Studies on pearl millet blast [*Pyricularia grisea* (Cooke) Sacc.] with Special Reference to its Integrated Management.

THESIS

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In

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PLANT PATHOLOGY

By

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CERTIFICATE–I

This is to certify that the thesis entitled **"Studies on pearl millet blast [*Pyricularia grisea* (Cooke) Sacc.] with special reference to its integrated management.** *Submitted in partial fulfilment of the requirement for the degree of* **MASTER OF SCIENCE** in **PLANT PATHOLOGY** *of* **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya**, **Gwalior** *is a record of the bona-fied research work carried out by* **Mr. DEEPAK SINGH CHAUHAN (I.D. No. 18111801)** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

No part of the thesis has been submitted for any degree or diploma or has been published. All the assistance and help received during the course of the investigation has been acknowledged by the scholar.

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This is to certify that the thesis entitled **"Studies on pearl millet blast [*Pyricularia grisea* (Cooke) Sacc.] with special reference to its integrated management** *submitted by* **Mr. Deepak Singh Chauhan (18111801)** *to the* **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** *in partial fulfilment of the requirements for the degree of* **Master in Science** *in* **Plant Pathology** in **Department of Plant Pathology, College of Agriculture, Gwalior** *has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination on the same.*

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Deepak Singh Chauhan

CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF PLATE

LIST OF SYMBOL

Symbol	Abbreviation	Stand for
@		At the rate of
%		Per cent
±		Plus or minus
%		Percentage
^{0}C		Degree centigrade
µ		Micron
	µm	Micrometer
	Avg.	Average
	WP	Wettable powder
	W / W	Weight by weight
	spp.	Species
	Conc.	Concentration
	Ss	*Sclerotinia sclerotiorum*
	i.e.	That is
	viz.,	Namely
	et al.	Co- workers
	Fig.	Figure
	CD	Critical difference
	Cm	Centimeter
	Ha	Hectare
	Hrs	Hours
	Mt	Million tones
	Ml	Milliliter
	Mm	Millimeter
	G	Gram
	Mg	Milligram
	NS	Non significant
	SEm±	Standard error of mean
	Psi	Pound square inch
	Ppm	Parts per million
	Temp	Temperature

Chapter - I

INTRODUCTION

The pearl millet [*Pennisetumm glaucumm* (L.R.Br.) is an important grain and feed crop in India. It is also known as bajra. In Asia and Africa, pearl millet is primarily farmed as a staple food crop by the majority of poor and small landholders. It is used as cattle feed as well as fodder. Pearl millet has been genetically modified to grow in a variety of agro-climatic situations, including drought, low soil productivity, and high temperatures. After rice, wheat, and maize, pearl millet is India's fourth most extensively produced food crop. It covers 7.4 million hectares and produces 9.13 million tonnes per year on average, with a yield of 1237 kg/ha in 2017-18 (Anon, 2019). Rajasthan, Maharashtra, Gujarat, Haryana, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, and Karnataka are the most major pearl millet growing states, with over 90% of pearl millet land in the countryside and frequently planted during the Kharif (rainy) season**.** Madhya Pradesh has a land area of 0.29 million hectares, produces 0.69 million tonnes, and has a productivity of 2212 kg/ha (Anon. 2018).

Energy, carbohydrate, fat, ash, dietary fibers, iron, and zinc are all abundant in pearl millet. Fibre content is considerable (1.2g/100g). It's also high in vitamins like riboflavin, thiamine, and niacin, as well as minerals like phosphorus, magnesium, potassium, zinc, iron, manganese, and copper (2.3mg/100g). Pearl millet has a high fat content (5mg/100g) and is easier to digest. Because of its high protein content, high concentration of key amino acids, double the extract, and greater foul energy than maize, its grain has essentially served as a diet (Ejeta *et a*l., 1987; Davis *et al.,* 2003).

Downy mildew, blast, smut, rust, ergot, and other biotic limitations affect pearl millet, including pearl millet blast caused by *Pyricularia grisea*, which is a known disease in the country. The frequency of Pearl millet blast disease on commercial hybrids has escalated at an alarming rate in numerous Indian states. (Thakur *et.al*., 2009). The infection has recently been causing chronic yield reductions and has become a serious disease affecting pearl millet forage and grain. The disease was first detected in Kanpur, Uttar Pradesh, in India. Despite the fact that blast was once thought to be a minor pearl millet disease, its frequency has increased alarmingly in recent years. Several cereal crops, including rice, wheat, pearl millet, finger millet, and foxtail millet, as well as grasses, are infected by the blast pathogen. The pathogen is exceedingly changeable, but its host is highly specialized.

The pathogen is remarkably adaptable to its surroundings, yet certain strains have a narrow host range. *Pyricularia grisea* strains from pearl millet, on the other hand, do not contaminate rice (Mehta *et al.,* 1953). The fungus can infect plants at every stage of development, from seedling to adult, reducing grain yield and forage production in a wide range of quantities (Lukose *et al.,* 2007).

The management of the disease through resistant cultivars is the most cost-effective and important method of controlling pearl millet blast, especially for resource-poor and small-scale farmers who cannot afford to control the disease using chemicals and pesticides. The most effective way to control the disease is to use chemicals. The best strategy to combat yield losses caused by *Pyricularia grisea* is to employ resistant cultivars.

Since, substantial investigations on the rice blast patho-system, there is a need for a comprehensive understanding of the pathogen's biology (Sere *et. al*., 2007). With the pearl millet blast patho-systems, such research is limited (Sharma *et. al.,* 2013). Culture, chemical, and biological treatments, as well as the utilization of resistant cultivars, can all be used to combat the blast disease. As a result, the current investigations are being carried out with the following objectives:

1. To find out status of pearl millet blast in Morena, Bhind and Gwalior Districts of Madhya Pradesh.
2. To evaluate homeopathic drugs against *Pyricularia grisea* under *in vitro* condition.
3. To study the changes in sugar and phenol content in pearl millet leaves due to blast infection.
4. To screen pearl millet material against blast disease.
5. To evaluate popular pearl millet hybrid variety against blast.
6. To manage the pearl millet line through the application of bio-agents and chemicals.

Chapter – II

REVIEW OF LITERATURE

2.1 THE DISEASE

Pearl millet (*Pennisetum glaucam*) is known by numerous names in diverse languages: pearl, cattail or spiked millet, bulrush in English, bajra in Hindi, *mil a chandelles* in French and dukhn in Arabic. Pearl millet originated in Africa and was consequently introduced into India. Some investigators believe that millets were the first cultivated crops used for human food in prehistoric times. The crop is mainly grown for grain and stover in the earlier and driest areas of Africa and Asia where dry land crop production is possible. Pearl millet is mainly grown as food grain intended for 80 million individuals who live in the semi-arid tropical regions of Africa and the Indian sub-continent. Pearl millet grains have 28 to 31% of protein, high concentration of essential total amino acids and high gross energy than maize (Ejeta *et. al.*, 1987; Davis *et. al.*, 2003). In India, 70 % or more of the 9 million hectare of this crop is sown as single-cross hybrids that are predominantly susceptible to downy mildew and leaf spot disease.

Pyricularia leaf spot, also called as blast disease of pearl millet caused by *Pyricularia grisea* (perfect stage: *Magnaporthe grisea),* has become a severe hazard to pearl millet grain and fodder productivity. According to Mehta *et. al.*, (1953) pearl millet blast was first reported in India from Kanpur, Uttar Pradesh.

2.2 CAUSAL ORGANISM

The pathogen *Pyricularia grisea* (Cooke) Sacc. was recognized by Saccardo (1880) which was initially described from crabgrass. The "*Pyricularia*" refers to the pyriform nature of the conidia. Successively Cavara (1892) described *Pyricularia oryzae* Cav. from rice a species with related morphology to *Pyricularia grisea*. These two species are similar in morphology.

The fungus *Magnaporthe grisea* having 3-celled, pyriform macro conidia in the inadequate stage, kidney-shaped ascospores in the perfect stage (Barr, 1977; Hebert, 1971; Kato *et al.*, 1976). In 1994 Kato *et al.* (1994) found micro conidia in *Magnaporthe oryzae* culture on non-natural media. Morphological distinctive as of macro conidia, they were categorized through distinctive structures such as a single cell with no septum, small size (0.71 m broad and 0.61 m lengthy), lunate and hyaline.

Mycelium is airborne or immersed, transparent otherwise olivaceous, 1.4 – 5.1 um within breadth, septate branched, conidiophores one towards more, fasciculate, simple or infrequently branched, 2 – 4 septate, somewhat classify at septa; at first monosporic, then pleurogenous on sympodium, olivaceous to fuliginous, base swollen, dark coloured and becoming lighter coloured on the way to the head. Conidia uneven in shape and size, pyriform to obclavate, bottom is curved, top pointed, 2 – septate or slightly restricted at septa, approximately hyaline to pale olive, 15 – 42 X 5 – 12 um in dimension, frequently 18 – 22 x 8 – 10 um, with small appendages. Basal appendage 1.7-2.5 um (2um) in breadth; basal cell 4.8–10um (6.3 um), middle cell 4.8–12.8um, apical cell 4.7–10.8um. Hyphae transparent, rigid at septa, branched, 4–6um in width (Shirai, 1896; Nishikado, 1926)

SYSTEMATIC POSITION:

Kingdom	**:**	**Fungi**
Phylum	**:**	**Ascomycota**
Class	**:**	**Sordariomycetes**
Order	**:**	**Magnaporthales**
Family	**:**	**Magnaporthaceae**
Genus	**:**	**Pyricularia (Anamorph)**
		Magnaporthe (Teleomorph)
Species	**:**	**Grisea**

2.3 SYMPTOMS

The disease shows darkish, water-soaked lesions on leaves which expand and develop into necrotic, resulting in extension of chlorosis and early drying of young leaves. Depending on the confrontation level of the host, the lesion size varies from small, spherical, oval, to lengthened; measuring 1.1-2.1 mm to 22 mm. Lesions are frequently encircled by a chlorotic halo, which turn necrotic, found in the exterior of concentric rings. The lesions are usually restricted towards intervene spaces on the foliage. In case of a vulnerable cultivar, the whole plant gives a blistered appearance. Rigorously contaminated plants produce unfilled grains or few shrunken grains in blast florets. Blast on pearl millet was found to be negatively correlated with green-plot yield, also dry matter from dry stuff-crop (Wilson and Gates, 1993) therefore disturbing the yield and superiority of the crop (Thakur *et. al.*, 2011).

