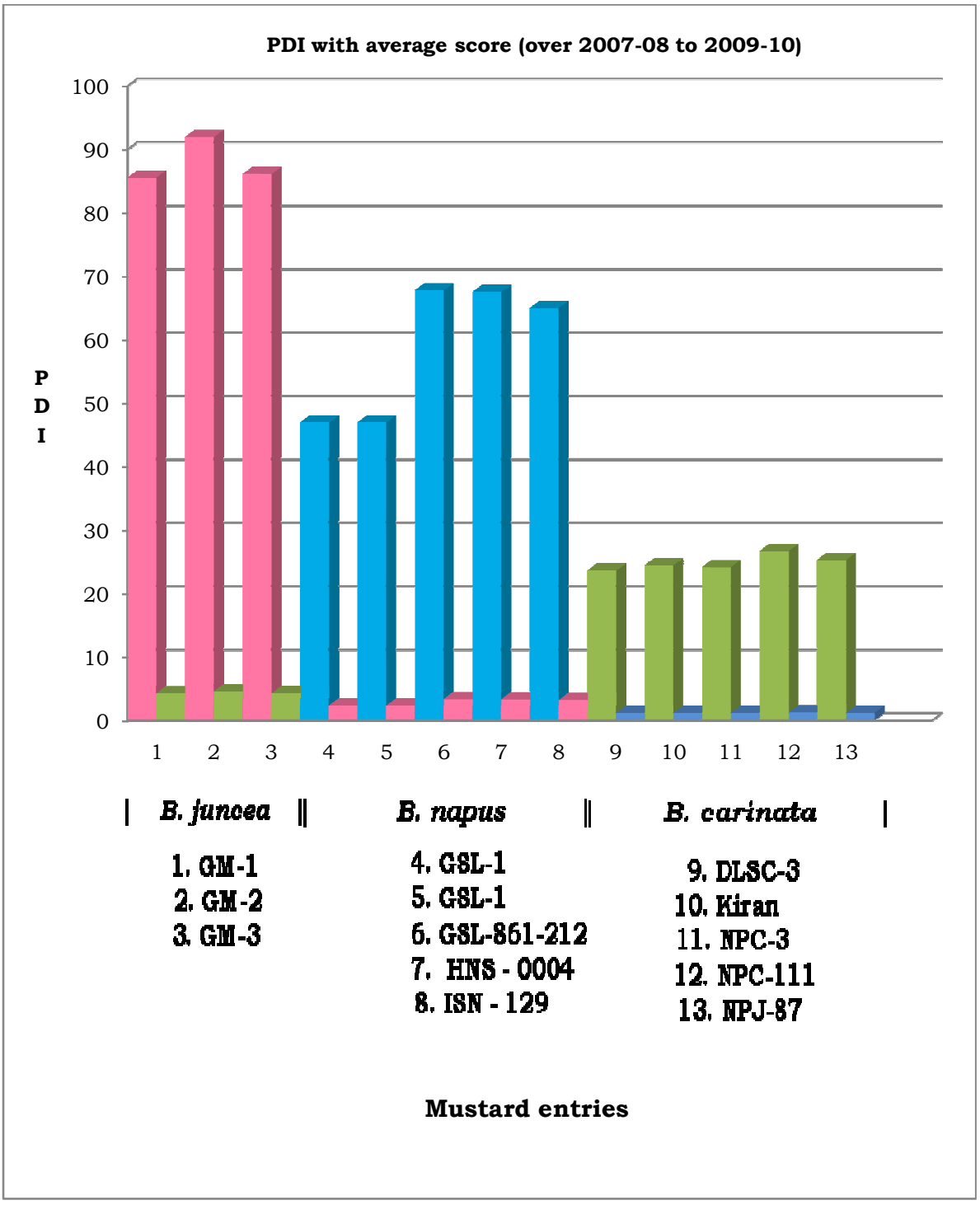



**Fig.2: Reaction of mustard entries against powdery mildew *in vivo***

**Effect of meteorological factors on disease development**

The relationship of meteorological factors and per cent disease intensity (PDI) was assessed by the average of four previous days of the observation day, i.e. on which PDI was recorded. The PDI was recorded from the initiation of the disease to the crop harvest at an interval of four days. Correlation coefficient values 'r' based on the data of four consecutive years were calculated.

The average meteorological data and intensity of disease are given in Appendix – I (A & B). The data on per cent disease intensity (PDI) are presented in Table 4.9. It is observed that powdery mildew appeared on 28th, 20th, 28th and 24th December with the intensity ranging from 1.25 to 88.82, 2.50 to 91.74, 2.09 to 87.15 and 1.67 to 85.90 during 2007-08, 2008-09, 2009-10 and 2010-11, respectively.

The average temperature and relative humidity of four seasons are mentioned in Table 4.10. The average and ranges are based on 15, 14, 13 and 15 observations for 2007, 2008, 2009 and 2010. The average minimum and maximum air temperature during the year 2007-08, 2008-09, 2009-10 and 2010-11 ranged from 10.9 to 27.2°C, 12.6 to 28.2°C, 12.4 to 27.6°C and 12.5 to 28.9°C, respectively. The average morning and afternoon relative humidity recorded during same period were in the range of 76-27, 77-42, 69-30 and 83-40 per cent. The four years average temperature and relative humidity were in the range of 12.1 to 28.0°C and 76 to 35 per cent.

The results of correlation coefficient between disease intensity and weather parameters for the *rabi* seasons of the four seasons and pooled are presented in the Table 4.11.

**Table 4.9: Year wise per cent disease intensity (PDI)**

| Sr. No. | 2007 | | 2008 | | 2009 | | 2010 | |
|---|---|---|---|---|---|---|---|---|
| | Date* | PDI** | Date | PDI | Date | PDI | Date | PDI |
| 1 | 28.12.07 | 1.25 | 20.12.08 | 2.5 | 28.12.09 | 2.09 | 24.12.10 | 1.67 |
| 2 | 01.01.08 | 3.34 | 24.12.08 | 6.67 | 01.01.10 | 6.26 | 28.12.10 | 4.17 |
| 3 | 05.01.08 | 7.09 | 28.12.08 | 12.09 | 05.01.10 | 11.26 | 01.01.11 | 9.59 |
| 4 | 09.01.08 | 11.68 | 01.01.09 | 20.43 | 09.01.10 | 17.10 | 05.01.11 | 15.01 |
| 5 | 13.01.08 | 16.68 | 05.01.09 | 28.77 | 13.01.10 | 23.77 | 09.01.11 | 21.68 |
| 6 | 17.01.08 | 22.52 | 09.01.09 | 37.11 | 17.01.10 | 30.44 | 13.01.11 | 30.02 |
| 7 | 21.01.08 | 28.77 | 13.01.09 | 45.45 | 21.01.10 | 37.53 | 17.01.11 | 38.36 |
| 8 | 25.01.08 | 35.86 | 17.01.09 | 53.79 | 25.01.10 | 45.87 | 21.01.11 | 46.29 |
| 9 | 29.01.08 | 43.79 | 21.01.09 | 62.13 | 29.01.10 | 54.21 | 25.01.11 | 54.21 |
| 10 | 02.02.08 | 51.29 | 25.01.09 | 69.64 | 02.02.10 | 62.55 | 29.01.11 | 61.72 |
| 11 | 06.02.08 | 57.96 | 29.01.09 | 76.31 | 06.02.10 | 70.89 | 02.02.11 | 67.97 |
| 12 | 10.02.08 | 65.05 | 02.02.09 | 82.15 | 10.02.10 | 79.23 | 06.02.11 | 73.39 |
| 13 | 14.02.08 | 72.14 | 06.02.09 | 87.57 | 14.02.10 | 87.15 | 10.02.11 | 78.81 |
| 14 | 18.02.08 | 80.48 | 10.02.09 | 91.74 | | | 14.02.11 | 83.82 |
| 15 | 22.02.08 | 88.82 | | | | | 18.02.11 | 85.90 |

* Observation date. **At four days interval

**Table 4.10: Mean weather data and per cent disease intensity (PDI) of powdery mildew**

| Year* | Temperature Range (°C ) | | Relative humidity (%) | | Per cent disease intensity |
|---|---|---|---|---|---|
| | Maximum | Minimum | Morning | Afternoon | |
| 2007 | 21.4-32.1 | 9.0-13.4 | 59.0-83.0 | 14.0-39.8 | 88.82 |
| Av. | 27.2 | 10.9 | 76 | 27 | |
| 2008 | 25.3-29.9 | 10.2-15.4 | 67.3-84.3 | 22.0-56.5 | 91.74 |
| Av. | 28.2 | 12.6 | 77 | 42 | |
| 2009 | 24.5-30.8 | 10.0-17.3 | 40.8-79.3 | 14.3-40.3 | 87.15 |
| Av. | 27.6 | 12.4 | 69 | 30 | |
| 2010 | 27.5-31.5 | 10.5-16.1 | 71.3-88.3 | 29.0-48.3 | 85.90 |
| Av. | 28.9 | 12.5 | 83 | 40 | |
| Mean | 28.0 | 12.1 | 76 | 35 | |

* The range and average of weather data are based on 15, 14, 13 and 15 observations for 2007, 2008, 2009 and 2010, respectively.

The results in Table 4.11 indicated positive and significant relationship of PDI with maximum air temperature (r=0.5311) during the year 2008-09, whereas during 2010-11 (r=0.7583) and in pooled (r=0.4704) it was found highly significant and positive. During 2007-08 (r=0.3627) and 2009-10 (r=0.5455), the effect of maximum air temperature was non significant. The relationship of minimum air temperature with PDI was found to be insignificant during all the years and in pooled results.

The morning RH was found to be positive with PDI during 2008-09 and 2010-11 and negative during 2007-08 and 2009-10 and in pooled. In 2008-09, morning relative humidity (r=0.6153) revealed significant and positive relationship with PDI, whereas during the year 2009-10, morning relative humidity (r=-0.5534) performed significant and negative relationship with PDI. The afternoon relative humidity exhibited highly significant and

negative relationship (r=-0.7058, r=-0.7121 and r=-0.2845) with PDI during 2007-08, 2008-09 and in pooled results, whereas, during 2009-10 and 2010-11 it was non significant.

**Table 4.11: Relationship of powdery mildew intensity with meteorological factors**

| Sr. No. | Meteoro-logical factors | Correlation coefficient ' r ' | | | | |
|---|---|---|---|---|---|---|
| | | 07-08 | 08-09 | 09-10 | 10-11 | Average |
| 1 | Maximum Temp.(°C) | 0.3627 | 0.5311* | 0.5455 | 0.7583** | 0.4704** |
| 2 | Minimum Temp.(°C) | 0.3926 | -0.2345 | 0.0841 | 0.4792 | 0.1785 |
| 3 | Morning RH (%) | -0.2944 | 0.6153* | -0.5534* | 0.4614 | -0.0046 |
| 4 | Afternoon RH(%) | -0.7058** | -0.7121** | -0.4277 | 0.1214 | -0.2845** |
| *Critical value (0.05) = | | 0.5124 | 0.5307 | 0.5511 | 0.5124 | 0.2606 |
| **Critical value (0.01) = | | 0.6410 | 0.6610 | 0.6840 | 0.6410 | 0.3400 |
| No. of obs. (n)= | | 15 | 14 | 13 | 15 | 57 |

**Regression**

**PDI with meteorological factors**

To formulate the simple and effective linear regression equation for the prediction of powdery mildew disease, the meteorological factors were assessed. Under congenial environmental conditions, the pathogen becomes most agressive to attack susceptible host. These important factors were critically studied for four years (2007-08 to 2010-11). The meteorological parameters *viz.*, temperature and humidity of the same period

were identified as most responsible factors for the disease development under natural condition (Table 4.12).

In multiple regression analysis four independent variables were considered for prediction of PDI. Out of four variables most contributing variable was afternoon relative humidity (%) as identified for the disease development under natural condition during the year 2007-08.

The regression equation for the prediction of PDI was

$Y = 68.8098-0.3030X_1+7.1330X_2-0.5567X_3-2.1298\ X^*_4$.....(1)

Variation accounted by this regression equation is 60 per cent ($R^2 = 0.5995$).

The effect of weather variables with PDI during the year 2008-09 was found to be non significant.

The regression equation for the prediction of PDI was

$Y = -58.3115+1.3011X_1+2.6481X_2+1.4709X_3-1.8462\ X_4$.....(2)

Variation accounted by this regression equation is 59 per cent ($R^2 = 0.5918$).

Out of four variables most contributing variable was maximum temperature (°C), for the disease development under natural conditions during the year 2009-10.

The regression equation for the prediction of PDI was

$Y = -123.5512+10.9165X_1^*-2.4366X_2-2.0121X_3+1.0931X_4$.....(3)

Variation accounted by this regression equation is 68 per cent ($R^2 = 0.6812$).

Out of four variables the most contributing variables were maximum temperature (°C) and afternoon relative humidity (%) for the disease development under natural conditions during the year 2010-11 and in pooled results.

**Table 4.12: Regression analysis of per cent disease intensity with meteorological factors**

| Year | Independent variable | Constant | Regression coefficient ' b ' | $R^2$ | Std. error of Reg. Co-eff.($b_i$) | Std. error of estimate |
|---|---|---|---|---|---|---|
| 2007-08 | Maximum Temp.(°C) | 68.8098 | -.3030 | 0.5995 | 2.9798 | 21.7938 |
| | Minimum Temp.(°C) | | 7.1330 | | 6.0921 | |
| | Morning R.H.(%) | | -.5567 | | 1.2958 | |
| | Afternoon R.H. (%) | | -2.1298* | | 0.7228 | |
| 2008-09 | Maximum Temp.(°C) | -58.3115 | 1.3011 | 0.5918 | 5.7158 | 23.7811 |
| | Minimum Temp.(°C) | | 2.6481 | | 4.4494 | |
| | Morning R.H.(%) | | 1.4709 | | 1.5963 | |
| | Afternoon R.H. (%) | | -1.8462 | | 0.9319 | |
| 2009-10 | Maximum Temp.(°C) | -123.5512 | 10.9165* | 0.6812 | 4.1528 | 19.7031 |
| | Minimum Temp.(°C) | | -2.4366 | | 5.7995 | |
| | Morning R.H.(%) | | -2.0121 | | 1.1634 | |
| | Afternoon R.H. (%) | | 1.0931 | | 2.4191 | |
| 2010-11 | Maximum Temp.(°C) | -604.2570 | 22.9234** | 0.8076 | 5.2162 | 15.5288 |
| | Minimum Temp.(°C) | | 5.9336 | | 3.6156 | |
| | Morning R.H.(%) | | 0.2071 | | 1.1756 | |
| | Afternoon R.H. (%) | | -2.6668** | | 0.7955 | |
| Average | Maximum Temp.(°C) | -133.0856 | 5.5663** | 0.3620 | 1.6890 | 24.1018 |
| | Minimum Temp.(°C) | | 3.8247 | | 2.2602 | |
| | Morning R.H.(%) | | 0.2426 | | 0.4122 | |
| | Afternoon R.H. (%) | | -1.2826** | | 0.3895 | |

*Significant at 5 per cent level of probability

** Significant at 1 per cent level of probability

The regression equation for the prediction of PDI was

$Y = -604.2570+22.9234X^*_1+5.9336X_2+0.2071X_3- 2.6668X^*_4$....(4)

Variation accounted by this regression equation is 81 per cent ($R^2 = 0.8076$).

The regression equation for the prediction of PDI in pooled is given below.

$Y = -133.0856+5.5663X^*_1+3.8247X_2+0.2426X_3-1.2826X^*_4$.....(5)

Variation accounted by this regression equation is 36 per cent ($R^2 = 0.3620$).

**Evaluation of agrochemicals and phytoextracts in inhibition of spore germination**

To determine the relative efficacy of various agrochemicals and botanicals in inhibiting spore germination of *E. cruciferarum,* various systemic and non systemic fungicides, insecticides and phytoextracts were tested. The observations on the spore germination inhibition of the fungus in each treatment including check were taken and percentage inhibition was calculated on the basis of the difference in inhibition obtained in the treatment and check.

**Effect of systemic fungicides on spore germination**

The efficacy of various systemic fungicides in inhibiting the spore germination of *E. cruciferarum* at given concentration was tested by using poisoned food technique.

Data on spore germination inhibition are given in Table 4.13 and depicted in Fig. 3. It is clear from the results that all the systemic fungicides were effective in spore germination inhibition. Hexaconazole (0.005%) was found significant and the most effective fungicide with 84.10 per cent inhibition of spore germination. It was followed by penconazole (0.010%) and

difenoconazole (0.025%) with 80.05 and 78.09 per cent inhibition of spore germination, respectively.

**Table 4.13: Effect of systemic fungicides on spore germination inhibition of *E. cruciferarum in vitro***

| **Fungicides** | **Concentrations (%)** | **Mean inhibition (%)** |
|---|---|---|
| Hexaconazole 5% EC | 0.005 | 66.50 (84.10)* |
| Propiconazole 25% EC | 0.025 | 61.02 (76.53) |
| Difenoconazole 25% EC | 0.025 | 62.09 (78.09) |
| Azoxystrobin 25% SC | 0.025 | 47.28 (53.98) |
| Penconazole 10% EC | 0.010 | 63.79 (80.05) |
| Tebuconazole 25% EC | 0.025 | 49.66 (58.10) |
| Carbendazim 50% WP | 0.005 | 54.49 (66.27) |
| Check | 0.00 | 0.00 |
| S.Em.± | | 1.74 |
| C.D. at 5% | | 5.09 |
| C.V.% | | 6.89 |

* Data given in parenthesis are retransformed values.

