STUDIES ON POWDERY MILDEW OF CORIANDER AND FENUGREEK

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UNIVERSITY OF HORTICULTURAL SCIENCES, BAGALKOT
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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON POWDERY MILDEW OF CORIANDER AND FENUGREEK"** submitted by **MR. MUSTAKBEG M. JAMADAR, ID No. UHS17PGM866** for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **PLANT PATHOLOGY** to the University of Horticultural Sciences, Bagalkot, is a record of research work carried out by him during the period of his study at University of Horticultural Sciences, Bagalkot under my guidance, supervision and the thesis has not previously been formed the basis for the award of any other degree, diploma, associateship, fellowship or similar titles.

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Symbols and abbreviations

et al.	:	and others/associates/co-workers
%	:	Per cent
@	:	at the rate of
^{0}C	:	Degree Celsius
C. D. at 1%	:	Critical Difference at 1 per cent level
C. D. at 5%	:	Critical Difference at 5 per cent level
cm	:	Centimeter
Fig.	:	Figure
ha	:	Hectare
kg	:	Kilogram
m	:	Meter
mg	:	Milligram
min	:	Minute
ml	:	Milliliter
mm	:	Millimeter
No.	:	Number
RCBD	:	Randomized Complete Block Design
S. Em.±	:	Standard Error mean ±
Wt.	:	Weight
µg	:	Microgram

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1. INTRODUCTION

India has been known as the “Home of Spices” from ancient times. It is the largest producer, consumer and exporter of spices in the world. Spices are the low volume, high value and export oriented commodity crops and contributes about 38.78 lakh hectare area with the production of 81.24 lakh tonnes (Anon., 2018). Based on the economical parts used, spices are classified into various groups, among them seed spices are the important group being cultivated in the arid and semi-arid region of the country. The importance of seed spices in India is well recognized. The most important seed spices cultivated in India are coriander, cumin, fennel, fenugreek (methi), carom seed (ajwain) and dill (Hiwale *et al.*, 2010). These crops are attaining importance day by day due to their aromatic and medicinal values in the present era is reflecting high international demand of Indian seed spices (Singh and Solanki, 2015).

Seed spices contribute about 22 per cent of total area and 13 per cent of production of spices in the country. Presently 8.4 lakh hectare area is under seed spices cultivation with a production of 10.79 lakh tonnes annually. Seed spices are mainly cultivated in the states of Rajasthan and Gujarat and also has sizeable area in the states of Madhya Pradesh, Uttar Pradesh, Andhra Pradesh and Karnataka. In the year 2017-18, 770 tonnes of coriander seeds were produced from 1780 hectare area in Karnataka (Anon., 2018). Among the seed spices, coriander and fenugreek gaining much more importance and hence during these days the area and production is considerably increasing.

Coriander (*Coriandrum sativum* L.) is an important spice crop belonging to the family Apiaceae (Umbelliferae). Being an annual herb, it is most commonly used for seasoning purpose. It’s all the tender aerial parts including stem, leaf, flowers and fruits are used due to aromatic flavour. It can be used as whole plant for culinary purpose and can be processed, because of its perishable nature and to increase the palatability of ripe fruits (seeds) before using it as flavouring agent in different food preparations. It is well known for its anti-oxidant, anti-diabetic, anti-mutagenic, anti-anxiety and anti-microbial activity along with analgesic and hormone balancing effect that promotes its use in foods due to numerous health benefits and its protective effect to preserve the food for longer period. Leaves of plant are rich source of vitamins while seeds are rich in

polyphenols and essential oils. Coriander is a rich reservoir of micronutrients and nutritional elements (Bhat *et al.*, 2014).

India accounts for approximately 80 per cent of the total world coriander production. The leading coriander growing states in India are Rajasthan, Madhya Pradesh and Gujarat (D'Souza and Shah 2016). In the year 2017-18, 24,000 tonnes of coriander seeds were produced from 35,000 hectare area (Anon., 2018).

Fenugreek (*Trigonella foenum-graecum* L.) is another important spice crop, commonly known as 'methi' has tremendous importance in the life of human beings. It belongs to family leguminaceae. It is consumed as a food, fodder, medicines and used in perfumery, cosmetic products and religious rituals also. It is commercially cultivated for its seeds, which are used as condiments and as a flavouring agent for flavouring food preparation. The leaves are used as a vegetable for human consumption and forage for cattle and to some extent for medicinal purpose, being carminative as a tonic and aphrodisiac. Its seeds contained important steroid 'diosgenin' which is used in preparation of contraceptives. Medicinal properties of fenugreek are due to the presence of antioxidant and anti-inflammatory compounds such as genistein, kaempfeorl, quercetin, rutin, apigenin, selenium and superoxide-dismutase (Girardon *et al.*, 1985).

India accounts for total acreage of 1.49 hectares and production of 2.02 lakh tonnes during 2017-2018. Rajasthan is the largest fenugreek producing state in India. Other major fenugreek producing states in India are Gujarat, Haryana, West Bengal and Uttarakhand (Anon., 2018).

Coriander and fenugreek affected by certain diseases. In case of coriander, wilt (*Fusarium oxysporum*), stem gall (*Protomyces macrosporus*), stem rot *(Alternaria* spp.), grain molds (*Curvularia* spp.) and blight disease complex (*Helminthosporium* and *Colletotrichum* spp.) and powdery mildew (*Erysiphe polygni* DC) are major diseases (Khare *et al.*, 2017). In fenugreek, downy mildew (*Perenospora trigonella* Goumann), rust (*Uromyces anthyllidis* (Grev.) Schroet), leaf spot (*Cercospora traversiana* Sacc.), collar rot (*Rhizoctonia solani*), root rot (*Alternaria alternata* (Fr.) Kessiler) and powdery mildew (*Erysiphe polygni* DC) are major diseases (Acharya *et al.*, 2014). Out of which, powdery mildew (*E. polygoni*) is an important disease reducing the yield to

considerable extent and thus became a serious menace in recent past (Singh and Rao, 2016).

Powdery mildew disease is a major problem in coriander cultivation. The affected plants produce small shriveled seeds and also reduce the yield and quality of the produce (Bandela *et al.,* 2014). The crop suffers from powdery mildew disease (*E. polygoni*) every year and cause 0-50% loss in quality and quantity of produce (Akbari and Parakhia, 2010; Anon., 2014).

Powdery mildew of fenugreek caused by *E. polygoni* is an important and serious disease especially during flowering and pod formation stage of the crop and cause significant losses (27-33 per cent) in grain quantity as well as quality (Prakash and Saharan, 2002).

Losses caused in spice crops due to powdery mildew varies from crop to crop as in coriander (0-50%), cumin (5-30%) fenugreek (0-70%) and in fennel (0-80%). The disease was prevalent in major spice growing areas in India (Anon., 2014).

Powdery mildew disease is characterized by white floury patches appear on upper and lower surface of leaves as well as tendril, stems and pods in fenugreek whereas umbels in coriander. As the plant become older, the powdery growth almost covers the entire plant, become more or less greyish brown and the infected part impart dirty appearance. Later stage, powdery growth also covers the pods. The seed in pods do not either set or remain very small (Godara *et al.,* 2010).

By considering the overall increase in the problem of powdery mildew in recent past with heavy economic losses, the present research work is focused on the below mentioned objectives.

1. Screening of coriander and fenugreek genotypes against powdery mildew.
2. To study the biochemical parameters in relation to disease resistance.
3. *In vitro* evaluation of different fungicides, botanicals, bio agents and organics against powdery mildew.
4. Management of powdery mildew of coriander and fenugreek.

2. REVIEW OF LITERATURE

Coriander and fenugreek have gained lot of importance as spice and condiments. Curation of literature on powdery mildew disease indicated that, the disease is a major constraint in the production of the coriander and fenugreek cultivars/varieties. Although lot of literature is available on powdery mildew of vegetables, cereals and other crops, not much work was carried out on different aspects and management of powdery mildew in coriander and fenugreek. Therefore, here the literatures pertaining to powdery mildew of various crops caused by *Erysiphe polygoni* DC are reviewed along with other genera of powdery mildew fungi.

2.1 Symptomatology and etiology

Gaetan and Madia (2004) studied the powdery mildew of canola caused by *E. polygoni* and reported that, the mycelium with multi lobed haustoria, white to grey, dense or fine, and in patches or covering the entire adaxial leaf surfaces. Appressoria were lobed and conidiophores were straight. Foot cells were cylindrical, straight, measured 35 to 42 × 7 to 10 µm, and were followed by two cells. Conidia were produced singly, cylindrical to ovoid and measured 36 to 40 × 18 to 20 µm. The conidial length-to-width ratio was 2:0. No fibrosin bodies were observed in the conidia and conidia germinated at the ends.

The powdery mildew fungi belong to the order Erysiphales and to its single family *Erysiphaceae* and sub division Ascomycotina. Powdery mildews appear as spots or patches of a white to grayish, powdery, mildew growth on young plant tissues or as entire leaves and other organs being completely covered by the white powdery mildew. Tiny, pinhead-sized, spherical, at first white, later yellow-brown, and finally black cleistothecia may be present singly or in groups on the white to grayish mildew in the older areas of infection. Powdery mildew is most common on the upper side of leaves, but it also affects the underside of leaves, young shoots and stems, buds, flowers, and young fruit (Agrios, 2005).

Jacobsen and Johnston (2005) reported the occurrence of perfect stage of powdery mildew pathogen on sugar beet is *E. polygoni*. Lower leaves of the plants were heavily covered by the vegetative stage of the fungus with plants at the edge of the field

having clearly visible abundant mature (black) and immature (brown) globose ascocarps on the leaf surfaces and stems. The fruiting structures had mostly branched appendages and were imbedded in the superficial mycelium. Their diameter ranged from 70 to 100 µm. Each ascocarp contained five to eight asci with one to four ascospores (mostly three) per ascus. Elliptical ascospores were hyaline and measured 20 to 25 µm long and 12 to 20 µm wide.

Basu *et al.* (2006) reported that the powdery mildew is most common and serious disease of fenugreek. The conidiophores of *E. polygoni* are simple, erect with conidia unicellular, ellipsoidal to cylindrical in shape and hyaline in colour. The conidia are ovate to barrel-shaped, unicellular hyaline and dimensions are 22.6 - 48.4 µm × 12.4 - 20.8 µm and the conidiospores vary in size from 32.5 - 65.6 µm × 9.7 - 13.6 µm. Ascocarps contained five to eight asci with one to four ascospores and the asci walls are disintegrated during ascospores release.

Akhtar *et al.* (2009) reported that in powdery mildew of lentil (*E. polygoni*), the cleistothecia bearing myceloid appendages appeared as black spots scattered on the surface of mycelial growth. Cleistothecia measured 80-95 µm with 6-8 ovate and sessile asci measuring 50-75x10-15 µm.

Powdery mildew disease is characterized by white floury patches appear on both sides of leaves as well as tendril, stems, pods etc. As the plant become older, the powdery growth almost covers the entire plant, become more or less greyish brown and the infected part impart dirty appearance. Later stage, powdery growth also covers the pods. The seed in pods do not either set or remain very small (Godara *et al.*, 2010).

Gupta and Bharat (2010) reported the occurrence of powdery mildew caused by *E. polygoni* DC in French bean under protected cultivation in Himachal Pradesh and reported the morphology of pathogen. The conidiophores were upright, hyaline, bearing conidia either singly or in chains. Conidia were hyaline, ovate to barrel-shaped, unicellular and measured 30-45x 10-20 µm.

Rajasab and Rajashekhar (2011) reported that the powdery mildew of *Launea procumbens* produce several brown coloured cleistothecia on leaf surface. Each cleistothecium comprised of a single ascus and each ascus produced eight ascospores.

Based on cleistothecial appendages and number of asci and ascospores the pathogen was identified as *Sphaerotheca macularis* (Wallr) Magnus.

Powdery mildew disease is a major problem in coriander cultivation. The affected plants produce small shrivelled seeds and also reduce the yield and quality of the produce (Bandela *et al.,* 2014).

Cho *et al* (2015) studied powdery mildew of fennel caused by *E. heraclei* in Korea and reported that, the hyphae were septate, branched, and 4 to 7 μm wide. Appressoria were multilobed to moderately lobed, and solitary or in opposite pairs. Conidiophores were cylindrical, 80 to 140 × 8 to 10 μm, and composed of 3 to 4 cells. Foot-cells of conidiophores were straight to substraight, cylindrical, and 25 to 50 μm long. Singly produced conidia were oblong-elliptical to oblong, occasionally ovate, 30 to 50 × 12 to 16 μm with a length/width ratio of 2.4 to 3.6, had angular/rectangular wrinkling of outer walls, and lacked distinct fibrosin bodies.

Khare *et al.* (2017) studied the disease problems in cultivation of coriander and their management and reported that powdery mildew is caused by *E. polygoni*.

2.2 Screening of coriander and fenugreek genotypes against powdery mildew

Iqbal *et al.* (2000) evaluated 25 genotypes of pea (*Pisum sativum*) for resistance against powdery mildew (*E. polygoni*). Genotype DMR-20 was highly resistant. Other two genotypes, DMR-4and DMR-7 appeared to be resistant.

Malhotra and Singh (2000) assessed 51 genotypes of pea (*Pisum sativum* var. arvense) for resistance against powdery mildew (*E. polygoni*). Only VG-1 was showed highly resistant reaction, whereas nine genotypes, *viz*., HPPC 16, HPCC 77, HPCC 95, Rachna, Pant P-9, PH-1, JP 514-A, VG-9 and Sugar Giant were scored as resistant and the others were categorized from moderately susceptible to highly susceptible.

Raguchander *et al.* (2001) evaluated 16 urdbean (*Vigna mungo*) genotypes against powdery mildew (*E. polygoni*) under field conditions. Two genotypes, PDU-0 and IC- 12, showed partial resistance, the lowest percentage of mildew cover, and the apparent rate of infection.

Tripathi *et al.* (2001) screened 64 pea cultivars for resistance to powdery mildew. Three cultivars (Rachana, HFP-4 and DMR-7) were moderately resistant, 46 cultivars were susceptible, and one cultivar (Bonnevile) was highly susceptible.

Pratap *et al.* (2002) identified Hisar methi 350, a single plant selection from cv. PLME-46-1, is a new fenugreek cultivar resistant to powdery mildew caused by *E. polygoni*.

Raje *et al.* (2002) determined the inheritance pattern of resistance to fenugreek powdery mildew (*Erysiphe polygoni*) using cultivars UM-305 and Rmt-143 as parental and Rmt-1 and a local cultivar as the control. The plant of UM-305 showed resistance reaction while plant of Rmt-143 and the F1 showed susceptible reaction.

Kunkalikar and Padaganur (2004) examined 99 gram cultivars for resistance against powdery mildew. Out of ninety cultivars tested, three (Cob-g, Co-4 and Bgg-2) were resistant and eighteen were moderately resistant.

Barhate *et al.* (2003) screened 45 cultivars of urd bean (*Vigna mungo*) against powdery mildew (*E. polygoni*). Among the 45 cultivars, 9 were resistant and 22 moderately resistant to powdery mildew.

Basandrai *et al.* (2003) evaluated 250 different germplasm of black gram against powdery mildew under field conditions and reported 3 genotypes *viz.*, HPU-3, UG-349 and LU-1018 as highly resistant (<1%PDI), 7 genotypes as resistant (<25% PDI) and 6 genotypes as moderately resistant (26 to 50% PDI) to the powdery mildew.

Davidson *et al.* (2004) screened sixty seven pea varieties against the powdery mildew. In the field trial, 10 of 67 varieties were resistant, 4 were moderately resistant and 53 were identified as susceptible lines.

Zote *et al.* (2004) assessed new mungbean cultivar Badnapur against Powdery Mildew Resistant-145 (BPMR-145) and had better yield character compared to control cultivars BM-4, Kopergaon, TARM-18 and AKM-8802. BPMR-145 has resistance to powdery mildew (*E. polygoni*).

Dhutraj and Bastewad (2005), screened out eighteen mung bean genotypes, along with two controls (Kopergaon and JL-781), for their resistance to powdery mildew (*E. polygoni*) and reported that all genotypes were resistant to powdery mildew.

Saifulla *et al.* (2005) assessed 18 genotypes to identify resistant sources against green gram powdery mildew. They reported as moderately susceptible 3 genotypes, i.e., TM-97-55, Kopergaon and COGG-913, Pusa Baisaki and ML-11-08, as susceptible and 12 genotypes as highly susceptible to the powdery mildew disease.

Gulldekar *et al.* (2007) screened 17 cultivars of soybean against powdery mildew caused by *E. polygoni*. Among them four were found resistant, six were found moderately resistant, four were found moderately susceptible and three were found susceptible to powdery mildew of pathogen.

Hamidullah *et al.* (2007) evaluated ten advanced pea lines along with two commercial cultivars against powdery mildew (*E. polygoni*) and reported that five lines were resistant, one tolerant and four susceptible to the disease.

Singh *et al.* (2007) tested 215 mungbean germplasm lines against powdery mildew (*E. polygoni*) of these, only DMG1030 did not support growth of *Erysiphe polygoni*. Five other genotypes, namely DMG 1045, DMG 1130-2, LM 164, LM 421 and CO 4 showed moderately resistant reaction to powdery mildew.

Mandhare and Suryawanshi (2008) inspected 82 green gram genotypes against powdery mildew (*E. polygoni*) by growing susceptible rows of Phule M-2 (powdery mildew infector). The greengram genotypes Vaibhav, BPMR-145, TARM-18, Phule M-2003-3, Phule M-2002-13, Phule M-2002-17, Phule M-2001-3 and Phule M-2001-5 exhibited resistance against powdery mildew.

Singh and Gurha (2007) used infector-cum-spreader row technique to evaluate 89 urdbean genotypes and 91 mung bean genotypes against *E. polygoni*. OBG 16 exhibited a consistent resistant reaction and a moderately resistant 5 genotype HPU 227, UL 23, Pant U 35, IC106088, CN 28/1 among 89 urdbean genotypes. Thirteen genotypes were moderately sensitive, 32 were susceptible and 38 were highly

susceptible. Out of 91 mungbean genotypes screened, only 2, BPMR 1 and BPMR 115 exhibited consistently resistant reaction and 5 genotypes Pusa 9531, TM 98-50, TM 99-37, TM 99-50 and UPM 99 3 were moderately resistant. Four genotypes proved moderately susceptible, 8 were susceptible and 72 were highly susceptible.

Ramappa *et al.* (2008) investigated 50 lines of pea against powdery mildew. Out of 50 lines ten namely HUDP 37, IPF 0602, VL 27, IPF0616, IPFD 06-3, VL-47, IPF 0616, IPF 0602, IPFD 5-8 and IFD 5-8 were completely free from powdery mildew incidence.

Sharan *et al.* (2008) evaluated 45 genotypes of linseed against powdery mildew (*Oidium lini* and *Leveillula taurica*) raised at two dates *i.e.*, first timely (27.10.2005) and second delayed sown (25.11.2005) crop and reported that 18genotypes were free from powdery mildew at both the sowing dates A-127, H-24, H-34, LC-2045, LH-1, Mahoba local, mayurbhanj local,NP-27, NP-24, RR4455K, NP-100, NPHY-10, NP (RR) 88R, RL-903, RLC-95, R-552, Nagarkot and Sheela etc.

Chovatiya and Dhruj (2010) screened twenty entries of fenugreek (*Trigonella foenum-graecum*) against powdery mildew (*E. polygoni*) under natural epiphytotic conditions during *Rabi* 2007-08 and 2008-09. Among the 20 entries tested for two seasons, one entry (Jfg-191) showed highly resistant response, four entries *viz.*, Jfg-228, Jfg-224, Jfg-194, and Jfg-234 showed resistant reaction nine and six entries showed moderately susceptible and susceptible reaction, respectively.

Dhondiram (2010) screened 10 genotypes of fenugreek against powdery mildew, none of them were found to immune and resistant. However, eight genotypes were found moderately resistant and two were moderately susceptible.

Shahid *et al.* (2010) assessed eight pea lines against powdery mildew and certain quantitative traits during 2009-10. Out of eight, four test entries were found to be resistant, one moderately resistant and three were susceptible. The lines, 6713 and 27315 showed maximum resistance to the disease while the line 27313 was the most susceptible.

Parashar and Lodha (2012) screened seventeen varieties of *Foeniculum vulgare* (fennel) against powdery mildew. The variety UF-206 was highly resistant to powdery mildew and. UF-207, FNL-25, FNL-26, FNL-27, FNL-28 and FNL-29 were found fairly susceptible to powdery mildew.

Vikas and Ratnoo (2012) evaluated twenty lines of fenugreek for resistance to powdery mildew (*E. polygoni*) under field conditions. Most of the lines were observed moderately susceptible to susceptible. Rmt-303, PRM-45 and PRM-57 were found moderately resistant. PRM-57 recorded the highest yield followed by Rmt-303 and PRM-45.

Bandela *et al.* (2014) screened the 25 genotypes of coriander for resistance against powdery mildew disease. Among them eight genotypes were susceptible and seventeen were highly susceptible and none of them showed immune, resistant or moderately resistant reaction.

Channaveeresh *et al.* (2014) evaluated 126 genotypes of black gram, none of them were found to be immune, however, three genotypes *viz*., LBG-17, LBG-685 and LBG-685 × VT were found to be resistant. Fourteen genotypes *viz*., VBN-4, VBN-5, VBN-7, LBG-752, T-9, KU-12-40, KU-12-43, KU-12-53, KU-12-42, KU-12-44, KU-12-57, DU-1 × LBG-685, LBG-685 xTAU-1 and TU-94-2 were found to be moderately resistant and twenty one genotypes were found to be moderately susceptible. Eighty five genotypes were found to be susceptible and three genotypes were highly susceptible.