2.4 YIELD LOSSES

Pyricularia grisea, causing blast disease, is predominantly important in pearl millet cultivars. The pathogen *Magnaporthe grisea* is a universal infection accomplished of great pearl millet resultant in major yield production reduction. The blast disease affects all the growth stages of crop from seedlings to panicle causing blast of florets. The pathogen is extremely caustic and economically important and cause unceasing yield loss of grains (Timper *et al.*, 2002) and forage (Wilson and Gates, 1993). In India, the disease was reported to be a minor disease, but severe outbursts of Pyricularia blast have sporadically been reported in northern India (Williams and Andrews, 1983).

The disease becomes more rigorous during humid climate condition particularly with dense plant stand. The production and quality of the pearl millet crop is affected by Magnaporthe blast and have been negatively correlated with green grain yield, dry matter yield and digestive dry material (Wilson and Hanna, 1992). The blast yield loss estimation with reference to grain and fodder yield due to the prevalence and brutality of the Magnaporthe blast disease in pearl millet needs to be worked out.

2.5 *Pyricularia grisea* SPECIES COMPLEX

The ‘Pyricularia’ has pyriform nature of the fungus conidia. The type species ‘*Pyricularia grisea’* which originally was described from crab grass (*Digitaria sanguinalis* L.) was recognized by Saccardo (1880).

The genus *Pyricularia* is an important blast pathogen causing devastating blast disease in members of graminaceous family including rice, wheat, millets and many other hosts of grass species. Recently Choi *et al.* (2013) spotted that the members of *Pyricularia grisea* spp. compound causing bajra blast on a broad range of graminaceous cultivars, involve the cultivated rice and grass spp. In recent times, based on phylogenetic analysis as well as mating tests, isolates from grass were separated from the species complex and named *Magnaporthe grisea.* Blast was overwhelming endemic in 1919 at Tanjore delta of Tamil Nadu (Padmanabhan, 1965). *Magnaporthe grisea* (T.T. Herbert) Yaegashi and Udagawa (anamorph = *Pyricularia grisea* (Cooke) Sacc.) caused disease in >50 graminaceous species plus essential food crops such as rice (Tosa *et al.*, 2004).

Dagdas *et. al.,* (2012) have observed that the pathogen showed its pressure, to make a infection peg that breaches the rice leaf surface and noticed the particular group of proteins called septins helped infection of plants. Bussaban *et. al.,* (2005) indicated that molecular and genetic analyses of *Pyricularia* species isolated from different hosts are genetically distinct.

According to Uddin *et. al.,* (2003), *Magnaporthe grisea* is infectious to over 50 graminaceous hosts together with small grains, forage and turf grass with rice, wheat, pearl millet and finger millet. Pathogen is extremely changeable, but greatly specialized in their host variable.

2.6 DISEASE SURVEY

Central African countries namely Burkina Faso, Nigeria, Upper Volta, represent parts of the Africa which are reported to be centres of origin of pearl millet and also the blast pathogen (Wilson *et al.,* 1989). Centre of origin of host and the pathogen are also the source of resistance for the host as well as virulence of the pathogen and their co-evolution existence. Pearl millet spread to other countries like India, South East Asian countries, USA by subsequent traders. Along with the host, pathogens might have also spread to pearl millet growing countries of the world today. The pathogen *Magnaporthe grisea* infecting bajra has been reported from Tifton, Georgia (Wells *et al.,* 1965), Singapore (Buckley and Allen 1951) and India (Mehta *et al*., 1953).

Pearl millet blast is prevalent in bajra emergent states of India since 1970; its increased incidence has been observed recently in most pearl millet growing states like Gujarat, Madhya Pradesh, Uttar Pradesh, Delhi, Maharashtra, Rajasthan and Karnataka.

Wilson and Hanna (1992) provided some information on the lesion length, width and areas of infected pearl millet leaf and analyzed by the general linear model procedure.

The severity of pearl millet blast in northern Madhya Pradesh during 2005 and 2006 was in the range of 1-15 and 1-10 %, respectively (Anon., 2005, 2006).

Devda (2009) surveyed the pearl millet fields of Morena, Bhind and Gwalior and reported 5.5, 3.8 and 5.4 % severity of blast respectively.

Yadav *et.al.,* (2012) observed pearl millet blast as an important biotic constraint in northern Madhya Pradesh and reported that the average severity of blast in Morena, Bhind and Gwalior was 11.53, 13.40 and 11.28 percent respectively.

Naik (2013) carried out the survey during Kharif 2012 and noted that, the maximum infection was in Koppal district with the intensity of blast 76.1%, while least was in Bijapur (31.1%) district.

Field surveys carried out during Kharif 2014 revealed that blast and downy mildew continued to be the main diseases of pearl millet. The blast become more Vigorous in the states like Rajasthan (0-50%), Maharashtra (0-60%), Madhya Pradesh (2- 20%) as well as in Gujarat (0-15%). A field survey in Districts of Rajasthan like Jaipur, Churu, Bikaner, Nagaur and Sikar was conducted during Kharif 2014 to observe the incidence of various pearl millet diseases like blast, downy mildew, smut and ergot. The major diseases were observed at flowering to dough stages. Among the major pearl millet diseases the blast incidence was maximum (0-50%), downy mildew ranged from 0-35 %, ergot prevalence ranged between 0-40 % (Anon., 2015).

Kaurav *et. al.,* (2017) surveyed the blast severity, the block ranged between 1 to 5.48% and 3.6 to 13.8% correspondingly. From corner to corner the state amongst all pearl millet growing districts, in 2015-16, the highest blast severity was recorded in Morena (5.48%), followed by 5.08% Morar, 4.92 % in Lahar, 4.76% Seopur, 4.24% Vijaypur, 4.12% Shivpuri. During 2016-17, the highest blast severity was found 13.80% in Sabalgarh followed by 12.92% in Lahar, 12.32% in Joura, 11.48% in Ater, 11.28% in Morena, 11.24% in Ambha. None of the surveyed fields were free from the Blast disease.

2.7 Biochemical Changes

Pathogen affects various changes of amino acids of plant metabolism. Mostly the host parasites affect by in excess of amino acid along with the active amino acids are efficient in opposition to the major diseases. Some amino acids found to increase inclination in its place of reducing it by chemotherapeutic action. Appliance of asparagine or glycine to wheat leaves promoted rust contamination (Gassner and Hasserbrauk, 1933).

Nema (1983) recommended that reduction is due to deprivation of metabolism in diseased tissues. The data also reveal that total phenols reduced gradually in all the diseased, pre-halo and intervening tissues.

Neeraj *et al.,* (2010) experimented the quantitative estimations after 40 days of sowing *i.e.* before inoculation, 20 days after inoculation (DAI) and 40 DAI. It was observed that total sugars and non-reducing sugars decreased with age and infection. Total phenols were reduced with both, plant age and infection.

Hosagoudar (1997) worked on different biochemical parameters viz., soluble sugar, starch, total protein, total amino acid, total phenol, proline and total chlorophyll contents. There were estimated in the healthy and infected leaves by following evaluation methods. The biochemical analyses showed a reduction in the primary metabolites of the infected leaves except for the total phenol and proline content as compared to healthy leaves. Total chlorophyll, starch as well as soluble sugars decreased to half in the infected leaves. Increased polyphenol content in the infected leaves can be recognized to the resistance reaction of the plant to infection. Reduced protein and amino acid contents along with starch and soluble sugars in the infected leaves indicate a decrease in the metabolic activity in leaves. No considerable distinction in the proline substance of healthy and infected leaves was noticed.

Khan *et al.,* (2001) reported the function of phenolics, orthodihydroxy phenols and glycosidic showed extensive changes. While vital in addition to acid phenols showed minute or no change through disease growth. Levels of phenolic compounds improved four days after inoculation and decreased after that, but the absorption was higher at every stage of disease enlargement comparative to healthy sorghum tissues.

Kumar (2005) reported the resistant genotypes of barley exhibited the amounts of sugar and reducing sugar as compared to susceptible genotypes throughout, due to leaf blight infection, total sugar and reducing sugar were declined in all the genotypes but degree of decrease was highest in susceptible genotypes than in resistant genotypes.

Yadav *et al.,* (2012) indicated that 11.8% protein in the leaves of vigorous pearl millet hybrid which were augment by 0.95% due to per unit increased in the blast severity.

Sowmya *et al.,* (2014) evaluated the biochemical factors concerned in disease reaction, phenol, ortho dihydroxy phenol, protein and enzyme PAL at dissimilar crop growth. Total phenol, OD phenol and PAL amassing and enhance were expressed and more in resistant landraces on top of improved lines due to blast infection.

Bisen *et al.,* (2015) studied the resistance having high amount of total phenol and soluble protein in rice leaves with lower disease incidence. The rice genotype IRRON M2 205 is having maximum amount of soluble protein, representative 22.46, 21.94 and 21.27mg/gm and total phenol of 1.79, 1.68 and 1.61mg/gm of fresh leaves at vegetative, panicle initiation and milk dough stage, respectively. Correlation between total phenol and soluble protein with disease severity at different growth stages showed that there was a negative correlation in all the rice genotypes.

Gashaw *et .al.* ,(2014) evaluated the morphological and physiological variability of finger millet on Host Seed Extract + 2% Sucrose Agar, Oat Meal Agar, Potato Dextrose Agar and Richard's Agar culture Media at varying temperature, pH, carbon and nitrogen sources. Oat meal agar and Richard agar media showed maximum mycelial growth.

2.13 *In-vivo* evaluation of fungicides

Singh *et. al.,* (1991) observed that Carbendazim @ 0.2% was largely efficient for decline of neck as well as swelling blast by 57.82% and 55.48%t, followed by Edifenphos (0.1%) and Thiophanate-methyl (0.1%).

Dubey (1997) conducted the field trail by using three sprays of Tricyclazole (0.03%) in combination with Mancozeb (0.25%) and declined neck and node blast infection with maximum grain yield. Sood and Kapoor (1997). Fungicides in with Tricyclazole were found most successful as they reduced leaf and neck blast by

88.3% and 95.6%, respectively. Chlorothalonil and Hexaconazole were more effective in controlling the rice blast.

Tiwari *et al.,* (2002) reported that Kitazin, Isoprothiolane and Ediphenphos were more efficient followed by Hexaconazole, Carbendazim and Vlidamycin in controlling leaf blast disease of rice.

Upadhyay *et al.,* (2002) found least leaf and neck blast in addition to highest yield in plot treated with beam (Tricyclazole 75% WP) 0.6 g/l, followed by Hinosan (Ediphenphos 50% EC) 1 ml/l and Bavistin (Carbendazim 50% WP) 1 ml/l.