The next effective fungicide in inhibition of spore germination (76.53%) was propiconazole (0.025%). The comparatively lower inhibition of spore germination 66.27 per cent was recorded in the treatment of carbendazim which was at par with tebuconazole (58.10%). The fungicide azoxystrobin

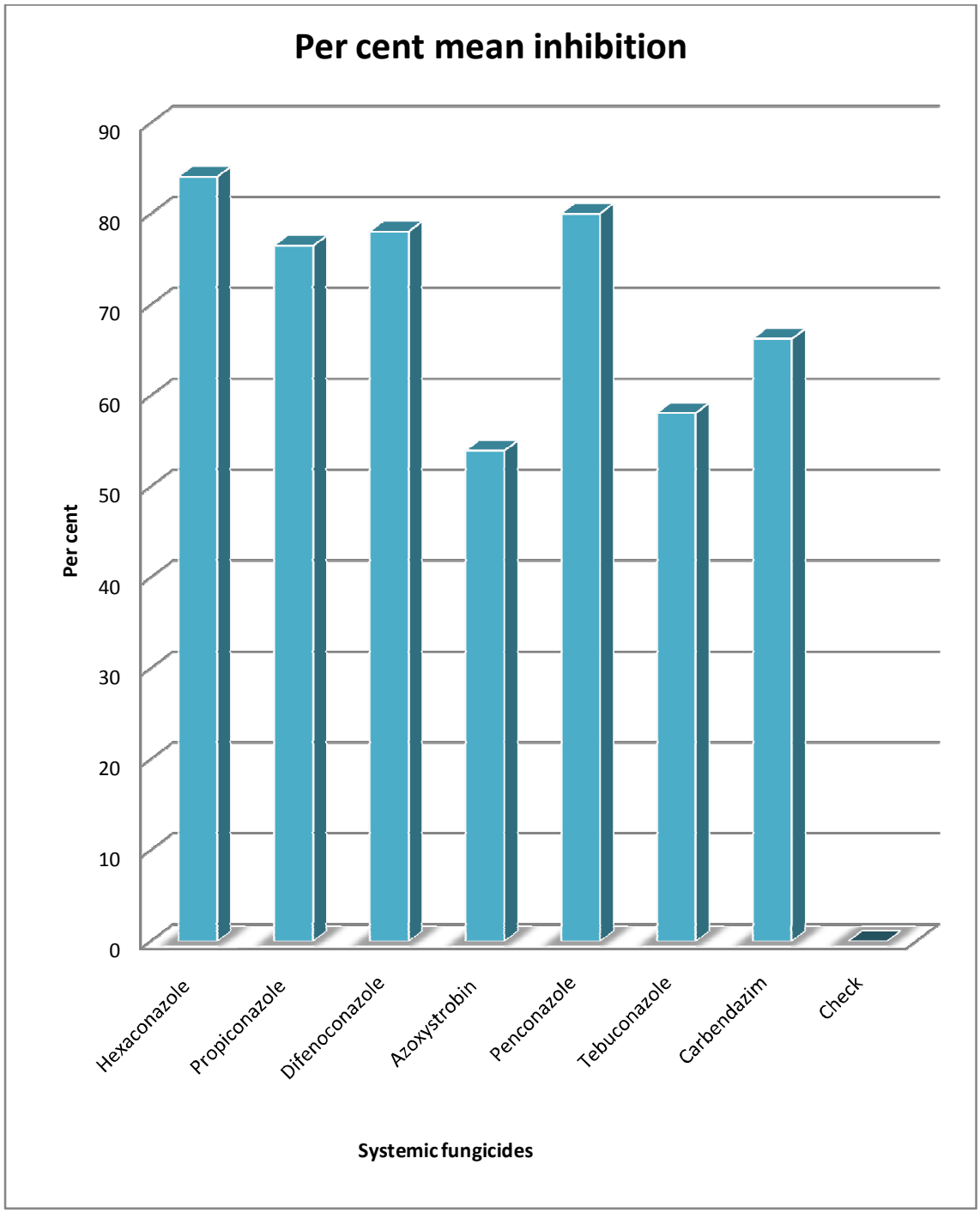



**Fig.3: Per cent spore germination inhibition of *E. cruciferarum* by different systemic fungicides *in vitro***

showed the lowest efficacy among all fungicides tested with 53.98 per cent inhibition of spore germination.

**Effect of non systemic fungicides on spore germination**

For testing the efficacy of non systemic fungicides, the poisoned food technique was used. The different fungicides were tested *in vitro*. The per cent inhibition of spore germination recorded for given concentrations are presented in Table 4.14 and depicted in Fig. 4.

It is revealed from the results that all the non systemic fungicides were capable of inhibiting the spore germination at given concentration. The results indicated that the most effective fungicide was dinocap followed by wettable sulphur with 79.98 and 77.00 per cent inhibition of spore germination, respectively. The next effective fungicide in inhibition of spore germination was mancozeb with 73.00 per cent. Thiram and chlorothalonil exhibited 57.50 and 53.98 per cent inhibition and were at par. The lowest inhibition of spore germination was recorded in zineb followed by captan with 49.46 and 51.47 per cent, respectively.

**Effect of insecticides on spore germination**

The insecticides were tested to evaluate their efficacy against *E. cruciferarum in vitro* using poisoned food technique. Data on spore germination inhibition are presented in Table 4.15 and shown in Fig. 5. It is evident from the Table 4.15 that significantly higher spore germination inhibition was observed in the treatment of methyl-o-demeton (54.97%) followed by triazophos (54.48%) and quinalphos (53.46%). In azadirachtin 45.94 per cent spore germination inhibition was observed but it was at par with triazophos + deltamethrin (44.46%) and cypermethrin + profenophos (42.94%). Acephate (40.97%) remained at par with imidacloprid (40.95%) in inhibition of spore

germination. The lowest inhibition of spore germination 33.21 per cent was recorded in the treatment of carbosulfan.

**Table 4.14: Effect of non systemic fungicides on spore germination inhibition of *E. cruciferarum* in *vitro***

| **Fungicides** | **Concentrations (%)** | **Mean inhibition (%)** |
|---|---|---|
| Mancozeb 75% WP | 0.2 | 58.69 (73.00)* |
| Chlorothalonil 75% WP | 0.2 | 47.28 (53.98) |
| Thiram 75% WP | 0.2 | 49.31 (57.50) |
| Dinocap 48% EC | 0.048 | 63.42 (79.98) |
| Zineb 75% WP | 0.2 | 44.69 (49.46) |
| Captan 75% WP | 0.2 | 45.84 (51.47) |
| Wettable Sulphur 80% WP | 0.2 | 61.34 (77.00) |
| Check | 0.00 | 0.00 |
| S.Em. $\pm$ | | 0.95 |
| C.D. at 5% | | 2.76 |
| C.V.% | | 4.09 |

* Data given in parenthesis are retransformed values.

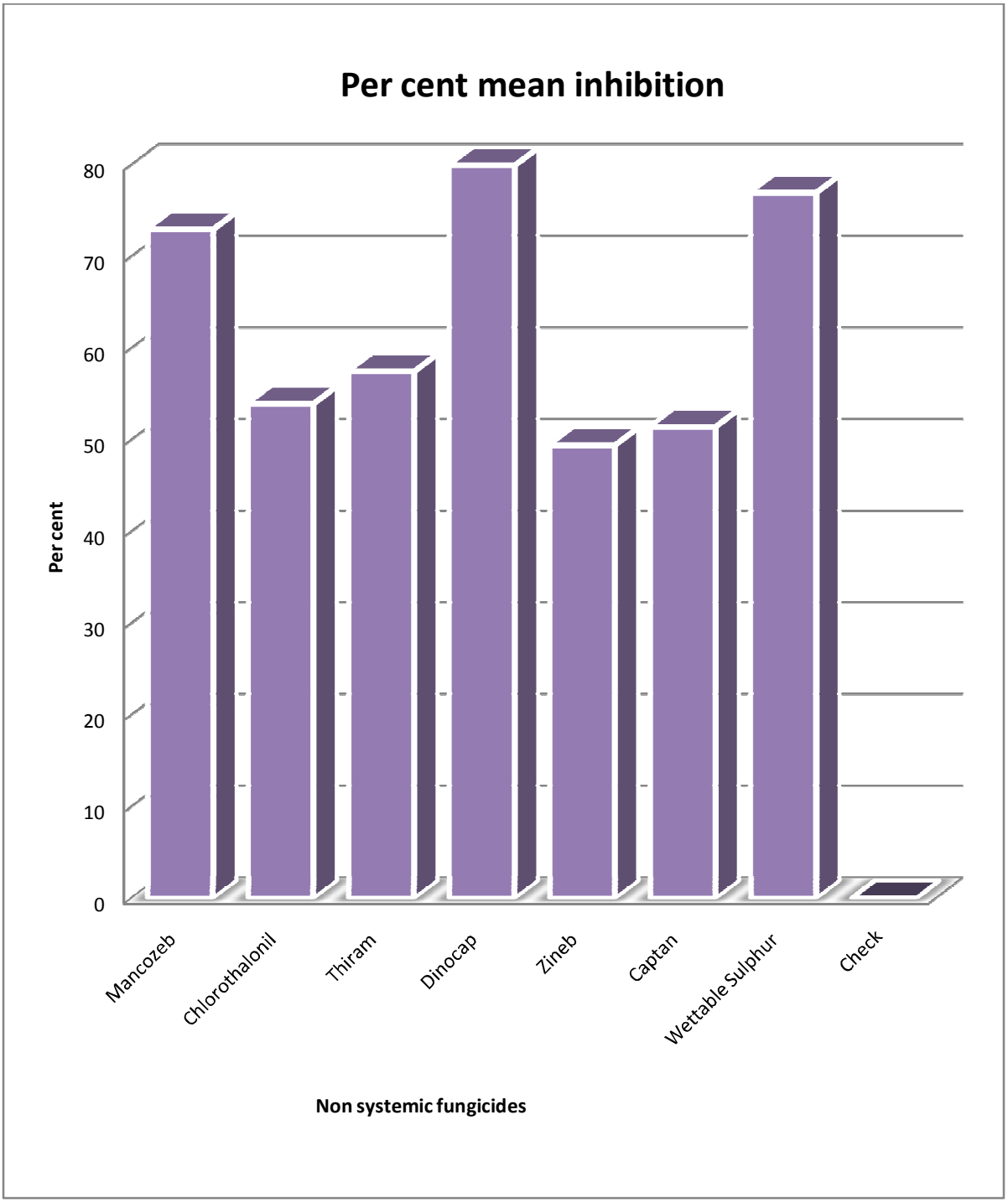



**Fig.4: Per cent spore germination inhibition of *E. cruciferarum* by different non systemic fungicides *in vitro***

**Table 4.15: Effect of insecticides on spore germination inhibition of E. *cruciferarum* in *vitro***

| **Insecticides** | **Concentrations (%)** | **Mean inhibition (%)** |
|---|---|---|
| Triazophos 35% EC | 0.03 | 47.57 (54.48)* |
| Triazophos 35% EC + Deltamethrin 1% EC | 0.036 | 41.82 (44.46) |
| Imidacloprid 17.8% SL | 0.005 | 39.79 (40.95) |
| Carbosulfan 25% EC | 0.03 | 35.19 (33.21) |
| Acephate 75% WP | 0.05 | 39.80 (40.97) |
| Cypermethrin 4% EC + Profenophos 40% EC | 0.04 | 40.94 (42.94) |
| Methyl-o-demeton 25% EC | 0.03 | 47.86 (54.97) |
| Quinalphos 25% EC | 0.03 | 46.99 (53.46) |
| Azadirachtin 0.15% W/W | 0.00075 | 42.68 (45.94) |
| Check | 0.00 | 0.00 |
| S.Em. $\pm$ | | 0.97 |
| C.D. at 5% | | 2.80 |
| C.V.% | | 5.07 |

* Data given in parenthesis are retransformed values.

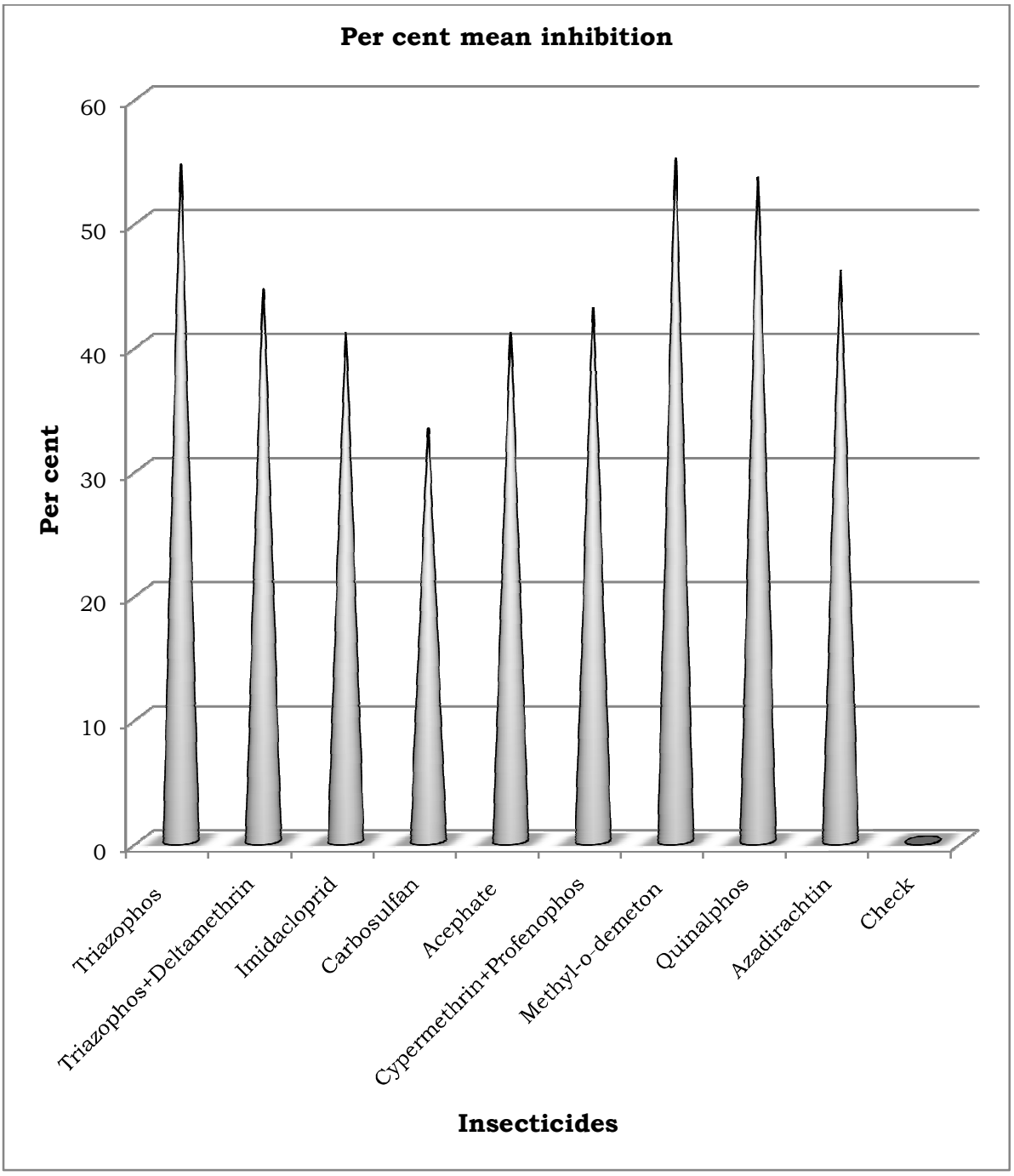



**Fig.5: Per cent spore germination inhibition of *E. cruciferarum* by different insecticides *in vitro***

**Effect of phytoextracts on spore germination**

Twelve phytoextracts were tested against spore germination of *E. cruciferarum* at two per cent concentration using poisoned food technique. The per cent spore germination inhibition obtained was statistically analyzed and illustrated in Table 4.16 and depicted in Fig. 6.

It is evident from Table 4.16 that all the phytoextracts were capable of inhibiting the spore germination at different degrees. Clove extracts of garlic (*Allium sativum)* provided the highest spore germination inhibition of 74.08 per cent followed by leaf extract of neem (*Azadirachta indica*) with 68.47 per cent inhibition of spore germination and remained statistically at par. They were also significantly superior over rest of the treatments. Bulb extracts of onion (*Allium cepa*) recorded 63.00 per cent inhibition of spore germination followed by leaf extract of henna (*Lawsonia inermis*) and rhizome extract of turmeric (*Curcuma longa*) which exhibited 58.00 and 57.05 per cent inhibition of spore germination. Indian Laburnum (*Cassia fistula*) showed 54.98 per cent inhibition of spore germination followed by rhizome extract of ginger (*Zingiber officenale*) and leaf extract of *bataj* (*Clerodendrum inerme*) with 53.49 and 50.47 per cent inhibition of spore germination, respectively. The least effective phytoextract found was *karanj* (*Derris indica*) which recorded 23.93 per cent inhibition of spore germination.

**Evaluation of different fungicides *in vivo***

For studying the efficacy of different fungicides against *E. cruciferarum* on mustard, six different fungicides *viz.*, hexaconazole, difenoconazole, penconazole, azoxystrobin, dinocap and wettable sulphur were tested on mustard variety

Gujarat Mustard-2 under field conditions during the *rabi* season of 2007-08 to 2009-10.