Divya Ramkrishnan and Savithramma (2014) screened 374 genotypes of mungbean and reported that among them six were highly resistant, 68 were resistant, 47 were moderately resistant, 50 were moderately susceptible, 99 were susceptible and 104 were highly susceptible.

Vidhate *et al.* (2014) examined 20 different varieties and advanced lines against powdery mildew disease of okra on field under agro climatic conditions of Maharashtra State and reported that none of the varieties showed resistant reaction. Eight advanced lines were moderately resistant, while 12 varieties were moderately susceptible.

Yadav *et al.* (2014) screened sixty five genotypes of mungbean against powdery mildew and reported that among them genotype LGG-460 was found resistant where as one genotype BRS-2435 was found highly susceptible to powdery mildew caused by *E. polygoni*.

Kumawat (2015) revealed that the fenugreek germplasm entries, UM-301 and UM-302 were found resistant to powdery mildew, germplasm entries, UM-127, UM-128, UM-136, UM- 140, UM-222, UM-322, UM-353 and UM-354 were moderately resistant and UM-137, UM-152, UM-163, UM-321 and Rmt-1 were susceptible and none of the fenugreek germplasm was found completely free from disease.

Mohitkar *et al.* (2015) screened fifteen varieties of mustard against powdery mildew (*E. cruciferarum*) and reported that out of fifteen genotypes three were resistant (Boi-902, PCR-7 and Laxmi), one was moderately resistant (JD-6), six were moderately susceptible (Urvashi, PusaBold, Ashirwad (Shatabdi), Sej-2, ACN-9, and Gm-2), two were susceptible (Pusa Bahar and Seeta) and three were highly susceptible (Varuna, Vardhan and Kranti) to the powdery mildew.

Singh and Rao (2016) screened 12 genotypes of coriander against powdery mildew. Out of 12 genotypes four lines of coriander Cor-25, Cor-26, Cor-27 and Cor-30 were found susceptible to disease and remaining were moderately resistant. Cor-31 (DH-220) produced the highest yield of 1021.53 Kg/ ha with moderately resistant reaction against powdery mildew.

Shah *et al.* (2016) screened six sunflower varieties at two different locations against powdery mildew and showed that no one was highly resistant or resistant against powdery mildew at both locations. Out of them A -18 and Hysun-33 were found susceptible while G-12 were observed as moderately resistant. Varieties G-36, G-55 and G-57 were found moderately susceptible.

Vaishnav (2017) screened 13 genotypes of coriander against powdery mildew, none of them were found to immune and resistant. However, only one genotype was moderately resistant, six genotypes were found moderately resistant, and six genotypes were highly susceptible.

2.3 To study the biochemical parameters in relation to disease resistance

Biochemical factors plays an important role in defence mechanism of host plant against diseases. Several changes are observed in the plant constituents in reaction to the disease among susceptible and resistant hosts.

2.3.1 Sugars

In general, infection by pathogen leads to lot of changes in vital process like respiratory pathway and photosynthesis leading to wide fluctuations in sugars.

Singh and Saksena (1983) reported that pea varieties resistant to powdery mildew containing less of total sugars than susceptible varieties and They listed powdery mildews as high sugar diseases and attributed their susceptibility to increased level of sugars.

Parashar and Sindhan (1986) reported that powdery mildew resistant pea varieties (P185 and P388) had low concentration of total sugars and reducing sugars, than susceptible varieties (Bourneville and Multifreezer).

Baka and Aldesuquy (1992) reported that decrease in reducing sugars in sqush affected by powdery mildew caused by *Spaerotheca fuliginea*.

Awad (2000) reported positive correlation between susceptibility to powdery mildew and leaf sugar content in cucurbit varieties.

Gawande *et al.* (2002) carried out a biochemical study on reducing, non-reducing and total sugars before and after powdery mildew (*E. polygoni*) infection in seven mungbean genotypes. They concluded that sugars were negatively associated with disease resistance.

Hattappa *et al.* (2003) who worked with pea and mulberry powdery mildew that concentration of non-reducing sugars was negatively correlated with degree of resistance.

2.3.2 Phenols

It has been widely recognised that the aromatic compounds such as mono and dihydroxy phenols, phenolic glucoside, flavonoids, anthocyanin, aromatic amino acids and coumarin derivatives were increased in host tissues invaded by pathogen. One of the major biological properties of phenolic compounds is their antimicrobial activity and their main role in plants is to act as protective compounds against disease causing agents such as fungi, bacteria and viruses.

Parashar and Sindhan (1986) reported that powdery mildew resistant pea varieties (P185 and P388) had higher contents of total phenols in stem and leaf than susceptible varieties (Bourneville and Multifreezer).

Sindhan and Jaglan (1987) reported higher amounts of total phenols in resistant genotypes of ground nut affected by tikka leaf spot as compared to the susceptible ones.

Kalia *et al.* (1988) revealed that the resistant cultivars contained higher levels of phenolics and phenol-oxidizing enzymes than the susceptible ones in pea cultivars.

Awad (2000) reported that leaf tissues of incompatible water melon contained higher levels of free and total phenols than those of susceptible varieties infected with powdery mildew.

Bhattacharya *et al.* (2000) noticed higher phenol levels in resistant genotypes and healthy plants of susceptible cultivars in pea affected by powdery mildew caused by *Erysiphe pisi*.

Gawande *et al.* (2002) carried out a biochemical study on total phenols before and after powdery mildew (*E. polygoni*) infection in seven mungbean genotypes. They concluded that resistant genotypes had higher total phenols before and after infection and positively correlated with resistance.

Avtar *et al.* (2003) observed higher levels of total phenols in resistant genotypes (NLM and HM 350) than susceptible (T8 and HM 65) fenugreek genotypes before and after the appearance of powdery mildew (*E. polygoni*) in artificially inoculated and natural environments. In response to infection, an increase was observed in total

phenols in all the genotypes. However, at higher disease severity total phenol content has been decreased invariably in all the genotypes.

Dinesh (2009) showed that initially healthy leaves of susceptible variety of Sunflower (Morden) had 1.204 mg/g of total phenols and it was increased to 3.980 mg/g after infection by *E. cichoracearum*. Whereas, healthy leaves of resistant cultivar KBSH-44 had 1.362 mg/g of total phenols and it was increased to 4.817 mg/g in diseased leaves.

Divyajyothi (2012) recorded 6.8 mg/g of total phenol in healthy leaves of highly susceptible greengram genotype (shining mung) and it increased to 9.18 mg/g after infection by *E. polygoni*.

2.4 *In vitro* evaluation of different fungicides, botanicals, bio agents and organics

2.4.1 *In vitro* evaluation of fungicides

Rakhonde *et al.* (2011) studied the management of powdery mildew of greengram. They were conducted experiments to assess the efficiency of different fungicides, plant extracts and culture filtrate of bio agents against the powdery mildew of green gram caused by *E. polygoni* under *in vitro* and *in vivo* conditions. Among all the tested fungicides 0.05% tridemorph recoded highest inhibition of spore germination in *in vitro*.

Vikas and Ratnoo (2011) evaluated seven fungicides in *in vitro* condition against pea powdery mildew and reported, amongst the fungicides dinocap and sulphur dust were found most effective for spore inhibition at concentrations 500ppm followed by 250 and 100 ppm. Maximum spore inhibition obtained by dinocap (0.00%) and suphur (0.00%) at 500 ppm concentration followed by tridemorph (1.90%), tridemefone (2.20%), sulphur WP (2.80%), carbedazim (2.80%) and penconazole (3.00%), respectively.

Divyajyothi (2012) reported that the maximum reduction in conidial germination of *E. polygoni* in green gram powdery mildew was observed with azoxystrobin 250%

SC (93.16%) and followed by hexaconazole 5% EC (86.59%), difenconazole 25% EC (85.13%) and myclobutanil 10% WP (84.78%).

Channaveeresh and Kulkarni (2015) evaluated fungicides against powdery mildew of black gram caused by *E. polygoni* under *in vitro* conditions and reported that the azoxystrobin at 0.1 per cent concentration (94.16%) inhibited maximum conidial germination and it was followed by hexaconazole (90.51%).

2.4.2 *In vitro* evaluation of botanicals and organics

Maurya *et al.* (2004) observed that extracts of *Azadirachta indica* bark and *Cyperus rotndus* inhibit more than 80% of germination of *E. pisi* at 500ppm followed by extract of *Ocimum sanctum*, cashew nut shell and *Madhuca indica* leaves.

Amar *et al.* (2008) showed effect of methanolic extract of cashew nut (*Anacardium occidentale*) shell extract was seen on conidial germination of *E. pisi* and powdery mildew development in pea (*Pisum sativum*). Maximum inhibition of conidial germination of *E. pisi* on glass slides was observed at 300 ppm.

Dinesh *et al.* (2009) reported that organics, azadirachtin (0.5%) and NSKE (5%) were found most effective in inhibiting conidial germination of powdery mildew of sunflower (in vitro) and reduced the disease incidence under field condition.

Vikas and Ratnoo (2011) evaluated two phyto extracts in *in vitro* conditions against pea powdery mildew and reported that the minimum conidial germination recorded at 500 ppm both in azadirachtin (40.70%) and neem oil (42.80%) followed by concentration of 250 ppm and 100 ppm of both these phyto extracts.

Rakhonde *et al.* (2011) conducted experiments to assess the efficacy of different plant extracts against green gram powdery mildew caused by *Erysiphe polygoni* under *in vitro* conditions and reported that among all the tested plant extracts, 5% *Terminalia belerica* (66.45%) recorded highest per cent of conidial inhibition.

Divyajyothi (2012) reported azadirachtin 0.15% EC showed maximum conidial inhibition of 46.66% and azadirachtin 0.03% EC (44.52%) and azadirachtin 1500ppm (40.57%) in green gram powdery mildew caused by *E. polygoni*.

Mahalakshmi and Alice (2013) evaluated different plant extracts including weeds under *In vitro* to study their efficacy in inhibiting the conidial growth of *E. polygoni* by spore germination assay and reported that among the 31 plant extracts tested *Allium sativum* (10%) significantly inhibited the conidial germination of *E. polygoni* followed by *Prosopis juliflora* (10%), and *Trianthimum portulacastrum* (10%), which accounted of 93.90, 92.39 and 91.23 per cent, respectively.

Gupta and Kumar (2014) evaluated eleven botanicals as ethanolic extracts *In vitro* and *In vivo* at different concentrations for their effectiveness against *E. pisi* and reported that the ethanol extract of *A. calamus* (1.0%) caused maximum inhibition of conidial germination (98.13%) and germ tube length (82.99%) followed by *L. camara, U. dioica* and *M. azedarach*.

Channaveeresh and Kulkarni (2015) evaluated botanicals against powdery mildew of black gram caused by *E. polygoni* under *in vitro* conditions and reported that the among botanicals maximum of 79.93% conidial inhibition was observed with Azadirachtin (1500ppm) followed by NSKE @ 5% (76.64%).

Patil *et al.* (2017) reported cow urine and butter milk were found most effective in inhibiting conidial germination of powdery mildew of garden pea.

2.4.3 *In vitro* evaluation of bio agents

Sudha and Lakshmanan (2007) observed maximum reduction in conidial germination of causal agent of chili powdery mildew (*Leveillula taurica*) by the culture filtrates of the *Trichoderma viridae*, *T. harzianum* and *Pseudomonas fluorescens* under in vitro condition.

Rakhonde *et al.* (2011) conducted experiments to assess the efficacy of different culture filtrates of bio agents against green gram powdery mildew caused by *E. polygoni* under *in vitro* conditions and reported that among all the tested culture filtrate of *P. fluorescens* (63.93%) inhibited maximum conidial germination.

Channaveeresh and Kulkarni (2015) evaluated bio agents against powdery mildew of black gram caused by *E. polygoni* under *in vitro* conditions and reported that

the among bioagents @ 6 g/l concentration *Bacillus subtilis* (75.47%) inhibited maximum conidial germination followed by *P. fluorescens* (72.19%).

2.5 Management of powdery mildew of coriander and fenugreek

2.5.1 *In vivo* evaluation of fungicides

Dhruj *et al.* (2000) reported that hexaconazole, penconazole and wettable sulphur were found effective against powdery mildew of fenugreek.

Khunti *et al.* (2005) evaluated ten fungicides against powdery mildew of mungbean and reported hexaconazole (0.005%), dinocap (0.024%), carbendazim (0.025%) and sulphur (0.20%) were most effective in controlling powdery mildew of mungbean. Based on cost: benefit ratio, they reported hexaconazole as most economical fungicide followed by carbendazim and sulfex.

Saxena and Saxena (2002) evaluated the fungicides against powdery mildew of mungbean and reported that the carbendazim (0.05%) reduced powdery mildew of mungbean with low (11.44%) intensity. Other fungicides like tridemorph (0.05%) and penconazole (0.05%) were equally effective, where the powdery mildew intensity was less than 20 per cent.

Kunkalikar and Padaganur (2004) studied the rate of development of powdery mildew on green gram and reported that tridemorph was the effective fungicide in reducing the powdery mildew disease spread from first spray.

Solanki (2004) reported that two sprays of bayleton @ 0.1% at an interval of 15 days was found most effective in reducing the fenugreek powdery mildew disease and increasing the seed yield in both the crop years followed by karathane (0.1%), calixin (0.1%) and sultaf (0.2%). The highest cost: benefit ratio was recorded from sultaf treated plots followed by sulphur dust @ 25 kg/ha and karathane.

Singh (2006) conducted field experiment in which six fungicides were evaluated against powdery mildew of coriander such as mancozeb (0.3%), carbendazim (0.1%), wettable sulfur (0.3%), thiophanate methyl (0.1%), hexaconozol (0.1%) and propiconazole (0.1%). Among them efficacy of wettable sulfur (0.3%) was good.

Fungicides hexaconozol and propiconazole increased the yield of coriander and reduced disease severity.

Suryawanshi *et al.* (2009) reported that karathane (0.1%) was most effective, recording least mean powdery mildew intensity (15.14%) highest grain yield (1425Kg/ha) and test weight (58.00g) in mungbean crop. The most economical treatment, considering the cost: benefit ratio was sulfex (1:2).

Akbari and Parakhia (2010) conducted studies on chemical control of coriander powdery mildew and reported that the minimum disease intensity of 23.97% was recorded with three sprays of propiconazole (0.025%) which was closely followed by difenconazole (0.025%), hexaconazole (0.005%) and tridemefon where disease intensity of 26.15, 30.18 and 30.56% were recorded, respectively.

Khunti *et al.* (2010) studied efficacy of various fungicides for control of powdery mildew of black gram under dry farming and reported that significantly minimum powdery mildew disease intensity of 3 to 13% with average 7.63% was recorded in the treatment of hexaconazole 0.005% during all the four (2002, 2004, 2006 and 2007) years as well as in pooled data and it was on par with carbendazim 0.05% in which 3.5 to 15% with average 9.5% disease intensity were recorded. Thus hexaconazole 0.005% and carbendazim0.05% was found most effective and equivalent for control of powdery mildew in black gram.

Kachhot *et al.* (2011) studied powdery mildew of pea in field during *Rabi* season (2009-10) and reported that minimum disease occurred in plots receiving hexaconazole (0.06%), triademefon (0.04%) and triflumizole (0.04%).

Adinarayana *et al.* (2012) conducted a field experiment to evaluate the efficacy of penconazole 10 EC (NS) against urdbean powdery mildew for two seasons and reported that penconazole 10 EC (NS) at 1.0 ml/L was found significantly superior followed by penconazole 10 EC (NS) at 0.6 ml/L with low disease incidence of urdbean powdery mildew. Further, phytotoxicity was not observed in penconazole treated plots even at higher dose in urdbean.

Dabbas and Prakash (2012) evaluated nine fungicides against powdery mildew and yield of pea during 2008-09, 2009-10 and 2010-11 to know the effective fungicidal practice for management of the disease and reported that three foliar sprays of bayleton (0.25%) at 10 days interval from initiation of the disease gave average minimum (5.65%) disease intensity and maximum grain yield 3.080 kg/ plot (3.2m × 3.0 m). In term of cost-benefit ratio treatment (T5), three foliar sprays of bayleton (0.25%) at 10 days interval from initiation of the disease gave ICBR of 1:2.03, which was higher than other treatments.

Jagtap and Khalikar (2012) reported that in the integrated disease management trail application of different bio agents showed reduced disease severity. The disease severity ranges 13.84 to 27.68 per cent. In chemical management experiment the fungicide bayleton (0.05%) showed significantly lowest pea powdery mildew disease severity (15.93%) with maximum (26.87%) disease control. On the basis of effectiveness in controlling the powdery mildew disease of pea, the most effective fungicide recorded in the order of merit were bayleton (0.01%), tridemorph (0.05%) and dinocap (0.05%).

Nargund *et al.* (2012) studied the management of green gram powdery mildew through fungicides for two consecutive years during *Kharif* season (2004 and 2005) and reported that the tested fungicides were found effective in managing the powdery mildew disease of green gram over untreated control and increased the seed yield. The pooled data of two years revealed that the least PDI was noticed with myclobutanil (12.52 %) which was at par with propiconazole. carbendizim at 0.05% per cent was also found to be effective.

Singh and Banwasi (2012) evaluated fungicides and bio agents against powdery mildew of coriander and reported that minimum disease intensity (20.6%) and maximum yield (810kg/ha) were obtained with application of carbendazim as soil drench and 0.1% spray at 60 days after sowing which was on par with spray of wettable sulphur 0.2% spray at 60 days after sowing.

Chavan *et al.* (2014) tested the efficacy of the test fungicides against powdery mildew of cowpea and reported that all the treatments were found significantly superior over unsprayed control. It was found that 2-3 sprayings of the fungicides either of

tridemorph (0.05%), tridemefon (0.25%), sulphur (0.2%), carbendazim (0.1%), propiconazole (0.1%) and mancozeb (0.25%) were effective. Among these six tested fungicides; tridemorph was found to be the most effective in reducing the disease intensity (5.46%).

Bachihal *et al.* (2014) conducted an experiment to manage okra powdery mildew by using fungicides and bio agents and reported that three spray of difenconazole (17.26% PDI) followed by two sprays of difenconazole in combination with *P. fluorescens* (19.21% PDI) were found effective in managing powdery mildew of okra. The maximum benefit cost ratio was recorded in three sprays of propiconazole which was followed by three sprays of difenconazole. Thus, among the treatment combination *P. fluorescens* and nimbicidin intermixed with propiconazole and difenconazole spray schedule not only reduce the cost of protection but also gave higher benefits.

Narendra *et al.* (2015) reported that in a field trail, propiconazole as foliar spray was found most effective with minimum per cent powdery mildew disease intensity on fenugreek leaves and pods followed by mancozeb, carbendazim, *Trichoderma harzianum*, *T. viride* and neem leaf extract. Propiconazole (13.06), as foliar spray was found most effective with maximum length of pods (cm) and weight of pods followed by mancozeb (12.03), carbedazim (11.25), *T. harzianum* (10.60), *T. viride* (9.81) and neem leaf extract (9.01).

Channaveeresh and Kulkarni (2015) evaluated fungicides, botanicals and bio agents against powdery mildew of black gram caused by *E. polygoni* DC under *In vitro* conditions and reported that the azoxystrobin at 0.1per cent concentration (94.16%) inhibited maximum conidial germination and it was followed by hexaconazole (90.51%). Among botanicals maximum of 79.93% conidial inhibition was observed with Azadiractin (1500ppm) followed by NSKE @ 5% (76.64%). Among bioagents @ 6g/L concentration *Bacillus subtilis* (75.47%) inhibited maximum conidial germination followed by *P. fluorescens* (72.19%).

Khunti *et al.* (2010) evaluated relative efficacies of six different fungicides at different concentrations against powdery mildew of cumin under *in vivo* and reported that among the different fungicides, propiconazole (0.025%) was the most effective

fungicide with mean 4.43 per cent (pooled) disease intensity and maximum disease control of 79.28 per cent followed by wettable sulphur (0.2%). The highest yield of 798 kg/ha (two year pooled) was obtained in the treatment of propiconazole closely followed by wettable sulphur with 701 kg/ha.

Patel *et al.* (2017) studied integrated management of powdery mildew of coriander and reported that the fungicides were found effective against the disease and significantly reduced the powdery mildew intensity and thereby increased the seed yield, number of seeds per umbel and oil content in coriander over unsprayed control. However, among fungicides, hexaconzole (0.05%), wettable sulphur (0.30%), dinocap (0.1%) and penconazole (0.05%) were found highly effective for controlling the disease with better seed yield and oil content.

2.5.2 *In vivo* evaluation of botanicals and organics

Rettinassababady *et al.* (2000) conducted a pot culture experiment to find out the efficacy of various plants extracts in comparision with conventional fungicides against powdery mildew of blackgram caused by *Erysiphe polygoni* and reported that three neem extracts (neem seed kernel extracts, neem oil and neem cake extract), leaf extracts of prosophis (*Prosophis juliflora)* and Ipomea (*Ipomea carnea)* and fungicide mancozeb and carbendazim were effective against *E .polygoni*. Among the plants extracts tested Neem Seed Kernel Extract (5%) was found to be superior in containing the powdery mildew disease and increasing the grain yield of black gram under pot culture experiment.