Vijaya (2002) found highest decline in leaf blast incidence as well as superior yield by spraying Tricyclazole (PDI 17.6), followed by Thiophanate methyl (PDI 19.3).

Prajapati *et al.,* (2004) tested fungicides management of blast of rice (*Pyricularia grisea*) on highly blast vulnerable inhabitant cultivar Pankhali. They tested tricyclazole @ 0.045% it declined the leaf and neck blast by 62.9% and 64.1%, respectively, and 72.3% whereas in grain yield.

Dubey (2005) observed that Carpropamid @ 0.1% proved largely efficient in falling node and neck infection and increase in grain yield followed by Tricyclazole (0.03%) and Thiophanate methyl (0.05%).

Jadhav and Thombare (2007) evaluated the successfully managing the blast of rice by 2% brine solution with foliar spray application of Carbendazim 0.1 % and Monocrotophos 0.14% were found most promising against rice blast whereas, seed treatment with 2% brine solution and seed dressing with *Trichoderma viride (*0.5%) was found relatively slightest effective over fungicides.

Gouramanis (2007) observed the fungicide Derosal (Carbendazim) @ 1.5 lb/100 gallons and Beam (Tricyclazole) @ 0.75 kg/ha successfully decline rice neck blast followed by Fongoren (Pyroquilon) @ 2 kg/ha while, Kitazin (Iprobenfos) @ 750 g/ha and bla-s (Blasticidin) @ 100 µg/ml reduced leaf blast but not neck blast infection.

Lukose *et al.,* (2007) evaluated eight fungicides, for controlling the disease in the field during 2001, 2003 and 2004, in Jamnagar, Gujarat, India. Out of these fungicides, Carbendazim at 0.05 % was considerably effective in controlling the disease followed by Thiophanate methyl and Mancozeb. There was a significant increase in grain yield in Carbendazim (2239 kg/ha), followed by Thiophanate methyl

(2014 kg/ha) and Mancozeb (1910 kg/ha). The fodder yield was also increased significantly in Carbendazim treatment (3241 kg/ha).

Singh and Prasad (2007) tested fungicides against rice blast under *in-vivo* conditions in addition to reported that tricyclazole 50 WP (0.5 l/ha) and Carbendazim 50 WP (1 l/ha) showed the least blast incidence and obtained superior grain yield.

Ghazanfar *et al.,* (2009) reported that the fungicides, viz., Rabicide and Nativo were the most effective against leaf blast disease with greater reduction in the disease percentage.

Kaurav *et al.,* (2018) tested botanicals and fungicides as foliar sprays on blast disease using susceptible variety RHB-177. The two years joint data showed that the minimum blast PDI was obtained in Trifloxystrobin + Tebuconazole (18.9), followed by Propiconazole (20.0), Tricyclazole (22.5), Iprobenphos (24.2), Hexaconazole (25.0), Azoxistrobin (24.4), Neem seed karnel extract (31.9), Aloe vera (36.4) and Lantana camera (38.6), while it was maximum in control (44.4). Trifloxystrobin + Tebuconazole was significantly superior to all the three botanicals. It was also superior to Azoxistrobin and Hexaconazole but it was at par with Propiconazole, Tricyclazole, Iprobenphos. Propiconazole was significantly superior to Azoxistrobin but was statistically at par over rest of the tested fungicides.

2.15 Screening

Prabhu *et al.,* (1996) screened 39 accessions under dry land field conditions at 13 sites over three years for resistance to brown spot (*Drechslera oryzae*), leaf and neck blast (*Pyricularia grisea*), leaf scald (*Micro dochiumoryzae*), narrow brown leaf spot (*Cercospora janseana*) and grain discoloration (caused by various fungal pathogens). A number of accessions had a high level of resistance to grain discoloration. Early improved line M 39 had a high amount of multiple disease resistance.

Diaz *et al*., (2000) collected 124 entries of rice germplasm and by means of two methodologies: standard evaluation system for rice and varietal description form for rice, with the objective of evaluating germplasm and putting at the breeders' disposal the information retrieved to be used in future breeding programmes. The evaluated variables comprised morphological and agronomical descriptors other than resistance to *Pyricularia grisea* (*Magnaporthe grisea*) and devastating, lodge and senescence.

Kumar (2008) screened 138 lines of pearl millet against blast under natural condition and reported MH 148 and MH149 to be blast free entries. The other five entries viz. MH 1411, MH1417, MH1421, MH1424 and MH 1246 showed only 0.5% blast severity. The highest rigorousness was noticed in MH 1395 (37.5%) followed by MH 1343 and MH 1396 (35.0%).

Kumar (2008) evaluated 19 promising pearl millet hybrids & varieties and reported the blast severity in the range of 0-37.5%. GHB558 absolutely free from blast followed by Pusa 23, GHB 538, ICMV 221, PB 106, ICMH 356, HHB 67 Improved, JBV 3 and Saburi, whereas the greatest blast severity was recorded in ICTP 8203 and RHB 121.

Nagaraja and Gowda (2008) found 173 entries resistant and 125 entries moderately resistant to neck and finger blast caused by *Pyricularia grisea*.

Devda , B. S. (2009) screened 135 pearl millet lines against blast at Gwalior and reported blast severity in the range of 0 - 47.5 per cent. One entry *viz.* MH 1541 remained completely free from blast, whereas its highest severity *i.e.* 47.5% was recorded in MH 1513.

Thakur *et al.,* (2009) screened highly susceptible line with non-natural spray inoculation of 30-days-older plants using *Pyricularia grisea* spore suspension and maintain high moisture through irrigation for 2 weeks following inoculation. In all, 211 elite hybrid parental lines, including 126 designated B-lines, 20 selected R-lines and 65 potential R-lines were evaluated for blast resistance in the disease nursery. 45 lines recognized as blast resistant to be further screened through greenhouse screening technique.

Thakur *et al.,* (2011) measured the disease of pearl millet, occurrence of blast disease caused by *Pyricularia grisea* which increased at a distressing rate, predominantly on industrial hybrids in several States of India. The disease can be managed by host plant resistance.

Barnwal (2012) screened in field trials to identify the resistant cultivars of finger millet against blast disease. The results depicted that the least neck blast of 2.5%, finger blast of 12.1% and highest grain yield of 27.4 q/ha in OEB 225. Other cultivars, A 404, JWM 1, GPU 45, GPU 67, OEB 225, IE 7 and PR 202 showed moderately resistant reaction against neck blast.

Feng and Correll (2012) reported 192 rice breeding lines against *Magnaporthe oryzae* in which 12 from reference isolates and one isolate from hybrid rice. The 14 cultivars were resistant to all 13 rice blast isolates, 16 lines resistant to 12 isolates, and 46 lines resistant to 11 isolates. However, 8 lines were susceptible to all the isolates, 16 lines were resistant to only one of the 13 isolates, and 12 were resistant to two of the 13 isolates.

Barnwal *et al*., (2012) screened 193 entries of rice (*Oryza sativa* L.) genotypes for disease resistance against blast caused by *Pyricularia oryzae* Its showed differential reactions indicating genetic variation in rice for blast resistance. Nine genotypes viz., (RP 4075-345-132-27, CN 1918, CN 1383-5-11, RR 440-167, NDR 9211, OR 1924-4, SJR 5, GP DHAN and CRHR-29) were found highly resistant to leaf blast which may be utilized as donors in resistance breeding programme.

Gupta *et al., (*2012) studied the heritage of resistance to this disease; two resistant restorer lines (ICMR 06222 and ICMR 07555) and two susceptible maintainer lines (ICMB 95444 and ICMB 89111) were tested under field conditions. Each of the two resistant parents was crossed with two susceptible parents to generate 4 sets of F1s, F2s and their backcrosses with both resistant and susceptible parental lines. These were evaluated by disease reaction with artificial inoculation under field conditions.

Sharma *et al.,* (2013) studied pathogenic variation in greenhouse using 25 *M. grisea* isolates viz., ICMB 02444, ICMB 02777, ICMB 06444, ICMB 93333, ICMB 96666, ICMB 97222, ICMB 99444, 863B, ICMR 06222, and ICMB 95444. Degree of difference reactions to the test isolates were recorded on ICMB 02444, ICMB 93333, ICMB 97222, 863B, and ICMR 06222. Only 25 isolates were grouped into five different pathotypes based on their reaction types (virulent = score >4 and avirulent = score <3 on a 1 to 9 scale).

Yadav *et al.,* (2013) evaluated 25 promising hybrids and varieties against blast under natural condition. Out of them none of the entries were found free from the blast, however the minimum severity of 7.5% was recorded in PB 106, GHB-744, and GHB-732, while its maximum severity (32.50%) was recorded in B-2301, PB 106, GHB 744 and GHB-732 which were significantly superior over GHB 588, GHB

719, Nandi 62, B-2301, Saburi, Pusa-383, ICMV 221, Pusa 226, ICTP 8203, Pusa443 and HHB 67.

Meena, R (2016) evaluated 112 entries against blast in which only four entries were free from blast and were kept in the category of highly resistant. Six entries showed 2-3 rating and placed under resistant category. The blast severity rating 4-5 was recorded in forty entries hence were kept in the group of moderately resistant entries. Out of 112 entries 55 were found susceptible to the disease as these entries showed 6-7 rating. The remaining seven entries *viz.* ICMB 89111, ICMB 95444, ICMB 9222, 863B-P2, IP 22303, JMSB-20091 and JMSB-2042 were severely infected by the disease and showed 8-9 rating. In these seven entries the most of foliage was damaged due to the disease. Such entries were placed in the category of highly susceptible.

Divya *et al.,* (2017) screened 10 genotypes for resistance to blast, no genotype was found free from the disease incidence. Minimum percentage of neck blast severity was recorded in VL379 (14.82%), while the minimum finger blast severity (13.70%), was recorded in GPU 45.

Patro *et al.,* (2018) evaluated 30 varieties of finger millet against major blast diseases. None of the variety could show evidence of the immune reaction, five varieties were found to be highly resistant and nineteen varieties are resistant while VR 708 recorded as highly susceptible to leaf blast. The percent disease incidence of neck blast ranged from 13.67 to 84.13 where it was 91.11 in susceptible check VR 708. In case of finger millet blast, it was ranged from 11.58 to 82.56, whereas the incidence was 92.26 in check. The mean of all locations revealed that seven varieties were resistant to leaf blast.