**Table 4.16: Effect of phytoextracts on spore germination inhibition of *E. cruciferarum* in *vitro***

| **Botanical name of plant species used** | **English/ Common name** | **Plant parts used** | **Mean inhibition (%)** |
|---|---|---|---|
| *Allium sativum* | Garlic | Cloves | 59.40 (74.08)* |
| *Allium cepa* | Onion | Bulbs | 52.53 (63.00) |
| *Zingiber officenale* | Ginger | Rhizomes | 47.00 (53.49) |
| *Curcuma longa* | Turmeric | Rhizomes | 49.06 (57.05) |
| *Vinca rosea* | Periwinkle | Leaves | 34.11 (31.45) |
| *Ocimum sanctum* | Holy basil | Leaves | 42.11 (44.46) |
| *Cassia fistula* | Indian Laburnum | Leaves | 47.86 (54.98) |
| *Clerodendrum inerme* | Bataj | Leaves | 45.27 (50.47) |
| *Lawsonia inermis* | Henna | Leaves | 49.60 (58.00) |
| *Azadirachta indica* | Neem | Leaves | 55.84 (68.47) |
| *Polyalthia longifolia* | Pendula | Leaves | 41.82 (44.47) |
| *Derris indica* | Karanj | Leaves | 29.29 (23.93) |
| Check (without phytoextracts) | - | - | 0.00 |
| S.Em. $\pm$ | | | 1.31 |
| C.D. at 5% | | | 3.75 |
| C.V.% | | | 6.16 |

* Data given in parenthesis are retransformed values.

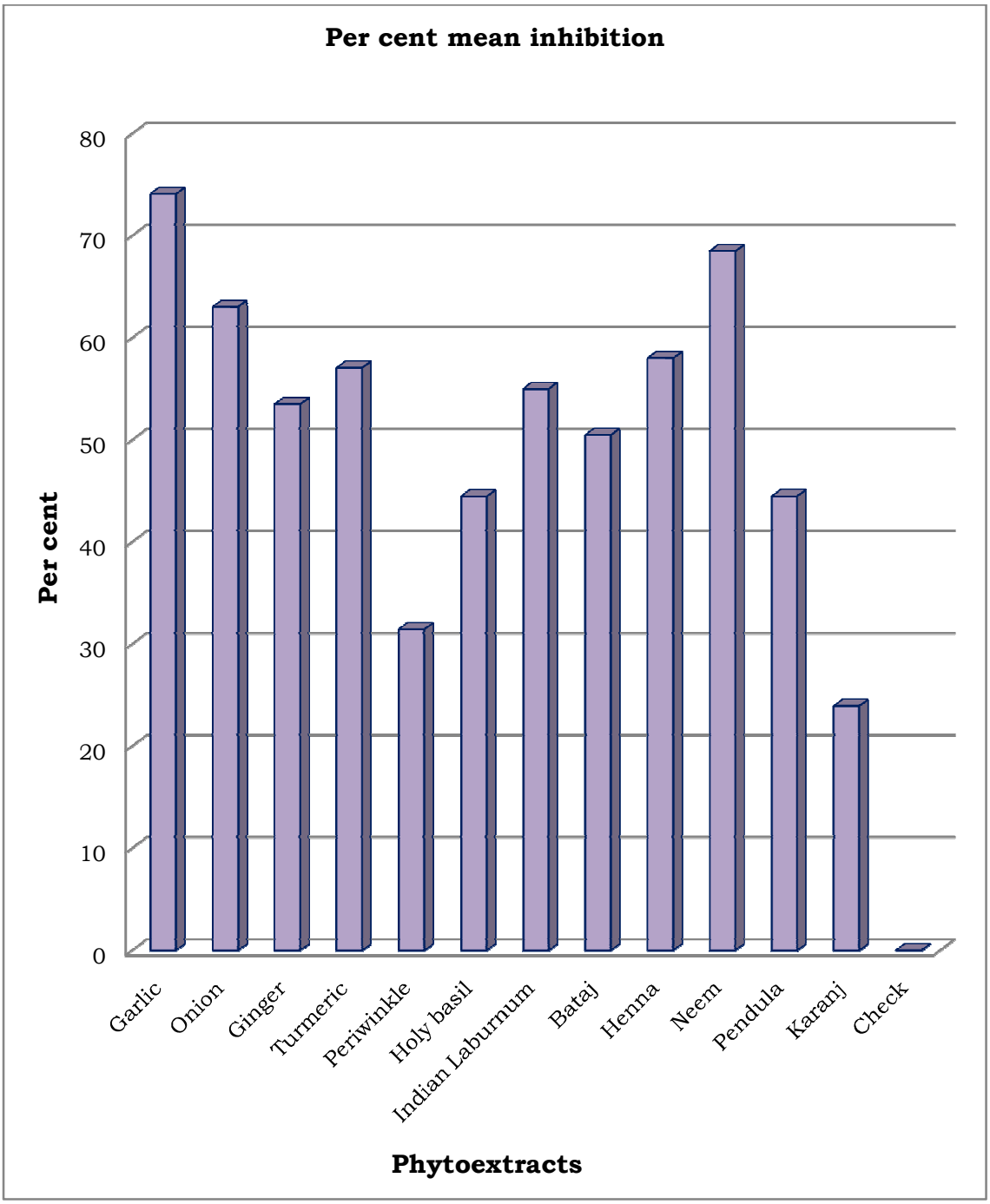



**Fig.6: Per cent spore germination inhibition of *E. cruciferarum* by different phytoextracts *in vitro***

The first spray of the fungicide was started after onset of the disease and remaining sprays of fungicides were carried out at 12 days interval. Observations on powdery mildew intensity was recorded at seven days after last spray by selecting 10 plants randomly from each plot using 0-12 scale as described earlier. Treatment wise data on per cent disease intensity (PDI) and per cent disease control are given in Table 4.17 and Fig. 7. The mustard yield, economics, oil and protein content of mustard seeds and test weight of 1000-seeds were also identified under different fungicidal treatments are given in Table 4.18, 4.19, 4.20, 4.21 and 4.22 respectively and depicted in Fig. 7 and 8.

**Per cent Disease intensity**

Data presented in Table 4.17 revealed the significant differences in per cent disease intensity (PDI) as compared to control. Hexaconazole, a systemic fungicide, performed the best as evident from significantly minimum PDI of 27.81, 29.09 and 27.65 during the years 2007-08, 2008-09 and 2009-10, respectively and found to be at par with penconazole and difenoconazole with 32.42, 33.47 and 30.98 and 33.65, 33.67 and 32.78 PDI, respectively for the corresponding years above. It was also at par with dinocap with PDI 34.16 and 34.30 during 2007-08 and 2008-09, respectively. The next effective fungicide during the year 2009-10 was dinocap and found to be at par with wettable sulphur and azoxystrobin with 34.06, 35.11 and 36.15 PDI, respectively.

The water spray control and no spray control recorded the maximum PDI (84.00, 85.43 and 82.92) and (88.80, 90.27 and 85.43), respectively during the year 2007-08 to 2009-10.

**Table 4.17: Per cent disease intensity influenced by different fungicides**

| Treatment | Disease intensity (%) | | | Pooled mean | Disease control (%) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Hexaconazole 5% EC | 31.83 (27.81)* | 32.64 (29.09) | 31.72 (27.65) | 32.06 (28.17) | 54.17 |
| Difenoconazole 25% EC | 35.46 (33.65) | 35.47 (33.67) | 34.93 (32.78) | 35.29 (33.38) | 49.55 |
| Penconazole 10% EC | 34.71 (32.42) | 35.35 (33.47) | 33.82 (30.98) | 34.63 (32.30) | 50.49 |
| Azoxystrobin 25% SC | 36.59 (35.52) | 36.71 (35.73) | 36.96 (36.15) | 36.76 (35.81) | 47.45 |
| Dinocap 48% EC | 35.77 (34.16) | 35.85 (34.30) | 36.03 (34.06) | 35.88 (34.35) | 48.71 |
| Wett. Sulphur 80% WP | 36.11 (34.74) | 36.58 (35.52) | 36.34 (35.11) | 36.34 (35.11) | 48.05 |
| Control (Water spray) | 66.42 (84.00) | 67.56 (85.43) | 65.59 (82.92) | 66.53 (84.14) | 4.89 |
| Control (No spray) | 70.45 (88.80) | 71.82 (90.27) | 67.56 (85.43) | 69.95 (88.25) | - |
| S.Em.± | 1.36 | 1.35 | 1.38 | 0.74 | |
| C.D. at 5% | 4.00 | 3.96 | 4.06 | 2.08 | |
| C.V.% | 6.27 | 6.12 | 6.45 | 6.28 | |

* Data given in parenthesis are retransformed values.

The pooled results over three years data revealed significant difference in PDI as compared to control. Significantly the minimum per cent disease intensity 28.17 was recorded in the treatment of hexaconazole with 54.17 per cent disease control and recorded 22.25 q/ha of mustard yield. Yield

increased with decreased in per cent disease intensity as illustrated in Fig. 7. The next best fungicide was penconazole with per cent disease intensity of 32.30 and recorded 50.49 per cent disease control and found at par with difenoconazole, dinocap and wettable sulphur with the per cent disease intensity of 33.38, 34.35 and 35.11 with per cent disease control of 49.55, 48.71 and 48.05, respectively. The fungicide azoxystrobin recorded the highest PDI 35.81 among different fungicides tried and gave minimum per cent disease control of 47.45 as compared to no spray control with 88.25 PDI.

**Seed yield (kg/ha)**

The results presented in Table 4.18 and graphically presented in Fig. 7 indicated that all fungicidal treatments significantly increased the mustard yield ranging from 20.51 to 30.04 per cent as compared to no spray control. During the years 2007-08, 2008-09 and 2009-10 seed yield was significantly maximum in the treatment of hexaconazole which recorded 2250, 2160 and 2266 kg/ha, respectively. Hexaconazole treatment was found at par with penconazole, difenoconazole, dinocap, wettable sulphur and azoxystrobin during all the three consecutive *rabi* seasons.

Three years pooled data indicated significant differences due to fungicidal sprays of different treatments. Seed yield was found to be significantly maximum in the treatment of hexaconazole (2225 kg/ha) and was at par with penconazole (2160 kg/ha), difenoconazole (2130 kg/ha), dinocap (2117 kg/ha), wettable sulphur (2090 kg/ha) and azoxystrobin (2062 kg/ha). Water spray control produced 1768 kg/ha seed yield as compared to no spray control with the minimum seed yield of 1711 kg/ha. Similarly, per cent increase in seed yield over no

spray control was also higher in the treatment of hexaconazole (30.04%) followed by penconzole (26.24%), difenoconazole (24.49%), dinocap (23.73%), wettable sulphur (22.15%) and azoxystrobin (20.51%), respectively.

**Table 4.18: Fungicidal control of powdery mildew of mustard with their impact on seed yield**

| Treatment | Seed yield (kg/ha) | | | Pooled mean | Yield increase (%) |
|---|---|---|---|---|---|
| | 2007 - 08 | 2008 - 09 | 2009 - 10 | | |
| Hexaconazole 5% EC | 2250 | 2160 | 2266 | 2225 | 30.04 |
| Difenoconazole 25% EC | 2114 | 2076 | 2199 | 2130 | 24.49 |
| Penconazole 10% EC | 2161 | 2105 | 2213 | 2160 | 26.24 |
| Azoxystrobin 25% SC | 2082 | 2001 | 2104 | 2062 | 20.51 |
| Dinocap 48% EC | 2104 | 2053 | 2193 | 2117 | 23.73 |
| Wett. Sulphur 80% WP | 2091 | 2046 | 2133 | 2090 | 22.15 |
| Control (Water spray) | 1791 | 1709 | 1804 | 1768 | 3.33 |
| Control (No spray) | 1747 | 1635 | 1752 | 1711 | - |
| S.Em.± | 111.26 | 118.38 | 117.00 | 60.53 | |
| C.D. at 5% | 327.27 | 348.22 | 344.17 | 170.73 | |
| C.V.% | 10.89 | 12.00 | 11.23 | 11.37 | |

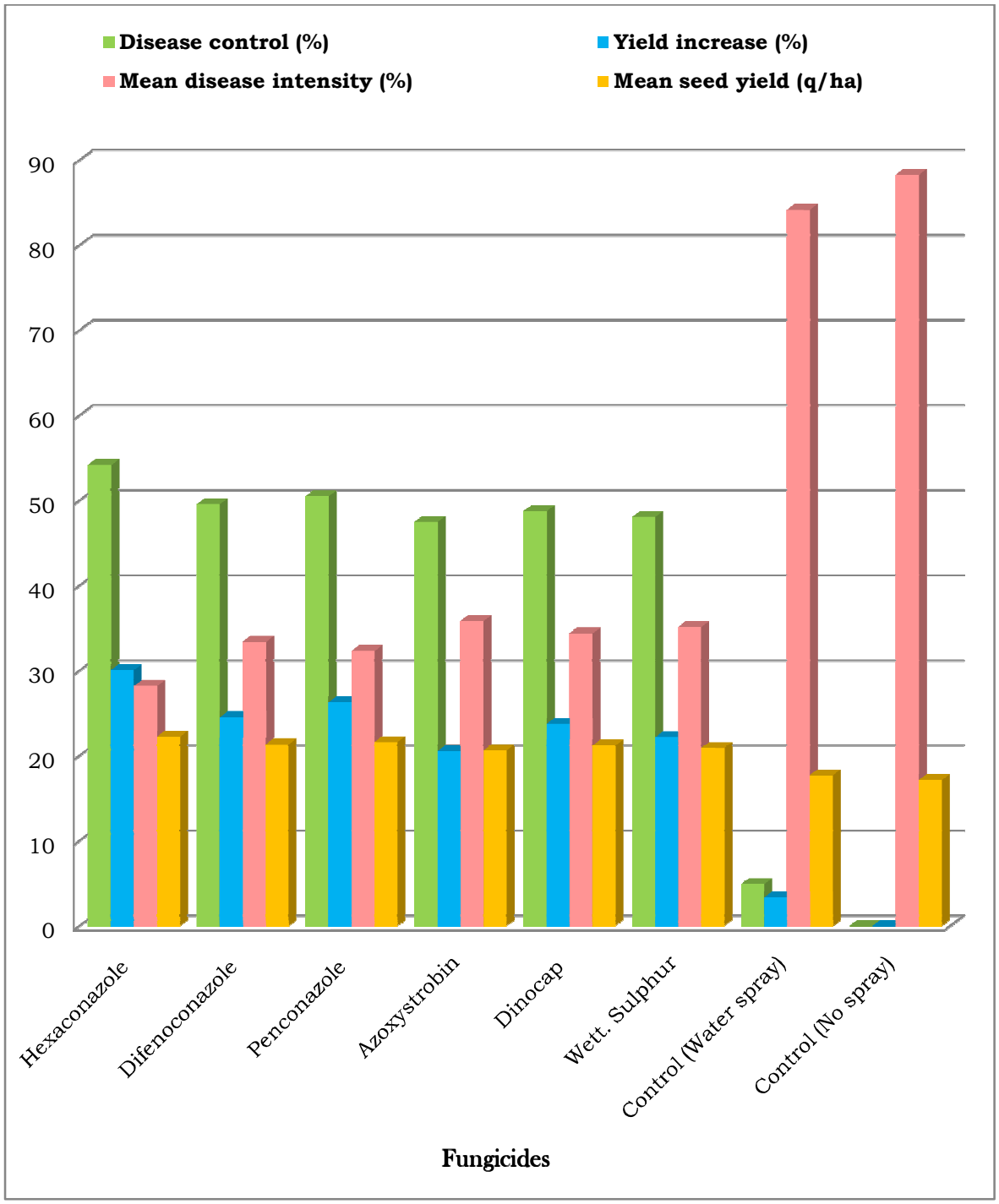



**Fig.7: Per cent disease control, increase in seed yield (%), mean PDI and seed yield as influenced by different fungicides *in vivo***

**Incremental cost: benefit ratio**

The economics of different fungicides for the control of powdery mildew of mustard (Table 4.19) indicated that the highest incremental cost benefit ratio (ICBR) of 1:4.63 was found in four sprays of hexaconazole 0.005 per cent followed by wettable sulphur 0.2 per cent (1:3.36) and penconazole 0.010 per cent (1:1.07).

**Table 4.19: Economics of various fungicides for controlling powdery mildew of mustard**

| Treatment & Concentration | Increased over control | | Cost of fungicides | Total Expen-diture (Rs./ha) | ICBR |
|---|---|---|---|---|---|
| | Seed yield (Kg/ha) | Income (Rs./ha) | | | |
| Hexaconazole 5% EC | 514 | 11822 | 900 | 2100 | 1:4.63 |
| Difenoconazole 25% EC | 452 | 10396 | 5320 | 6520 | 1:0.59 |
| Penconazole 10% EC | 449 | 10327 | 3800 | 5000 | 1:1.07 |
| Azoxystrobin 25% SC | 351 | 8073 | 13200 | 14400 | 1:-0.44 |
| Dinocap 48% EC | 406 | 9338 | 3900 | 5100 | 1:0.83 |
| Wett. Sulphur 80% WP | 379 | 8717 | 800 | 2000 | 1:3.36 |

**Oil content (%)**

It is evident from the pooled mean data presented in Table 4.20 and Fig. 8 that all fungicidal treatments significantly increased the oil content ranging from 6.32 to 11.95 per cent as compared to no spray control. Among different fungicides tested, hexaconazole recorded significantly the maximum oil content of 34.37 per cent and found at par with penconazole (34.03%) and

difenoconazole (33.57%). In the individual year, these three fungicides significantly increased oil content except in the year 2008-09 for difenoconazole in comparison to both the checks.