Singh (2008) evaluated five plant extracts namely, *Andrographis paniculata, Azadirachta indica, Polyalthia longifolia, Saraca indica and Adinacardi folia* for the control of powdery mildew of coriander in comparison with wettable sulphur (0.3%) and reported that among them *A. paniculata* and *A.indica* were significantly superior in reduction of disease severity and increase in grain yield over control indicating their potential for use as a component in integrated management of disease.

Segarra *et al.* (2009) reported that the compost treatment reduced the incidence of the powdery mildew disease in tomato by 19% as compared to untreated plants.

Application of compost did not significantly affect the number of leaves per plant. However, plants treated with compost tea appeared to be greener than untreated plants.

Chhata *et al.* (2010), reported that soil application of neem cake + seedtreatment with *Trichoderma* @ 8 Kg/ha + foliar spray of neem formulation (*Azadirachtin*) was found effective for organic pest and disease management module for fenugreek. Powdery mildew was observed at minimum level *i.e.* 21.45 and 26.78% at 70 and 100 DAS, respectively.

Kachhot *et al.* (2011) studied powdery mildew of pea in field during *Rabi* season (2009-10) and reported that minimum disease, occurred in plots receiving hexaconazole (0.06%), triademefon (0.04%) and triflumizole (0.04%) botanical, azadirachtin (0.3%) was better than turmeric powder (0.4%).

Mahalakshmi and Alice (2013) evaluated different plant extracts including weeds under *in vitro* to study their efficacy in inhibiting the conidial growth of *Erysiphe polygoni* by spore germination assay and reported that among the 31 plant extracts tested *Allium sativum* (10%) significantly inhibited the conidial germination of *E. polygoni* followed by *Prosopis juliflora* (10%), and *Trianthimum portulacastrum* (10%), which accounted of 93.90, 92.39 and 91.23 per cent, respectively. The treatments proved effective under *in vitro* studies were tested under pot culture condition for managing the disease and revealed that among the botanicals, *A. sativum* (10%) significantly reduced the disease incidence of green gram powdery mildew (60.90 %) followed by *P. juliflora* and *T. portulacastrum* (10%), which recorded 58.95and 54.93 per cent reduction over control.

Gupta and Kumar (2014) evaluated eleven botanicals as ethanolic extracts *in vivo* at different concentrations for their effectiveness against *E. pisi* and reported that though no botanical was as effective as the standard check *i.e.* hexaconazole but among botanicals three sprays of *U. dioica* (2.0 %) showed least disease severity and increased green pod yield.

Jayasekhar and Ebenezar (2016) conducted two field experiments by using cheap and eco-friendly plant products and bio control agents for the management of black gram powdery mildew caused by *E. polygoni* which was causing severe yield loss

and reported that the mean per cent disease incidence ranged from 15.80 to 47.70 in different treatments. The maximum reduction of disease incidence was recorded in wettable sulphur 0.25% (15.80%) followed by carbendazim 0.1% (58.91%) and castor oil 1% with *Ampelomyces quisqualis* (48.53 %). However castor oil 1% followed by *A. quisqualis* application at 10 days interval recorded 20.28 per cent increased yield with maximum cost benefit ratio of 1 : 2.01.

Patil *et al.* (2017) studied eco-friendly management of powdery mildew of garden pea (*Pisum sativium* L.) with different bio agents, bio rationals and botanicals to control powdery mildew of pea. During evaluation all the seven treatments (*viz.* hexaconazole, NSKE, *Lantana camera* leaves extract, *B. subtilis*, *T. harzianum*, cow urine and butter milk) were found to be significantly superior over control in managing the powdery mildew disease. Among all treatments, T1 (Hexaconazole- 0.05%), T2 (NSKE 5%), T5 (*T. harzianum* 0.4%), T6 (cow urine 10%) and T3 (*Lantana camara* leaves extract10%) were significantly superior over other treatments for managing powdery mildew. Neem seed kernel extract at 5% concentration and cow urine (15%) were found as best treatment to control for powdery mildew disease.

2.5.3 *In vivo* evaluation of bio agents

Elad (2000) reported that T39 isolate of *Trichoderma harzianum* has got promising result in controlling of powdery mildew (*Sphaerotheca fusca*) of cucumber under greenhouse condition with different mode of actions.

Levente (2003) reported that there are approximately 40 fungal species that have so far been reported as natural antagonists of powdery mildews or have been tested as their potential bio-control agents.

Sudha and Lakshmanan (2007) reported *T. harzianum* recorded maximum disease reduction of 66.0%, followed by *T. viride* (48.9%) and *Pseudomonas fluroscence* (39.9%) against chilli powdery mildew in green house. Same trend was observed in field also, where in 54.9, 47.8 and 36.1 per cent disease reduction were recorded respectively against chilli powdery mildew.

Romero *et al.* (2007) reported that three strains of *Bacillus subtilis*, to manage powdery mildew disease, caused by *Podosphaera fusca* on melon seedlings. The strains of *B. subtilis* provided disease control similar to that achieved with the mycoparasites or the fungicide azoxystrobin. Microscopic analysis showed the ability of these bacterial strains to efficiently colonize leaf surfaces and revealed the occurrence of antagonistic interactions between biological agents and *P. fusca* structures.

Gilardi *et al.* (2008) reported the activity of two bio fungicides based on *Bacillus subtilis* and *Ampelomyces quisqualis* alone and in combination with fungicides against powdery mildew (*Podosphaera xanthii*) of zucchini in five experimental trials carried out under greenhouse conditions. *B. subtilis* when combined with azoxystrobin against *P. xanthii* at the recommended field dosages provided better powdery mildew control than the two other control measures alone.

Anand *et al.* (2009) opined that foliar application of *P. fluroscence* (Pf1) (2.5 kg /ha) and azoxystrobin (250 ml /ha) in combination, reduced downy mildew as well as powdery mildew disease severity more than azoxystrobin (250 and 500 ml / ha) alone. An application of Pf1 + azoxystrobin treatment recorded only 2.22 and 1.00% (PDI) of downy mildew and 1.85 and 0.50 PDI of powdery mildew during the first and second seasons, respectively. The treatment also recorded a maximum fruit yield of 14.30 and 15.65 tonnes/ ha for the first and second seasons, respectively. Application of Pf1 along with azoxystrobin significantly increased the survival of Pf1 in the phylloplane of cucumber crop.

Nargund *et al.* (2012) reported that *P. flourescence* recorded minimum disease incidence (38.18%) followed by hexaconazole @ 0.1% (45.38%) in sunflower powdery mildew.

Fungi *viz., T. viride, Ampelomyes quisqualis, F. moniliforme, Aspergillus fumigalus, A. niger, Alternaria alternata* and *Pestalotiopsis dissiminata* were identified and found to be antagonist against *Sphaerotheca fuliginea* causing powdery mildew of cucumber (Singh, 2004).

Sudha and Lakshmanan (2007) observed that *T. harzianum* recorded maximum reduction of 66.00 per cent followed by *T. viride* and *Pseudomonas fluorescens* in chilli powderymildew caused by *Leveillula taurica*

Surwase *et al.* (2009) observed that *T. harzianum* was found highly effective and economic against *E. polygoni* causing pea powdery mildew and giving better seed yield.

Ranjale *et al.* (2012) recorded that *T. viride* was most superior against powdery mildew of chilli. Dhutraj (2011) observed that bioagents like, *P. fluorescens* and *T. viride* was recorded 43.05and 44.30 per cent disease control, respectively.

Gilardi *et al.* (2012) tested *Bacillus subtilis* and *Ampelomyces quisqualis* alone and in combination with fungicides (azoxystrobin and penconazole) against powdery mildew of zucchini. *Bacillus subtilis* when combined with azoxystrobin provided better disease control than the two control measure alone.

3. MATERIAL AND METHODS

During the studies on powdery mildew of coriander and fenugreek, caused by *Erysiphe polygoni* DC number of experiments were planned and conducted (*in vitro* and *in vivo*) during *rabi* 2018 at Horticulture Research and Extension Centre, Devihosur, Haveri. Details of the material used and methods followed in the present studies are presented in the following paragraphs.

3.1 Experimental location and climate

The field experiment on management of powdery mildew of coriander and fenugreek was carried out at Experimental fields of HREC, Devihosur, Haveri. Haveri is situated in Northern transitional agro-climatic zone (Zone-8) 14°47' North latitude and 75°21' East longitudinal at 563 m above Mean Sea Level (MSL). Among the agro climatic zone of Karnataka, Haveri has benefits of both South-West and North-East monsoons. The annual average rainfall for last 36 years is 728 mm per year. The meteorological data recorded at the meteorological observatory of the HREC, Devihosur, Haveri is presented in Appendix I.

3.2 Field preparation and sowing

Available genotypes of coriander (92+3 checks) and fenugreek (24+2 checks) were collected from germplasm pool of HREC, Devihosur, Haveri**.** The experimental plot was ploughed and brought to a fine tilth. The recommended dosage of fertilizers was applied along with neem cake and vermicompost. Seeds were sown in a rows spaced at 30 cm and 10 cm from plant to plant.

3.3 Experimental details

a. Location	:	Horticulture Research and Extension Centre, Devihosur, Haveri - 581110
b. Season and Year	:	*Rabi* 2018-19
c. Crop	:	Coriander and Fenugreek

d. Soil Type	:	Medium Black Soil
e. No. of genotypes	:	Coriander (92+3 checks) Fenugreek (24+2 checks)
f. No. of replications	:	Coriander - 2 Fenugreek - 3
g. Plot size	:	2 m × 2 m
h. Spacing	:	30cm × 10 cm
i. Fertilizer dose	:	Coriander - 30:40:20 kg/ha. (NPK) Fenugreek -50:25:40 kg/ha. (NPK)
j. Date of sowing	:	25/10/2018
k. Date of Harvesting	:	30/01/2019

3.4 Screening of coriander and fenugreek genotypes against powdery mildew

3.4.1 Source of genotypes

The genotypes used for the experiment were selected from the germplasm pool of HREC, Devihosur, Haveri. The coriander genotypes selected for screening against powdery mildew are Devihosur Coriander Collection, DCC-1 to DCC- 49, DCC- 51 to DCC- 92 along with three checks *viz*., DWD-3, CO (CR)-4 and Ajjampur Local and fenugreek genotypes selected for screening are Devihosur Fenugreek Collection, DFC-1to DFC-24 along with two checks *viz*., LS- 1and LS- 3.

3.4.2 Scoring technique followed for powdery mildew of coriander and fenugreek

The scoring of genotypes against powdery mildew was carried out in an experimental plot during grand growth period of the above listed coriander genotypes.

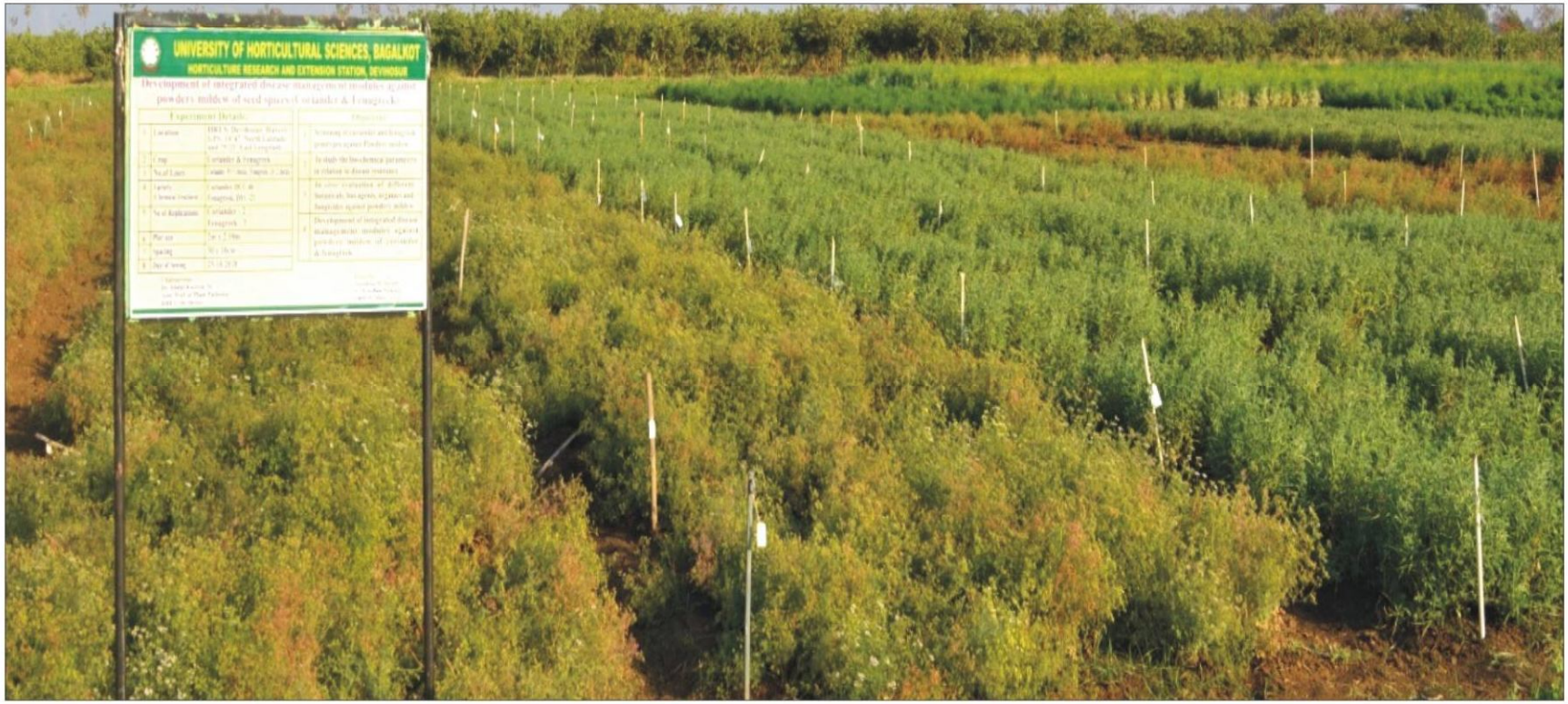


Plate 1: Field view of experimental plot

Total ten plants from each genotype were used to screen against powdery mildew and each plant was scored based on the per cent of disease index, and the genotypes were categorized based on the reaction to disease incidence. Observations were taken on severity of the powdery mildew and converted into PDI by using the formula given by Mc Kinney (1923).

$$PDI = \frac{\text{Summation of numerical ratings}}{\text{No. of leaves / plants observed} \times \text{maximum rating}} \times 100$$

3.4.3 Disease rating scale for powdery mildew of coriander

The powdery mildew intensity was recorded for each individual plant of each treatment based on the ratings using the following scale (Ushamalini and Nakkeeran, 2017).

Grade	Description	Reaction
0	Healthy	Immune
1	Whitish small spots on leaves	Resistant
2	Whitish growth covering entire leaf	Moderately resistant
3	Growth on leaf and stem	Susceptible
4	Growth on leaf, stem and umbel	Highly susceptible

3.4.4 Disease rating scale for powdery mildew of fenugreek

The powdery mildew intensity was recorded for each individual plant of each treatment based on the ratings using the following scale (Kumawat, 2015).

Grade	Description/ Per cent infection	Reaction
0	Healthy	Immune
1	1-10 per cent of leaves/ plant parts infected	Resistant
2	11-25 per cent of leaves/ plant parts infected	Moderately resistant





Plate 2a: Disease rating scale for powdery mildew of coriander

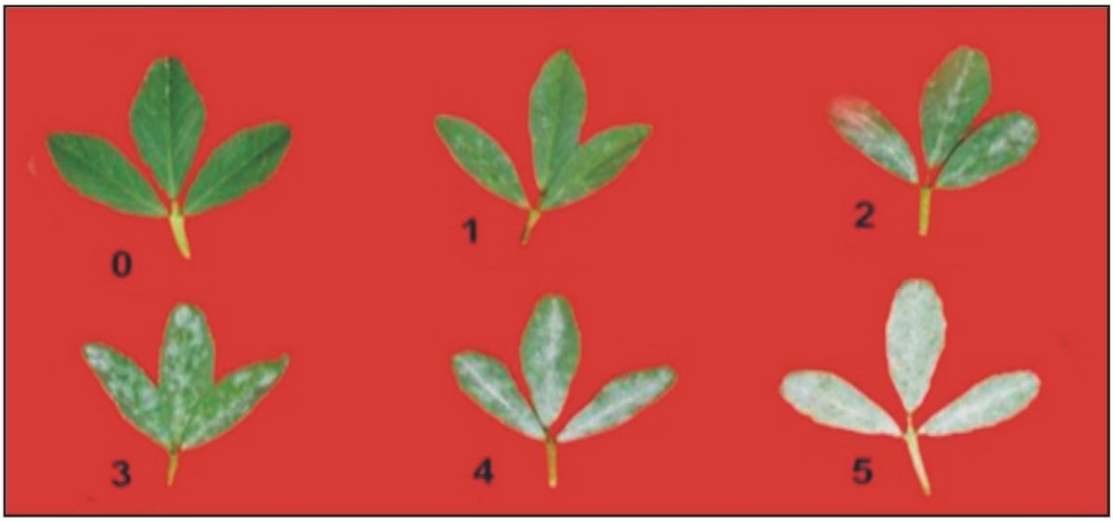


Plate 2b: Disease rating scale for powdery mildew of fenugreek

3	26-50 per cent of leaves/ plant parts infected	Moderately susceptible
4	51-75 per cent of leaves/ plant parts infected	Susceptible
5	More than 75 per cent of leaves/ plant parts infected	Highly susceptible

3.5 To study the biochemical parameters in relation to disease resistance

3.5.1 Biochemical studies

The influence of disease on the biochemical parameters of the leaf such as total sugars, reducing sugars, non reducing sugars and total phenols were studied. Both the healthy and diseased leaf samples, for the estimation of the above mentioned biochemical parameters were collected from the four genotypes used for screening *viz*., DCC- 46 (Moderately resistant) and DCC-24 (Highly susceptible) from coriander and DFC-21 (Moderately resistant) and DFC-22 (Highly susceptible) from fenugreek. The reducing sugars and total sugars were estimated by dinitrosalicylic acid (DNS) and anthrone reagent method (Sadasivam and Manickam, 1996) respectively. The concentration of non reducing sugars in the leaf was obtained by substracting the total sugars from reducing sugars. Total phenols present in the leaf samples were analysed by the Folin-Ciocalteau reagent method (Sadasivam and Manickam, 1996).

3.5.2 Estimation of total sugars (mg/g FW)

Total sugar content was estimated by Anthrone Reagent method (Sadasivam and Manickam, 1996).

Materials

- **2.5 N HCl**
- **Anthrone reagent**- 200 mg of anthrone was dissolved in 100 ml ice cold 95 per cent H_2SO_4. The Reagent was prepared fresh before use.
- **Standard glucose solution**: 100 mg of glucose was dissolved in 100 ml distilled water.

Procedure

100 mg of leaf sample was grinded using 5 ml of 2.5 N HCl. The samples extracted in the test tubes were kept in water bath at 100 ˚C for about three hours. As sodium carbonate was added the effervescence was observed and sodium carbonate was added pinch by pinch until the effervescence was ceased. The contents were centrifuged at 12,000 rpm for ten minutes and the supernatant was collected. The volume of aliquot was made to 10 ml and from this 50 µl was pipetted out. Standards were prepared by taking 0, 100, 150, 200, 250 and 300 µl of the standard glucose solution. '0' served as blank. All the aliquots were made up to 2.5 ml by adding distilled water. Then 5 ml of anthrone reagent was added slowly and the contents were stirred gently using the glass rod. The test tubes were heated in a boiling water bath for 8 minutes. Then the test tubes were cooled rapidly and the green to dark green colour developed was read at 630 nm. The standard graph was prepared by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. The amount of total sugar present in the sample was calculated using standard graph.

3.5.3 Estimation of reducing sugars by Dinitrosalicylic acid method (mg/g FW)

The reducing sugars present in the leaves were estimated using DNS method (Sadasivam and Manickam, 1996).

Dinitro salicylic acid reagent: Dissolve by stirring one g dinitrosalicylic acid, 200 mg crystalline phenol and 50 mg sodium sulphite in 100 ml of one per cent NaOH and stored at 4 ˚C.

40 per cent Rochelle salt: Prepared by dissolving 40 g potassium sodium tartarate in 100 ml water.

Standard glucose solution: Prepare 100 mg of glucose in 100 ml of distilled water in a volumetric flask.

Methodology:

100 mg of the leaf sample was weighed and crushed with hot solution of 80 per cent ethanol twice (5 ml each time). The extract was centrifuged at 12,000 rpm for 14

minutes and the supernatant was collected. The test tubes containing the supernatant were kept in the boiling water to allow the evaporation of ethanol. The sugars present in the tubes dissolved by adding 10 ml distilled water. One ml of the extract was pippetted out. Standards were prepared by taking 0, 50, 150, 250, 350, 450 and 550 µl of the standard glucose solution. '0' served as blank and the volume made up to 1.5 ml by adding distilled water. 1.5 ml of DNS reagent was added and then the contents were heated in boiling water for about five minutes. When the contents of the test tube were still warm, 0.5 ml of 40 per cent rochella salt solution was added. After the cooling of the test tubes, the absorbance of the dark red colour was taken at 510 nm. The reducing sugar content was obtained by plotting the standard graph using the glucose standards.

3.5.4 Estimation of Non-reducing sugar (mg/g FW)

The reducing sugar in the hydrolysate was a measure of total sugar. The quantity of reducing sugar was subtracted from total sugar and was multiplied by a conversion factor 0.95 to get non-reducing sugar.

3.5.5 Estimation of total phenols (mg/g FW)

The phenols present in the samples were estimated by Folin-Ciocalteau reagent method (Sadasivam and Manickam, 1996).