Parihar *et al.,* (2019) screened 50 promising pearl millet hybrid and varieties against blast under favorable circumstances. The screened hybrids showed a large difference in reaction to blast as their blast PDI ranged from 0.0 to 99.99%. Three entries viz. GHB538, MPMH17 and NHB5061 were completely free from the disease. In respect of blast reaction these three entries were significantly superior over rest of the 47 entries. The maximum blast PDI 99.9% was recorded in the susceptible check ICMB95444.

Effect of homeopathic drugs

Rissato *et al.,* (2016a) conducted two assays, the first one using Nosode of *S. sclerotiorum*, and the second with Sulphur, both at 0, 6, 12, 24, 36 and 48 CH and distillated water as control treatment. The dilution 0 CH was the hydro alcoholic solution with ethanol 30%. The number of sclerotia and the mycelial growth were evaluated *in vitro*. None of the drugs reduced the mycelial growth of *S. sclerotiorum*, but, Nosode 24 CH and Sulphur 36 CH and 48 CH completely inhibited the production of sclerotia.

Rissato *et al.,* (2016b) tested the efficacy of two medicine *viz., Calcarea carbonica* and. Both medicines were administered at dynamizations of 6, 12, 24, 36, and 48 CH (Hahnemanniana Centesimal). *Calcarea carbonica* at 6 CH and Phosphorus at 6 CH, 12 CH, 24 CH, 36 CH, and 48 CH reduced the intensity of white mold in bean plants. With the exception of *Calcarea carbonica* at 12 CH and 24 CH, no other medicine reduced the percentage of plant death due to white mold disease.

Toledo *et al*., (2016) evaluated fungitoxicity of homeopathic medicines Propolis, Isotherapic, Sulphur, Silicea terra, Staphysagria, Phosphorus, Ferrum sulphuricum and Kali iodatum at 6, 12, 30 and 100CH dynamizations. against *A. solani*. The results indicated that for mycelial growth only in Sulphur and Staphysagria 100CH showed suppressive effect compared to both controls. For sporulation, Propolis 6, 30 and 60CH and Ferrum sulphuricum 6 and 30CH caused inhibition and differed from both controls. Isotherapic of A. solani 6CH, Isotherapic of ash 6CH and Ferrum sulphuricum 30CH reduced spores germination of the pathogen.

Rissato *et al*., (2018) evaluated homeopathic drugs viz., Phosphorus and Calcarea carbonica, at 6CH, 12CH, 24CH, 36CH and 48CH dynamizations (centesimal Hahnemannian) against *S. sclerotiorum*. The treatments Phosphorus 12CH, Phosphorus 48CH, Calcarea carbonica 12CH, and Calcarea carbonica 48CH presented resistance-inducing action by slowing down the disease progression up to 83% and decreasing the number of dead plants up to 90%. *In vitro* tests showed that the treatments Phosphorus 12CH, Phosphorus 48CH and Calcarea carbonica 48CH slowed down the mycelial growth. The latter also completely inhibited the production of sclerotia. These results indicate the potential of Phosphorus 12CH, Phosphorus

48CH, Calcarea carbonica 12CH, and Calcarea carbonica 48CH for controlling *S. sclerotiorum* in common beans.

According to Asha *et al*. (2014), Thuja occidentalis (Q, 30 C, 1 M, 10 M and 50 M) had a significant inhibition among all the 5 fungal genera species of *Fusarium, Aspergillus flavus, Bipolaris, Exserohilum* and *Curvularia;* however, exact mechanism of action of Thuja is unknown and can be future perspective of research in this fungal cultures.

Marcia *et al.,* (2016) evaluated the fungi toxicity action of homeopathic medicine against black rot disease of tomato crops. Sulphur and Staphysagria 100CH showed suppressive activity as compared to both controls in mycelium growth, even when successed distilled water at 60CH and 100CH inhibited mycelium growth. Propolis 6CH, 30CH and 60CH and *Ferrum sulphuricum* 6CH and 30CH caused inhibition and differed from both controls in sporulations. Also, spores germination of the pathogen was found to be reduced by Isotherapic of A. solani in 6CH, Isotherapic of ash in 6CH and Ferrum sulphuricumin 30CH medicines.

According to the study of Hanif, A and Dawar, S (2016), both *in vitro* and *in vivo* experiment showed fungicidal potentials of homeopathic medicines of T. occidentalis and Arnica montana in globules 30CH against root rot disease in non-leguminous plants.

In the study of Prajapati *et al*. (2017), homeopathic mother tincture *S. jambolanum, F. religiosa, O. sanctum, A. cepa, T. occidentalis* and *H. antidysenterica* showed inhibitory action against human pathogenic fungi *Candida albicans.*

Chapter - III

MATERIAL AND METHODS

The present study entitled "Studies on Pearl millet blast [*Pyriculariaa grisea* (Cooke) Sacc.] with special reference to its integrated Management" was carried out in the field and laboratory of Department of Plant Pathology RVSKVV, Gwalior (M.P.) during *Kharif* 2019-20. The disease survey was carried out on farmers' fields of Morenaa, Bhind and Gwalior district of Madhya Pradesh. Gwalior is situated in Northern part of Madhya Pradesh at an altitude of 211.52 meters from mean sea level and lies between latitude and longitude of 26º14' North and 78º15' East, respectively.

3.1 Climate

The climate of Gwalior is subtropical and the rainy season usually starts from third week of June after initiation of south-west heavy shower and last upto September. Highest rainfall occurred in the month of July and August. Winter season usually occurs in between November to March and summer season from April to mid-June. October is the transitory month during rainy and winter season. The weekly meteorological data during the study period is given in appendices I.

3.2 Experimental site

The present studies were conducted at Research Farm, College of Agriculture, Gwalior during *Kharif* season of 2019-20. The soil of the experimental site was alluvial clay loam texture. The accessible nitrogen, phosphorus and potassium content of soil were 200.7 kg, 10.1 kg and 260.9 kg per hectare, respectively. The water holding capacity of soils is medium.

3.3 Materials:

3.3.1 Isolation of pathogen

The pathogen *Pyricularia grisea* was isolated from the blast infected leaves of pearl millet collected from experimental field, after isolation the respective pure culture was prepared and it was used for the study.

3.3.2 Glass wares and other experimental equipment

Corning and Borosil made glassware's were used during the investigational study. Glassware's were cleaned by washing with detergent and then rinsed with tap water. After drying glassware's were sterilized in hot air oven at 180^{o}C for two hours. The metallic equipment's like forceps, needle and cork borer were sterilized by dipping in alcohol and heating to red hot over flame of a spirit lamp. The surface sterilization of infected leaf was done by dipping in 1% Sodium hypochlorite solution for few minutes. The culture medium was sterilized in an autoclave at 121.6^{o}C, 15 Ibs pressure per square inch (1.05 kg/cm^{2}) for 20 minutes.

3.3.3: Culture media

Two culture media were used in the course of investigation with the ingredients in Table 1.

Name of Media	Ingredients	Quantity
Potato dextrose agar	Peeled and sliced potato	200.0 g
	Dextrose	20.0g
	Agar-agar	20.0g
	Distilled water	1000 ml
Potato dextrose broth	Peeled and sliced potato	200.0 g
	Dextrose	20.0g
	Distilled water	1000 ml

3.4 Methods:

3.4.1 Survey of pearl millet blast

A well planned survey was conducted during 2019-20 on the farmer's field of major pearl millet growing districts *viz.,* Morena, Bhind and Gwalior, (table-2) to find out the status of blast disease. For such survey, five villages from the surveyed districts were taken. From each location (villages), three fields were randomly selected. The blast severity was recorded on 25 randomly selected plants from each field by adopting blast severity rating scale 0-9. Thereafter, PDI were calculated. The representative disease samples from the locations were collected for isolation.

Percent disease index (PDI) was worked out by using the formula given by **Wheeler (1969).**

$$\text{Percent Disease Index (PDI)} = \frac{\text{Sum of individual disease ratings}}{\text{No. of leaves assessed x Maximum grade}} \text{ x } 100$$

A

B

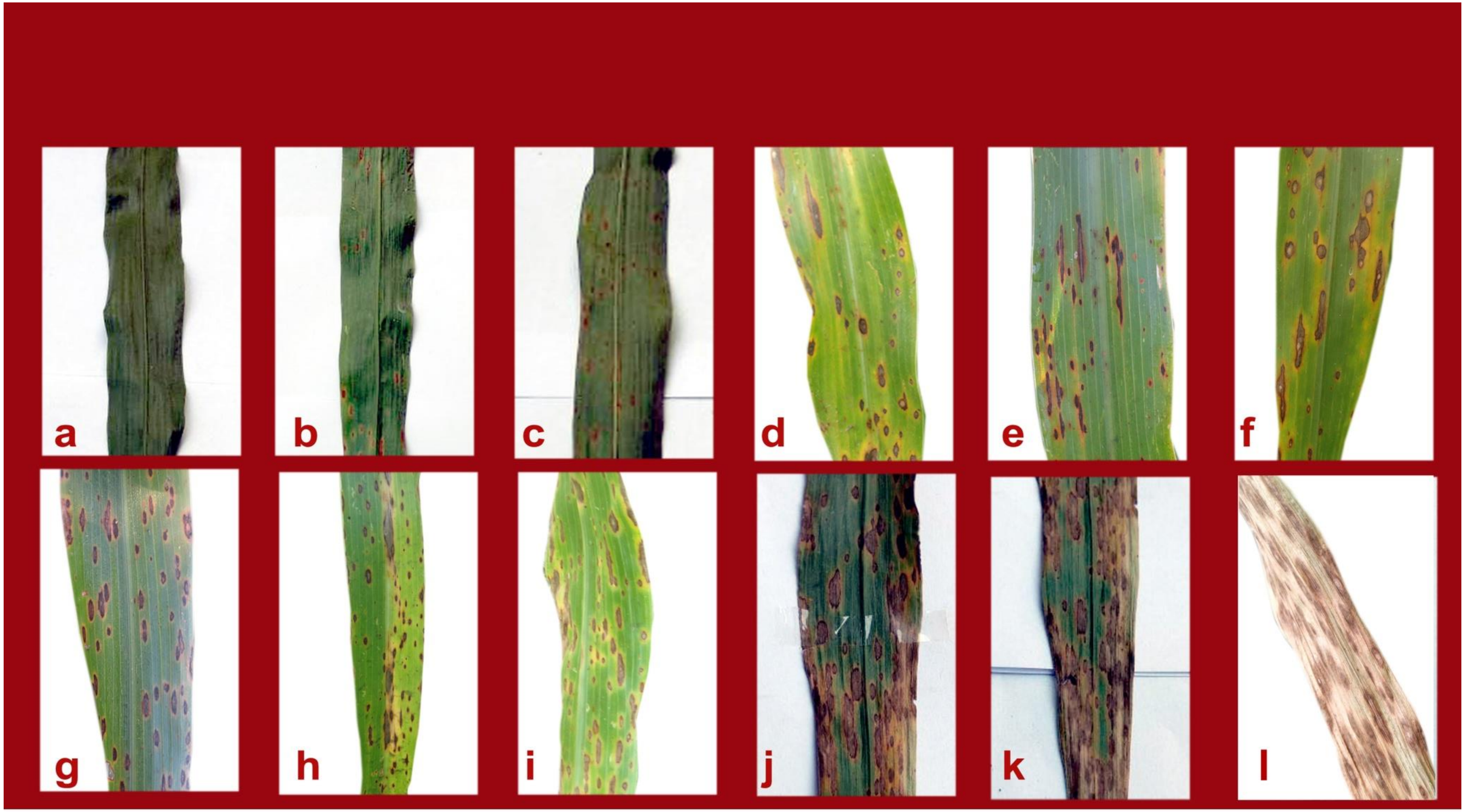
Plate-1. (A) Experimental field view (B) Popular pearl millet hybrid variety against blast