The next better fungicides were dinocap (33.12%), wettable sulphur (32.99%) and azoxystrobin (32.64%) as compared to control (30.70%).

**Table 4.20: Effect of fungicides applied for control of powdery mildew on oil content of mustard**

| Treatment | Oil content (%) | | | Pooled mean | Oil content increase (%) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Hexaconazole 5% EC | 33.48 | 34.03 | 35.61 | 34.37 | 11.95 |
| Difenoconazole 25% EC | 32.75 | 33.40 | 34.56 | 33.57 | 9.35 |
| Penconazole 10% EC | 33.04 | 33.97 | 35.08 | 34.03 | 10.85 |
| Azoxystrobin 25% SC | 32.21 | 32.59 | 33.12 | 32.64 | 6.32 |
| Dinocap 48% EC | 32.63 | 33.05 | 33.68 | 33.12 | 7.88 |
| Wett. Sulphur 80% WP | 32.53 | 33.02 | 33.43 | 32.99 | 7.46 |
| Control (Water spray) | 30.55 | 31.29 | 31.81 | 31.21 | 1.66 |
| Control (No spray) | 30.40 | 30.14 | 31.56 | 30.70 | - |
| S.Em.± | 0.71 | 0.82 | 0.78 | 0.41 | |
| C.D. at 5% | 2.09 | 2.40 | 2.28 | 1.15 | |
| C.V.% | 4.40 | 5.00 | 4.62 | 4.68 | |

Similarly, the maximum per cent increased in oil content was recorded in the treatment of hexaconazole (11.95%) followed by penconazole (10.85%), difenoconazole (9.35%), dinocap (7.88%), wettable sulphur (7.46%) and azoxystrobin (6.32%) over no spray control.

**Protein content (%)**

It is evident from the data presented in Table 4.21 and Fig. 8 that all fungicidal treatments significantly increased the protein content ranging from 17.04 to 26.05 per cent as compared to control. Among different treatments tried, hexaconazole found significantly superior over rest of the treatments and recorded maximum protein content of 18.05 per cent and found at par with penconazole (17.52%). The next best treatment was difenoconazole (17.29%), dinocap (17.07%) and wettable sulphur (16.84%). Azoxystrobin recorded minimum 16.76 per cent protein content as compared to no spray control (14.32%) under pooled analysis.

In the individual year, all fungicidal treatments significantly increased protein content as compared to both the checks. During the year 2007-08, hexaconazole found effective and recorded 18.07 per cent protein content followed by penconazole (17.47%), difenoconazole (17.39%), dinocap (17.33%) and wettable sulphur (17.06%). Similar trend was also notice in the year 2008-09 and 2009-10. The azoxystrobin was the least effective among the all fungicides tested during the three years.

Similarly, the maximum 26.05 per cent increased in protein content was recorded in the treatment of hexaconazole followed by penconazole (22.35%), difenoconazole (20.74%),

dinocap (19.20%), wettable sulphur (17.60%) and azoxystrobin (17.04%) over no spray control.

**Table 4.21: Effect of fungicides applied for control of powdery mildew on protein content of mustard**

| Treatment | Protein content (%) | | | Pooled mean | Protein content increase (%) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Hexaconazole 5% EC | 18.07 | 17.49 | 18.60 | 18.05 | 26.05 |
| Difenoconazole 25% EC | 17.39 | 16.67 | 17.81 | 17.29 | 20.74 |
| Penconazole 10% EC | 17.47 | 17.06 | 18.03 | 17.52 | 22.35 |
| Azoxystrobin 25% SC | 16.96 | 16.41 | 16.91 | 16.76 | 17.04 |
| Dinocap 48% EC | 17.33 | 16.60 | 17.29 | 17.07 | 19.20 |
| Wett. Sulphur 80% WP | 17.06 | 16.46 | 17.00 | 16.84 | 17.60 |
| Control (Water spray) | 15.52 | 14.97 | 15.38 | 15.29 | 6.77 |
| Control (No spray) | 14.49 | 14.02 | 14.45 | 14.32 | - |
| S.Em.± | 0.42 | 0.35 | 0.47 | 0.24 | |
| C.D. at 5% | 1.23 | 1.02 | 1.39 | 0.68 | |
| C.V.% | 5.00 | 4.30 | 5.59 | 5.01 | |

**Test weight (g)**

It is evident from the data presented in Table 4.22 and Fig. 8 that all fungicidal treatments significantly increased the 1000-seeds weight as compared to no spray control. During the year 2007-08, hexaconazole recorded significantly the maximum 1000-seeds weight 5.53 g, which was at par with penconazole (5.42 g) and dinocap (5.40 g). Difenoconazole was the next best fungicide with a 1000-seeds weight of 5.31 g followed by wettable sulphur (5.29 g) and azoxystrobin (5.17 g). Interestingly, during the year 2008-09, all the tested fungicides *viz.*, hexaconazole, penconazole, difenoconazole, dinocap, wettable sulphur and azoxystrobin were equally good with 5.30, 5.26, 5.21, 5.18, 5.17 and 5.17 g weight of 1000-seeds, respectively as compared to no spray control (4.11g). During the year 2009-10, hexaconazole was significantly superior over rest of the treatments with maximum 1000-seeds weight of 5.35 g followed by penconazole (5.28 g), difenoconazole (5.20 g) and dinocap (5.18 g) as compared to no spray control (4.45 g). The fungicides wettable sulphur and azoxystrobin were equally effective and exhibited 1000-seeds weight 5.14 and 5.13 g, respectively. Pooled analysis of results of three years indicated equally good effect of hexaconazole (5.39 g) followed by penconazole (5.32 g), dinocap (5.25 g) and difenoconazole (5.24 g). Wettable sulphur and azoxystrobin recorded 5.20 and 5.16 g of 1000-seed weight over no spray control (4.39 g). The maximum per cent increased in 1000-seed weight was recorded in the treatment of hexaconazole (22.78%) followed by penconazole (21.18%), dinocap (19.59%), difenoconazole (19.36%), wettable sulphur (18.45%) and azoxystrobin (17.54%) over no spray control.

**Table 4.22: Effect of fungicides applied for control of powdery mildew on 1000-seeds weight (g) of mustard**

| Treatment | 1000-seeds weight (g) | | | Pooled mean | Increase in test weight (%) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Hexaconazole 5% EC | 5.53 | 5.30 | 5.35 | 5.39 | 22.78 |
| Difenoconazole 25% EC | 5.31 | 5.21 | 5.20 | 5.24 | 19.36 |
| Penconazole 10% EC | 5.42 | 5.26 | 5.28 | 5.32 | 21.18 |
| Azoxystrobin 25% SC | 5.17 | 5.17 | 5.13 | 5.16 | 17.54 |
| Dinocap 48% EC | 5.40 | 5.18 | 5.18 | 5.25 | 19.59 |
| Wett. Sulphur 80% WP | 5.29 | 5.17 | 5.14 | 5.20 | 18.45 |
| Control (Water spray) | 4.69 | 4.19 | 4.63 | 4.50 | 2.51 |
| Control (No spray) | 4.61 | 4.10 | 4.45 | 4.39 | - |
| S.Em.± | 0.07 | 0.06 | 0.07 | 0.06 | |
| C.D. at 5% | 0.21 | 0.19 | 0.20 | 0.19 | |
| C.V.% | 2.73 | 2.58 | 2.63 | 2.65 | |

**Evaluation of different biopesticides *in vivo***

For studying the efficacy of different biopesticides against *E.cruciferarum* on mustard *in vivo*, four different biopesticides *viz.*, neem seed kernel extract (NSKE), neem leaf extract (NLE),

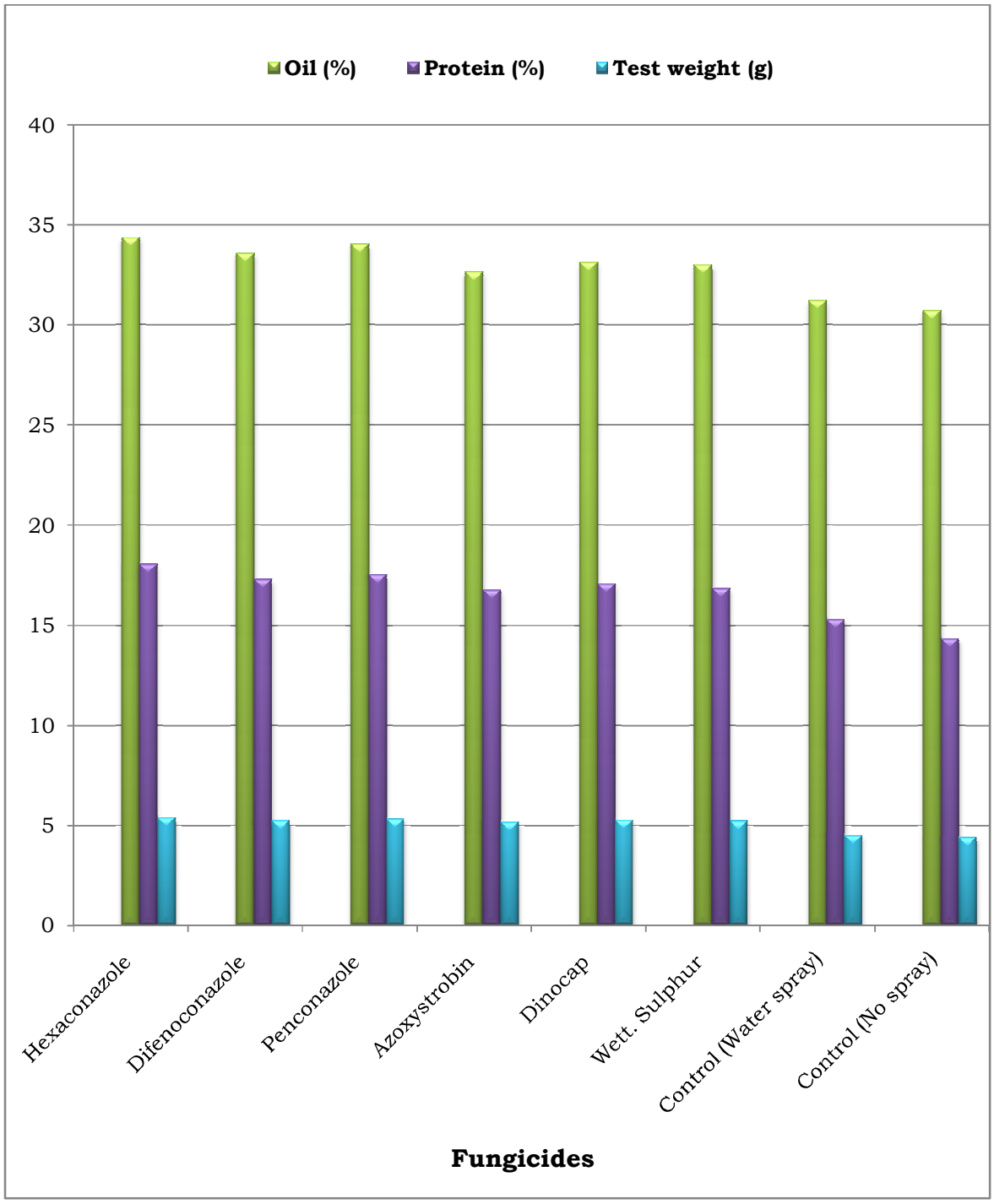



**Fig.8: Oil, protein content (%) and test weight (g) as influenced by different fungicides *in vivo***

azadirachtin including wettable sulphur were tested on mustard variety Gujarat Mustard-2 during the *rabi* 2007-08 to 2009-10. The first spraying of the biopesticides and fungicide was started after onset of the disease and remaining sprays were carried out at 12 days interval. Observations on powdery mildew intensity was recorded at seven days after last spray by selecting ten plants randomly from each plot and plants were rated on 0-12 scale as described earlier. Treatment wise disease intensity and per cent disease control, grain yield, economics, oil and protein content and test weight of 1000-seeds data are given in Table 4.23, 4.24, 4.25, 4.26, 4.27 and 4.28 and depicted in Fig. 9 and 10.

**Per cent Disease intensity**

Data presented in Table 4.23 and depicted in Fig. 9 revealed that all biopesticides were effective in reducing disease significantly as compared to control. The minimum disease intensity 33.98 per cent (pooled) and maximum disease control 47.99 per cent was registered with the application of wettable sulphur (0.2%). During the three years wettable sulphur also was effective and exhibited minimum PDI (35.80, 34.35, 31.84 and 33.98) during the years 2007-08, 2008-09, 2009-10 and pooled analysis, respectively and was at par with neem leaf extract with PDI of 35.39 during 2009-10. In pooled analysis, the leaf extract of neem recorded 38.35 PDI followed by neem seed kernel extract and azadiracthtin with 44.53 and 50.80 PDI, respectively as compared to control 86.65. The foliar spray of neem leaf extract among the biopesticides was found to be better in controlling the disease and showed 40.37 and 39.35 per cent disease intensity during the year 2007-08 and 2008-09, respectively. The next best biopesticide was neem seed kernel

extract with 44.94 and 44.55 PDI during the year 2007-08 and 2009-10, respectively. In the same treatment during 2008-09, the PDI was 44.13 and was at par with azadirachtin with 49.34 PDI.

**Table 4.23: Per cent disease intensity of powdery mildew influenced by biopesticides in mustard**

| Treatment | Disease intensity (%) | | | Pooled mean | Disease control (%) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Neem seed kernel extract 2% | 42.09 (44.94) | 41.63 (44.13) | 41.87 (44.55) | 41.86 (44.53) | 38.95 |
| Neem leaf extract 2% | 39.45 (40.37) | 38.85 (39.35) | 36.50 (35.39) | 38.26 (38.35) | 44.20 |
| Azadirachtin 0.5% | 47.38 (54.15) | 44.62 (49.34) | 44.39 (48.94) | 45.46 (50.80) | 33.70 |
| Wettable Sulphur 0.2% | 36.75 (35.80) | 35.88 (34.35) | 34.35 (31.84) | 35.66 (33.98) | 47.99 |
| Control (Water spray) | 65.90 (83.33) | 67.38 (85.21) | 63.43 (79.99) | 65.57 (82.90) | 4.38 |
| Control (No spray) | 67.90 (85.85) | 70.60 (88.97) | 67.22 (85.01) | 68.57 (86.65) | - |
| S.Em.± | 0.83 | 0.69 | 0.80 | 0.66 | |
| C.D. at 5% | 2.51 | 2.08 | 2.42 | 2.09 | |
| C.V.% | 3.34 | 2.77 | 3.34 | 3.16 | |

*Data given in parenthesis are retransformed values.

The water spray control showed 83.33, 85.21 and 79.99 PDI as compared to no spray control 85.85, 88.97 and 85.01 PDI during three consecutive *rabi* seasons of 2007-08 to 2009-10 and were at par only during 2007-08.

The per cent disease control ranged from 33.70 to 47.99. Maximum disease control of 47.99 per cent was observed in the

treatment of wettable sulphur followed by neem leaf extract (44.20%), neem seed kernel extract (38.95%) and azadirachtin (33.70%) as compared to no spray control.

**Seed yield (kg/ha)**

It is evident from the data presented in Table 4.24 and Fig. 9 that biopesticidal treatments significantly increased the mustard yield ranging from 17.13 to 29.92 per cent as compared to no spray control. During the year 2007-08, 2008-09 and 2009-10 wettable sulphur recorded significantly the highest mustard yield of 2111, 2100 and 2252 kg/ha, respectively followed by neem leaf extract (1987, 1935 and 2116 kg/ha), neem seed kernel extract (1967, 1901 and 2089 kg/ha) and azadirachtin (1894, 1871 and 2060 kg/ha) as compared to no spray control (1652, 1616 and 1705 kg/ha). In pooled results analysis, significantly highest mustard seed yield of 2154 kg/ha was recorded in the treatment of wettable sulphur and was found to be equally good as neem leaf extract 2013 kg/ha. The next best treatment was neem seed kernel extract (1986 kg/ha) which was at par with azadirachtin (1942 kg/ha) as compared to no spray control (1658 kg/ha). Decreased per cent disease intensity from 86.65 to 33.98 resulted in per cent increase in seed yield over control in all the tested biopesticides with best being wettable sulphur (29.92%) followed by neem leaf extract (21.41%), neem seed kernel extract (19.78%) and azadirachtin (17.13%).

**Table 4.24: Biopesticidal control of powdery mildew of mustard with their impact on seed yield**

| Treatment | Seed yield (kg/ha) | | | Pooled mean | Seed yield increase (%) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Neem seed kernel extract 2% | 1967 | 1901 | 2089 | 1986 | 19.78 |
| Neem leaf extract 2% | 1987 | 1935 | 2116 | 2013 | 21.41 |
| Azadirachtin 0.5% | 1894 | 1871 | 2060 | 1942 | 17.13 |
| Wettable Sulphur 0.2% | 2111 | 2100 | 2252 | 2154 | 29.92 |
| Control (Water spray) | 1710 | 1691 | 1800 | 1734 | 4.58 |
| Control (No spray) | 1652 | 1616 | 1705 | 1658 | - |
| S. Em.± | 94.64 | 106.27 | 120.50 | 56.57 | |
| C.D. at 5% | 285.22 | NS | 363.16 | 160.37 | |
| C.V.% | 10.03 | 11.47 | 12.03 | 11.25 | |

**Incremental cost: benefit ratio**

The economics of different biopesticides for the control of powdery mildew of mustard (Table 4.25) indicated that the highest incremental cost benefit ratio (ICBR) of 1:5.19 was realized in four sprays of neem leaf extract (2%) followed by wettable sulphur 0.2 per cent (1:4.70), neem seed kernel extract two per cent (1:3.72) and azadirachtin 0.5% (1:1.08).