Materials

- **80 per cent Ethanol**
- **Folin-Ciocalteau reagent**: Commercial grade reagent was diluted in 1:1 with water
- **20 per cent sodium Carbonate solution**: 20 g of Na_2CO_3 was dissolved in water and volume was made up to 100 ml
- **Stock catechol solution**: The stock solution was prepared by dissolving 50 mg in 1 ml of ethanol and volume was made up to 50 ml using distilled water. The working standard was prepared by pipetting 5 ml from the stock and volume was made up to 100 ml (0.05 mg catechol in 1 ml).

Procedure

100 mg of the leaf sample was grinded in 5 ml of 80 per cent ethanol and centrifuged at 10000 rpm for 20 minutes. The supernatant was pooled and 0.1 ml of the supernatant was evaporated on a water bath. For the preparation of standard graph 0.1, 0.2, 0.3, 0.4 and 0.5 ml of the working standard was pipetted out in to the test tubes. The volume of all the aliquots were made up to 3 ml using distilled water and shaken well followed by addition of 0.5 ml of Folin-Ciocalteau reagent (1:1). After 3 minutes, 2 ml of 20 per cent sodium carbonate was added to each tube and mixed thoroughly and incubated for 30 minutes. The absorbance was measured at 650 nm. Using the standard curve the phenol concentration was calculated.

3.6 *In vitro* evaluation of different botanicals, bio agents, fungicides and organics

3.6.1 Spore germination studies

The inhibitory effect of various fungicides, botanicals, bio agents and organics on conidial germination was evaluated using the cavity slide method in which the spore suspension was prepared in 1.5 per cent sucrose solution and the experiment was laid out using completely randomized design (CRD). The fungicides or biocides and their respective concentrations were prepared by mixing the requisite quantities of fungicides or biocides with two times (double concentration) in the distilled water. Single drop of conidial suspension was placed in the wells of series of cavity slides by using one ml pipette to which single drop of different fungicides\ or biocide (double concentration) was also added to get the required concentrations. Treatment without any fungicide or biocide served as control. Cavity slides containing spore suspension were incubated at 25 ± 1˚C and each microscopic field is considered as a replication and three replications of each treatment were maintained and the germinated and ungerminated spores were counted for each slide after 48 h incubation (Soude, 2017; Anusha, 2018).

Spore suspension was diluted up to 30 spores per microscopic field through hemocytometer with 40X magnification.

Percent conidial germination and inhibition was calculated by the following formula given by Vincent, 1947.

$$\text{Per cent conidial germination} = \frac{A}{B} \times 100$$

Where,

A - Number of conidia germinated

B - Number of conidia observed

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

Where,

C - Germination of conidia in control

T - Germination of conidia in treatment

The per cent values were transformed to arc sine values and later the data was analyzed statistically.

3.6.2 *In vitro* evaluation of fungicides:

Seven fungicides were tested against *E. polygoni* and their details are given below**,**

Sl. No.	Common Name	Trade Name	Concentration (%)
1	Hexaconazole	Contaf 5% EC	0.1
2	Wettable sulphur	Sulfex 80% WP	0.3
3	Azoxystrobin	Amistar 250% SC	0.1
4	Carbendazim	Bavistin 50% WP	0.1
5	Dinocap	Karathane 48% EC	0.2

6	Difenconazole	Score 25% EC	0.05
7	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l	Merivon 500 SC	0.05

3.6.3 *In vitro* evaluation of botanicals

Botanicals are relatively cheaper, safe and non-hazardous and they can be used easily and successfully against the plant pathogenic fungi. The present investigation was aimed to study the anti-fungal activity of botanicals. Details of the botanicals, which were tested against *E. polygoni* are given below.

Sl. No.	Botanicals	Part used	Scientific name	Conc. (%)
1	Neemazol	Azadirachtin (Seed kernal)	*Azadirachta indica* (A. Juss)	0.2
2	NSKE	Seed kernal	*Azadirachta indica* (A. Juss)	5.0
3	Ajwain seed extract	Seeds	*Trachyspermum ammi* L.	5.0
4	Garlic bulb extract	Clove/bulb	*Allium sativum* L.	5.0

3.6.3.1 Preparation of botanicals

Ajwain and garlic bulb extract were prepared by following the method given by Rakhonde *et al.* (2011) as described here under.

The standard aqueous extracts of plant materials were obtained by grinding 100g washed economic parts of above mentioned botanicals in mortar and pestle in equal amount of sterile distilled water (w/v). The plant extracts so prepared were filtered using two folds of muslin cloth. These plant extracts thus obtained were considered as 100 per cent and tested against powdery mildew fungus after dilution to get the required concentration.

3.6.3.2 Neem Seed Kernel Extract (NSKE)

The Neem Seed Kernel Extract (NSKE) required for the evaluation was prepared by grinding 5 g neem seed kernel and soaking the ground powder in 100 ml distilled water for overnight (Mohan *et al.,* 2018). The extract obtained was considered as stock solution from which the required concentrations were prepared and evaluated using the cavity slide method.

3.6.4 *In vitro* evaluation of bio agents

Four bio agents were tested at 1% concentrations. Details of the bio agents, which are given below,

Sl. No.	Bio agents	Conc. (%)	Accession No.
1	*Trichoderma harzianum*	1.00	-
2	*Pseudomonas fluorescens*	1.00	-
3	*Bacillus subtilis*	1.00	KX950668
4	Arka microbial consortia	1.00	-

Arka microbial consortia is a carrier based product which contains N fixing, P and Zn solubilizing and plant growth promoting microbes as a single formulation released from Indian Institute of Horticultural Research, Bengaluru. *T. harzianum*, *P. fluorescens* and *B. subtilis* were collected from University of Horticultural Sciences, Bagalkot.

3.6.5 *In vitro* evaluation of organics:

Five different treatments of organics were tested against *E. polygoni* are given below,

Sl. No.	Details
1	Butter milk - 10%
2	Cow urine - 5%
3	Panchagavya - 5%
4	Butter milk (10%) + Cow urine (5%)
5	Butter milk (10%) + Panchagavya (5%)

3.6.5.1 Preparation of panchagavya

Seven kilograms of fresh cow dung and one kilogram of fresh cow ghee were mixed thoroughly and incubated for two days. On third day, three litres of cow urine and 10 litres of water were added to the above mixture and kept for incubation and regular stirring (morning and evening) was also done. After 15 days of incubation, three litres of sugarcane juice, two litres of cow milk, two litres of cow curd, three litres of tender coconut water and 12 ripe bananas were added and mixed thoroughly. This mixture was again incubated for 15 days and stirred regularly and then used (Patil, 2006).

3.7 Management of powdery mildew of coriander and fenugreek.

Field experiments will be conducted at HREC, Devihosur, Haveri to find out the effective for management of powdery mildew disease in seed spices (coriander and fenugreek).

3.7.1 Treatment details

a. Replication	:	3
b. Treatments	:	15
c. Spacing	:	30 cm × 10 cm
d. Plot size	:	2 m × 2 m
e. Variety	:	Coriander - DCC 46 Fenugreek - DFC 21
f. Design	:	Randomized Complete Block Design
g. Location	:	Horticulture Research and Extension Centre, Devihosur, Haveri - 581110

The different treatments imposed were as follows,

Treatments	Details
T_1	Hexaconazole 5% EC @ 0.1%
T_2	Azoxystrobin 250% SC @ 0.1%
T_3	Difenconazole 25% EC @ 0.05%
T_4	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l – 500 SC @ 0.05%
T_5	Neemazol (10,000ppm) @ 0.2 %
T_6	Ajwain seed extract @ 5.0 %
T_7	Garlic bulb extract @ 5.0 %
T_8	*Pseudomonas fluorescens* @ 1%
T_9	Arka microbial consortia @ 1%
T_{10}	Butter milk @ 10%
T_{11}	Cow urine @ 5%
T_{12}	Panchagavya @ 5%
T_{13}	Butter milk @ 10% + Cow urine @5%
T_{14}	Butter milk @10% + Panchagavya @ 5%
T_{15}	Control

3.7.2 Per cent Disease intensity (PDI)

Field observations were taken on severity of the powdery mildew and converted into PDI by using the formula given by Mc Kinney (1923).

$$PDI = \frac{\text{Summation of numerical ratings}}{\text{No. of plants observed} \times \text{maximum rating}} \text{ X } 100$$

3.7.3 Yield parameters

. The weight of the harvested seeds per plot was recorded for each treatment separately and the seed yield per hectare was calculated.

3.7.3.1 Benefit cost ratio (B:C ratio)

Total cost incurred for the application of each treatment was worked out (Appendix II). Gross returns was calculated on the basis of prevailing market price of the produce during the harvesting season. Net returns were calculated by deducting the total cost from the gross return and the cost of cultivation was presented in Appendix II. Benefit cost ratio was calculated by using the formula.

$$\text{B: C ratio} = \frac{\text{Gross returns (Rs./ha)}}{\text{Total cost (Rs./ha)}}$$

3.7.4 Statistical analysis

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

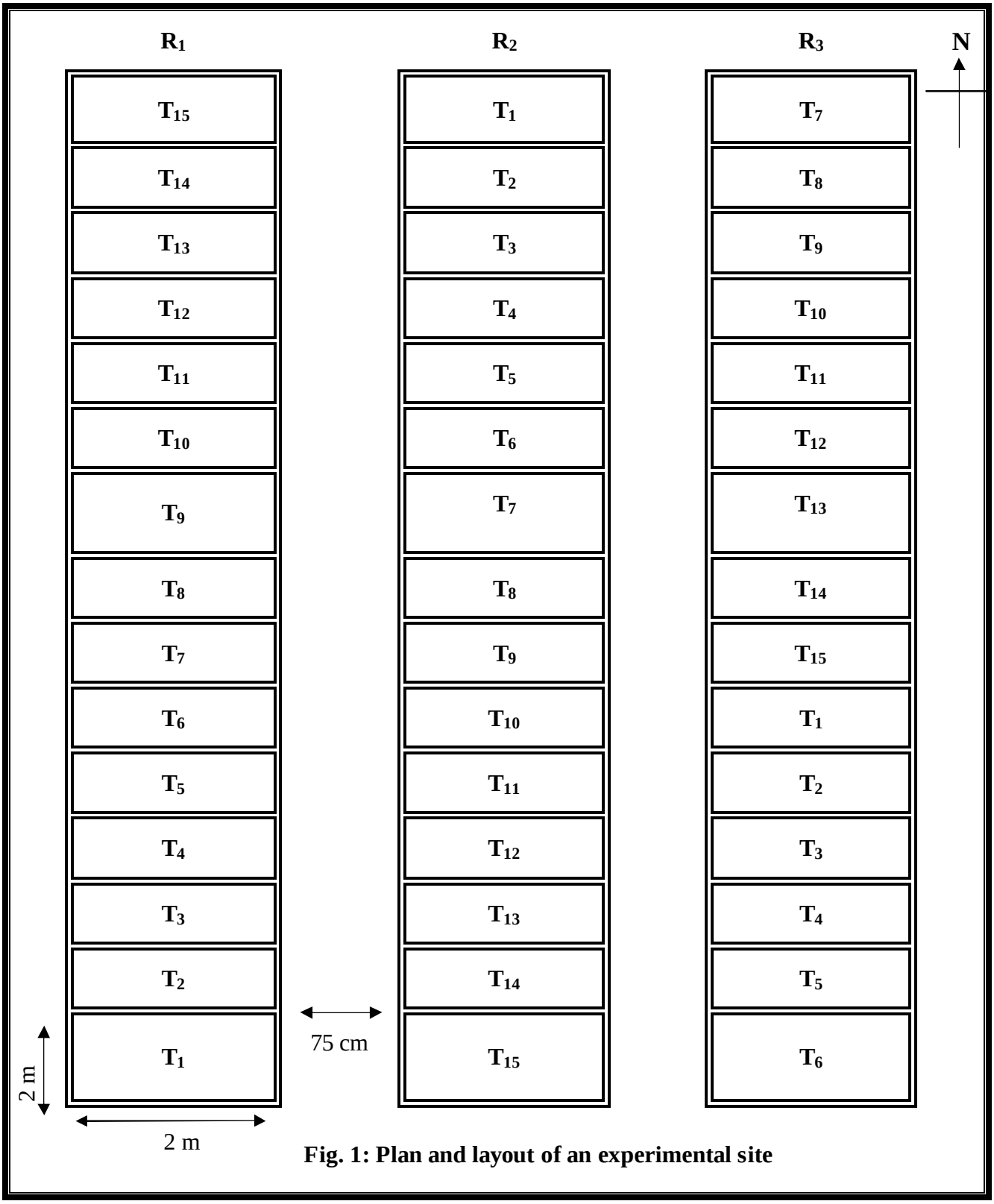


Fig. 1: Plan and layout of an experimental site

4. EXPERIMENTAL RESULTS

The results on screening of genotypes, biochemical factors governing disease resistance, *in vitro* evaluation of fungicides, botanicals, bio agents and organics and disease management studies against powdery mildew of coriander and fenugreek carried out during *rabi* 2018-19 are presented in different sections under this chapter.

4.1 Symptomatology

The symptoms of the disease were observed on leaves, stems and pods in the present study. The initial symptoms are faintly dark areas on the lower leaves. These areas develop small, white specks on the upper surface of the leaves which enlarge and coalesce forming bigger patches. Later the disease spreads to upper leaves also and appears on both the surfaces. Coalescing of spots and enlargement in their size ultimately results in complete coating of white powdery fungal mass on leaves, stems, pods and leads to defoliation (Plate 3 and 4).

4.2 Pathogen

The powdery mildew pathogen *Erysiphe polygoni* DC on coriander and fenugreek was easily detected by the presence of white floury patches appeared on both side of the leaves as well as tendrils, stems, pods etc. As the plant become older, the symptoms almost cover the entire plant, become more or less greyish brown and the infected parts impart dirty appearance. In extreme severe conditions the infected leaves were shed leaving stem devoid of them.

Based on the microscopic observations it was confirmed that the coriander and fenugreek were infected by *E. polygoni*. Microphotograph of oidia/spore shows the morphology of conidia and conidiophore. It was observed that, the conidiophores were upright, hyaline, bearing conidia either single or in chain and conidia were hyaline, unicellular and barrel- shaped (Plate 5).

4.3 Screening of coriander and fenugreek genotypes against powdery mildew

The genotypes of the coriander and fenugreek were naturally screened against the powdery mildew disease caused by *E. polygoni* at HREC, Devihosur, Haveri during *rabi* 2018 and reactions were recorded by using 0-4 disease rating scale for coriander (Plate 2a) and 0-5 disease rating scale for fenugreek (Plate 2b) .

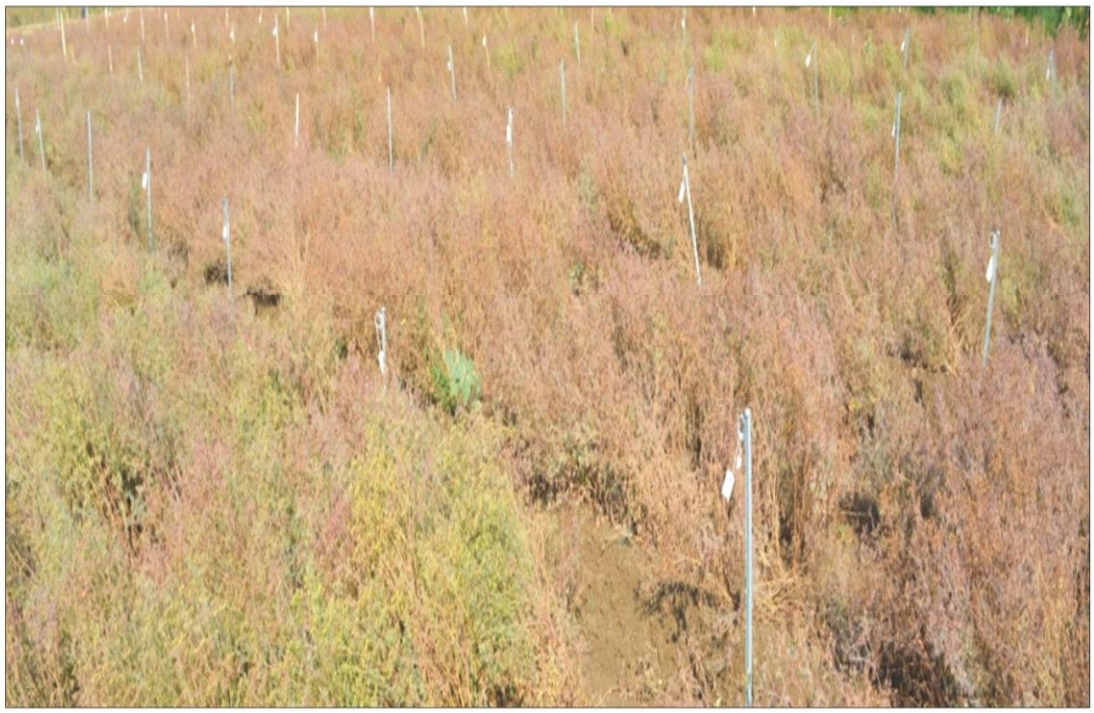
4.3.1 Screening of coriander genotypes under natural field condition

A total of 95 coriander genotypes including three checks *viz*., DWD3, CO (CR) 4 and Ajjampur Local were screened in natural endemic condition at HREC, Devihosur, Haveri during *rabi* 2018 (Plate 6a). The disease severity was recorded using 0-4 disease rating scale as described in material and methods and the results are presented in Table 1.

Among the 95 coriander genotypes screened, none of them were found to be immune and resistant to powdery mildew. However, 19 genotypes *viz.*, DCC12, DCC 15, DCC 21, DCC 35, DCC 40, DCC 46, DCC 60, DCC 61, DCC 63, DCC 68, DCC 69, DCC 70, DCC 72, DCC 80, DCC 81, DCC 87, DCC 89, DCC 93 and DWD 3 were found to be moderately resistant. 71 genotypes *viz.*, DCC 1-11, DCC 13, DCC 14, DCC DCC 16, DCC 17, DCC 18, DCC 19, DCC 20, DCC 22, DCC 23, DCC 25, DCC 6, DCC 27, DCC 29, DCC 31, DCC 32, DCC 33, DCC 36, DCC 37, DCC 39, DCC 41-45, DCC 47, DCC 48, DCC 49, DCC 51-59, DCC 62, DCC 64, DCC 65, DCC 66, DCC 67, DCC 71, DCC 73-79, DCC 82-86, DCC 88, DCC 90, DCC 91, DCC 92, Co(CR)-4 and Ajjampur local were found to be susceptible and 5 genotypes *viz.*, DCC-24, DCC 28, DCC 30, DCC 34 and DCC 38 were found to be highly susceptible.

4.3.2 Screening of fenugreek genotypes under natural field condition

A total of 26 fenugreek genotypes including two checks *viz.*, LS-1 and LS-3 were screened in natural endemic condition at HREC, Devihosur, Haveri during *Rabi* 2018 (Plate- 6b). The disease severity was recorded using 0-5 disease rating scale as described in material and methods and the results are presented in Table 2.