Table 2: List of blast surveyed districts of Madhya Pradesh

Districts / Locations	**Bhind**	**Morena**	**Gwalior**
	Barohi	Joura	Bhandoli
	Phoop	Morenagayaon	Sonsa
	Lahar	Sainthara	Padampur
	Surpura	Dimni	Utila
	Mehwa	Kuthiyana	Maharajpura

Table 3: Blast severity rating scale: 0 – 9.

Score	Percent leaf area infected	Host response
0	No lesion	Highly resistant
1	No lesion to small brown specks of pinhead size	Resistant
2	larger brown specks	Moderately resistant
3	Small, roundish to slightly elongated, necrotic gray spots, about 1–2 mm in diameter with a brown margin	
4	Typical blast lesions, elliptical, 1–2 cm long, usually confined to the area between main veins, covering <2% of the leaf area	Moderately susceptible
5	Typical blast lesions covering <10% of the leaf area	
6	Typical blast lesions covering 10–25% of the leaf area	Susceptible
7	Typical blast lesions covering 26–50% of the leaf area	
8	Typical blast lesions covering 51–75% of the leaf area and many leaves dead	Highly susceptible
9	All leaves dead	



06 (a) : Minute to circular slightly linear dark brown specks on the leaf surface, 06 (b-e) : Dark-brown specks gradually increase 06 (f-h) : Lesion with dark brown margin and light greyish centre, 06 (i-j) :Overlapping of lesion with necrotic holes, 06 (k) : Lesion collapse and cover whole leaf, 06 (l) :Severely infected plant.

Plate-2. Development of blast on leaves at (0-9) scale

Plate-3. Blast lesions on pearl millet stem

3.4. Biochemical method

The biochemical constituents *viz.,* total soluble sugars and total phenols were analyzed from blast infected leaf of pearl millet to know the effect of blast disease on total soluble sugars and total phenols. Hybrid Dhanshakti was used for this experiment. Different categories of blast infected leaves (0-9 scale) were collected from field and brought to the laboratory. Biochemical constituents were analyzed from these leaves and correlation coefficient was calculated between diseases scale and biochemical constituents.

3.4.1 Estimation of total soluble sugars

The concentration of pentoses, hexoses, disaccharides with sucrose, lactose, maltose and hexuronic acids present either liberally or all along with polysaccharides were estimated using anthrone method (Sadasivam and Manikam 1992).

3.8.2.1 Principle

Anthrone 10-keto-9.10-dihydro-anthracene the product of anthoquinone reacts by condensing with carbohydrate furfural derived to generate a green color in solution and a blue color in a concentrated solution.

Reagents: Anthrone reagent: 2g of anthrone in 11 parts of conc.H_2SO_4 (Prepared fresh).

Procedure

- Aliquots of 1ml of the extract was pipetted into test tubes.
- To each tube 4ml of the anthrone reagent was added allowing with reagent to run downwards the side of the test tube.
- Tubes were capped to prevent the evaporation of water. Reaction mixture was incubated in boiling water bath for l0 min.
- Tubes were chilled to room temperature in a cold water bath.
- Absorbance was calculated at 625 nm by using spectrophotometer. Calculation of standard curve of glucose was organized and deliberate.

3.4.2 Estimation of total phenols

Infection of plants induces change in phenolic substances. Genotypes differ in their reaction to phenolic changes. It has been recommended that the major difference between resistant and susceptible genotypes is in the rapidity of increase of phenols. The total phenol content was estimated by Folin-Ciocalteu (Bray and Thorpe 1954).

Principle

Assessment of phenols with Folin-Ciocalteu reagent is based on the reaction between phenols and an oxidizing agent Phospho-molybdate which results in the formation of a blue complex. The concentration of the color is measured in a colorimeter.

Reagents

- Folin-Ciocalteu reagent
- 20% Na_2CO_3

Protocol

- 1ml of alcohol evaporated plant extract was taken in a test tube.
- 1ml of Folin- Ciocalteau reagent was added to it.
- 2 ml of Na_2CO_3 solution was added to the above reaction mixture and heated in a boiling water bath exactly for 1min.
- Tubes were cooled and mixed into 25ml with distilled water.
- The absorbance was measured at 650nm.
- A standard curve was made from different concentrations of catechol.
- Total phenol content was calculated by comparing absorbance value with standard.

3.5: *In-vitro* evaluation of homeopathic drugs against *Pyricularia grisea*.

Ten homeopathic drugs *viz., Thuja occidentalis,* Sulphur, *Arsenicum album,* Belladona, *Natrum muriaticum,* Silecia. *Ferrum metallicum,* Sepia, *Carbo vegetabilis* and *Kali iodatum* were evaluated against the growth of *Pyricularia grisea* at 500 ppm under *in vitro* conditions by adopting poisoned food technique as suggested by (Nene and Thapliyal, 1979). The experiment was laid out in complete randomized design and replicated thrice. Required quantity of homeopathic drugs was added separately into sterilized, molten and cooled Potato dextrose agar. Later, 20 ml of the poisoned medium was poured into sterilized Petriplates. Mycelial discs of 5 mm size from seven days old actively growing culture of the fungus were cut out by a sterile cork borer and one such disc was placed at the centre of each poured plate. Control was maintained without adding any chemicals to the medium. Such plates were incubated at 25 ± 1^{O}C and radial colony growth was measured at 2, 4 and 6 days after inoculation. The efficacy of homeopathic drugs was expressed as per cent inhibition of mycelial growth over control that calculated by using the formula suggested by Vincent (1947).

$$\text{Percent inhibition} = \frac{C-T}{C} X\ 100$$

where, PGI = Per cent growth inhibition

C = Growth in control,

T = Growth in treatment

3.6: Field screening of pearl millet materials against blast.

Classification of disease resistant lines and their exploitation in resistance breeding program is the most successful method for the management of the disease (table-4). Thus, the pearl millet material consisting of 100 lines was evaluated against blast in the sick soil.

Details of the experiment are as follows:

Entries	-	100
Design	-	R.B.D
Replication	-	2
Row length	-	4 m
Spacing	-	50 cm x 10 cm
Fertilizer	-	80 kg N, 40 kg P, 20 kg K

The percent disease index was designed by using the following formula (Wheeler, 1969).

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of individual disease ratings}}{\text{No. of leaves assessed x max. Grade}} \times 100$$

Table 4: List of pearl millet genotypes

S. No.	Entries	S. No.	Entries
1	98444-A X RBR-246	26	98555-A X RBR-309
2	98444-A X RBR-160	27	05333-A X 15042
3	96222-A X RBR-160	28	97111-A X RBR-186
4	96222-A X RBR-186	29	15071
5	97111-A X RBR-306	30	15072
6	97111-A X 15045	31	15076
7	97111-A X 15042	32	15081
8	96222-A X RBR-220	33	15083
9	96222-A X RBR-281	34	15090
10	02555-A X RBR-186	35	15493
11	02555-A X RBR-220	36	15514
12	93333-A X RBR-186	37	RBR- 188
13	93333-A X RBR-214	38	RBR- 189
14	05333-A X RBR-186	39	RBR- 190
15	05333-A X RBR-220	40	RBR- 191
16	05333-A X RBR-296	41	RBR- 194
17	97111-A X RBR-202	42	RBR- 195
18	97111-A X RBR-214	43	RBR- 196
19	02555-A X RBR-295	44	RBR- 193
20	02555-A X RBR-302	45	RBR- 192
21	02555-A X RBR-309	46	RBR- 236
22	02555-A X 15045	47	RBR- 159
23	02555-A X 15581	48	RBR- 224
24	98555-A X RBR-246	49	RBR- 229
25	98555-A X RBR-281	50	RBR- 305
51	RBR- 216	76	81-A5 X RBR 281
52	96222 – A	77	81-A5 X RBR 181
53	96666 – A	78	98444 B
54	02555 – A	79	81-A5 X RBR 183
55	93333 – A	80	81-A5 X RBR 15045
56	05333- A	81	81-A5 X RBR 15581
57	97111- A	82	96222 B

58	98555 – A	83	81-A5 X RBR 220
59	81-A1 X RBR 269	84	RVBH 18-36
60	81-A1 X RBR 211	85	RVBH 18-38
61	81-A1 X RBR 259	86	RVBH18-39
62	81-A1 X RBR 161	87	RVBH18-40
63	81-A1 X RBR 281	88	RVBH18-41
64	81-A1 X RBR 261	89	KAVERY SUPER BOSS
65	81-A1 X RBR 214	90	86M86
66	81-A1 X RBR 246	91	KBH-108
67	81-A1 X RBR 186	92	GHB-732
68	81-A1 X RBR 269	93	GHB-744
69	81-A1 X RBR 262	94	RHB-173
70	81-A5 X RBR 296	95	PRO AGRO-9444
71	81-A5 X RBR 214	96	GHB-558
72	81-A5 X RBR 289	97	RHB-177
73	81-A5 X RBR 211	98	GHB- 538
74	81-A5 X RBR 269	99	86M01
75	81-A5 X RBR 186	100	MPMH- 17

3.7: Evaluation of promising hybrids/varieties.

A total thirty (table 5) promising pearl millet hybrids/varieties were evaluated against blast in the Blast sick field. The details of the experiment are as follows: -

Hybrid - 30
Design - RBD
Replication - 02
Row Length - 4 m
Spacing - 50 cm x 10 cm
Fertilizer - 80 kg N, 40 kg P, 20 kg K

Table 5: List of hybrids/varieties of pearl millet.