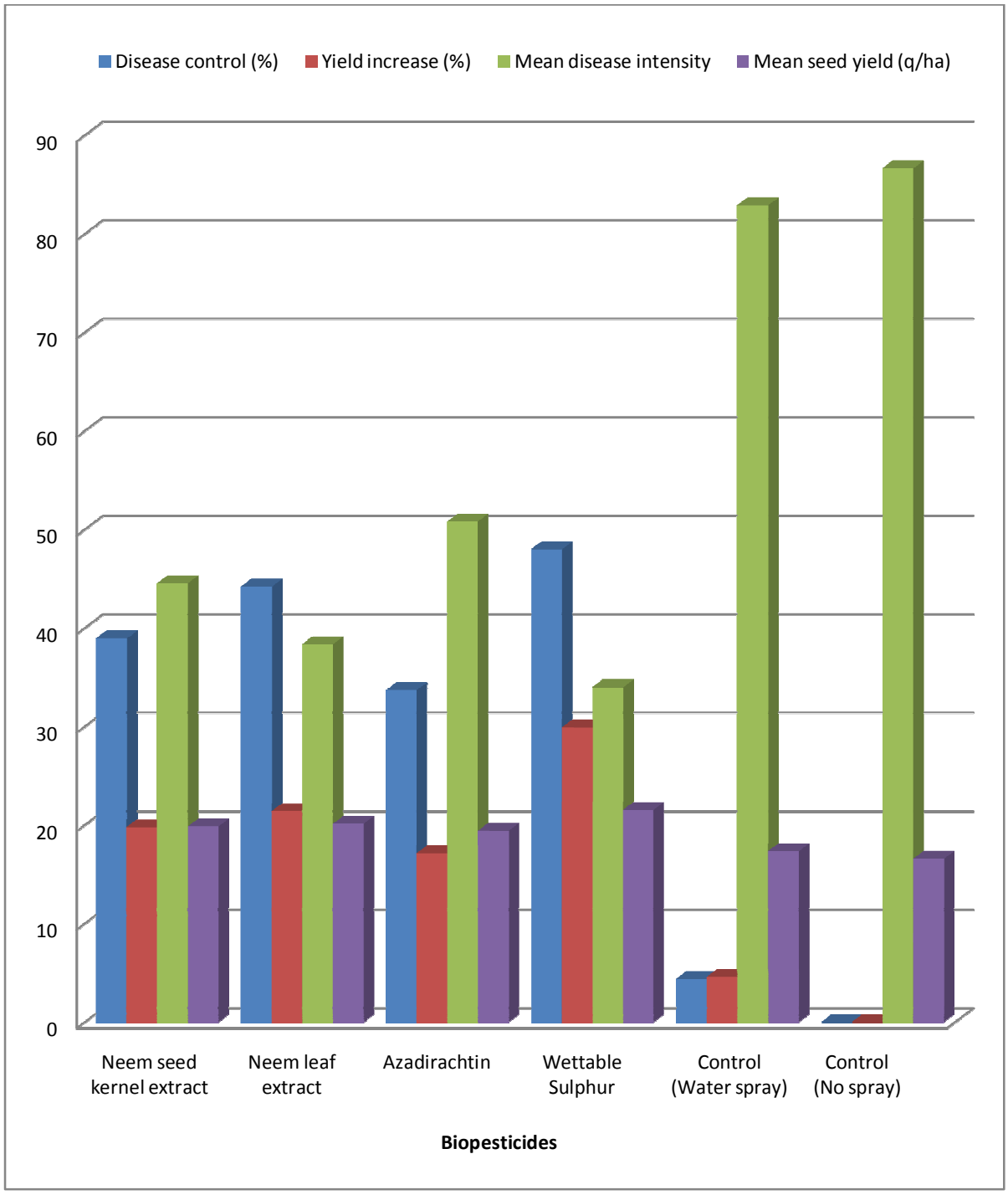



**Fig.9: Per cent disease control, increase in seed yield (%), mean PDI and seed yield as influenced by different biopesticides *in vivo***

**Table 4.25: Economics of various biopesticides for controlling powdery mildew of mustard**

| Treatment & Concentration | Increased over control | | Cost of fungicides | Total expen-diture (Rs./ha) | ICBR |
|---|---|---|---|---|---|
| | Seed yield (Kg/ha) | Income (Rs./ha) | | | |
| Neem seed kernel extract 2% | 328 | 7544 | 400 | 1600 | 1:3.72 |
| Neem leaf extract 2% | 355 | 8165 | 120 | 1320 | 1:5.19 |
| Azadirachtin 0.5% | 284 | 6532 | 1947 | 3147 | 1:1.08 |
| Wettable Sulphur 0.2% | 496 | 11408 | 800 | 2000 | 1:4.70 |

**Oil content (%)**

It is evident from the data presented in Table 4.26 and Fig. 10 that, among different treatments tried, wettable sulphur recorded significantly high oil content of 34.12 per cent followed by neem leaf extract (33.97%) and neem seed kernel extract (33.50%). Azadirachtain spray was least effective in improving oil content (32.94%) as compared to no spray control (30.89%) in pooled analysis.

Wettable sulphur among all treatments tried, recorded the highest amount of oil content 35.40, 32.59 and 34.36 per cent and were at par with neem leaf extract (35.28, 32.50 and 34.12%) followed by neem seed kernel extract (34.49, 32.38 and 33.65%) and azadirachtin (34.47, 31.71 and 32.63%), during the years 2007-08, 2008-09 and 2009-10, respectively as compared to no spray control with 32.12, 29.93 and 30.63 per cent for the corresponding years.

All the treatments were effective and recorded 6.64 to 10.46 per cent increased in oil content over no spray control. The maximum per cent increased in oil content was recorded in the treatment of wettable sulphur (10.46%) followed by neem leaf extract (9.97%), neem seed kernel extract (8.45%) and azadirachtin (6.64%) over no spray control.

**Table 4.26: Effect of biopesticides applied for control of powdery mildew on oil content of mustard**

| Treatment | Oil content (%) | | | Pooled mean | Oil content increase (%) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Neem seed kernel extract 2% | 34.49 | 32.38 | 33.65 | 33.50 | 8.45 |
| Neem leaf extract 2% | 35.28 | 32.50 | 34.12 | 33.97 | 9.97 |
| Azadirachtin 0.5% | 34.47 | 31.71 | 32.63 | 32.94 | 6.64 |
| Wettable Sulphur 0.2% | 35.40 | 32.59 | 34.36 | 34.12 | 10.46 |
| Control (Water spray) | 33.37 | 30.87 | 30.93 | 31.72 | 2.69 |
| Control (No spray) | 32.12 | 29.93 | 30.63 | 30.89 | - |
| S.Em.± | 0.72 | 0.55 | 0.67 | 0.35 | |
| C.D. at 5% | 2.17 | 1.66 | 2.01 | 1.00 | |
| C.V.% | 4.22 | 3.49 | 4.09 | 3.96 | |

**Protein content (%)**

The data in Table 4.27 and Fig. 10 revealed that among different treatments tried, the lowest protein content of 16.34 was observed in azadirachtin treated plants, whereas, foliar

spray with wettable sulphur was significantly superior over rest of the treatments and recorded maximum protein content of 17.11 per cent followed by neem leaf extract (16.69%) and neem seed kernel extract (16.54%) when pooled analysis was done. In individual years, the significantly higher protein content was recorded in the treatment of wettable sulphur followed by neem leaf extract and neem seed kernel extract during 2007-08 and 2008-09 as compared to no spray control. They were also statistically at par. In the year 2009-10, all treatments significantly increased protein content in comparison to both the checks.

All the treatments were effective and recorded 12.92 to 18.24 per cent increased in protein content over control. The maximum per cent increased in protein content was recorded in the treatment of wettable sulphur (18.24%) followed by neem leaf extract (15.34%), neem seed kernel extract (14.31%) and azadirachtin (12.92%) over no spray control.

**Test weight (g)**

It is evident from the data presented in Table 4.28 and Fig. 10 that during the year 2007-08, significantly the maximum 1000-seed weight 5.67 g was recorded in the treatment of wettable sulphur. The next best treatment was neem leaf extract (5.45 g) which was at par with neem seed kernels extract (5.30 g). Minimum 1000-seed weight was recorded in azadirachtin (5.16 g) as compared to no spray control (4.51 g), while, during the year 2008-09, wettable sulphur recorded maximum 1000-seed weight of 5.66 g. The other treatments *viz*, neem leaf extract, neem seed kernel extract and azadirachtin were equally good and reported 5.42, 5.35 and 5.28 g of 1000-seed weight,

respectively as compared to no spray control (4.33 g). During the year 2009-10, all the tested biopesticides were on par.

**Table 4.27: Effect of biopesticides applied for control of powdery mildew on protein content of mustard**

| Treatment | Protein content (%) | | | Pooled mean | Protein content increase (%) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Neem seed kernel extract 2% | 15.98 | 17.22 | 16.44 | 16.54 | 14.31 |
| Neem leaf extract 2% | 16.35 | 17.26 | 16.45 | 16.69 | 15.34 |
| Azadirachtin 0.5% | 15.96 | 16.90 | 16.16 | 16.34 | 12.92 |
| Wettable Sulphur 0.2% | 16.54 | 18.08 | 16.72 | 17.11 | 18.24 |
| Control (Water spray) | 15.11 | 16.10 | 14.54 | 15.25 | 5.39 |
| Check (No spray) | 14.63 | 15.66 | 13.10 | 14.47 | - |
| S.Em.± | 0.31 | 0.36 | 0.38 | 0.21 | |
| C.D. at 5% | 0.92 | 1.10 | 1.16 | 0.60 | |
| C.V.% | 3.88 | 4.32 | 4.93 | 4.39 | |

Wettable sulphur recorded 5.42 g seed weight followed by neem leaf extract (5.27 g), neem seed kernel extract (5.24 g) and azadiractin (5.23 g) as compared to control 4.22 g. Pooled analysis showed significantly the maximum 1000-seeds weight of 5.58 g in the treatment of wettable sulphur. The next best treatment was neem leaf extract with 5.38 g of 1000-seeds weight and was at par with neem seed kernel extract treatment that recorded 5.29 g of test weight. The minimum test weight of

5.23 g was recorded in the treatment of azadirachtin as compared to no spray control 4.35 g. The maximum per cent increased in 1000-seeds weight was recorded in the treatment of wettable sulphur (28.28%) followed by neem leaf extract (23.68%), neem seed kernel extract (21.61%) and azadirachtin (20.23%) over no spray control.

**Table 4.28: Effect of biopesticides applied for control of powdery mildew on 1000-seeds weight (g) of mustard**

| Treatment | 1000-seeds weight (g) | | | Pooled mean | Increase in test weight (%) |
|---|---|---|---|---|---|
| | 2007-08 | 2008-09 | 2009-10 | | |
| Neem seed kernel extract 2% | 5.30 | 5.35 | 5.24 | 5.29 | 21.61 |
| Neem leaf extract 2% | 5.45 | 5.42 | 5.27 | 5.38 | 23.68 |
| Azadirachtin 0.5% | 5.16 | 5.28 | 5.23 | 5.23 | 20.23 |
| Wettable Sulphur 0.2% | 5.67 | 5.66 | 5.42 | 5.58 | 28.28 |
| Control (Water spray) | 4.64 | 4.46 | 4.34 | 4.48 | 2.99 |
| Check (No spray) | 4.51 | 4.33 | 4.22 | 4.35 | - |
| S.Em.± | 0.07 | 0.07 | 0.07 | 0.04 | |
| C.D. at 5% | 0.20 | 0.21 | 0.21 | 0.12 | |
| C.V.% | 2.60 | 2.73 | 2.85 | 2.72 | |

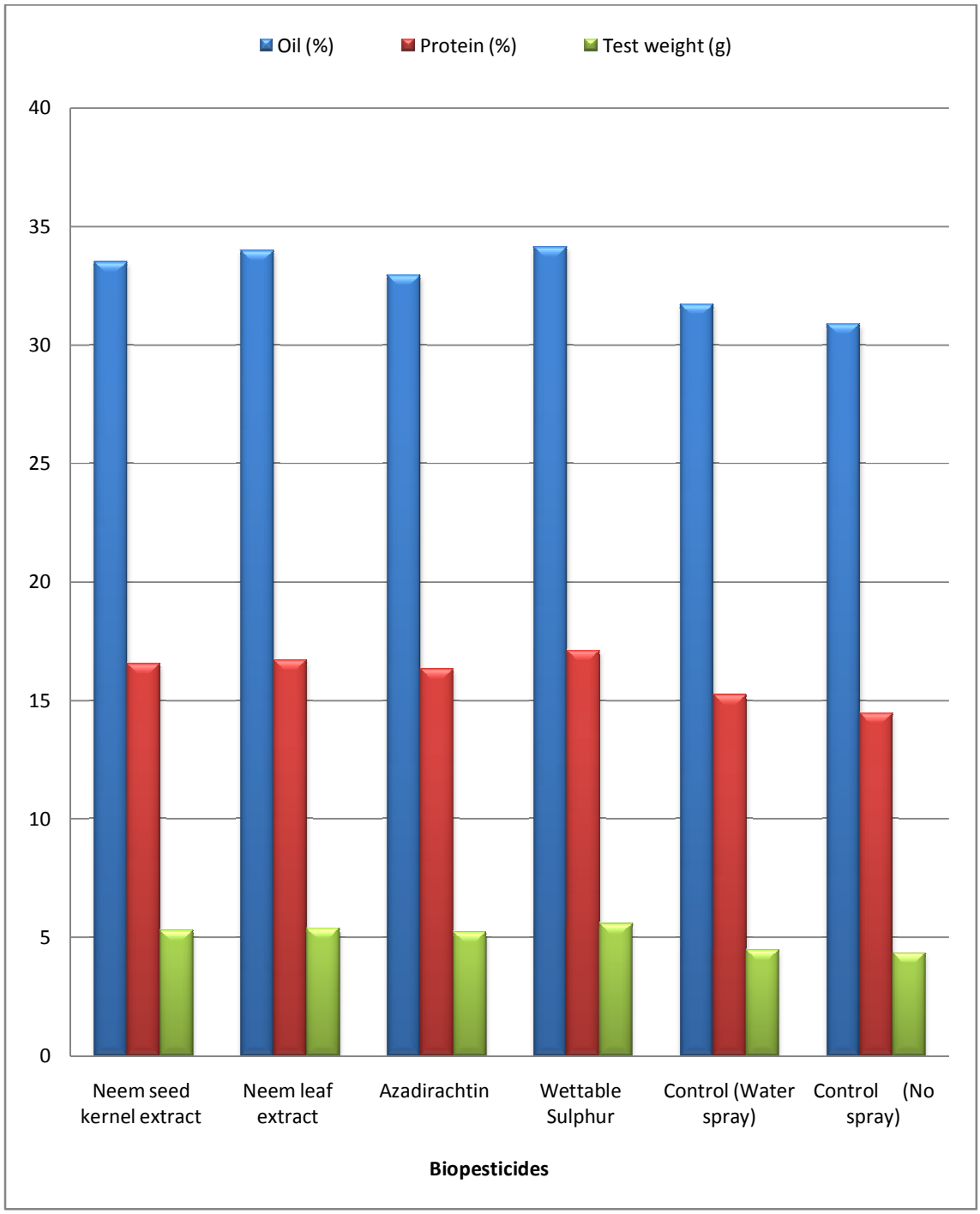



**Fig.10: Oil, protein content (%) and test weight (g) as influenced by different biopesticides *in vivo***

# DISCUSSION

# CHAPTER - V

# DISCUSSION

The rapeseed and mustard group dominates amongst oilseed crops in area and production all over the globe. Different types of oleiferous *Brassicae*, grown in India, among them Indian mustard (*Brassica juncea*) is the most popular and widespread oilseed crop grown during winter season in India.

Rapeseed and mustard are considered to be of high economic importance in national and international trade with significant implications as they yield 30-48 per cent edible oil which is used as the main cooking medium in India. The seed and oil are used as a condiment in the preparation of pickles and for flavouring the curries and vegetables. Rapeseed and mustard are very important from nutritional point of view as well because they contain 38-57 per cent erucic acid, 4.7 to 13 per cent linolenic acid along with 27 per cent of oleic acid and lenolic acid which are of high nutritive value required for the human body.

The mustard crop suffers from fungal, bacterial and viral diseases which are considered economically important as they cause considerable yield losses.

Amongst the major constraints in obtaining higher yield, the diseases like powdery mildew caused by *Erysiphe cruciferarum* Opiz ex. Junell is the most important and becoming widespread disease in most mustard growing areas of India including Gujarat. The weather conditions during December and January are the most congenial for outbreak of powdery mildew.