Powdery mildew affected coriander field



Symptoms on leaves



Healthy and infected leaves

Plate 3: Symptomatology of powdery mildew (*Erysiphe polygoni*) on coriander



Powdery mildew affected field

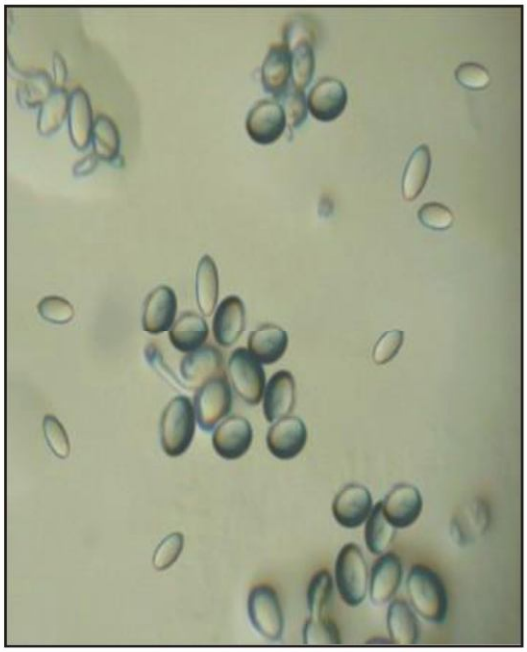


Powdery growth on leaves

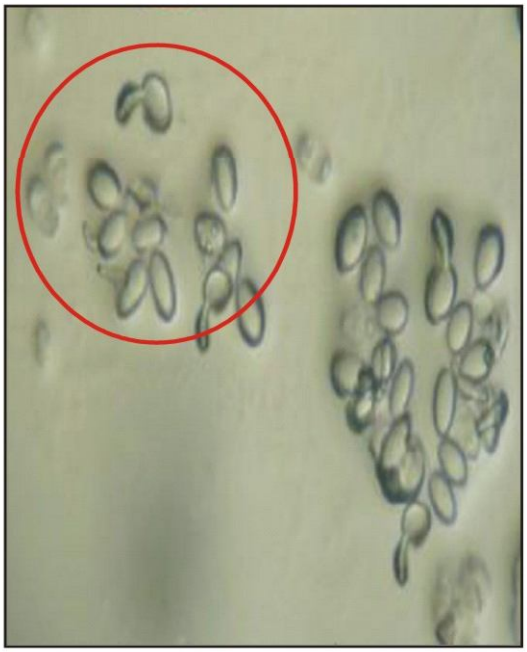


Healthy and infected leaves

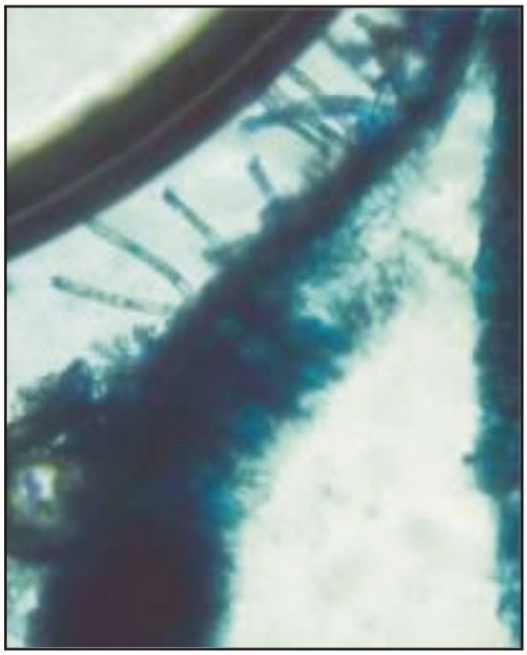
Plate 4: Symptomatology of powdery mildew (*Erysiphe polygoni*) on fenugreek



Conidia (100X)



Germinated conidia (100X)





Conidia and conidiophores (100X)

Plate 5: Microphotograph showing conidia and conidiophores of *E. polygoni* DC

Table 1: Screening of coriander genotypes against powdery mildew under natural field condition

Grade	Reaction	No. of Genotypes	Genotypes
0	Immune	-	-
1	Resistant	-	-
2	Moderately resistant	19	DCC12, 15, 21, 35, 40, 46, 60, 61, 63, 68, 69, 70, 72, 80, 81,87, 89, 93 and DWD 3
3	Susceptible	71	DCC1-11, 13, 14, 16, 17, 18, 19, 20, 22, 23, 25, 26, 27, 29,31, 32, 33, 36, 37, 39, 41-45, 47, 48, 49, 51-59, 62, 64, 65, 66, 67, 71, 73-79, 82-86, 88, 90, 91, 92, Co(Cr)-4 and Ajjampur local
4	Highly susceptible	5	DCC-24, 28, 30, 34 and38

DCC- Devihosur Coriander Collection DWD3- Dharwad 3
Co(Cr)-4 – Coimbatore Coriander 4

Table 2: Screening of fenugreek genotypes against powdery mildew under natural field condition

Grade	Reaction	Per cent infection	No. of Genotypes	Genotypes
0	Immune	0	-	-
1	Resistant	1-10	-	-
2	Moderately resistant	11-25	3	DFC-20, 21 and 23
3	Moderately susceptible	26-50	4	DFC1, 8, 12 and 13
4	Susceptible	51-75	14	DFC-2, 3, 4, 5, 6, 9, 10, 11, 14, 15, 16, 17, 19 and 24
5	Highly susceptible	> 75	5	DFC-7, 18, 22, LS- 1 and LS- 3

DFC- Devihosur Fenugreek Collection LS- Local Selection

Among the 26 fenugreek genotypes screened, none of them were found to be immune and resistant to powdery mildew. However, 3 genotypes *viz.*, DFC-20, DFC-21 and DFC-23 were found to be moderately resistant, 4 genotypes *viz.*, DFC-1, DFC-8, DFC-12 and DFC-13 were found to be moderately susceptible, 14 genotypes *viz.*, DFC-2, DFC-3, DFC-4, DFC-5, DFC-6, DFC-9, DFC-10, DFC-11, DFC-14, DFC-15, DFC-16, DFC-17, DFC-19 and DFC-24 were found to be susceptible and 5 genotypes *viz.*, DFC-7, DFC-18, DFC- 22, LS-1 and LS-3 were found to be highly susceptible.

4.4 To study the biochemical parameters in relation to disease resistance

The amount of total sugars, reducing sugars and non-reducing sugars in both healthy and diseased leaves of both moderately resistant (DCC-46 and DFC-21) and highly susceptible (DCC-24 and DFC- 22) genotypes of coriander and fenugreek were estimated.

4.4.1 Total Sugars

The total sugar content in all the genotypes both for diseased and healthy plants was estimated. The total sugar content was least in moderately resistant genotype when compared to highly susceptible genotype both in coriander and fenugreek. The data on the results are tabulated and presented in the Table 3 and 4 and Fig. 2 and 3.

In coriander, the amount of total sugars in healthy leaves of highly susceptible genotype, DCC-24 (13.33 mg/g) was least than compared to diseased leaves (17.68 mg/g). Similarly in moderately resistant genotype, DCC-46 the amount of total sugars in healthy leaves (7.93 mg/g) was least than compared to diseased leaves (10.12 mg/g). Highly susceptible genotype recorded highest per cent increase in total sugars (53.07%) than compared to moderately resistant genotype (27.61%).

In fenugreek, the amount of total sugars in healthy leaves of highly susceptible genotype, DFC-22 (16.08 mg/g) was least than compared to diseased leaves (21.67 mg/g). Similarly in moderately resistant genotype, DFC-21 the amount of total sugars in healthy leaves (13.33 mg/g) was least than compared to diseased leaves (15.91 mg/g).



Plate 6a: Screening of coriander genotypes against powdery mildew under natural field condition



Plate 6b: Screening of fenugreek genotypes against powdery mildew under natural field condition

Highly susceptible genotype recorded highest per cent increase in total sugars (34.76%) than compared to moderately resistant genotype (19.35%).

4.4.2 Reducing sugars

In coriander, the reducing sugar content was least in moderately resistant genotype than compared to highly susceptible genotype. The amount of reducing sugars in healthy leaves of highly susceptible genotype, DCC -24 (7.12 mg/g) was higher than compared to diseased leaves (5.86 mg/g). Similarly in moderately resistant genotype, DCC-46 the amount of reducing sugars in healthy leaves (3.12 mg/g) was higher than compared to diseased leaves (2.71 mg/g). Highly susceptible genotype recorded highest per cent reduction in reducing sugars (17.69%) than compared to moderately resistant genotype (13.14%).

In fenugreek, the reducing sugar content was least in moderately resistant genotype than compared to highly susceptible genotype. The amount of reducing sugars in healthy leaves of highly susceptible genotype, DFC-22 (9.84 mg/g) was higher than compared to diseased leaves (8.99 mg/g). Similarly in moderately resistant genotype, DFC-21 the amount of reducing sugars in healthy leaves (8.11 mg/g) was higher than compared to diseased leaves (6.00 mg/g). Highly susceptible genotype recorded least per cent reduction of reducing sugars (8.63%) than compared to moderately resistant genotype (26.01%).

4.4.3 Non-Reducing sugars

In coriander, the non-reducing sugar content was least in moderately resistant genotype than compared to highly susceptible genotype. The amount of non-reducing sugars in healthy leaves of highly susceptible genotype, DCC -24 (6.21 mg/g) was least than compared to diseased leaves (12.24 mg/g). Similarly in moderately resistant genotype, DCC-46 the amount of non-reducing sugars in healthy leaves (4.81 mg/g) was least than compared to diseased leaves (7.41 mg/g). Highly susceptible genotype recorded highest per cent increase in non-reducing sugars (97.10%) than moderately resistant genotype (54.05%).

In fenugreek, the non-reducing sugar content was least in moderately resistant genotype than compared to highly susceptible genotype. The amount of non-reducing sugars in healthy leaves of highly susceptible genotype, DFC-22 (6.24 mg/g) was least than compared to diseased leaves (11.68 mg/g). Similarly in moderately resistant genotype, DFC-21 the amount of non-reducing sugars in healthy leaves (5.22 mg/g) was least than compared to diseased leaves (9.91 mg/g). Highly susceptible genotype recorded 87.17% and moderately resistant genotype recorded 89.84% increase in non-reducing sugars.

4.4.4 Total Phenols

Plant tissue responds to injury with the production of chemical substances which includes mostly phenols and phytoalexins. Study was undertaken to know the accumulation of phenols in coriander and fenugreek genotypes in powdery mildew infected leaves. The level of total phenols was analyzed in both healthy and diseased leaves in resistant and susceptible genotypes and results are presented in the Table 3, 4, Fig. 4 and 5.

In coriander, the total phenol content was higher in moderately resistant genotype than compared to highly susceptible genotype. Initially, the healthy leaves of susceptible genotype (DCC -24) recorded 4.60 mg/g of total phenols and it was increased to 5.53 mg/g after infection by *E. polygoni*. Whereas, healthy leaves of resistant genotype DCC-46 recorded 6.93 mg/g of total phenols and it was increased to 8.67 mg/g in diseased leaves. It indicates enhanced phenol production in response to infection. The per cent increase in phenol content was highest in resistant genotype (25.10%) than compared to susceptible genotype (20.21%).

In fenugreek, the total phenol content was higher in moderately resistant genotype than compared to highly susceptible genotype. Initially, the healthy leaves of susceptible genotype (DFC-22) recorded 7.11 mg/g of total phenols and it was increased to 8.99 mg/g after infection by *E. polygoni*. Whereas, healthy leaves of resistant genotype DFC-21 had 9.00 mg/g of total phenols and it was increased to 12.36 mg/g in diseased leaves. Indicating enhanced phenol production in response to infection. The

per cent increase in phenol content was highest in resistant genotype (37.33%) than susceptible genotype (26.44 %).

4.5 *In-vitro* evaluation of different fungicides, botanicals, bio agents and organics against powdery mildew

4.5.1 *In vitro* evaluation of fungicides against *Erysiphe polygoni*

Among the fungicides evaluated, Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05 % recorded highest reduction of spore germination (83.34%) and it was followed by Hexaconazole 5 EC @ 0.1% (80.00%), Azoxystrobin 250% SC @ 0.1% (77.78%), Difenconazole 25% EC @ 0.05% (75.56%) and Carbendazim 50% WP @ 0.1% (75.56%). Least reduction of spore germination was recorded with Wettable sulphur 80% WP @ 0.3% (72.23%) and Dinocap 48% EC (70.01%). The data on the results are tabulated and presented in the Table 5 and Fig. 6

4.5.2 *In vitro* evaluation of botanicals, bio agents and organics against *Erysiphe polygoni*

Among the 14 treatments evaluated, Neemazol (10,000 ppm) @ 0.2% recorded highest reduction of spore germination (72.23%) and it was followed by NSKE @ 5% (71.11%), Arka microbial consortia @ 1% (66.67%), *Pseudomonas fluorescens* @ 1% (65.56%), *Trichoderma harzianum* @ 1% (63.34%), *Bacillus subtilis* @ 1% (63.34%), Garlic bulb extract @ 5% (63.34%), Butter milk @ 10% + Panchagavya @ 5% (61.12%), Butter milk @ 10% + Cow urine @ 5% (60.01%). Least reduction of spore germination was recorded with Butter milk @ 10% (58.90%), Panchagavya @ 5% (57.79%), Ajwain seed extract @ 5% (55.57%) and Cow urine @ 5% (53.50%). The data on the results are tabulated and presented in the Table 6 and Fig. 7

4.6 Management of powdery mildew of coriander and fenugreek.

A Field experiment was conducted to find out the effective fungicides, botanicals, bio agents and organics for the management of powdery mildew of coriander and fenugreek during *Rabi* 2018 (Plate 7). Per cent Disease Index (Table 7 and 9) and

Table 3: Comparison of biochemical parameters of susceptible and resistant genotypes of coriander

Biochemical parameters		DCC -24 (Highly Susceptible)		Per cent increase	Per cent reduction	DCC -46 (Moderately Resistant)		Per cent increase	Per cent reduction
		Healthy leaves	Diseased leaves			Healthy leaves	Diseased leaves		
Phenols (mg/g)		4.60	5.53	20.21	-	6.93	8.67	25.10	-
Sugars (mg/g)	Total sugars	13.33	17.68	53.07	-	7.93	10.12	27.61	-
	Reducing sugars	7.12	5.86	-	17.69	3.12	2.71	-	13.14
	Non reducing sugars	6.21	12.24	97.10	-	4.81	7.41	54.05	-

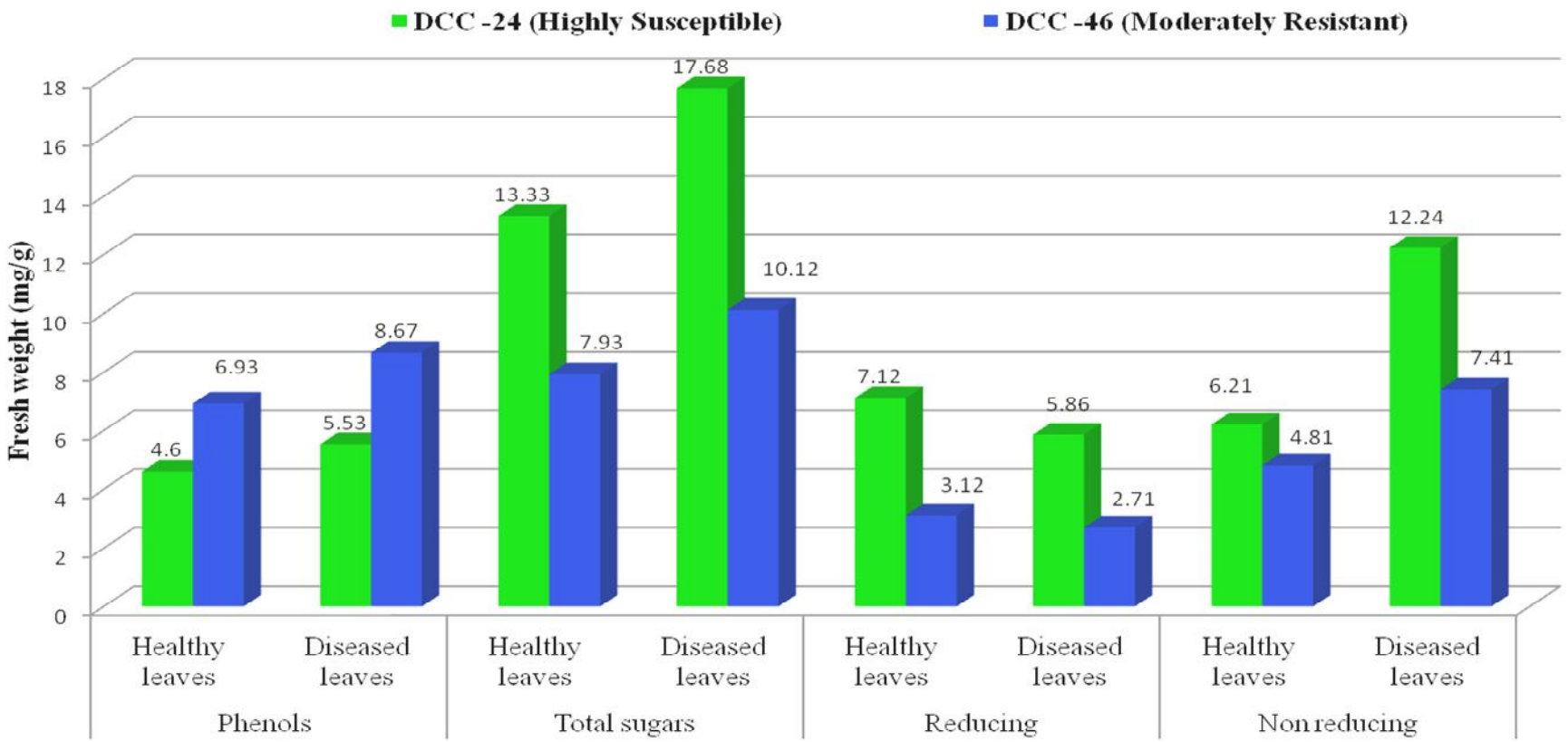


Fig. 2 Comparison of biochemical parameters in susceptible and resistant genotypes of coriander

Table 4: Comparison of biochemical parameters of susceptible and resistant genotypes of fenugreek

Biochemical parameters		DFC-22 (Highly Susceptible)		Per cent increase	Per cent reduction	DFC-21 (Moderately Resistant)		Per cent increase	Per cent reduction
		Healthy leaves	Diseased leaves			Healthy leaves	Diseased leaves		
Phenols (mg/g)		7.11	8.99	26.44	-	9.00	12.36	37.33	-
Sugars (mg/g)	**Total sugars**	16.08	21.67	34.76	-	13.33	15.91	19.35	-
	Reducing sugars	9.84	8.99	-	8.63	8.11	6.00	-	26.01
	Non reducing sugars	6.24	11.68	87.17	-	5.22	9.91	89.84	-

Table 5: *In vitro* evaluation of fungicides against *Erysiphe polygoni* DC

Sl. No.	Fungicides Details	Inhibition of Spore germination (%)	Increase in germination inhibition of spores over control (%)
1	Hexaconazole 5% EC @ 0.1%	80.00 (63.41)	85.84
2	Wettable sulphur 80% WP @ 0.3%	72.23 (58.18)	84.31
3	Azoxystrobin 250% SC @ 0.1%	77.78 (61.87)	85.43
4	Carbendazim 50% WP @ 0.1%	75.56 (60.36)	85.01
5	Dinocap 48% EC @ 0.2%	70.01 (56.77)	83.82
6	Difenconazole 25% EC @ 0.05%	75.56 (60.36)	85.01
7	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05%	83.34 (65.88)	86.41
8	Control	11.33 (19.61)	-
	C.D. at 1%	**2.02**	
	S. Em.±	**0.67**	

Figures in parenthesis are in angular transformed values

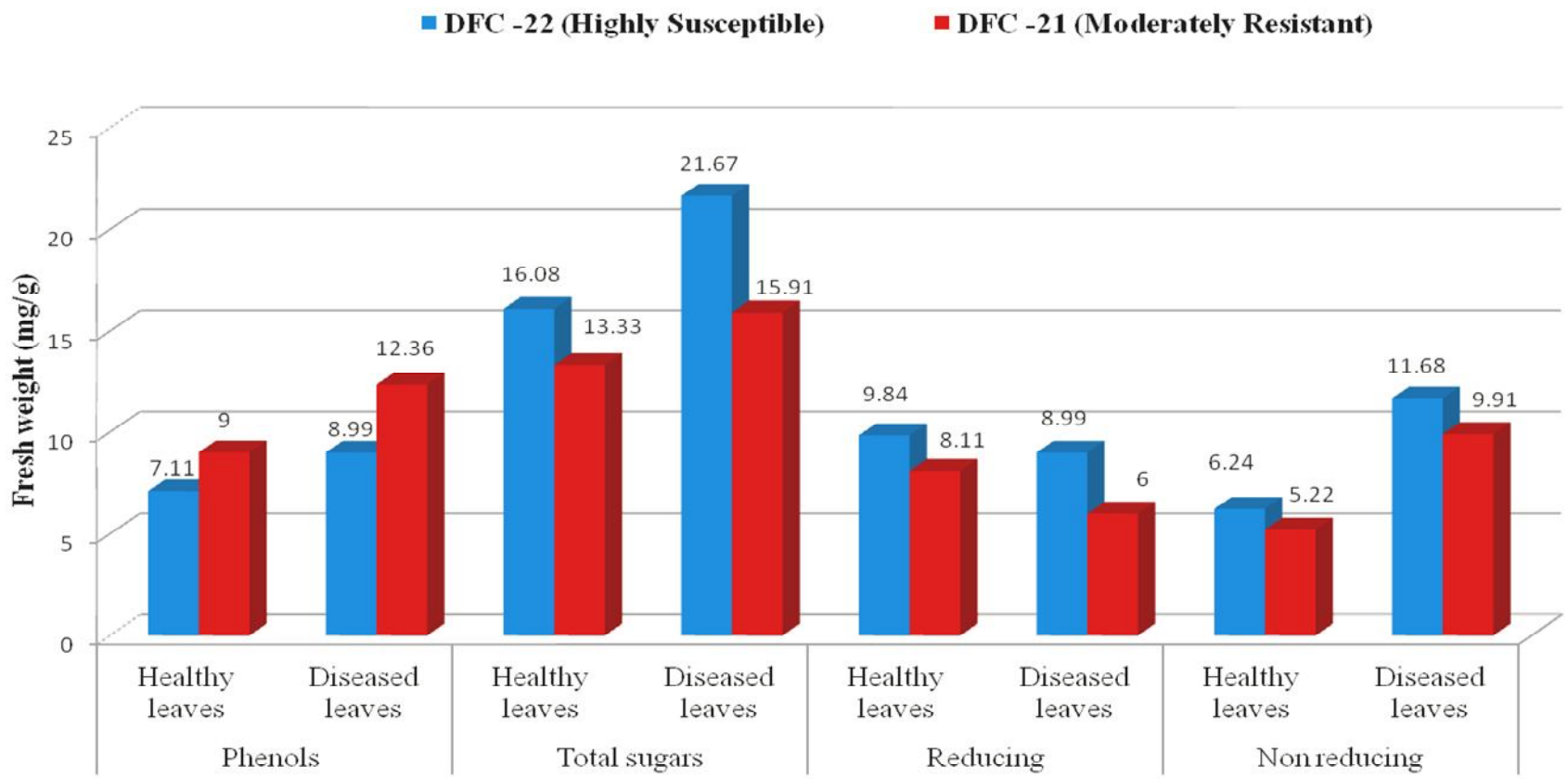


Fig. 3 Comparison of biochemical parameters in susceptible and resistant genotypes of fenugreek