S. No.	Hybrid/Variety	S. No.	Hybrid/Variety
1	HHB 272	16	KAVERI SUPER BOSS
2	MPMH 21	17	JK26Gold
3	HHB 67 Improved	18	PROAGRO 9450
4	AHB 1269	19	NBH 4903
5	AHB 1200	20	Raj 171
6	86M01	21	ICMV 221
7	86M86	22	Pusa Comp. 383
8	Pusa composite 383	23	pratap
9	Krishna 9119	24	ICMV 155
10	Pioneer 86M90	25	Pusa Comp. 612
11	Super 27	26	ABV 04
12	Pioneer 86M84	27	JBV 2
13	NBH 20	28	JBV 3
14	Vardan bajra hybrid	29	JBV 4
15	NBH 21	30	RHB 173

3.8: To manage the pearl millet line through the application of bio-agents and chemicals.

A field experiment was conducted at Research Farm, College of Agriculture, Gwalior during *Kharif* season of 2019-20 for evaluation of different treatment combinations against blast of pearl millet. Hybrid Dhanshakti of pearl millet was used in the experiment. The experiment was laid out in Randomize Block Design (RBD) with four replications. Standard agronomical practices were followed as per recommendations. Observations on disease incidence were recorded at 60 days after sowing.

Experiment details

Design	:	RBD
Replication	:	04
Spacing	:	50 X 10 cm
Fertilizers (N: P: K)	:	60: 40: 20
Plot size	:	4 x 2m
Treatment	:	06

Table-6: Combination of chemicals and bio-agents evaluated against blast of pearl millet.

S. No	Treatment
T1	Seed treatment with Chitosan @ 3.75g/kg seed + two sprays of *Pseudomonas fluorescens* @10g/litre after 20 DAS and 35 DAS
T2	Seed treatment with Chitosan @3.75g/kg seed + two sprays of *Bacillus subtilis* @10g/litre after 20 DAS and 35 DAS
T3	Spray with *P. fluorescens* @ 10g/litre after 20 DAS + Trifloxystrobin +Tebuconazole @ 0.04% after 35 days
T4	Spray with Trifloxystrobin+Tebuconazole @ 0.04% after 20 days and *B.subtilis* @10g/litre after 35 DAS
T5	Trifloxystrobin + Tebuconazole @ 0.04% 2 sprays after 20 DAS and 35 DAS
T6	Untreated control

Chapter - IV

RESULTS

4.1. Disease survey

A well planned survey was conducted in major pearl millet cultivated districts of Madhya Pradesh *viz.,* Morena, Bhind and Gwalior. During survey A total fifteen villages (five from each district) were visited to know the per cent disease index of blast in the village. During the year 2019-20, the overall blast PDI in all the three districts was 8.98 percent.

Among all the villages, highest blast PDI was noticed in Surpura of Bhind district (13.44%) followed by Sainthara village of Morena district (12.26 %), Bhandoli village of Gwalior district(12.11%), Lahar village of Bhind district (10.74%), Kuthiyana village of Morena district (10.15%), Joura village of Morena district (9.70%), Morenagayaon village of Morena district (8.59%) and Sonsa village of Gwalior district (8.56%), while lowest Blast PDI was recorded in Maharajpura village of Gwalior district (5.59 %) followed by Dimni village of Morena district (6.41%) padampur village of Gwalior district (6.70%), Phoop village of Bhind district (6.89%), Utila village of Gwalior district (7.26%), Mehwa village of Bhind district (7.85%) and Barohi village of Bhind district (8.44%).

In Morena district, maximum blast PDI was recorded in Sainthara (12.26%), followed by Kuthiyana (10.15%), Joura (9.70%), and Morenagayaon (8.59%) while minimum Blast PDI was recorded at Dimni (6.41 %).

In Bhind district, highest blast PDI was noticed at Surpura (13.44%) followed by Lahar (10.74 %), Barohi (8.44 %) and Mehwa (7.85 %), while lowest blast PDI was recorded at Phoop (6.89 %).

In Gwalior district, maximum PDI of blast disease was noticed at Bhandoli (12.11 %) followed by Sonsa (8.56 %), Padampur (6.70%) and Utila (7.26 %), while least blast disease PDI was observed at Maharajpura (5.59 %).

Table 7: Status of pearl millet blast in Morena, Bhind and Gwalior districts of Madhya Pradesh

Districts	Village	Blast PDI
Morena	Joura	9.70
	Morenagayaon	8.59
	Sainthara	12.26
	Dimni	6.41
	Kuthiyana	10.15
Mean		**9.42**
Bhind	Barohi	8.44
	Phoop	6.89
	Lahar	10.74
	Surpura	13.44
	Mehwa	7.85
Mean		**9.47**
Gwalior	Bhandoli	12.11
	Sonsa	8.56
	Padampur	6.70
	Utila	7.26
	Maharajpura	5.59
Mean		**8.04**
Overall mean		**8.98**

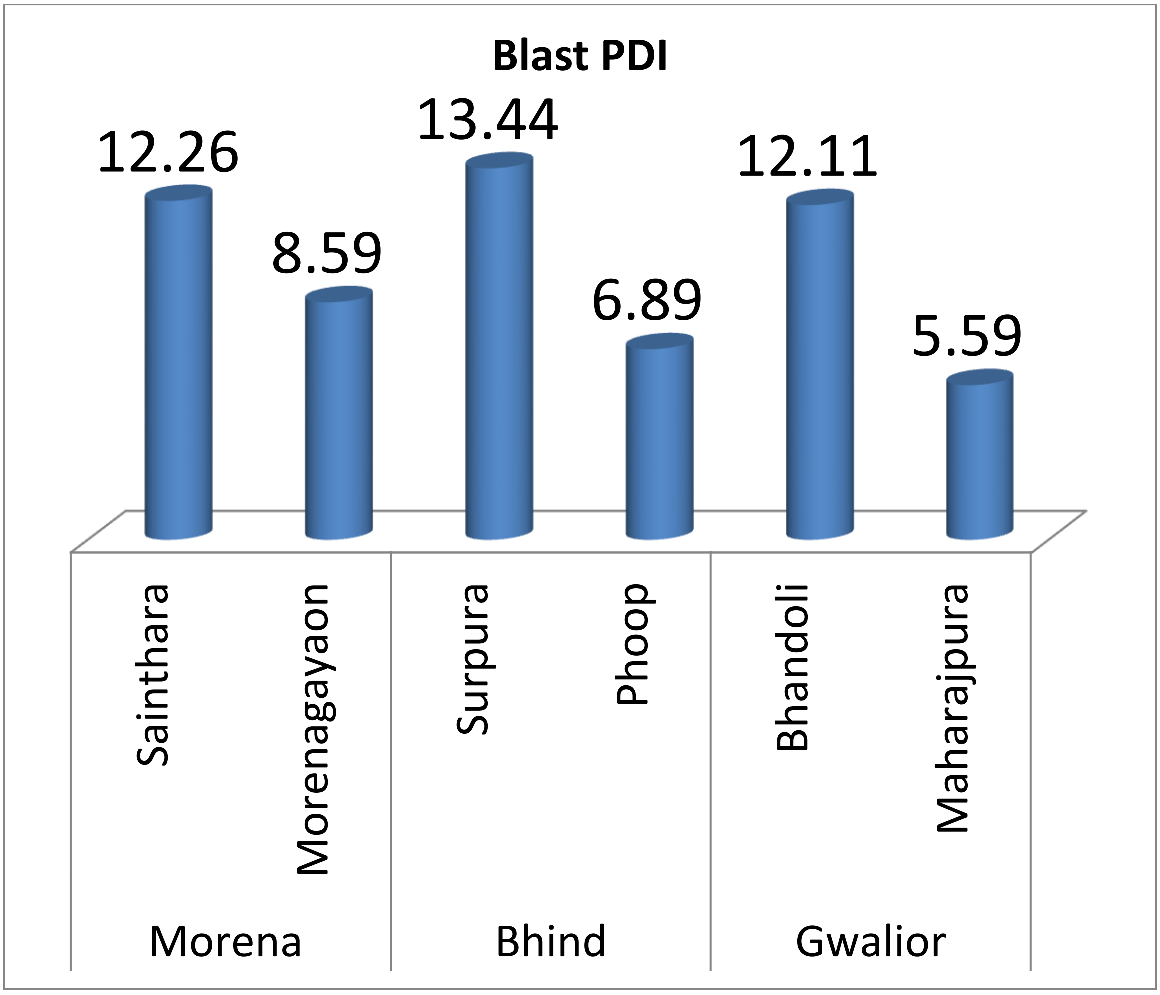


Fig1 : Village wise Per cent disease index of Pearl millet blast.

4.2: Biochemical changes in pearl millet leaves due to blast disease.

4.2.1 Total sugar

It is obvious from the table 8 that the quantity of total sugar gradually increased with increasing infection of blast in the leaf of pearl millet. Maximum total sugar (15.94 mg/g) was recorded in highest blast infection scored leaf (9), while minimum sugar content (14.54 mg/g) was noticed in blast infection free leaf of pearl millet. The correlation coefficient between disease score and sugar content was found significantly positive (0.9724). It is clearly indicated that sugar content increased by infection of blast in pearl millet.

4.2.2 Total phenol

The data summarized in the table 8 reveal that highly blast infected leaves of pearl millet had significantly maximum quantity of total phenol (5.24 mg/g) as compared to healthy leaves of pearl millet (4.15 mg/g). Correlation coefficient between blast score and total phenol was found significantly positive (0.9924), which was clearly indicated that the total phenol content increased gradually with increasing of blast infection in pearl millet leaf.

Table 8: Biochemical contents in leaves of pearl millet with corresponding blast score.