The initial symptoms in field were observed during 60-63 days after sowing (DAS) which coincides with completion of flowering period. The symptoms appeared in a few plants as

minute visible and almost circular fungal colony of 2-3 mm in size on upper surface of lower most leaf. The fungal colony gradually expanded in size with whitish visible floury patches. The scattered fungal colony became quite conspicuous within 10-12 days of initial infection and coalesced. The disease progressed towards upper leaves on both the surfaces, stems & branches and on the siliquae, thereby whole plant was covered with white powdery fungal growth shows within a period of one month after initiation of the symptoms. On the stems, purple blue patches were seen in advanced stage. Such plants were conspicuous from a distance. Heavily infected leaves turned pale yellow in due course, dried early and shedding of leaves was a common feature. Infected siliquae produced poor quality shrivelled seeds. The heavily infected plant matured earlier than healthy plants. The present findings were in close conformity with Sankhla *et al.* (1967). They observed powdery mildew attack on lower leaves first and gradually the entire plant. Defoliation of the *B. juncea* and *Brassica campestris* var. *sarson* plants infected by powdery mildew (*Erysiphe polygoni*) was seen by Singh and Solanki (1974). Similar types of symptoms on mustard were also reported by Sharma (1979); Saharan and Kaushik (1981) and Singh (2000). Extensive stem colonization by powdery mildew caused by *E. cruciferarum* at the end of the flowering period was also noted by Kaur *et al.* (2008).

Microscopic studies of *E. cruciferarum* showed that conidiophores were erect, stout, ellipsoid to cylindrical in shape measuring 67.4 ± 6.2 µm and were more or less erect with moderately straight foot cells with an average length of 19.8 $\pm$ 2.1 µm in size with 2-3 conidia in chain. Conidia were unicellular, hyaline, elliptical to cylindrical in shape measuring

26.5-39.8 µm x 12.4-16.6 µm in size without fibrosin bodies. Sankhla *et al.* (1967) and Shabbir and Yadav (2009) also studied morphology of fungus and reported similar type of findings.

Assessment of yield loss study indicated significantly the minimum per cent disease intensity (27.67) due to powdery mildew disease of mustard and maximum seed yield 2244 kg/ha in the treatment of hexaconazole than that of sprayed with water (83.25%) and no spray control (86.75%). The minimum yield was recorded in no spray control 1739 kg/ha, but it was at par with water spray control 1814 kg/ha. The maximum disease control 53.77 per cent was observed with hexaconazole 0.005 per cent and 22.50 per cent loss in seed yield due to powdery mildew disease in mustard was observed when not followed any control measures against the disease. The avoidable economic loss due to powdery mildew of mustard revealed significant reduction in yield when crop was not protected by hexaconazole 0.005 per cent, which exhibited significant higher net income of Rs.49,512/ha in comparison to corresponding yield of un protected plot (Rs.39,997/ha). The 23.48 per cent avoidable loss and net profit of Rs.9,390/ha was found due to spray with hexaconazole 0.005 per cent. Significantly the maximum amount of oil, protein and 1000-seeds weight (34.72%, 15.41% and 5.67 g) was found in the treatment of hexaconazole as compared to water spray control (32.75%, 13.22% and 4.55 g) and no spray control (32.20%, 12.06% and 4.45 g) with 7.26, 21.74 and 21.52 per cent loss, respectively.

The present findings are corroborated with the results of Saharan and Sheoran (1985). They reported 17.5 per cent loss in total yield and reduction in oil content up to 6.47 per cent. Singh (1986) estimated 17.4 and 6.47 per cent reduction in mustard

seed yield and oil content, respectively. A 22 per cent yield loss in mustard was reported in Gujarat (Anon., 1993). Dange *et al.* (2002) observed 16.97 per cent reduction in seed yield due to powdery mildew in mustard cv. 'Varuna' in Gujarat, India during 1994-97 when disease intensity was 50.75 in control as compared to only 21.71 in treated plots. Hingole and Mayee (2004) reported highest disease incidence and severity in rapeseed mustard cultivar Bio-SYR and the lowest in TM-17 with highest loss in yield of 32.91 per cent in Bio-SYR and the lowest in Bio-902 which suffered only 6.08 per cent in Maharashtra.

Screening of mustard was undertaken with a view to find out the resistant entries of mustard, if any against powdery mildew. The results of consecutive three *rabi* seasons showed that out of 13 entries tested, none showed immunity to the disease. Entries of *B. juncea* species GM-2 exhibited highly susceptible reaction followed by GM-1 and GM-3 which exhibited susceptible reaction with mean average disease score of 4.58, 4.25 and 4.28, respectively. The entries of *Brassica napus* species HNS-0004, ISN-129 and NUDB-26-11 exhibited moderately susceptible reaction with 3.37, 3.35 and 3.23 mean disease score. Entries GSL-1 and GSL-861-212 exhibited resistant reaction with average disease score of 2.33 and 2.35. Entries belong to *Brassica carinata* species DLSC-3, Kiran, NPC-3, NPC-111 and NPJ-87 exhibited highly resistant reaction to powdery mildew infection with minimum disease score of 1.17, 1.20, 1.20, 1.28 and 1.23, respectively.

More or less similar findings were also reported by Narain and Siddiqui (1965), Dang *et al.* (2000), Kumar *et al.* (2002), Kumar and Saharan (2002), Singh and Singh (2003), Singh *et al.* (2006), Singh *et al.* (2010) and Mohitkar *et al.* (2012) in mustard.

Effect of meteorological factors on disease development indicated positive and significant relationship of PDI with maximum air temperature (r = 0.5311) during the year 2008-09, and 2010-11 (r = 0.7583) and in pooled analysis (r = 0.4704). During 2007-08 (r = 0.3627) and 2009-10 (r = 0.5455), the effect of maximum air temperature was non significant. The relationship of minimum air temperature with PDI was found to be insignificant during 2007-08, 2008-09, 2009-10, 2010-11 and in pooled results.

The morning relative humidity was found to be not significant in all the years and in pooled, except during the year 2008-09 and 2009-10. In 2008-09, morning relative humidity (r= 0.6153) was significantly positive with PDI, whereas during the year 2009-10, it was significant but negatively correlated (r = -0.5534). While, the afternoon relative humidity exhibited highly significant and negative relationship with PDI with r values being -0.7058, -0.7121 and -0.2845 during 2007-08, 2008-09 and in pooled results, respectively. During 2009-10 and 2010-11 it was non significant.

In multiple regressions analysis four independent variables were considered with PDI as dependent variable. Out of four variables, most contributing variable was afternoon relative humidity (%) as identified for the disease development under natural condition during the year 2007-08.

The regression equation for the prediction of PDI was

$Y=68.8098-0.3030X_1+7.1330X_2-0.5567X_3-2.1298\ X_4$*.....($R^2$=0.5995).

The effect of weather variables with PDI during the year 2008-09 was to be non significant.

The regression equation for the prediction of PDI was

$Y=-58.3115+1.3011X_1+2.6481X_2+1.4709X_3-1.8462X_4$.....($R^2=0.5918$).

During the year 2009-10, maximum temperature (°C) was identified as main parameter for the disease development under natural conditions.

The regression equation for the prediction of PDI was

$Y=-123.5512+10.9165X_1$*$-2.4366X_2-2.0121X_3+1.0931X_4$....($R^2=0.6812$).

The maximum temperature (°C) and afternoon relative humidity (%) were identified for the disease development under natural condition during the year 2010-11 and in pooled results.

The regression equation for the prediction of PDI was

$Y=-604.2570+22.9234X_1$*$+5.9336X_2+0.2071X_3-2.6668X_4$*($R^2=0.8076$).

The regression equation for the prediction of PDI in pooled was

$Y=-133.0856+5.5663X_1$*$+3.8247X_2+0.2426X_3-1.2826X_4$*..($R^2=0.3620$).

Present findings are in close conformity with the results obtained by Saharan and Kaushik (1981). They reported moderate temperature coupled with low humidity and dry weather during the month of February and March as congenial for disease development in mustard. Dang *et al*. (1998) also reported relationship between environmental factors and disease development of *E. cruciferarum* on Indian mustard (*B. juncea*) and concluded that temperature had significant positive relationship with the disease in stepwise multiple regression analysis. Gadre *et al*. (2002) investigated simple correlation analysis between various weather factors and disease including powdery mildew (*E. cruciferarum*) in mustard (*Brassica nigra*) and revealed that maximum, minimum and mean air temperatures were significant for powdery mildew. Desai *et al.* (2004) studied the relationship of weather parameters with the powdery mildew disease at Sardarkrushinagar (Gujarat) and Bharatpur with Indian mustard

(*B. juncea*) cultivars 'Varuna' and local ('GM-2' at Sardarkrushinagar and 'PCR-7' at Bharatpur) and concluded that severity of the powdery mildew disease of *B. juncea* was favoured by >5 days of ≥9.1 h of sunshine, >2 days of morning (maximum) relative humidity (RH) of <90 per cent, afternoon (minimum) relative humidity (RH) 24-50 per cent, minimum temperature >5ºC and a maximum temperature of 24-30ºC. Regression analysis showed maximum temperature, minimum (afternoon) RH of the week preceding the date of observation had positive and negative correlation to disease severity in cvs. 'Varuna' and 'GM-2' within the specified ranges, respectively. Kohire *et al*. (2008) determined the suitability of physical factors for disease development by *E. cruciferarum* in mustard (*B. campestris*) grown in India. They concluded that temperature with relative humidity played an important role in disease development. *E. cruciferarum* did not respond to high humidity. Ideal humidity (30.2-48.8%) with 12.2-22.8ºC favoured powdery mildew of mustard.

Different agrochemicals were evaluated *in vitro* to choose the promising chemicals against powdery mildew of mustard caused by *E. cruciferarum*. All the systemic fungicides were effective in spore germination inhibition. Hexaconazole (0.005%) was found to be significantly most effective fungicide with 84.10 per cent inhibition of spore germination followed by penconazole and difenoconazole with 80.05 and 78.09 per cent inhibition of spore germination, respectively. The next effective fungicide in inhibition of spore germination was propiconazole (76.53%). The comparatively lower inhibition of spore germination 66.27 per cent was recorded in the treatment of carbendazim which was at par with tebuconazole (58.10%). The fungicide azoxystrobin

showed the lowest efficacy among all fungicides tested with 53.98 per cent inhibition of spore germination.

The effectiveness of carbendazim against *E. polygoni*, *Oidium erysiphoides* f. sp. *ziziphi*, *Podosphaera leucotricha* and *E. cichoracearum* was reported earlier (Kunkalikar, 1989; Sataraddi, 1994; Sharma and Gupta, 1994; Hiremath, 1996). Triazole fungicides namely hexaconazole, penconazole and difenconazole were highly effective in spore germination inhibition of *E. cruciferarum* in the present investigation. Similarly, they were also found to be effective for powdery mildew of green gram (*E. polygoni*), *Sphaerotheca pannosa*, powdery mildew of pea, powdery mildew of okra (*E. cichoracearum*) and powdery mildew of fenugreek (Venkatrao, 1997; Ravikumar, 1998; Biju, 2000; Shivanna *et al.*, 2006; Chovatiya, 2010).

Among non systemic fungicides, the most effective fungicide was dinocap followed by wettable sulphur with 79.98 and 77.00 per cent inhibition of spore germination, respectively. The next effective fungicide in per cent inhibition of spore germination was mancozeb with 73.00 per cent. Thiram and chlorothalonil exhibited 57.50 and 53.98 per cent inhibition and were at par. The lowest inhibition of spore germination was recorded in zineb followed by captan with 49.46 and 51.47 per cent, respectively.

Similar findings were also reported by Gohokar and Peshney (1981). They concluded that sulphur dust was highly effective in inhibition of spore germination followed by Sultaf, Karathane, Calixin, Benlate Miltox and Thiovit against *Laveillula taurica* of chilli *in vitro*. Among non systemic fungicides, wettable sulphur recorded maximum inhibition (80%) of spore

germination of *E. polygoni* in fenugreek followed by mancozeb (72.25%) and dinocap (70%) as reported by Chovatiya (2010).

The insecticides were evaluated for their efficacy against *E. cruciferarum in vitro* using poisoned food technique. Among different insecticides, significantly higher spore germination inhibition was observed in the treatment of methyl-o-demeton (54.97%) followed by triazophos (54.48%) and quinalphos (53.46%). In azadirachtin 45.94 per cent spore germination inhibition was observed but it was at par with triazophos + deltamethrin (44.46%) and cypermethrin + profenophos (42.94%). Acephate (40.97%) remained at par with imidacloprid (40.95%) in inhibition of spore germination. The lowest inhibition of spore germination 33.21 per cent was recorded in the treatment of carbosulfan.

Present findings are in line with the results obtained by Solanki (1995) who reported toxic effect of triazophos and methyl–o-demeton on conidia of *E. cruciferarum* causing powdery mildew of mustard. Similar type of toxic effect was also found in dimethoate and fenvalerate. Chovatiya (2010) also recorded maximum inhibition (71%) of spore germination of powdery mildew of fenugreek in cypermethrin + profenophos followed by carbosulfan (51.75%) *in vitro*.

The antifungal properties of naturally occurring substances in plant species showed that all the phytoextracts were capable of inhibiting the spore germination at different degrees. Clove extracts of garlic (*Allium sativum)* provided the highest spore germination inhibition of 74.08 per cent followed by leaf extract of neem (*Azadirachta indica*) with 68.47 per cent inhibition of spore germination and remained statistically at par. They were also significantly superior over rest of the treatments. Bulb

extracts of onion (*Allium cepa*) recorded 63 per cent inhibition of spore germination followed by leaf extract of henna (*Lawsonia inermis*) and rhizome extract of turmeric (*Curcuma longa*) which exhibited 58.00 and 57.05 per cent inhibition of spore germination. Indian Laburnum (*Cassia fistula*) showed 54.98 per cent inhibition of spore germination followed by rhizome extract of ginger (*Zingiber officenale*) and leaf extract of *bataj* (*Clerodendrum inerme*) with 53.49 and 50.47 per cent inhibition of spore germination, respectively. The least effective phytoextract found was *karanj* (*Derris indica*) which recorded 23.93 per cent inhibition of spore germination.

In the present investigation phytoextracts of garlic were highly effective in inhibition spore germination of *E. cruciferarum* followed by neem. Other extracts of onion, henna, turmeric, Indian laburnum, ginger and bataj inhibited spore germination in the range of 63.00 to 50.47 per cent. Dhaliwal *et al.* (2002) reported that garlic (*Allium sativum*) exhibited maximum efficacy providing complete inhibition of conidial germination at 100 µg/ml and above followed by *Cyperus scariousus* and *Cuminum cyminum* against *Uncinula necator* causing powdery mildew of grapevine. Raghavendra (2005) tested various botanicals against conidial germination of powdery mildew of chilli caused by *L. taurica in vitro*. Among botanicals, Neem Seed Kernel Extract (NSKE 10%) showed least conidial germination and was significantly superior over rest of the treatments. This was followed by nimbicidin (0.5%). A bulb extract of *A. sativum* was found most effective (even better than mancozeb) in reducing powdery mildew of mustard on leaves over control (Anon., 2007). Chovatiya (2010) concluded garlic as the best for spore germination inhibition (80.00%) followed by ginger (63.75%) and

onion (62.00%) *in vitro* against *E. polygoni* causing powdery mildew of fenugreek.

Effect of different fungicides against *E. cruciferarum* on mustard was tried in field condition during three *rabi* seasons. Among different fungicides, hexaconazole performed the best as evident from significantly minimum per cent disease intensity (PDI) of 27.81, 29.09 and 27.65 during the years 2007-08, 2008-09 and 2009-10, respectively and found to be at par with penconazole and difenoconazole with 32.42, 33.47 and 30.98 and 33.65, 33.67 and 32.78 PDI, respectively for the corresponding years above. It was also at par with dinocap with PDI 34.16 and 34.30 during 2007-08 and 2008-09, respectively. The next effective fungicide during the year 2009-10 was dinocap and found to be at par with wettable sulphur and azoxystrobin with 34.06, 35.11 and 36.15 PDI, respectively.

The pooled results over three years data revealed that hexaconazole was significantly the best with 54.17 per cent disease control and recorded 22.25 q/ha of mustard yield. The next best fungicide was penconazole with per cent disease intensity of 32.30 and recorded 50.49 per cent disease control and found at par with difenoconazole, dinocap and wettable sulphur with the per cent disease intensity of 33.38, 34.35 and 35.11 with per cent disease control of 49.55, 48.71 and 48.05, respectively. The fungicide azoxystrobin recorded the highest PDI among different fungicides tried and gave minimum per cent disease control of 47.45 as compared to no spray control with 88.25 PDI.

All fungicidal treatments significantly increased the mustard yield ranging from 20.51 to 30.04 per cent as compared to no spray control. During the years 2007-08, 2008-09 and

2009-10 seed yield were significantly maximum. In the treatment of hexaconazole the seed yields were 2250, 2160 and 2266 kg/ha, during the years 2007-08, 2008-09 and 2009-10, respectively. Seed yield was found to be significantly maximum in the treatment of hexaconazole (2225 kg/ha) and was at par with penconazole (2160 kg/ha), difenoconazole (2130 kg/ha), dinocap (2117 kg/ha), wettable sulphur (2090 kg/ha) and azoxystrobin (2062 kg/ha). Water spray control produced 1768 kg/ha seed yield as compared to no spray control with the minimum seed yield of 1711 kg/ha. Similarly, per cent increase in seed yield over no spray control was also higher in the treatment of hexaconazole (30.04%) followed by penconazole (26.24%), difenoconazole (24.49%), dinocap (23.73%), wettable sulphur (22.15%) and azoxystrobin (20.51%), respectively. The economics of different fungicides for the control of powdery mildew of mustard indicated that the highest incremental cost benefit ratio (ICBR) of 1:4.63 was found in four sprays of hexaconazole 0.005 per cent followed by wettable sulphur 0.2 per cent (1:3.36) and penconazole 0.010 per cent (1:1.07).