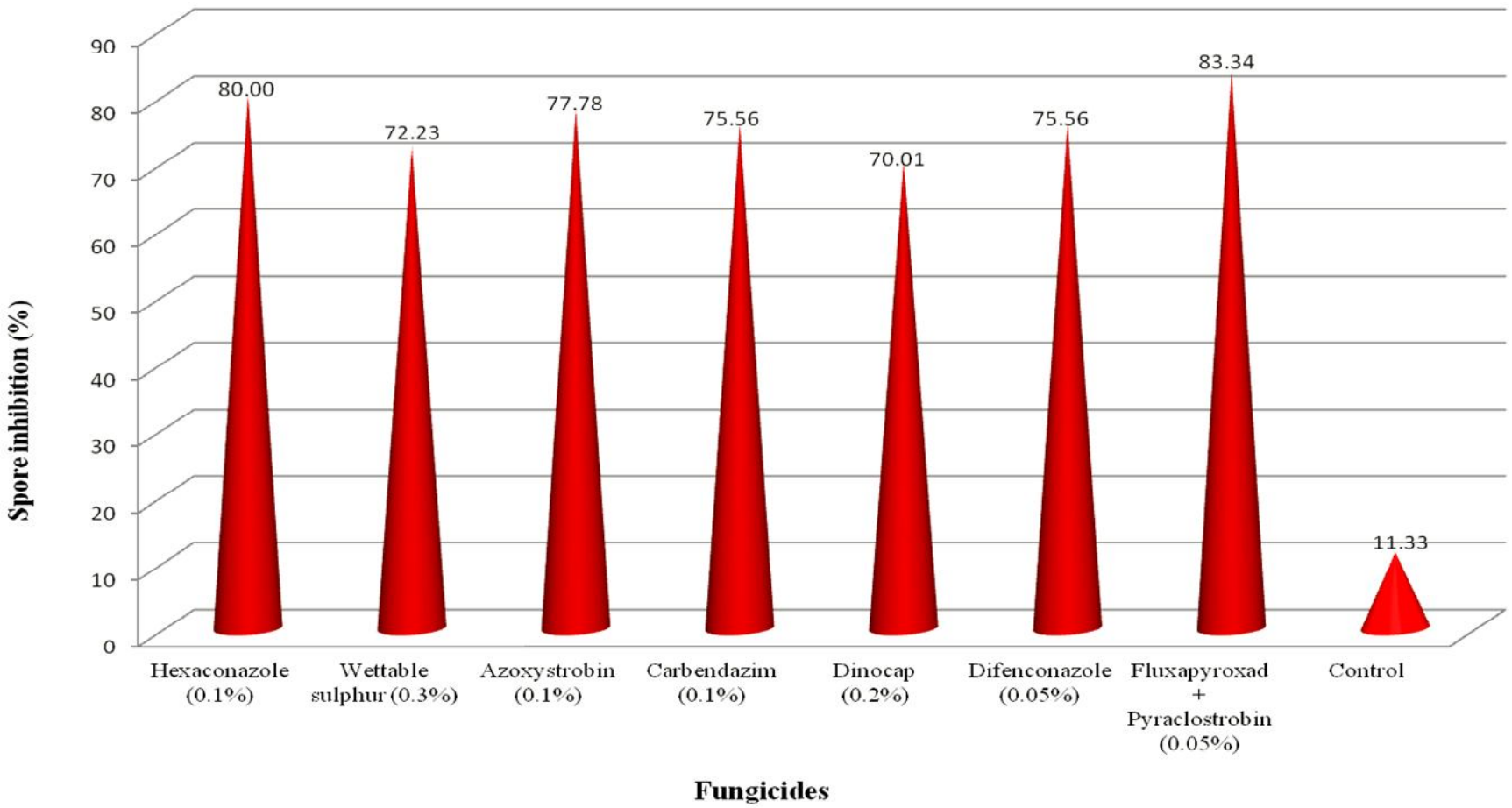


Fig. 4 Effect of different fungicides on spore inhibition (%)

Table 6: *In vitro* evaluation of botanicals, bio-agents and organics against *Erysiphe polygoni* DC

Sl. No.	Biocides	Spore inhibition (%)	Per cent increase in spore inhibition over control
1	Neemazol @ 0.2 %	72.23 (58.18)	84.31
2	NSKE @ 5.0 %	71.11 (57.47)	84.07
3	Ajwain Extract @ 5.0 %	55.57 (48.18)	79.61
4	Garlic extract @ 5.0 %	63.34 (52.72)	82.11
5	*Trichoderma harzianum* @ 1.0 %	63.34 (52.72)	82.11
6	*Pseudomonas fluorescens* @ 1.0 %	65.56 (54.05)	82.72
7	*Bacillus subtilis* @ 1.0 %	63.34 (52.72)	82.11
8	Arka microbial consortia @ 1.0 %	66.67 (54.72)	83.01
9	Butter milk @ 10.0 %	58.90 (50.11)	80.76
10	Cow urine @ 5.0 %	53.50 (46.99)	78.82
11	Panchagavya @ 5.0 %	57.79 (49.46)	80.39
12	Butter milk @ 10.0 % + Cow urine @ 5.0 %	60.01 (50.75)	81.12
13	Butter milk @ 5.0 % + Panchagavya @ 5.0 %	61.12 (51.41)	81.46
14	Control	11.33 (19.61)	
	C.D. at 1%	**1.65**	
	S. Em.±	**0.57**	

Figures in parenthesis are in angular transformed values

seed yield were recorded and the data on the results are tabulated and presented in Table 8, 10, Fig. 8 and 9.

Fungicides, botanicals, bio agents and organics which were found most efficient under *in vitro* studies were evaluated in the present study. All the 4 fungicides were found effective in reducing the severity of the disease and increased the seed yield compared to untreated check.

4.6.1 Management of powdery mildew of coriander by using fungicides

The disease severity before treatment imposition was relatively consistent on all the treatments and they were statistically on par with each other. However, treatments involving various chemicals differed significantly after the spray. Significantly highest severity of powdery mildew was recorded in untreated control of coriander, indicating sufficient disease pressure for drawing the conclusions.

In coriander, the severity of powdery mildew was found significantly least with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (15.00% PDI). It was followed by Hexaconazole 5% EC @ 0.1% (15.67% PDI) which was found on par with Azoxystrobin 250% SC @ 0.1% (16.00% PDI) and Difenconazole 25% EC @ 0.05% (17.33% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (60.67% PDI). Similarly, significantly highest seed yield was recorded with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (940 kg/ha). It was followed by Hexaconazole 5% EC @ 0.1% (853 kg/ha), Azoxystrobin 250% SC @ 0.1% (800 kg/ha) and Difenconazole 25% EC @ 0.05% (689 kg/ha). The untreated control recorded significantly least seed yield when compared to all the treatments (511 kg/ha).

4.6.2 Management of powdery mildew of fenugreek by using fungicides

In fenugreek, the severity of powdery mildew was found significantly least with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (17.33% PDI). It was followed by Hexaconazole 5% EC @ 0.1% (18.00% PDI), Azoxystrobin 250% SC @ 0.1% (18.67% PDI) and Difenconazole 25% EC @ 0.05% (19.33% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all

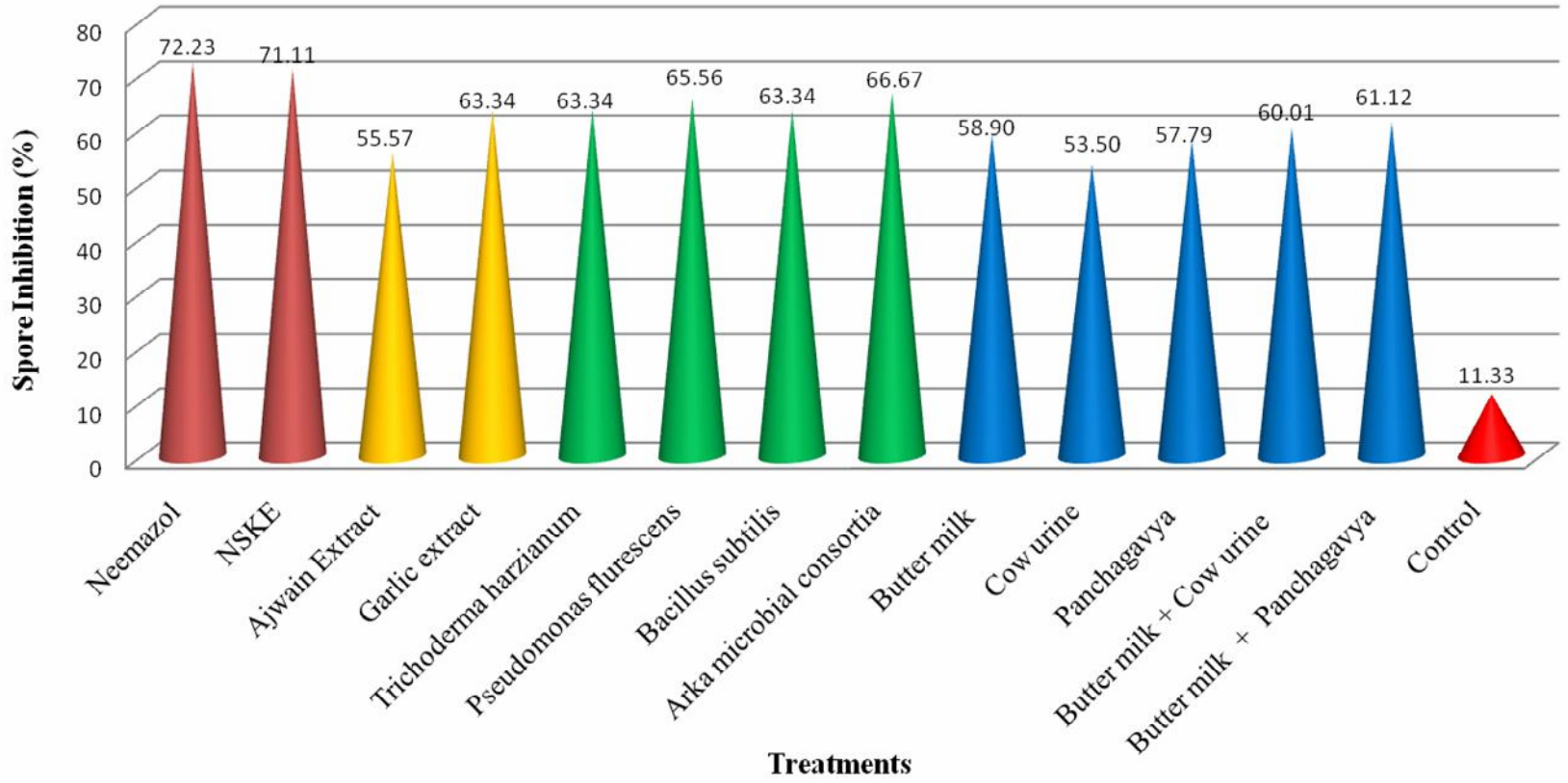


Fig. 5 Effect of different botanicals, bio agents and organics on spore inhibition (%)

the treatments (68.67% PDI). Similarly, significantly highest seed yield was recorded with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (1203 kg/ha). It was followed by Hexaconazole 5% EC @ 0.1% (1090 kg/ha), Azoxystrobin 250% SC @ 0.1% (1071 kg/ha) and Difenconazole 25% EC @ 0.05% (1047 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (848 kg/ha).

4.6.3 Management of powdery mildew of coriander by using botanicals

In coriander, the severity of powdery mildew was found significantly least with Neemazol (10,000 ppm) @ 0.2% (18.00% PDI). It was followed by Garlic bulb extract @ 5% (19.33% PDI) and Ajwain seed extract @ 5% (24.33% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (60.67% PDI). Similarly, significantly highest seed yield was recorded with Neemazol (10,000 ppm) @ 0.2% (654 kg/ha). It was followed by Garlic bulb extract @ 5% (599 kg/ha) and Ajwain seed extract @ 5% (541 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (511 kg/ha).

4.6.4 Management of powdery mildew of fenugreek by using botanicals

In fenugreek, the severity of powdery mildew was found significantly least with Neemazol (10,000 ppm) @ 0.2% (20.33% PDI). It was followed by Garlic bulb extract @ 5% (22.33% PDI) and Ajwain seed extract @ 5% (27.00% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (68.67% PDI). Similarly, significantly highest seed yield was recorded with Neemazol (10,000 ppm) @ 0.2% (1023kg/ha). It was followed by Garlic bulb extract @ 5% (933 kg/ha) and Ajwain seed extract @ 5% (881 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (848 kg/ha).

4.6.5 Management of powdery mildew of coriander by using bio agents

In coriander, the severity of powdery mildew was found significantly least with Arka microbial consortia @ 1% (18.33% PDI). It was followed by *Pseudomonas*

fluorescens @ 1% (19.00% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (60.67% PDI). Similarly, significantly highest seed yield was recorded with Arka microbial consortia @ 1% (633 kg/ha). It was followed by *Pseudomonas fluorescens* @ 1% (616 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (511 kg/ha).

4.6.6 Management of powdery mildew of fenugreek by using bio agents

In fenugreek, the severity of powdery mildew was found significantly least with Arka microbial consortia @ 1% (20.67% PDI). It was followed by *Pseudomonas fluorescens* @ 1% (21.33% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (68.67% PDI). Similarly, significantly highest seed yield was recorded with Arka microbial consortia @ 1% (953 kg/ha). It was followed by *Pseudomonas fluorescens* @ 1% (942 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (848 kg/ha).

4.6.7 Management of powdery mildew of coriander by using organics

In coriander, the severity of powdery mildew was found significantly least with Butter milk @ 10% + Panchagavya @ 5% (20.00% PDI). It was followed by Butter milk @10% + Cow urine @ 5% (21.00% PDI), Butter milk @ 10% (22.33% PDI), Panchagavya @ 5% (23.00% PDI) and Cow urine @ 5% (25.67% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (60.67% PDI). Similarly, significantly highest seed yield was recorded with Butter milk @ 10% + Panchagavya @ 5% (587 kg/ha) and it was found on par with Butter milk @10% + Cow urine @ 5% (575 kg/ha). It was followed by Butter milk @ 10% (570 kg/ha), Panchagavya @ 5% (559 kg/ha) and Cow urine @ 5% (531 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (511 kg/ha).

4.6.8 Management of powdery mildew of fenugreek by using organics

In fenugreek, the severity of powdery mildew was found significantly least with Butter milk @ 10% + Panchagavya @ 5% (23.00% PDI). It was followed by Butter



Plate 7a: Management studies on coriander powdery mildew



Plate 7b: Management studies on fenugreek powdery mildew

milk @10% + Cow urine @ 5% (24.00% PDI), Butter milk @ 10% (24.67% PDI), Panchagavya @ 5% (25.67% PDI) and Cow urine @ 5% (28.00% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (68.67% PDI). Similarly, significantly highest seed yield was recorded with Butter milk @ 10% + Panchagavya @ 5% (941 kg/ha). It was followed by Butter milk @10% + Cow urine @ 5% (923 kg/ha), Butter milk @ 10% (905 kg/ha), Panchagavya @ 5% (891 kg/ha) and Cow urine @ 5% (864 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (848 kg/ha).

4.6.9 Influence of treatments on total monetary returns

In coriander, highest yield was observed in Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (940 kg/ha) with cost benefit ratio 2.87 which was followed by Hexaconazole 5% EC @ 0.1% (853 kg/ha, B:C 2.83), Azoxystrobin 250% SC @ 0.1% (800 kg/ha, B:C 2.51) and Difenconazole 25% EC @ 0.05% (689 kg/ha, B:C 2.23), whereas lowest yield (511 kg/ha) was observed in control.

In fenugreek, highest yield was observed in Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (1203 kg/ha, B:C 3.66) which was followed by Hexaconazole 5% EC @ 0.1% (1090 kg/ha, B:C 3.62), Azoxystrobin 250% SC @ 0.1% (1071 kg/ha, B:C 3.40) and Difenconazole 25% EC @ 0.05% (1047 kg/ha, B:C 3.36). whereas lowest yield (848 kg/ha) was observed in control.

Table 7: Management of powdery mildew of coriander (DCC-46) using different fungicides, botanicals, bio-agents and organics during *Rabi* 2018

Sl. No.	Treatment	PDI Before Spray	PDI After Spray	
			10 days after 1st spray	10 days after 2nd spray
T_1	Hexaconazole 5% EC @ 0.1%	10.33 (18.74)	13.67 (21.69)	15.67 (23.31)
T_2	Azoxystrobin 250% SC @ 0.1%	10.00 (18.43)	14.33 (22.24)	16.00 (23.57)
T_3	Difenconazole 25% EC @ 0.05%	10.67 (19.05)	15.33 (23.04)	17.33 (24.59)
T_4	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05%	10.67 (19.05)	13.00 (21.13)	15.00 (22.78)
T_5	Neemazol @ 0.2 %	11.00 (19.35)	15.67 (23.31)	18.00 (25.09)
T_6	Ajwain Extract @ 5.0 %	11.00 (19.36)	22.33 (28.19)	24.33 (29.54)
T_7	Garlic extract @ 5.0 %	10.67 (19.05)	17.67 (24.84)	19.33 (26.07)
T_8	*Pseudomonas flurescens* @ 1%	11.00 (19.36)	17.00 (24.34)	19.00 (25.83)
T_9	Arka microbial consortia @ 1%	11.33 (19.66)	16.67 (24.08)	18.33 (25.34)
T_{10}	Butter milk @ 10%	11.33 (19.66)	20.00 (26.55)	22.33 (28.19)
T_{11}	Cow urine @ 5%	11.33 (19.66)	23.33 (28.87)	25.67 (30.43)
T_{12}	Panchagavya @ 5%	11.33 (19.66)	21.00 (27.26)	23.00 (28.65)
T_{13}	Butter milk (10%) + Cow urine (5%)	10.67 (19.05)	19.33 (26.07)	21.00 (27.26)
T_{14}	Butter milk (10%) + Panchagavya (5%)	11.33 (19.66)	19.00 (25.83)	20.00 (26.55)
T_{15}	Control	11.00 (19.36)	25.67 (30.43)	60.67 (51.14)
	C.D. at 5%	**NS**	**0.56**	**0.40**
	S. Em.±	**NS**	**0.19**	**0.14**

Figures in parenthesis are in angular transformed values

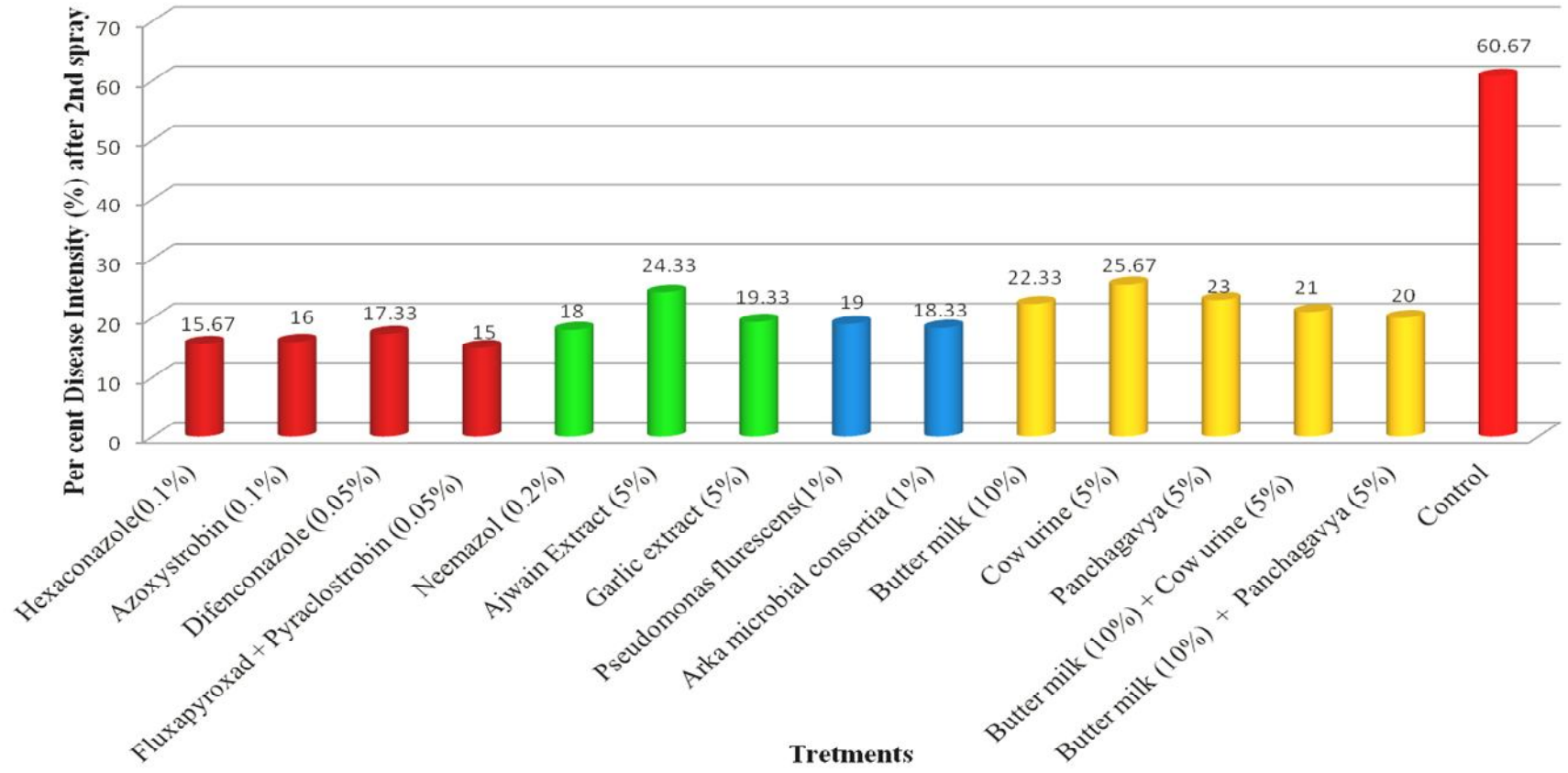


Fig. 6 Management of powdery mildew of coriander

Table 8: Effect of fungicides, botanicals, bio-agents and organics on seed yield of coriander (DCC-46) and its economic analysis during *Rabi* 2018