Blast score Scale (0-9)	Total sugar mg/g	Total phenol mg/g
0	14.54	4.15
1	14.60	4.24
2	14.69	4.39
3	14.75	4.55
4	14.81	4.72
5	15.29	4.86
6	15.55	5.00
7	15.62	5.06
8	15.78	5.15
9	15.94	5.24
Correlation coefficient (r)	0.9724*	0.9924*

* Highly significant

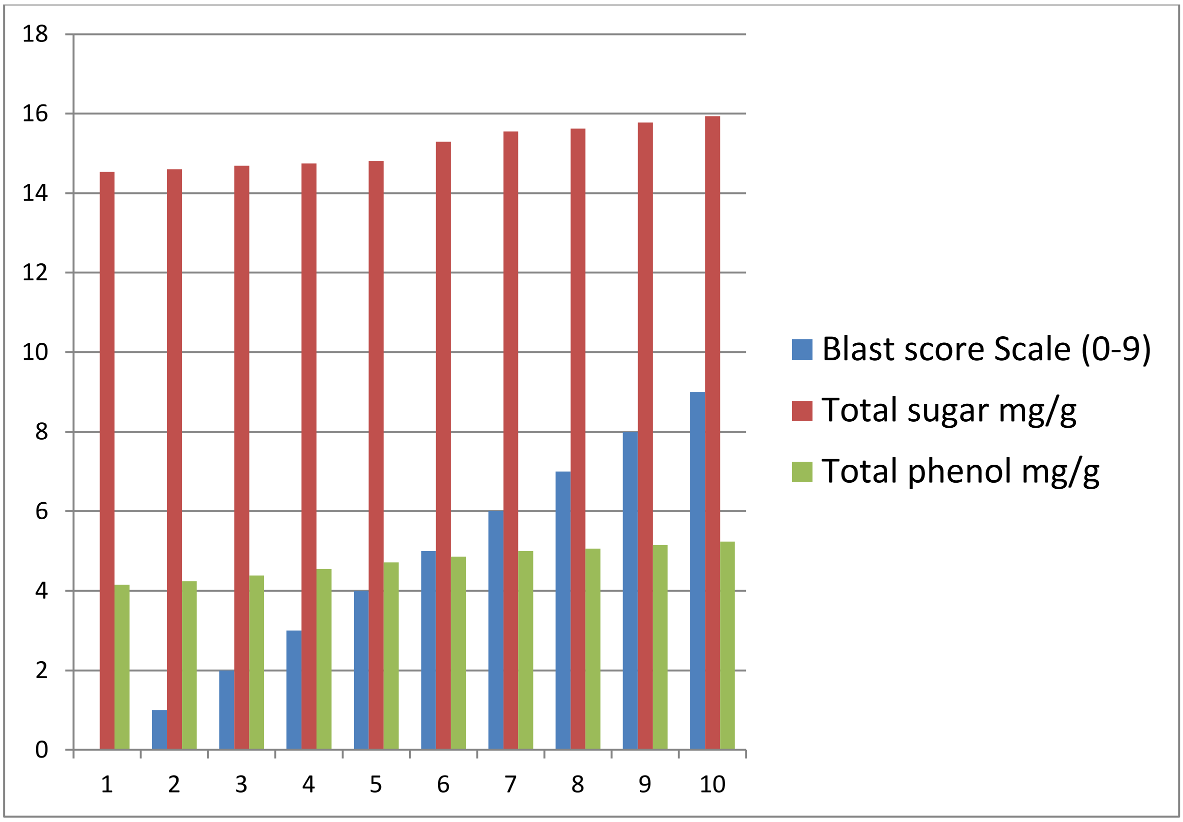


Fig 2: bio chemical content in leaves of pearl millet with blast score.

4.3: *In vitro* evaluation of homeopathic drugs against *Pyricularia grisea*.

An *in-vitro* experiments was conducted to evaluated ten homeopathic drugs *viz.,* Silecia, *Thuja occidentalis, Kali iodatum, Arsenicum album,* Belladona, *Ferrum metallicum, Carbo vegetabilis,* Sulphur, Sepia and *Natrum muriaticum* at 500, 1500 and 2000 ppm against *Pyricularia grisea.* Data presented in table 9 reveals that none of the homeopathic drugs completely inhibited the growth of *Pyricularia grisea* at 500 ppm, but Silecia and *Thujaa occidentaliss* at 1500 and 2000 ppm and *Arsenicum album* and *Ferrum metallicum* at 2000 ppm completely inhibited the growth of *Pyricularia grisea.*

At 500 ppm, significantly minimum mycelium growth was recorded in Silecia (37.33 mm) followed by *Thuja occidentalis* (54.67 mm), *Ferrum metallicum* (59.33 mm), Sulphur (61.33 mm), *Natrum muriaticum* (63.67 mm), *Arsenicum album* (65.67 mm), Sepia (70.00 mm), Belladona (71.33 mm) and *Kali iodatum* (73.00 mm), while maximum growth of pathogen was noticed in control (83.67 mm) which was found at par with *Carbo vegetabilis* (82.67 mm).

Two homeopathic drugs *viz., Thuja occidentalis* (0.00 mm) and *Silecia* (0.00 mm) were completely inhibited the mycelial growth of *Pyricularia grisea* at 1500 ppm and found most effective among all the homeopathic drugs. The next best homeopathic drug at 500 ppm was *Arsenicum album* (34.67 mm) followed by *Ferrum metallicum* (35.00 mm), Sulphur (41.00 mm), *Carbo vegetabilis* (50.67 mm), *Natrum muriaticum* (58.00 mm), Sepia (61.33 mm), *Kali Iodatum* (64.67 mm) and Belladona (65.33 mm) while maximum growth of pathogen was noticed in control (83.67 mm).

At 2000 ppm, *Thuja occidentalis* (0.00 mm), Silecia (0.00 mm), *Arsenicum album* (0.00 mm) and *Ferrum metallicum* (0.00 mm) completely inhibited the mycelia growth of *Pyricularia grisea* and found significantly superiors over other homeopathic drugs followed by Sulphur (34.33 mm) , followed by *Carbo vegetabilis* (39.67 mm), *Natrum muriaticum* (50.67 mm), Sepia (57.33 mm), *Kali Iodatum* (53.67 mm) and Belladona (59.33 mm), while maximum growth of *Pyricularia grisea* was recorded in control (83.67 mm).

Table 9: ***In-vitro*** **evaluation of homeopathic drugs against** ***Pyricularia grisea*** **at different concentrations**

Homeopathic drugs	Mycelium growth (mm) at different concentrations*(ppm)			Inhibition per cent at different concentrations(ppm)		
	500	1500	2000	500	1500	2000
Silecia	37.33	0.00	0.00	55.38	100.00	100.00
Thuja Occidentalis	54.67	0.00	0.00	34.66	100.00	100.00
Kali Iodatum	73.00	64.67	53.67	12.75	22.71	35.86
Arsenicum album	65.67	34.67	0.00	21.52	58.57	100.00
Belladona	71.33	65.33	59.33	14.74	21.92	29.09
Ferrum metallicum	59.33	35.00	0.00	29.09	58.17	100.00
Carbo vegetabilis	82.67	50.67	39.67	1.20	39.44	52.59
Sulphur	61.33	41.00	34.33	26.70	51.00	58.97
Sepia	70.00	61.33	57.33	16.34	26.70	31.48
Natrum muriaticum	63.67	58.00	50.67	23.91	30.68	39.44
Control	83.67	83.67	83.67	0.00	0.00	0.00
SEm ±	1.93	1.71	1.26	-	-	-
C.D. at 5 %	5.66	5.03	3.69	-	-	-

* Mean of three replications

Plate-4. *In-vitro* evaluation of homeopathic drugs at 500ppm against *Pyricularia grisea*

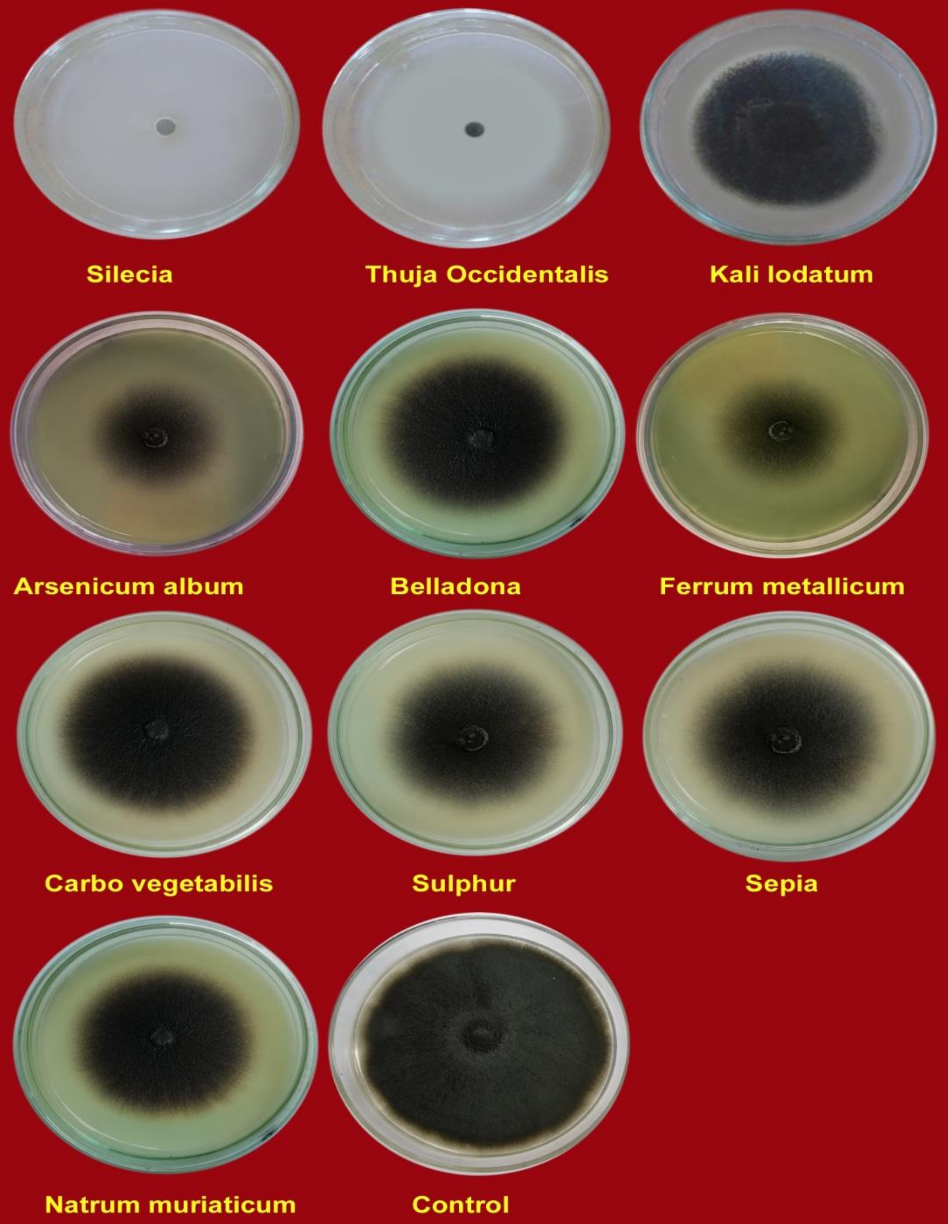


Plate-5. *In-vitro* evaluation of homeopathic drugs at 1500ppm against *Pyricularia grisea*