These results were in agreement with Singh (1986). He reported maximum control of powdery mildew of mustard with two foliar sprays of Karathane (0.1%) followed by Sulfex (0.3%) and Calixin (0.1%). Kamat *et al.* (1989) observed reduction of mustard powdery mildew in the field by 95 per cent with two foliar sprays of Karathane (0.2%). Three sprayings of dinocap @ 0.025 per cent were recommended for effective control of powdery mildew of mustard starting from appearance of disease in Gujarat (Anon., 1990; Jani *et al.,* 1991; Patel *et al.,* 1992). Similarly, foliar spray of Karathane at 0.2 per cent on *E. polygoni* on Indian mustard cv. 'Varuna' was most effective in reducing

disease and improving mustard yield (Singh and Chauhan, 1996; Singh and Chauhan, 1998). Even spraying of Karathane (0.1%) was effective for the control of powdery mildew of mustard caused by *E. cruciferarum* (Laxmanrao, 1998; Sangwan and Mehta, 2001).

Hexaconazole proved to be the best for control powdery mildew in the present investigation followed by penconazole and difenoconazole. Earlier researchers also noted that triazole fungicides were effective for control of powdery mildew of mustard. Dang *et al*. (1998) revealed that Punch 0.03 per cent was the most effective showing 84.7 per cent disease reduction over the control when mustard crop was sprayed just after the appearance of powdery mildew disease. Patel and Patel (2008) revealed that tridemorph was significantly the best with PDI of 23.33 followed by hexaconazole (35.00%), tebuconazole (35.33%) and wettable sulphur (38.67%) as against 80.67 PDI recorded in control treatment. Shabbir and Yadav (2009) noted minimum powdery mildew intensity on mustard cultivar 'Varuna' in hexaconazole treated plants (30.6%) followed by Calixin, wettable sulphur, Bavistin, Blitox-50, Sulphur dust and Topsin-M, respectively.

Effect of different fungicides on oil content of mustard seed was tested during three consecutive *rabi* seasons under field conditions. The maximum oil content of 34.37 per cent was recorded in the treatment of hexaconazole followed by penconazole (34.03), difenoconazole (33.57), dinocap (33.12), wettable sulphur (32.99) and azoxystrobin (32.64) as compared to no spray control (30.70). Similarly, the maximum per cent increase in oil content was also recorded in the treatment of hexaconazole (11.95) followed by penconazole (10.85),

difenoconazole (9.35), dinocap (7.88), wettable sulphur (7.46) and azoxystrobin (6.32) over no spray control.

The present investigation was in close conformity with the similar type of findings as reported from Canada for leaf blight of mustard caused by *Alternaria brassicae* by Degenhardt *et al.,* (1974). They noticed losses in oil content up to 4.8 per cent, but higher losses (14.58-35.97%) were recorded in India for same disease (Ansari *et al.,* 1988). Shrestha (2005) reported negative effect on oil content causing losses in mustard oil between 4.2 and 4.5 per cent under Nepal conditions due to *Alternaria* leaf blight disease.

Effect of different fungicides on protein content of mustard was tested against powdery mildew disease during three consecutive *rabi* seasons under field conditions. A maximum protein content of 18.05 per cent was recorded in the treatment of hexaconazole followed by penconazole (17.52%). The next best treatment was difenoconazole (17.29%), dinocap (17.07%) and wettable sulphur (16.84%) as compared to no spray control (14.32%) when pooled analysis was done. Similarly, all the fungicides were effective and recorded 17.04 to 26.05 per cent increase in protein content over no spray control. The maximum per cent increase in protein content was recorded in the treatment of hexaconazole (26.05%) followed by penconazole (22.35%), difenoconazole (20.74%), dinocap (19.20%), wettable sulphur (17.60%) and azoxystrobin (17.04%) over no spray control.

More or less similar type of findings was also reported by Mert-Turk *et al.* (2008). They investigated the effect of fungicidal treatment coupled with nitrogen fertilization on powdery mildew caused by *E. cruciferarum* of oilseed rape on protein, oil, oleic

acid, linolenic acid etc. using near infrared spectroscopy. They concluded that fungicidal treatments significantly increased oil contents in all varieties tested.

Effect of different fungicides on the 1000-seeds weight was tested during three consecutive *rabi* seasons. All fungicidal treatments significantly increased the 1000-seeds weight as compared to no spray control. During the year 2007-08, hexaconazole recorded significantly the maximum 1000-seeds weight (5.53 g), which was at par with penconazole (5.42 g) and dinocap (5.40 g). Difenoconazole was the next best fungicide with a 1000-seeds weight of 5.31 g followed by wettable sulphur (5.29 g) and azoxystrobin (5.17 g). Interestingly, during the year 2008-09, all the tested fungicides *viz*., hexaconazole, penconazole, difenoconazole, dinocap, wettable sulphur and azoxystrobin were equally good with 5.30, 5.26, 5.21, 5.18, 5.17 and 5.17 g weight of 1000-seeds, respectively, as compared to control (4.10 g). During the year 2009-10, hexaconazole was significantly superior over rest of the treatments with maximum 1000-seeds weight of 5.35 g followed by penconazole (5.28 g), difenoconazole (5.20 g) and dinocap (5.18 g) as compared to no spray control (4.45 g). The fungicides wettable sulphur and azoxystrobin were equally effective and exhibited 1000-seeds weight of 5.14 and 5.13 g, respectively. Pooled analysis of results of three years indicated equally good effect of hexaconazole (5.39 g) followed by penconazole (5.32 g), dinocap (5.25 g) and difenoconazole (5.24 g). Wettable sulphur and azoxystrobin recorded 5.20 and 5.16 g of 1000-seeds weight over no spray control (4.39 g). The maximum per cent increased in 1000-seeds weight was recorded in the treatment of hexaconazole (22.78%) and least in the treatment of azoxystrobin (17.54%) over no spray control.

Similar type of findings were also reported by Patel (2006) who concluded that foliar sprays of fungicides for the control of powdery mildew of mustard gave test weight in the range of 5.66 – 5.82 g as compared to 5.39 g in control.

Effect of different biopesticides against *E. cruciferarum* on mustard was tried in field condition during three consecutive *rabi* seasons. All biopesticides were effective in reducing disease significantly as compared to control. The minimum disease intensity 33.98 per cent (pooled) and maximum disease control 47.99 per cent was registered with the application of wettable sulphur (0.2%). During the three years wettable sulphur also was effective and exhibited minimum PDI of 35.80, 34.35 and 31.84 during the years 2007-08, 2008-09 and 2009-10 analysis, respectively and was at par with neem leaf extract with PDI of 35.39 during 2009-10. In pooled analysis, the leaf extract of neem recorded 38.35 PDI followed by neem seed kernel extract and azadirachtin with 44.53 and 50.80 PDI, respectively as compared to no spray control 86.65. The foliar spray of neem leaf extract among the biopesticides was found to be better in controlling the disease and showed 40.37 and 39.35 per cent disease intensity during the year 2007-08 and 2008-09, respectively. The next best biopesticide was neem seed kernel extract with 44.94 and 44.55 PDI during the year 2007-08 and 2009-10, respectively. In the same treatment during 2008-09, the PDI was 44.13 and was at par with azadirachtin with 49.34 PDI. The water spray control showed 83.33, 85.21 and 79.99 PDI as compared to no spray control 85.85, 88.97 and 85.01 PDI during three consecutive *rabi* seasons of 2007-08 to 2009-10 and were at par only during 2007-08. The per cent disease control ranged from 33.70 to 47.99. Maximum disease control of

47.99 per cent was observed in the treatment of wettable sulphur followed by neem leaf extract (44.20%), neem seed kernel extract (38.95%) and azadirachtin (33.70%) as compared to no spray control.

All biopesticidal treatments significantly increased the mustard yield ranging from 17.13 to 29.92 per cent as compared to no spray control. During the year 2007-08, 2008-09 and 2009-10 wettable sulphur recorded significantly the highest mustard yield of 2111, 2100 and 2252 kg/ha, respectively, followed by neem leaf extract (1987, 1935 and 2116 kg/ha), neem seed kernel extract (1967, 1901 and 2089 kg/ha) and azadirachtin (1894, 1871 and 2060 kg/ha) as compared to no spray control (1652, 1616 and 1705 kg/ha). In pooled result analysis significantly highest mustard seed yield of 2154 kg/ha was recorded in the treatment of wettable sulphur and was found to be equally good as neem leaf extract 2013 kg/ha. The next best treatment was neem seed kernel extract (1986 kg/ha) which was at par with azadirachtin (1942 kg/ha) as compared to no spray control (1658 kg/ha). Decreased per cent disease intensity from 86.65 to 33.98 resulted in per cent increase in seed yield over no spray control in all the tested biopesticides with best being wettable sulphur (29.92%) followed by neem leaf extract (21.41%), neem seed kernel extract (19.78%) and azadirachtin (17.13%).

The economics of different biopesticides for the control of powdery mildew of mustard indicated that the highest incremental cost benefit ratio (ICBR) of 1:5.19 was realized in four sprays of neem leaf extract (2%) followed by wettable sulphur 0.2 per cent (1:4.70), neem seed kernel extract two per cent (1:3.72) and azadirachtin 0.5% (1:1.08).

The use of neem based biopesticides for the management of powdery mildew of various crops under field condition was reported earlier. The spraying of fresh neem leaf extract at two per cent or 0.2 per cent wettable sulphur were better for the control of powdery mildew of mustard in South Saurashtra (Gujarat) conditions (Anon., 1996). Venkatrao (1997) observed that *Ocimum canum* leaf extract at 10 per cent and Nimbicidin at 0.3 per cent concentration reduced the powdery mildew of green gram caused by *E. polygo*ni. Laxmanrao (1998) reported that *behda (Terminalia belerica)* leaf extract (5%) was significantly superior against powdery mildew of mustard followed by neem leaf extract (5%). Ravikumar (1998) found that neem based products *viz*., Neemark (0.3%), Nimbicidin (0.3%) and NSKE (5%) were effective in controlling powdery mildew of rose. Sindhan *et al*. (1999) reported that Neemadol (a neem product) and extracts of *A. indica*, *Allium cepa*, *A. sativum* and *Zingiber officinale* were highly effective for powdery mildew of pea and were at par with Karathane in reducing disease intensity. Biju (2000) found that Ovis at 0.15 per cent was most effective against powdery mildew of pea followed by Nimbicidin at 0.4 per cent. Dinesh *et al*. (2011) revealed that at five per cent azadirachtin (1500 ppm, 1:10 dilution) was significantly superior. It was on par with NSKE and was followed by *Lantana* and turmeric leaf extracts in controlling sunflower powdery mildew. Chovatiya *et al*. (2012) evaluated different biopesticides against powdery mildew of fenugreek and reported that neem leaf extract (5%) was the most effective in controlling the disease and also for higher seed production. They also reported neem seed kernel extract as the next best effective treatment.

In contradiction to the present finding Patel and Patel (2008) used neem (*A. indica*), eucalyptus (*Eucalyptus globulens*), *karan* (*Nerium indicum*), *karanj* (*Pongamia pinnata*) and bulb extract of onion (*A. cepa*), each at five per cent, against powdery mildew of mustard. They found that none of the phytoextracts helped in reducing the disease significantly and all the phytoextracts failed to increase the yield significantly over the control. It could be possible that the isolate of the organism used in that study was not sensitive to these extracts.

Effect of different biopesticides on oil content of mustard was studied during three consecutive *rabi* seasons. Among different treatments tried, wettable sulphur recorded significantly high oil content of 34.12 per cent followed by neem leaf extract (33.97%) and neem seed kernel extract (33.50%) treatments. Azadirachtain spray was least effective in improving oil content (32.94%) as compared to no spray control (30.89%) in pooled analysis. Among all treatments tried, wettable sulphur treated plants showed the highest amount of oil content 35.40, 32.59 and 34.36 per cent and were at par with neem leaf extract (35.28, 32.50 and 34.12%) followed by neem seed kernel extract (34.49, 32.38 and 33.65%) and azadirachtin (34.47, 31.71 and 32.63%), during the years 2007-08, 2008-09 and 2009-10, respectively, as compared to no spray control (32.12, 29.93 and 30.63 per cent for the corresponding years). All the treatments were effective and recorded 6.64 to 10.46 per cent increase in oil content over control. The maximum per cent increase in oil content was recorded in the treatment of wettable sulphur (10.46%) followed by neem leaf extract (9.97%), neem seed kernel extract (8.45%) and azadirachtin (6.64%) over no spray control.

The present findings are in close conformity with the findings of Degenhardt *et al.* (1974). They noticed losses in oil content up to 4.8 per cent due to leaf blight disease in mustard. Higher losses (14.6-36 %) were recorded for the same disease in India (Ansari *et al.,* 1988).

Effect of different biopesticides on protein content of mustard was tested during three consecutive *rabi* seasons under field conditions. Among different biopesticides tried, the lowest protein content of 16.34 was observed in azadirachtin treated plants, whereas, foliar spray with wettable sulphur was significantly superior over rest of the treatments and recorded maximum protein content of 17.11 per cent followed by neem leaf extract (16.69%) and neem seed kernel extract (16.54%) when the pooled analysis was done. In individual years, the significantly higher protein content was recorded in the treatment of wettable sulphur followed by neem leaf extract and neem seed kernel extract during 2007-08 and 2008-09 as compared to no spray control. They were also statistically at par. In the year 2009-10, all treatments significantly increased protein content in comparison to both the checks. All the treatments were effective and recorded 12.92 to 18.24 per cent increase in protein content over control. The maximum per cent increase in protein content was recorded in the treatment of wettable sulphur (18.24%) followed by neem leaf extract (15.34%), neem seed kernel extract (14.31%) and azadirachtin (12.92%) over no spray control.

Similar findings were also reported by Mert-Turk *et al.* (2008). They concluded that nitrogen fertilization increased the protein, but lowered the oil content of the seeds. Fungicidal treatments significantly increased oil contents in all varieties

tested, however reduced protein levels in fertilized and non-fertilized plots.

Effect of different biopesticides on the 1000-seeds weight was tested during three consecutive *rabi* seasons. All biofungicidal treatments significantly increased the 1000-seeds weight. During the year 2007-08 significantly the maximum 1000-seeds weight 5.67 g was recorded in the treatment of wettable sulphur. The next best treatment was neem leaf extract (5.45 g) which was at par with neem seed kernel extract (5.30 g). Minimum 1000-seeds weight was recorded in azadirachtin (5.16 g) as compared to no spray control (4.51 g) while, during the year 2008-09, wettable sulphur recorded maximum 1000-seeds weight of 5.66 g. The other treatments *viz*, neem leaf extract, neem seed kernel extract and azadirachtin were equally good and reported 5.42, 5.35 and 5.28 g 1000-seeds weight respectively, as compared to no spray control (4.33 g). During the year 2009-10, all the tested biopesticides were on par. Wettable sulphur recorded 5.42 g seed weight followed by neem leaf extract (5.27 g), neem seed kernel extract (5.24 g) and azadirachtin (5.23 g) as compared to no spray control (4.22 g). Pooled analysis showed significantly the maximum 1000-seeds weight of 5.58 g in the treatment of wettable sulphur. The next best treatment was neem leaf extract with 5.38 g of 1000-seeds weight and was at par with neem seed kernel extract treatment that recorded 5.29 g of test weight. The minimum test weight of 5.23 g was recorded in the treatment of azadirachtin as compared to no spray control 4.35 g. The maximum per cent increase in 1000-seeds weight was recorded in the treatment of wettable sulphur (28.28%) followed by neem leaf extract (23.68%), neem seed kernel extract (21.61%) and azadirachtin

(20.23%) over no spray control. Patel (2006) also concluded that foliar sprays of fungicides for the control of powdery mildew of mustard gave test weight of 1000-seeds in the range of 5.66–5.82 g as compared to 5.39 g in control.

# SUMMARY AND CONCLUSION

# CHAPTER - VI

## SUMMARY AND CONCLUSION

Indian mustard (*Brassica juncea* (Linn.) Czern & Coss) is the most important oilseed crop in India next to groundnut grown under a wide range of agroclimatic conditions. It is cultivated in 53 countries spreading over the six continents across the globe. Among several factors responsible for low productivity, the diseases cause considerable losses. The mustard crop is ravaged by various biotic and abiotic stresses. Among biotic stresses, the damage caused by plant diseases is one of the major constraints in the crop production of mustard. Like other crops, rapeseed and mustard are subjected to attack by a number of fungal, bacterial and viral diseases, which are considered economically important. Among them powdery mildew caused by *Erysiphe cruciferarum* is an important disease and cause damage in terms of losses in seed yield.

Indian mustard is an important oilseed crop of North Saurashtra region of Gujarat state where scare irrigation facilities are prevailed. In this region, powdery mildew is regularly observed and causing considerable damage to the crop. This necessitated certain basic studies on symptomatology, epidemiology, losses in seed, oil and protein content, varietal behavior towards the pathogen and chemical control with fungicides and biopesticides.

The initial symptoms of powdery mildew disease were appeared in a few plants with minute visible and almost circular fungal colony of 2-3 mm in size on upper surface of lower most leaf at 60-63 days after sowing when flowering period tends to complete. The fungal colony gradually expanded in size with

whitish visible floury patches and became quite conspicuous within 10-12 days of initial infection and coalesced. The disease was progressed towards upper leaves on both the surfaces, stems, branches and siliquaes. Eventually whole plant covered with white powdery fungal growth shows a dusty appearance within a period of one month. In advanced stage, purple blue patches were seen on the stems and were conspicuous from a distance. Heavily infected leaves turned pale yellow in due course, dry earlier and shedding of leaves was a common feature. Infected siliquaes produced poor quality shrivelled seeds. The heavily infected plant shows early maturity than healthy plants.