Sl. No.	Treatment	Yield kg/ha	Cost of Cultivation (Rs/ha)	Cost of protection (Rs/ha)	Total cost (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
T_1	Hexaconazole 5% EC @ 0.1%	853	35720	400	36120	102360	66240	2.83
T_2	Azoxystrobin 250% SC @ 0.1%	800	35720	2520	38240	96000	57760	2.51
T_3	Difenconazole 25% EC @ 0.05%	689	35720	1280	37000	82680	45680	2.23
T_4	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500SC @ 0.05%	940	35720	3600	39320	112800	73480	2.87
T_5	Neemazol @ 0.2 %	654	35720	1460	37180	78480	41300	2.11
T_6	Ajwain Extract @ 5.0 %	541	35720	900	36620	64920	28300	1.78
T_7	Garlic extract @ 5.0 %	599	35720	200	35920	71880	35960	2.00
T_8	*Pseudomonas flurescens* @ 1%	616	35720	640	36360	73920	37560	2.03
T_9	Arka microbial consortia @ 1%	633	35720	640	36360	75960	39600	2.09
T_{10}	Butter milk @ 10%	570	35720	640	36360	68400	32040	1.88
T_{11}	Cow urine @ 5%	531	35720	0.00	35720	63720	28000	1.77
T_{12}	Panchagavya @ 5%	559	35720	1200	36920	67080	30160	1.82
T_{13}	Butter milk (10%) + Cow urine (5%)	587	35720	640	36360	70440	32880	1.88
T_{14}	Butter milk (10%) + Panchagavya (5%)	575	35720	1840	37560	69000	32640	1.90
T_{15}	Control	511	35720	0.00	35720	61320	25600	1.72
	C.D. at 5%	**14.15**						
	S. Em.±	**4.88**						

Average market price: Rs 120/ kg seed
Net return = Gross return – Total cost

Gross return = Yield * Market price
B: C ratio = Gross return/ Total cost

Table 9: Management of powdery mildew of fenugreek (DFC-21) using different fungicides, botanicals, bio-agents and organics during *Rabi* 2018

Sl. No.	Treatment	Before Spray (PDI)	After Spray (PDI)	
			10 days after 1st spray	10 days after 2nd spray
T_1	Hexaconazole 5% EC @ 0.1%	10.00 (18.43)	15.00 (22.78)	18.00 (25.09)
T_2	Azoxystrobin 250% SC @ 0.1%	10.33 (18.74)	15.33 (23.04)	18.67 (25.59)
T_3	Difenconazole 25% EC @ 0.05%	11.00 (19.35)	16.00 (23.57)	19.33 (26.07)
T_4	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC@ 0.05%	11.00 (19.35)	14.67 (22.51)	17.33 (24.59)
T_5	Neemazol @ 0.2 %	11.00 (19.35)	16.33 (23.83)	20.33 (26.79)
T_6	Ajwain Extract @ 5.0 %	11.33 (19.66)	22.00 (27.96)	27.00 (31.29)
T_7	Garlic extract @ 5.0 %	11.00 (19.36)	18.00 (25.09)	22.33 (28.19)
T_8	*Pseudomonas flurescens* @ 1%	10.67 (19.05)	17.00 (24.34)	21.33 (27.50)
T_9	Arka microbial consortia @ 1%	11.00 (19.35)	16.67 (24.08)	20.67 (27.03)
T_{10}	Butter milk @ 10%	11.00 (19.35)	20.00 (26.55)	24.67 (29.77)
T_{11}	Cow urine @ 5%	10.67 (19.05)	23.00 (28.65)	28.00 (31.94)
T_{12}	Panchagavya @ 5%	11.67 (19.96)	21.00 (27.26)	25.67 (30.43)
T_{13}	Butter milk (10%) + Cow urine (5%)	10.67 (19.05)	19.67 (26.31)	24.00 (29.32)
T_{14}	Butter milk (10%) + Panchagavya (5%)	11.33 (19.66)	18.67 (25.59)	23.00 (28.65)
T_{15}	Control	11.33 (19.66)	31.33 (34.03)	68.67 (55.94)
	C.D. at 5%	**NS**	**0.53**	**0.44**
	S. Em.±	**NS**	**0.18**	**0.15**

Figures in parenthesis are in angular transformed values

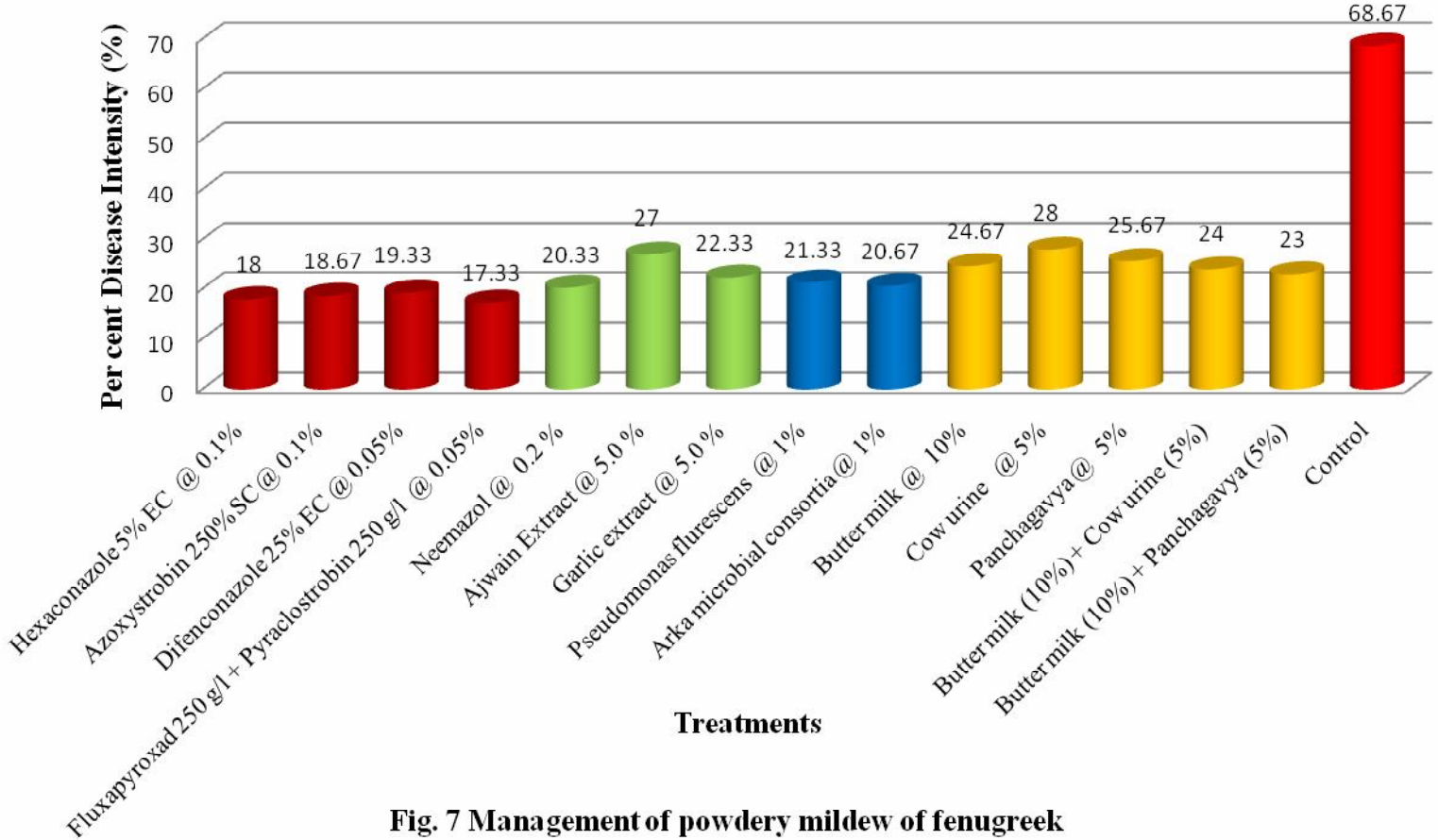


Fig. 7 Management of powdery mildew of fenugreek

Table 10: Effect of fungicides, botanicals, bio-agents and organics on seed yield of fenugreek (DFC-21) and its economic analysis during *Rabi* 2018

Sl. No.	Treatment	Yield kg/ha	Cost of Cultivation (Rs/ha)	Cost of fungicides (Rs/ha)	Total cost (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
T_1	Hexaconazole 5% EC @ 0.1%	1090	35720	400	36120	130800	94680	3.62
T_2	Azoxystrobin 250% SC @ 0.1%	1071	35720	2520	38240	128520	90280	3.40
T_3	Difenconazole 25% EC @ 0.05%	1047	35720	1280	37000	125640	88640	3.36
T_4	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05%	1203	35720	3600	39320	144000	104680	3.66
T_5	Neemazol @ 0.2 %	1023	35720	1460	37180	122760	85580	3.30
T_6	Ajwain Extract @ 5.0 %	881	35720	900	36620	105600	68980	2.89
T_7	Garlic extract @ 5.0 %	933	35720	200	35920	111600	75680	3.11
T_8	*Pseudomonas flurescens* @ 1%	942	35720	640	36360	112800	76440	3.10
T_9	Arka microbial consortia @ 1%	953	35720	640	36360	114000	77640	3.14
T_{10}	Butter milk @ 10%	901	35720	640	36360	108000	71640	2.97
T_{11}	Cow urine @ 5%	864	35720	0.00	35720	103200	67480	2.88
T_{12}	Panchagavya @ 5%	891	35720	1200	36920	106800	69880	2.89
T_{13}	Butter milk (10%) + Cow urine (5%)	941	35720	640	36360	112800	75240	3.00
T_{14}	Butter milk (10%) + Panchagavya (5%)	923	35720	1840	37560	110400	74040	3.04
T_{15}	Control	848	35720	0.00	35720	101760	66040	2.85
	C.D. at 5%	**12.15**						
	S. Em.±	**4.19**						

Average market price: Rs 120/ kg seed
Net return = Gross return – Total cost

Gross return = Yield x Market price
B: C ratio = Gross return/ Total cost

5. DISCUSSION

Coriander and fenugreek are the important seed spices grown in different parts of the country. The yield potential of these crops is affected by a number of plant pathogens. Among them, powdery mildew caused by *Erysiphe polygoni* DC is one of the economically important diseases. The disease spreads in epiphytotic proportions in areas where the coriander and fenugreek are grown regularly and it is more conspicuous during last few years. Hence, attempts have been made to identify the resistant genotypes for further breeding work and to work out the role of different biochemical parameters governing the resistance and present studies also involved management of the disease by using different fungicides, botanicals, bio-agent and organics. Hence, with the above objectives, the investigations were carried out at HREC, Devihosur, Haveri and the results obtained on these aspects are discussed here under.

5.1 Symptomatology

The initial symptoms first appeared on the bottom leaves of the plant. The spots were minute, small white powdery masses gradually grown on the upper surface of the leaves. White powdery spots of the disease further increased in number, enlarged and coalesced to form large spots, finally covering the entire leaf with dirty white fungal growth on surfaces. In later stage symptoms of the disease were noticed on middle leaves and then spread on all the aerial plant parts including leaves, stems and capsules. Symptoms included surface leaf necrosis, premature leaf fall, yellowing and chlorosis of the leaf at mature stage. Such severely infected leaves later dried and dropped off.

Similar symptoms of powdery mildew in coriander and fenugreek were earlier reported by Godara *et al.* (2010) that powdery mildew disease in fenugreek is characterized by white floury patches appear on both sides of leaves as well as tendril, stems, pods etc. As the plant become older, the powdery growth almost covers the entire plant, become more or less greyish brown and the infected part impart dirty appearance. Later stage, powdery growth also covers the pods. The seed in pods do not either set or remain very small. Bandela *et al.* (2014) reported that powdery mildew affected coriander plant produce small shrivelled seeds.

5.2 Pathogen

Based on microscopic observations it was confirmed that the coriander and fenugreek crop were infected by *Erysiphe polygoni* DC. Microphotograph of oidia/spore shows the morphology of conidia and conidiophore. It was observed that, the conidiophores were upright, hyaline, bearing conidia either single or in chain and conidia were hyaline, unicellular and barrel shape.

The present results are well supported by the reports of Basu *et al.* (2006) who reported that, the powdery mildew is most common and serious disease of fenugreek. The conidiophores of *Erysiphe polygoni* are simple, erect with conidia unicellular, ellipsoidal to cylindrical in shape and hyaline in colour. The conidia are ovate to barrel-shaped, unicellular hyaline. Gaetan and Madia (2004) studied the powdery mildew of Canola caused by *Erysiphe polygoni* DC and reported that, the mycelium, with multi lobed haustoria, white to grey, dense or fine, and in patches or covering the entire adaxial leaf surfaces. Appressoria were lobed and conidiophores were straight. Conidia were produced singly, cylindrical to ovoid.

5.3 Screening of coriander and fenugreek genotypes against powdery mildew

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

5.3.1 Screening of coriander genotypes under natural field condition

The results from this study revealed that, among 95 coriander genotypes screened, none of them were found to be immune and resistant. However, 19 genotypes were found to be moderately resistant, 71 genotypes were found to be susceptible and 5 genotypes were found to be highly susceptible.

The present results are well supported by the reports of Vaishnav (2017) who screened 13 genotypes of coriander against powdery mildew, none of them were found to immune and resistant. However, only one genotype was moderately resistant, 6 genotypes were found moderately susceptible, and 6 genotypes were highly susceptible. Bandela *et al.* (2014) screened the twenty 5 genotypes of coriander for resistance against powdery mildew disease. Among them 8 genotypes were susceptible and seventeen were highly susceptible and none of them showed immune, resistant or moderately resistant reaction. Singh and Rao (2016) screened 12 genotypes of coriander against powdery mildew. Out of 12 genotypes 4 lines of coriander were found susceptible to disease and remaining were moderately resistant.

5.3.2 Screening of fenugreek genotypes under natural field condition

The results from this study revealed that, among 26 fenugreek genotypes screened, none of them were found to be immune and resistant. However, 3 genotypes were found to be moderately resistant, 4 genotypes were found to be moderately susceptible, 14 genotypes were found to be susceptible and 5 genotypes were found to be highly susceptible.

The results from this study are in agreement with Dhondiram (2010) who screened 10 genotypes of fenugreek against powdery mildew, none of them were found to immune and resistant. However, 8 genotypes were found moderately resistant and 2 were moderately susceptible. Chovatiya and Dhruj (2010) screened 20 entries of fenugreek (*Trigonella foenum graecum*) against powdery mildew (*Erysiphe polygoni*) under natural epiphytotic conditions during *Rabi* 2007-08 and 2008-09. Of the 20 entries tested for two seasons, one entry showed highly resistant response, 4 entries showed resistant reaction 9 and 6 entries showed moderately susceptible and susceptible reaction, respectively.

Vikas and Ratnoo (2012) evaluated 20 lines of fenugreek for resistance to powdery mildew under field conditions. Most of the lines were observed moderately susceptible to susceptible. Kumawat (2015) revealed that the fenugreek germplasm entries, 2 were found resistant to powdery mildew, 9 were moderately resistant and 5 were susceptible and none of the fenugreek germplasm was found completely free from disease.

5.4 To study the biochemical parameters in relation to disease resistance

The common biochemical constituents like sugars and phenols are important in imparting resistance to the crop and plants against disease. Sometimes due to infection host plant is induced to synthesize these compounds. In the present study diseased leaves of moderately resistant and highly susceptible genotypes, were analysed for different biochemical parameters such as total sugars and phenols. An attempt has been made to find the role of some of the biochemical constituents present in coriander and fenugreek plants in imparting resistance against powdery mildew.

5.4.1 Total Sugars

Sugars are precursors and basic molecules for the synthesis of phenols, phytoalexins and form a skeleton for the synthesis of nucleic acids (Vidyasekaran, 1974). Sugars play important role in inhibition of pectiolytic and cellulolytic enzymes which are essential for pathogenicity (Vidyasekaran, 1987). In general, infection by pathogen bring about changes in respiratory pathway and photosynthesis, which are important vital processes taking place inside the plant leading to wide fluctuations in sugar content in plant system (Farkar and Kiraly, 1962; Klement and Goodman, 1967).

In the present study, the total sugar content in resistant genotypes was lower than compared to susceptible genotype before and after infection, in both coriander and fenugreek. However, the total sugar content has increased in leaves after infection in both resistant and susceptible genotypes.

The present results are well supported by the reports of Singh and Saksena (1983) who reported that pea varieties resistant to powdery mildew containing less of total sugars than susceptible varieties. Parashar and Sindhan (1986) reported that powdery mildew resistant pea varieties had low concentration of total sugars than susceptible varieties. Awad (2000) reported positive correlation between susceptibility to powdery mildew and leaf sugar content most cucurbit varieties.

5.4.2 Reducing sugars

The concentration of the reducing sugars in both resistant and susceptible genotypes before infection was higher and it was reduced after infection. However, resistant coriander and fenugreek genotypes had low concentration of reducing sugars than the susceptible genotypes. The results from this study are in agreement with Baka and Aldesuquy (1992) who reported that decrease in reducing sugars in sqush affected by powdery mildew caused by *Spaerotheca fuliginea*. Parashar and Sindhan (1986) reported that powdery mildew resistant pea varieties had low concentration of reducing sugars than susceptible varieties.

5.4.3 Non-Reducing sugars

Non-reducing sugars in leaves were less before infection and it has increased after infection in both resistant and susceptible genotypes of coriander and fenugreek. However, resistant coriander and fenugreek genotypes had low concentration of reducing sugars than the susceptible genotypes. It indicates that non-reducing sugars showed negative correlation with degree of resistance in both coriander and fenugreek.

The results from this study are in agreement with Hattappa *et al.* (2003) who worked on pea and mulberry powdery mildew that concentration of non-reducing sugars was negatively correlated with degree of resistance. Gawande *et al.* (2002) carried out a biochemical study on non-reducing before and after powdery mildew (*E. polygoni*) infection in seven mungbean genotypes and revealed that, non-reducing sugars were negatively associated with disease resistance.

5.4.4 Phenols

One of the major biological properties of phenol compounds is antimicrobial activity and their main role in plants is to act as protective compounds against disease causing pathogens such as fungi, bacteria and viruses. High concentration of phenols (toxic level) causes an instant lethal action by a general tanning effect. If the concentration does not occur in toxic level the inhibition will be low and pathogens readily detoxify lower concentration of toxicant (Dasgupta, 1988).

The phenolic compounds, which are antibiotic in nature, have been found in all the plants investigated to date (Nicholson and Hammerschmidt, 1992). These compounds are toxic to certain fungi and bacteria (Kosuge, 1969) and their appearance was considered as part of an active defence response. These compounds were involved in resistance mechanism (Farkar and Kiraly, 1962) and their concentration was much higher in resistant genotypes than in susceptible ones at all the growth stages (Parashar and Sindhan, 1986, Kalia and Sharma, 1988, Rathi *et al.*, 1998).

In the present investigation, resistant coriander and fenugreek genotypes had higher concentration of phenols than that of susceptible genotypes. Further, there was an increase in phenol concentration in response to infection of *E. polygoni* DC both in resistant and susceptible coriander and fenugreek genotypes. However, in resistant genotype the per cent increase in phenol concentration was higher than compared to susceptible genotype. It indicates that phenols showed positive correlation with degree of resistance in both coriander and fenugreek.

The results of the present study are in accordance with findings of Awad (2000) who reported that leaf tissues of incompatible water melon contained higher levels of free and total phenols than those of susceptible varieties infected with powdery mildew. Bhattacharya *et al.* (2000) noticed higher phenol levels in resistant genotypes and healthy plants of susceptible cultivars in pea affected by powdery mildew caused by *Erysiphe pisi*.

Avtar *et al.* (2003) observed higher levels of total phenols in resistant genotypes than susceptible fenugreek genotypes before and after the appearance of powdery mildew (*E. polygoni*) in artificially inoculated and natural environments. Dinesh (2009) showed total phenols in initially healthy leaves of susceptible variety of Sunflower was increased after infection by *E. cichoracearum*. Divyajyothi (2012) recorded total phenol in healthy leaves of highly susceptible greengram genotype (shining mung) was increased after infection by *E. polygoni*.

5.5 *In vitro* evaluation of different fungicides, botanicals, bio agents and organics against powdery mildew

In vitro evaluation of the fungicides, botanicals, bio agents and organics provide information confirming their efficacy against specific pathogen and therefore, serve as a guide for field testing.

5.6.1 *In vitro* evaluation of fungicides against powdery mildew

Although chemical control by fungicides may have negative environmental effects and limitations but fungicides still constitute the predominate part of the control measures used against powdery mildew. Use of chemicals has become more popular in recent times because of their quick results, especially in absence of resistant varieties.