Microscopic observation with the present fungal pathogen under study revealed that the conidiophores were erect, stout, ellipsoid to cylindrical in shape and measured 67.4 $\pm$ 6.2 µm having moderately straight foot cell with an average length of 19.8 $\pm$ 2.1 µm in size bearing 2-3 conidia in chain. Conidia were unicellular, hyaline, elliptical to cylindrical in shape and measured 26.5-39.8 µm x 12.4-16.6 µm in size without fibrosin bodies. On the basis of morphological characteristics, the fungus was identified as *E. cruciferarum*.

Estimation of seed yield loss due to *E. cruciferarum* was carried out under field condition during three *rabi* seasons of 2007-08 to 2009-10 using unprotected plot (control), water spray (control) and protected plot with hexaconazole 0.005 per cent. The seed yield and per cent disease intensity (PDI) in the protected plot with foliar spray of hexaconazole 0.005 per cent first at the initial appearance of the symptoms and thereafter ten days interval over unprotected plots were 2244 kg per ha and 27.67, respectively with 53.77 per cent disease control. The

avoidable loss 23.48 per cent and net profit of Rs.9,390 per hectare was achieved by spray with hexaconazole. The protected plots with hexaconazole recorded maximum per cent of oil (34.72), protein (15.41) and 1000-seeds weight (5.67 g) as against unprotected control. The per cent loss observed in seed yield, oil, protein and test weight due to powdery mildew disease in mustard were 22.50, 7.26, 21.74 and 21.52, respectively when not followed any control measures against the disease.

Management of powdery mildew disease through host resistance is an eco-friendly and cost effective approach. With a view to find out the resistant entries of mustard, if any against powdery mildew, screening of 13 entries was carried out during three consecutive *rabi* seasons. Out of which, none showed immunity to the disease. Entries of *Brassica juncea* species GM-2 exhibited highly susceptible reaction followed by GM-1 and GM-3 which exhibited susceptible reaction. The entries of *Brassica napus* species HNS-0004, ISN-129 and NUDB-26-11 exhibited moderately susceptible and GSL-1 and GSL-861-212 exhibited resistant reaction. Whereas, entries belong to *Brassica carinata* species DLSC-3, Kiran, NPC-3, NPC-111 and NPJ-87 exhibited highly resistant reaction to powdery mildew infection. The entries identified as highly resistant in this study had sown consistent resistant reaction over the years under high disease pressure. These entries may be used as sources of resistance for further development of resistant variety.

The relationship between meteorological factors on disease development of powdery mildew of mustard was studied for three consecutive *rabi* seasons. The first appearance of the powdery mildew disease takes place at the plant age of 66-74 days, which gradually increased till harvest of the crop. The congenial

condition for the disease development found when the maximum average temperature ranged between 12.1ºC to 28.0ºC with average morning and afternoon relative humidity 76 and 35 per cent, respectively. The present data revealed positive and highly significant relationship of PDI with maximum air temperature in pooled (r=0.4704). While, relationship of minimum air temperature with PDI was found non significant during all the four years pooled results. The morning relative humidity was found to be non significant in all the years and in pooled, except during the year 2008-09 and 2009-10. In 2008-09, morning relative humidity (r=0.6153) revealed significant and positive relationship with PDI, whereas during the year 2009-10, morning relative humidity (r=-0.5534) performed significant but negative relationship with PDI. Whereas, the afternoon relative humidity (r=-0.7058), (r=-0.7121) and (r=-0.2845) exhibited highly significant and negative relationship with PDI during 2007-08, 2008-09 and in pooled results, respectively. Whereas, during 2009-10 and 2010-11 it was non significant.

In multiple regressions analysis four independent variables were considered for dependent variable PDI. Stepwise multiple regression analysis showed that maximum temperature and afternoon relative humidity had significant positive and negative relationship, respectively with the disease. Out of four variables, the most contributing variables identified for the disease development under natural conditions during the year 2007-08 and 2009-10 were afternoon relative humidity (%) ($R^2$=0.5995) and maximum temperature (°C) ($R^2$=0.6812), respectively. While, during 2010-11 and in pooled results the maximum temperature (°C) and afternoon relative humidity (%) $R^2$=0.8076 and 0.3620, respectively were identified as the most contributing variables.

The effect of weather variables on PDI during the year 2008-09 was found non significant. Efforts should be initiated with proper fungicides for avoiding losses in yield on mid October sown mustard crop against powdery mildew disease, when the crop attained an age of two to two and half month, during this period congenial environmental conditions prevailed for disease development.

Different systemic and non systemic fungicides were tested against *E. cruciferarum* to know their relative efficacy *in vitro*. In spore germination inhibition with systemic fungicides, 84.10 per cent spore inhibition was observed in the treatment of hexaconazole (0.005%) followed by penconazole and difenoconazole with 80.05 and 78.09 per cent inhibition of spore germination, respectively. The fungicide azoxystrobin showed the lowest among all fungicides tested with 53.98 per cent inhibition of spore germination. Among non systemic fungicides, the most effective fungicide was dinocap followed by wettable sulphur with 79.98 and 77.00 per cent inhibition of spore germination, respectively. The lowest inhibition of spore germination was recorded in the treatment of zineb followed by captan with 49.46 and 51.47 per cent, respectively. This finding will be useful for planning of field trial for management of powdery mildew of mustard.

On the other hand, the insecticides used for the control of mustard pest under field conditions were also evaluated to know their antifungal activity if any, in inhibiting the spore germination of *E. cruciferarum* under laboratory conditions. Among different insecticides tested, significantly higher spore germination inhibition was observed in the treatment of methyl-o-demeton (54.97%) followed by triazophos (54.48%) and

quinalphos (53.46%). The lowest inhibition of spore germination 33.21 per cent was recorded in the treatment of carbosulfan.

Easily available indigenous plant species were tested against present fungus under *in vitro* condition for their effectiveness against spore germination inhibition. Clove extracts of garlic (*Allium sativum)* provided the highest spore germination inhibition of 74.08 per cent followed by leaf extract of neem (*Azadirachta indica*) with 68.47 per cent inhibition of spore germination and remained statistically at par. Bulb extracts of onion (*Allium cepa*) recorded 63.00 per cent inhibition of spore germination followed by leaf extract of henna (*Lawsonia inermis*) and rhizome extract of turmeric (*Curcuma longa*) which exhibited 58.00 and 57.05 per cent inhibition of spore germination. The least effective phytoextract found was *karanj* (*Derris indica*) which recorded 23.93 per cent inhibition of spore germination. The antifungal properties of naturally occurring substances in plant species were capable of inhibiting the spore germination at different degrees.

Effect of different fungicides against *E. cruciferarum* on mustard was tried in field condition during three consecutive *rabi* seasons of 2007-08 to 2009-10. The minimum per cent disease intensity 28.17 was recorded in the treatment of hexaconazole with 54.17 per cent disease control yielding 2225 kg/ha mustard seed (pooled) followed by penconazole (2160 kg/ha), difenoconazole (2130 kg/ha), dinocap (2117 kg/ha) wettable sulphur (2090 kg/ha) and azoxystrobin (2062 kg/ha). Similarly, per cent increase in seed yield over control was also recorded higher in the treatment of hexaconazole (30.04%) followed by penconzole (26.24%), difenoconazole (24.49%), dinocap (23.73%), wettable sulphur (22.15%) and azoxystrobin

(20.51%), respectively. The economics of different fungicides for the control of powdery mildew of mustard indicates the highest incremental cost benefit ratio (ICBR) of 1:4.63 in four sprays of hexaconazole 0.005 per cent followed by wettable sulphur 0.2 per cent (1:3.36) and penconazole 0.010 per cent (1:1.07).

The mustard crop sprayed with hexaconazole noted maximum oil content of 34.37 per cent followed by penconazole (34.03%), difenoconazole (33.57%), dinocap (33.12%), wettable sulphur (32.99%) and azoxystrobin (32.64%) as compared to no spray control (30.70%). Similarly, the maximum per cent increase in oil content was recorded in the treatment of hexaconazole (11.95%) followed by penconazole (10.85%), difenoconazole (9.35%), dinocap (7.88%), wettable sulphur (7.46%) and azoxystrobin (6.32%).

The maximum protein content (18.05%) was observed in the treatment of hexaconazole followed by penconazole (17.52%), difenoconazole (17.29%), dinocap (17.07%), wettable sulphur (16.84%) and azoxystrobin (16.76%) as compared to no spray control (14.32%) under pooled results. The maximum per cent increase in protein content was also found in the treatment of hexaconazole (26.05%) followed by penconazole (22.35%), difenoconazole (20.74%), dinocap (19.20%), wettable sulphur (17.60%) and azoxystrobin (17.04%).

Effect of fungicides on test weight of 1000-seeds of mustard over three years pooled results indicated equally good effect of hexaconazole (5.39 g) followed by penconazole (5.32 g), dinocap (5.25 g), difenoconazole (5.24 g) and wettable sulpur (5.20 g) on 1000-seeds weight over no spray control (4.39 g). Among different treatments tried, maximum per cent increase in 1000-seeds weight was recorded in hexaconazole (22.78%) and

least in the treatment of azoxystrobin (17.54%). In present investigation foliar sprays of fungicides significantly reduced the intensity of powdery mildew disease and found superior to water spray and no spray control, thereby indirectly they reduced stress of pathogen on mustard crop.

In order to find out an effective and eco-friendly approach in controlling the powdery mildew disease of mustard *in vivo*, three different biopesticides was tried. Among them, neem leaf extract prove the most effective biopesticide and recorded 38.35 PDI followed by neem seed kernel extract (44.53) and azadirachtin (50.80) in three year pooled results as against 86.65 PDI recorded in untreated control.

Maximum disease control of 44.20 per cent was found in the treatment of neem leaf extract followed by neem seed kernel extract (38.95%) and azadirachtin (33.70%) with 2013, 1986 and 1942 kg/ha of yield, respectively as compared to control. The highest incremental cost benefit ratio (ICBR) of 1:5.19 was found in four sprays of neem leaf extract two per cent followed by neem seed kernel extract two per cent (1:3.72) and azadirachtin 5000 ppm (1:1.08). Per cent increase in seed yield was also recorded higher in the treatment of neem leaf extract (21.41%) followed by neem seed kernel extract (19.78%) and azadirachtin (17.13%).

The maximum oil, protein and test weight (33.97%, 16.69% and 5.38 g) was recorded in the treatment of neem leaf extract followed by neem seed kernel extract (33.50%, 16.54% and 5.29 g.) and azadirachtain (32.94%, 16.34% and 5.23g) as compared to no spray control (30.89%, 14.47% and 4.35g). The maximum per cent increase in oil, protein and test weight (9.97%, 15.34% and 23.68%) was recorded in the treatment of neem leaf extract followed by neem seed kernel extract (8.45%, 14.31%, 21.61%)

and azadirachtin (6.64%, 12.92% and 20.23%). To avoid hazardous effect due to constant use of fungitoxic chemicals, neem base preparations are safe and found effective against powdery mildew disease of mustard under field condition.

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*Original not seen

# APPENDICES

## Appendix-I(A)

## Weather data and per cent disease intensity (PDI)

| S.N. | 2007-08 | | | | | 2008-09 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PDI* | Temp** | | RH** | | PDI | Temp | | RH | |
| | | Max. | Min. | M | E | | Max. | Min. | M | E |
| 1 | 1.25 | 25.90 | 9.00 | 77.30 | 33.80 | 2.50 | 25.3 | 15.4 | 67.3 | 56.5 |
| 2 | 3.34 | 28.50 | 9.90 | 69.80 | 37.50 | 6.67 | 29.6 | 13.1 | 72.5 | 50.3 |
| 3 | 7.09 | 27.50 | 12.30 | 76.80 | 39.80 | 12.09 | 27.1 | 12.0 | 82.5 | 53.5 |
| 4 | 11.68 | 27.80 | 10.80 | 76.80 | 35.80 | 20.43 | 28.4 | 10.8 | 77.3 | 34.8 |
| 5 | 16.68 | 28.40 | 11.90 | 73.80 | 29.50 | 28.77 | 27.6 | 11.9 | 71.8 | 41.5 |
| 6 | 22.52 | 25.20 | 9.00 | 77.50 | 14.30 | 37.11 | 25.4 | 11.1 | 67.3 | 46.8 |
| 7 | 28.77 | 24.00 | 11.00 | 78.30 | 22.30 | 45.45 | 29.2 | 14.0 | 77.0 | 49.5 |
| 8 | 35.86 | 27.40 | 10.90 | 83.00 | 30.50 | 53.79 | 27.0 | 14.4 | 73.3 | 47.8 |
| 9 | 43.79 | 24.10 | 10.80 | 80.80 | 33.00 | 62.13 | 29.9 | 15.6 | 80.8 | 38.3 |
| 10 | 51.29 | 21.40 | 9.50 | 79.80 | 31.00 | 69.64 | 27.8 | 12.8 | 83.3 | 35.3 |
| 11 | 57.96 | 24.00 | 10.40 | 71.50 | 16.80 | 76.31 | 29.3 | 10.2 | 84.3 | 22.0 |
| 12 | 65.05 | 28.70 | 9.70 | 71.00 | 24.50 | 82.15 | 29.9 | 10.6 | 82.0 | 43.0 |
| 13 | 72.14 | 31.90 | 13.10 | 77.80 | 19.50 | 87.57 | 29.6 | 12.0 | 78.0 | 28.3 |
| 14 | 80.48 | 30.90 | 13.40 | 79.00 | 19.30 | 91.74 | 28.9 | 12.4 | 82.3 | 34.5 |
| 15 | 88.82 | 32.05 | 11.45 | 59.00 | 14.00 | | | | | |
| **Total** | | **407.8** | **163.2** | **1132.2** | **401.6** | | **394.5** | **176.0** | **1079.3** | **581.8** |
| **Average** | | **27.18** | **10.88** | **75.48** | **26.77** | | **28.18** | **12.57** | **77.09** | **41.55** |

* At four days interval ** Average of four days

## Appendix-I(B)

## Weather data and per cent disease intensity (PDI)

| S. N. | 2009-10 | | | | | 2010-11 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PDI* | Temp** | | RH** | | PDI | Temp | | RH | |
| | | Max. | Min. | M | E | | Max. | Min. | M | E |
| 1 | 2.09 | 27.10 | 10.60 | 75.00 | 26.80 | 1.67 | 28.40 | 11.25 | 83.00 | 48.25 |
| 2 | 6.26 | 27.10 | 15.30 | 74.30 | 40.30 | 4.17 | 27.50 | 13.10 | 83.50 | 37.00 |
| 3 | 11.26 | 25.80 | 13.10 | 69.00 | 32.30 | 9.59 | 27.90 | 12.55 | 83.75 | 41.00 |
| 4 | 17.10 | 25.60 | 13.70 | 64.00 | 30.00 | 15.01 | 27.70 | 12.90 | 71.25 | 37.00 |
| 5 | 23.77 | 24.50 | 10.70 | 77.30 | 33.80 | 21.68 | 28.05 | 12.50 | 80.25 | 39.75 |
| 6 | 30.44 | 27.00 | 10.00 | 79.30 | 31.50 | 30.02 | 28.20 | 10.50 | 82.50 | 31.00 |
| 7 | 37.53 | 29.20 | 11.10 | 72.50 | 30.30 | 38.36 | 29.40 | 11.30 | 83.50 | 47.50 |
| 8 | 45.87 | 28.80 | 10.80 | 71.50 | 20.50 | 46.29 | 28.95 | 11.35 | 86.50 | 36.00 |
| 9 | 54.21 | 28.70 | 12.60 | 70.00 | 28.80 | 54.21 | 28.90 | 11.60 | 88.25 | 29.00 |
| 10 | 62.55 | 29.30 | 13.10 | 73.80 | 32.80 | 61.72 | 28.00 | 11.20 | 79.75 | 29.00 |
| 11 | 70.89 | 30.80 | 17.30 | 79.00 | 40.30 | 67.97 | 27.90 | 12.10 | 84.75 | 33.00 |
| 12 | 79.23 | 26.40 | 12.60 | 50.30 | 23.30 | 73.39 | 30.50 | 13.70 | 81.50 | 44.25 |
| 13 | 87.15 | 28.30 | 10.70 | 40.80 | 14.30 | 78.81 | 30.70 | 14.15 | 88.25 | 45.00 |
| 14 | | | | | | 83.82 | 31.50 | 13.60 | 87.50 | 47.25 |
| 15 | | | | | | 85.9 | 30.20 | 16.10 | 85.50 | 48.00 |
| **Total** | | **358.3** | **161.4** | **896.5** | **384.5** | | **433.8** | **187.9** | **1249.8** | **593.0** |
| **Average** | | **27.60** | **12.40** | **69.00** | **29.60** | | **28.92** | **12.53** | **83.32** | **39.53** |

* At four days interval ** Average of four days

## APPENDIX-II

**Price of fungicides**

| Sr. No. | Fungicides | Price of fungicides Rs./litre or Kg |
|---|---|---|
| 1 | Hexaconazole 5% EC | 450 |
| 2 | Difenoconazole 25% EC | 2660 |
| 3 | Penconazole 10% EC | 1900 |
| 4 | Azoxystrobin 25% SC | 6600 |
| 5 | Dinocap 48% EC | 1950 |
| 6 | Wettable Sulphur 80% WP | 160 |
| 7 | Neem Seed Kernel Extract 2% | 10 |
| 8 | Neem Leaf Extract 2% | 3 |
| 9 | Azadirachtin 0.15 w/w | 295 |