In the present study, *In vitro* evaluation of 7 fungicides was carried out with respect to inhibition of conidial germination of *E. polygoni* DC. Among the fungicides evaluated, Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05 % recorded highest reduction of spore germination (83.34%) and it was followed by Hexaconazole 5 EC @ 0.1% (80.00%), Azoxystrobin 250% SC @ 0.1% (77.78%), Difenconazole 25% EC @ 0.05% (75.56%) and Carbendazim 50% WP @ 0.1% (75.56%). Least reduction of spore germination was recorded with Wettable sulphur 80% WP @ 0.3% (72.23%) and Dinocap 48% EC (70.01%). Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05 %, a newer molecule, which was found to be the best treatment with respect to inhibition of conidial germination of *E. polygoni* DC.

The results of the present study are also in accordance with findings of Divyajyothi (2012) reported that the maximum reduction in conidial germination of *Erysiphe polygoni* in green gram powdery mildew was observed with Azoxystrobin 250% SC (93.16%) and followed by Hexaconazole 5% EC (86.59%), Difenconazole 25% EC (85.13%) and Myclobutanil 10% WP (84.78%). Channaveeresh and Kulkarni (2015) evaluated fungicides against powdery mildew of black gram caused by *Erysiphe polygoni* DC under *in vitro* conditions and reported that the Azoxystrobin at 0.1 per cent concentration inhibited maximum conidial germination and it was followed by Hexaconazole.

Vikas and Ratnoo (2011), evaluated 7 fungicides under *in vitro* condition against pea powdery mildew, amongst the fungicides Dinocap and sulphur dust were found most effective for spore inhibition at concentrations 500 ppm followed by 250 and 100 ppm. Maximum spore inhibition obtained by Dinocap and Suphur at 500 ppm concentration followed by Sulphur, Carbedazim and Penconazole. Patel *et al.* (1992) who reported that among the non-systemic fungicides Sulphur at 0.3% gave comparatively high conidial germination inhibition followed by Dinocap at 0.2% while working with powdery mildew of mustard.

5.6 *In-vitro* evaluation of different botanicals, bio agents and organics against powdery mildew

Now a day, use of plant extracts, bio agents and organics in managing the disease has gaining importance because of their eco-friendly nature and low cost. The concept of organic farming and eco-friendly management encouraged the plant protection specialists to go for the use of plant extracts, bio agents and organics for the management of pest and diseases. Recently use of fertilizers and chemicals has been discouraged to avoid the pollution of air, water and soil.

In the present study, *In vitro* evaluation of 14 treatments including plant extracts, bio agents and organics was carried out with respect to inhibition of conidial germination of *E. polygoni* DC. Among them, Neemazol (10,000 ppm) @ 0.2% recorded highest reduction of spore germination and it was followed by NSKE @ 5%, Arka microbial consortia @ 1%, *Pseudomonas fluorescens* @ 1%, *Trichoderma harzianum* @ 1%, *Bacillus subtilis* @ 1% , Garlic bulb extract @ 5%, Butter milk @ 10% + Panchagavya @ 5%, Butter milk @ 10% + Cow urine @ 5%. Least reduction of spore germination was recorded with Butter milk @ 10%, Panchagavya @ 5%, Ajwain seed extract @ 5% and Cow urine @ 5%.

The results of the present study are also in accordance with findings of Maurya *et al.* (2004) who observed that extracts of *Azadirachta indica* from bark inhibit more than 80% of germination of *Erysiphe pisi*. Dinesh *et al.* (2011) reported that organics, Azadirachtin (0.5%) and NSKE (5%) were found most effective in inhibiting conidial germination of powdery mildew of sunflower.

Vikas and Ratnoo (2011), evaluated phyto-extracts against powdery mildew of pea and reported that the minimum conidial germination was recorded by Azadirachtin (40.70%). Divyajyothi (2012) reported Azadirachtin 0.15% recorded maximum conidial inhibition of 46.66% and Azadirachtin 0.03% EC (44.52%) and Azadirachtin 1500ppm (40.57%) against green gram powdery mildew caused by *Erysiphe polygoni*.

Channaveeresh and Kulkarni (2015), evaluated botanicals against powdery mildew of black gram caused by *Erysiphe polygoni* DC under *in vitro* conditions and reported that the maximum of 79.93% conidial inhibition was observed with Azadirachtin (1500ppm) followed by NSKE @ 5% (76.64%).

Patil *et al.* (2017) reported cow urine and butter milk were found most effective in inhibiting conidial germination of powdery mildew of garden pea. Sudha and Lakshmanan (2007) observed maximum reduction in conidial germination of causal agent of chilli powdery mildew (*Leveillula taurica*) by the culture filtrates of the *Trichoderma viridae*, *T. harzianum* and *Pseudomonas fluorescens* under *in vitro* condition.

Rakhonde *et al.* (2011), conducted experiments to assess the efficacy of different culture filtrates of bio agents against green gram powdery mildew caused by *Erysiphe polygoni* under *in vitro* conditions and reported that among all the tested culture filtrate of *Pseudomonas fluorescens* (63.93%) inhibited maximum conidial germination.

Channaveeresh and Kulkarni (2015) evaluated bio agents against powdery mildew of black gram caused by *Erysiphe polygoni* DC under *in vitro* conditions and reported that the among bio agents *Bacillus subtilis* (75.47%) inhibited maximum conidial germination and it was followed by *Pseudomonas fluorescens* (72.19%).

5.7 Management of powdery mildew of coriander and fenugreek

A Field experiment was conducted to find out the effective fungicides, botanicals, bio agents and organics against powdery mildew of coriander and fenugreek during *Rabi* 2018.

5.7.1 Management of powdery mildew of coriander and fenugreek by using fungicides

In coriander, the severity of powdery mildew was found significantly least with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (15.00% PDI). It was followed by Hexaconazole 5% EC @ 0.1% (15.67% PDI) which was found on par with Azoxystrobin 250% SC @ 0.1% (16.00% PDI) and Difenconazole 25% EC @ 0.05% (17.33% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (60.67% PDI). Similarly, significantly highest seed yield was recorded with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (940 kg/ha). It was followed by Hexaconazole 5% EC @ 0.1% (853 kg/ha), Azoxystrobin 250% SC @ 0.1% (800 kg/ha) and Difenconazole 25% EC @ 0.05% (689 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (511 kg/ha). Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05%, a newer molecule was found very effective against the powdery mildew of coriander.

In fenugreek, the severity of powdery mildew was found significantly least with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (17.33% PDI). It was followed by Hexaconazole 5% EC @ 0.1% (18.00% PDI), Azoxystrobin 250% SC @ 0.1% (18.67% PDI) and Difenconazole 25% EC @ 0.05% (19.33% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (68.67% PDI). Similarly, significantly highest seed yield was recorded with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% (1203 kg/ha). It was followed by Hexaconazole 5% EC @ 0.1% (1090 kg/ha), Azoxystrobin 250% SC @ 0.1% (1071 kg/ha) and Difenconazole 25% EC @ 0.05% (1047 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (848 kg/ha). Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05%, a newer molecule was found very effective against the powdery mildew of coriander.

The results of the present study are also in accordance with findings of Patel *et al.* (2017) who reported that Hexaconzole (0.05%), Wettable sulphur (0.30%), Dinocap (0.1%) and Penconazole (0.05%) were found highly effective for controlling the

powdery mildew of coriander with better seed yield. Singh and Banwasi (2012) reported that minimum powdery mildew severity (20.6%) and maximum yield (810kg/ha) was obtained with application of Carbendazim as soil drench and 0.1% spray, which was found on par with spray of 0.2% wettable sulphur in coriander. Akbari and Parakhia (2010) conducted studies on chemical control of coriander powdery mildew and reported that the minimum disease intensity of 23.97% was recorded with Difenconazole (0.025%) followed by Hexaconazole (0.05%). Singh (2006) reported Wettable sulphur and Hexaconazole in reducing the powdery disease severity and increased the yield of coriander.

The results of the present study are also in accordance with findings of Solanki (2004) who reported that Karathane (0.1%) was found most effective in reducing the fenugreek powdery mildew disease and increasing the seed yield. Akbari and Parakhia (2010) conducted studies on chemical control of coriander powdery mildew and reported that the minimum disease intensity of 23.97% was recorded with Difenconazole (0.025%) followed by Hexaconazole (0.05%). Singh (2006) reported Wettable sulphur and Hexaconazole in reducing the powdery disease severity and increased the yield of coriander.

5.7.2 Management of powdery mildew of coriander and fenugreek by using botanicals

In coriander, the severity of powdery mildew was found significantly least with Neemazol (10,000 ppm) @ 0.2% (18.00% PDI). It was followed by Garlic bulb extract @ 5% (19.33% PDI) and Ajwain seed extract @ 5% (24.33% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (60.67% PDI). Similarly, significantly highest seed yield was recorded with Neemazol (10,000 ppm) @ 0.2% (654 kg/ha). It was followed by Garlic bulb extract @ 5% (599 kg/ha) and Ajwain seed extract @ 5% (541 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (511 kg/ha).

In fenugreek, the severity of powdery mildew was found significantly least with Neemazol (10,000 ppm) @ 0.2% (20.33% PDI). It was followed by Garlic bulb extract @ 5% (22.33% PDI) and Ajwain seed extract @ 5% (27.00% PDI). The untreated

control recorded significantly highest severity of powdery mildew than compared to all the treatments (68.67% PDI). Similarly, significantly highest seed yield was recorded with Neemazol (10,000 ppm) @ 0.2% (1023kg/ha). It was followed by Garlic bulb extract @ 5% (933 kg/ha) and Ajwain seed extract @ 5% (881 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (848 kg/ha).

The results of the present study are also in accordance with findings of Singh (2008) who reported that among the botanicals *Azadirachta indica,* for the control of powdery mildew of coriander was significantly superior in reduction of disease severity and increase in grain yield over control. Chhata *et al.* (2010), reported that soil application of neem cake + seed treatment with *Trichoderma* @ 8 Kg/ha + foliar spray of neem formulation (*Azadirachtin*) was found effective for organic pest and disease management module for fenugreek. Powdery mildew was observed at minimum level *i.e.* 21.45 and 26.78% at 70 and 100 DAS, respectively.

Chhata *et al.* (2010) who reported that foliar spray of neem formulation (*Azadirachtin*) was found effective against fenugreek powdery mildew. Kachhot *et al.* (2011) studied powdery mildew of pea in field during *Rabi* season (2009-10) and reported that minimum disease severity with azadirachtin (0.3%) than other botanicals.

5.7.3 Management of powdery mildew of coriander and fenugreek by using bio-agents

In coriander, the severity of powdery mildew was found significantly least with Arka microbial consortia @ 1% (18.33% PDI). It was followed by *Pseudomonas fluorescens* @ 1% (19.00% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (60.67% PDI). Similarly, significantly highest seed yield was recorded with Arka microbial consortia @ 1% (633 kg/ha). It was followed by *Pseudomonas fluorescens* @ 1% (616 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (511 kg/ha).

In fenugreek, the severity of powdery mildew was found significantly least with Arka microbial consortia @ 1% (20.67% PDI). It was followed by *Pseudomonas*

fluorescens @ 1% (21.33% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (68.67% PDI). Similarly, significantly highest seed yield was recorded with Arka microbial consortia @ 1% (953 kg/ha). It was followed by *Pseudomonas fluorescens* @ 1% (942 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (848 kg/ha).

The results from the present study are also in accordance with findings of Nargund *et al.* (2012) reported that *Pseudomonas fluorescence* recorded minimum disease incidence (38.18%) in sunflower powdery mildew. Sudha and Lakshmanan (2007) reported *Pseudomonas fluorescence* (39.9%) was effective against chilli powdery mildew. The results from the present study are also in accordance with findings of Anand *et al.* (2009) opined that foliar application of *Pseudomonas fluorescence* was effective against cucumber powdery mildew.

5.7.4 Management of powdery mildew of coriander and fenugreek by using organics

In coriander, the severity of powdery mildew was found significantly least with Butter milk @ 10% + Panchagavya @ 5% (20.00% PDI). It was followed by Butter milk @10% + Cow urine @ 5% (21.00% PDI), Butter milk @ 10% (22.33% PDI), Panchagavya @ 5% (23.00% PDI) and Cow urine @ 5% (25.67% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments (60.67% PDI). Similarly, significantly highest seed yield was recorded with Butter milk @ 10% + Panchagavya @ 5% (587 kg/ha). It was followed by Butter milk @10% + Cow urine @ 5% (575 kg/ha), Butter milk @ 10% (570 kg/ha), Panchagavya @ 5% (559 kg/ha) and Cow urine @ 5% (531 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (511 kg/ha).

In fenugreek, the severity of powdery mildew was found significantly least with Butter milk @ 10% + Panchagavya @ 5% (23.00% PDI). It was followed by Butter milk @10% + Cow urine @ 5% (24.00% PDI), Butter milk @ 10% (24.67% PDI), Panchagavya @ 5% (25.67% PDI) and Cow urine @ 5% (28.00% PDI). The untreated control recorded significantly highest severity of powdery mildew than compared to all

the treatments (68.67% PDI). Similarly, significantly highest seed yield was recorded with Butter milk @ 10% + Panchagavya @ 5% (941 kg/ha). It was followed by Butter milk @10% + Cow urine @ 5% (923 kg/ha), Butter milk @ 10% (905 kg/ha), Panchagavya @ 5% (559 kg/ha) and Cow urine @ 5% (864 kg/ha). The untreated control recorded significantly least seed yield than compared to all the treatments (848 kg/ha).

The results from the present study are also in accordance with findings of Patil *et al*, (2017) who reported that cow urine and butter milk were found to be significantly superior over control in managing the powdery mildew disease of garden pea.

6. SUMMARY AND CONCLUSIONS

Coriander and fenugreek are the important seed spices grown in different parts of the country. The lower productivity is mainly because of the cultivation in marginal land and due to biotic and abiotic stresses. Coriander and fenugreek affected by certain diseases. Among them, powdery mildew is one of the economically important diseases as it causes considerable yield losses under favourable environmental condition.

Based on microscopic observations it was confirmed that the coriander and fenugreek crop were infected by *Erysiphe polygoni* DC. The conidiophores were upright, hyaline, bearing conidia either single or in chain and conidia were hyaline, unicellular and barrel shape.

Out of 95 coriander genotypes screened, none of them were found to be immune and resistant. However, 19 genotypes were moderately resistant. 71 genotypes were susceptible and 5 genotypes were highly susceptible. Similarly out of 26 fenugreek genotypes screened, none of them were found to be immune and resistant. However, 3 genotypes were moderately resistant, 4 genotypes were moderately susceptible, 14 genotypes were susceptible and 5 genotypes were highly susceptible.

Resistant coriander and fenugreek genotypes had higher concentration of phenols than that of susceptible genotypes. However, in resistant genotype the per cent increase in phenol concentration was higher than compared to susceptible genotype. It indicates that total phenol is positively correlation with degree of resistance in both coriander and fenugreek. The total sugar and non-reducing sugar in resistant genotypes both coriander and fenugreek was lower than compared to susceptible genotype before and after infection. However, the total sugar and non-reducing sugar content has increased in leaves after infection in both resistant and susceptible genotypes. However, resistant coriander and fenugreek genotypes had low concentration of reducing sugars than the susceptible genotypes. Reduction in reducing sugar was observed in both resistant and susceptible genotypes after infection.

Among the fungicides evaluated, Fluxapyroxad 250 g/l + pyraclostrobin 250 g/l 500 SC @ 0.05 per cent concentration inhibited maximum conidial germination and it was followed by hexaconazole 5% EC. Least inhibition of conidial germination was

observed with 0.2 per cent dinocap 48% EC, 0.3% wettable sulphur 80% WP, 0.1% carbendazim 50% WP, 0.05% difenconazole 25% EC and 0.1% azoxystrobin 250% SC.

Among the botanicals evaluated, 0.2% neemazol was found most effective in inhibiting conidial germination followed by 5% NSKE, 5% garlic bulb extract and 5% ajwain seed extract. Similarly, among the bio-agent evaluated, arka microbial consortia were found most effective in inhibiting conidial germination followed by *Pseudomonas fluorescens*. It was followed *Bacillus subtilis* and *Trichoderma harzianum*. Similarly, among the organic evaluated, maximum conidial inhibition was observed with butter milk @ 10% + panchagavya @ 5% followed by butter milk @ 10% + cow urine @ 5%, panchagavya @ 5% , butter milk @ 10% and cow urine @ 5%.

The severity of powdery mildew of coriander and fenugreek was found significantly least with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05%. It was followed by Hexaconazole 5% EC @ 0.1%, Azoxystrobin 250% SC @ 0.1% and Difenconazole 25% EC @ 0.05%. The untreated control recorded significantly highest severity of powdery mildew than compared to all the treatments. Similarly, significantly highest seed yield was recorded with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05%. It was followed by Hexaconazole 5% EC @ 0.1%, Azoxystrobin 250% SC @ 0.1% and Difenconazole 25% EC @ 0.05%.

The severity of powdery mildew of coriander and fenugreek was found significantly least with Neemazol (10,000 ppm) @ 0.2%. It was followed by Garlic bulb extract @ 5% and Ajwain seed extract @ 5%. Similarly, significantly highest seed yield was recorded with Neemazol (10,000 ppm) @ 0.2%. It was followed by Garlic bulb extract @ 5% and Ajwain seed extract @ 5%.

The severity of powdery mildew was found significantly least with Arka microbial consortia @ 1%. It was followed by *Pseudomonas fluorescens* @ 1%. Similarly, significantly highest seed yield was recorded with Arka microbial consortia @ 1%. It was followed by *Pseudomonas fluorescens* @ 1%.

The severity of powdery mildew was found significantly least with Butter milk @ 10% + Panchagavya @ 5%. It was followed by Butter milk @10% + Cow urine @ 5%, Butter milk @ 10%, Panchagavya @ 5% and Cow urine @ 5%. Similarly,

significantly highest seed yield was recorded with Butter milk @ 10% + Panchagavya @ 5% (587 kg/ha) and it was followed Butter milk @10% + Cow urine @ 5%, Butter milk @ 10%, Panchagavya @ 5% and Cow urine @ 5%.

Future line work

Further, detailed studies need to be conducted in the following areas which will be helpful to develop the schedule for the effective management of the disease by utilizing the present outcomes.

- Identification of multiple resistant sources against foliar diseases and their utilization in resistance breeding programme needs to be attended.
- Development of spray schedule based on disease prediction model
- Pesticide residual analysis
- Molecular characterization of *Erysiphe polygoni* DC and different isolates by designing specific primers

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Appendix I: Monthly meteorological data during crop growth period at HREC, Devihosur, Haveri during the year 2018-19.

Month	Temperature °C		Relative humidity (%)		Rain fall (mm)	
	Maximum	Minimum	Morning	Evening	mm	days
December	29.44	15.83	77.83	52.48	0	0
January	29.96	12.8	66.83	34.45	0	0
February	33.08	16.27	65.32	44.28	0	0
March	35.69	19.54	72.12	33.67	2.6	1
Mean	32.04	16.11	70.52	41.22	0.65	0.25

Source: Automatic weather station, HREC, Devihosur, Haveri.

Appendix II: Cost of cultivation for coriander and fenugreek crop per hectare as per the package of practice during the year 2018-19.

Sl. No.	Materials/Works	Total production cost (Rs/ha)
1.	Land preparation	3,000
2.	Seeds	2,880
3.	Machine power	2,500
4.	Human labour	10,000
5.	Bullock labour	500
6.	Manures and Fertilizers	3,200
7.	Irrigation	650
8.	Harvesting and cleaning	9,000
9.	Other expenses	4,000
	Total	**35,720**

STUDIES ON POWDERY MILDEW OF CORIANDER AND FENUGREEK

MUSTAKBEG M. JAMADAR 2019 Dr. ABDUL KAREEM M.
Major Advisor

ABSTRACT

The present research work on "Studies on powdery mildew of coriander and fenugreek" was carried out at Horticulture Research and Extension Centre, Devihosur, Haveri, UHS, Bagalkote, Karnataka, during the year 2018-19.

The symptoms of powdery mildew on coriander and fenugreek were more pronounced on the leaves as white floury patches appear on both sides of leaves as well as tendril, stems, pods (fenugreek) or umbels (coriander) and later become more or less greyish brown and the infected part impart dirty appearance. The seed in pods/umbels do not set or remain very small. Based on microscopic observations it was confirmed that the coriander and fenugreek crop were infected by *Erysiphe polygoni* DC and the conidiophores were upright, hyaline, bearing conidia either single or in chain and conidia were hyaline, unicellular and barrel shape.

Out of 95 coriander genotypes screened, none of them were found immune and resistant. However, 19 were moderately resistant, 71 were susceptible and 5 were highly susceptible. Similarly out of 26 fenugreek genotypes screened, none of them were found immune and resistant. However, 3 were moderately resistant, 4 were moderately susceptible, 14 were susceptible and 5 were highly susceptible.

Resistant coriander and fenugreek genotypes had higher concentration of phenols than that of susceptible genotypes. It indicates that total phenol is positively correlation with degree of resistance. The total sugar and non-reducing sugar in resistant genotypes lower than compared to susceptible genotypes before and after infection and vice versa with reducing sugars. It indicates that sugars are negatively correlation with degree of resistance.

In vitro and *In vivo* efficacy of fungicides, botanicals, bioagents and organics indicated that maximum spore inhibition and least PDI was observed with fluxapyroxad + pyraclostrobin followed by hexaconazole, azoxystrobin and difenconazole, neemazol and NSKE, arka microbial consortia and *Pseudomonas fluorescens,* maximum spore inhibition was observed with butter milk @ 10% + panchagavya @ 5% followed by butter milk @ 10% + cow urine @ 5%.

Results obtained in this study could be utilize for management of powdery mildew in coriander and fenugreek.

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