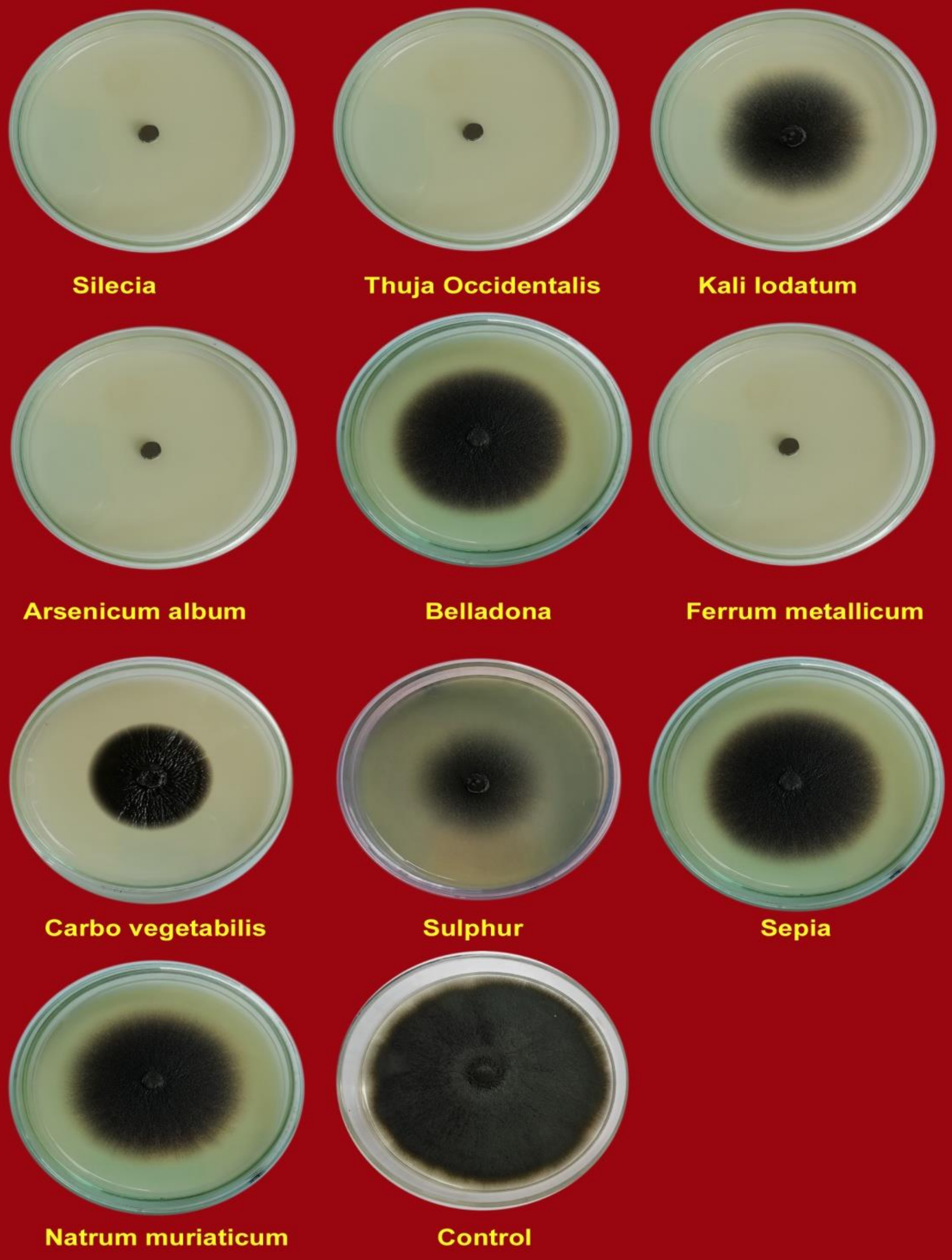


Plate-6. *In-vitro* evaluation of homeopathic drugs at 2000ppm against *Pyricularia grisea*

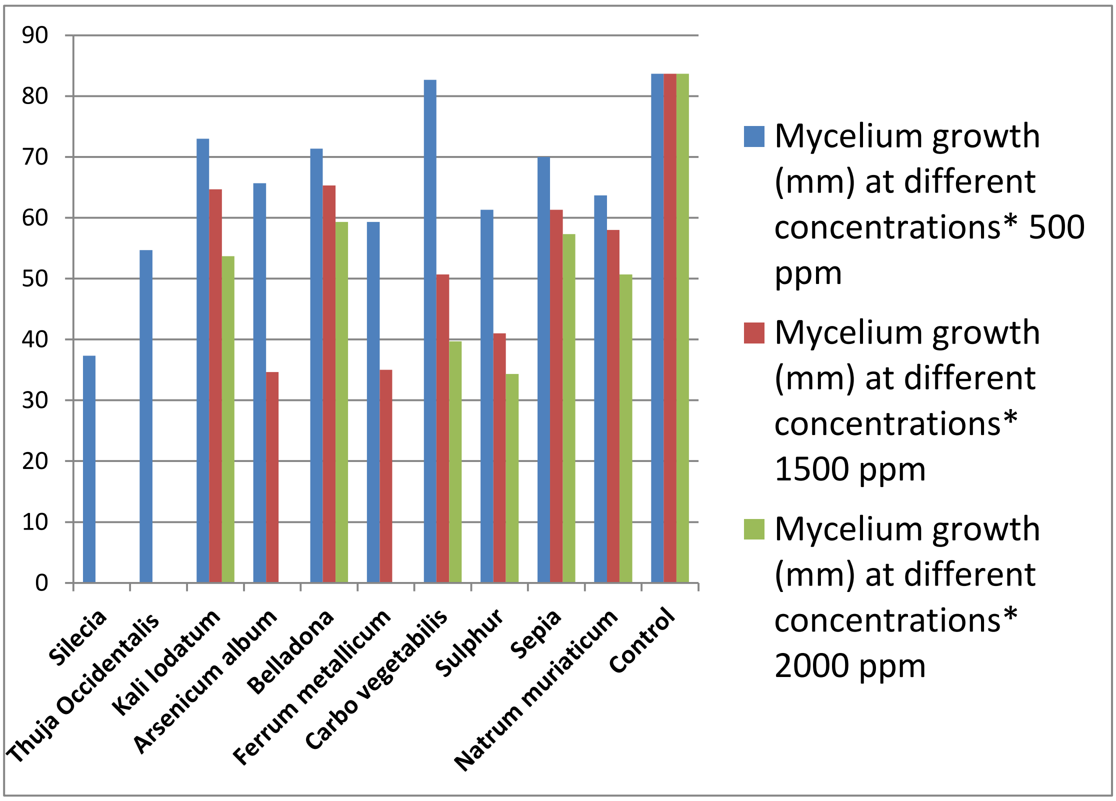


Fig 3: mycelial growth at different concentration

4.4: Evaluation of bio-agents and chemicals against blast under field condition.

A field experiment was carried out at Research Farm, College of Agriculture, Gwalior during *Kharif* season of 2019-20 for the management of pearl millet blast. Five treatment combinations were evaluated against the blast. Data presented in table 10 showed that all the treatment significantly reduced the severity of blast. Minimum blastt score was recorded in T5: Trifloxystrobin+Tebuconazole @ 0.04% 2 sprays after 20 DAS & 35 DAS (1.91) which was found significantly superiors over rest of the treatments. T3: Spray with *P. fluorescens* @ 10g/liter after 20 DAS + Trifloxystrobin + Tebuconazole @ 0.04% after 35 days (2.57) was the next best treatment which was followed by T4: Spray with Trifloxystrobin + Tebuconazole @ 0.04% after 20 days & *B. subtilis* @10g/liter after 35 DAS (2.30), T1: seed treatment with chitosan @ 3.75g/kg seed + 2 sprays of *P. fluorescens* @10g/liter after 20 DAS & 35 DAS (5.00) and T2: seed treatment with chitosan @3.75g/kg seed + 2 sprays of *B. subtilis* @ 10g/liter after 20 DAS & 35 DAS (2.30) while maximum disease severity was recorded in untreated control (6.39).

Data presented in table 10 showed that the maximum grain yield of pearl millet was recorded in T5: Trifloxystrobin + Tebuconazole @ 0.04% two sprays after 20 DAS & 35 DAS (14.25 Q/ha) which was found at par with T3: spray with *P. fluorescens* @ 10g/liter after 20 DAS + Trifloxystrobin + Tebuconazole @ 0.04% after 35 days (14.06.q/ha) followed by T2: seed treatment with chitosan @ 3.75g/kg seed + 2 sprays of *B. subtilis* @10g/liter after 20 DAS & 35 DAS (1318.75 kg/ha), T4: spray with Trifloxystrobin + Tebuconazole @ 0.04% after 20 days + *B. subtilis* @10g/liter after 35 DAS (12.56.q/ha) and T1: seed treatment with chitosan @ 3.75g/kg seed + 2 sprays of *P. fluorescens* @ 10g/liter after 20 DAS & 35 DAS (11.54 q/ha), while minimum yield was recorded in control (10.98q/ha).

Table 10: Evaluation of Bio-agent and chemicals against blast of pearl millet

Symbol	Treatments	Blast Score (0-9) Scale	Grain yield (q/ha)
T1	ST with Chitosan @3.75g/kg seed + 2 sprays of *P. fluorescens* @10g/lt after 20 DAS & 35 DAS	4.88	11.54
T2	ST with Chitosan @3.75g/kg seed + 2 sprays of *B. subtilis* @10g/lt. after 20 DAS & 35 DAS	5.00	13.18
T3	Spray treat. With *P. fluorescens* @10g/lt.after 20 DAS & Trifloxystrobin+Tebuconazole @ 0.04% after 35 days	2.57	14.06
T4	Spray treat. With Trifloxystrobin+Tebuconazole @ 0.04% after 20 days & *B.subtilis* @10g/lt.after 35 DAS	3.33	12.56
T5	Trifloxystrobin+Tebuconazole @ 0.04% 2 sprays after 20 DAS & 35 DAS	1.91	14.25
T6	Control	6.39	10.98
	SE.m±	0.21	
	C.D. at 5 %	0.63	

Mean of 120 observation of four replication, 30 samples from each treatment, each replications.

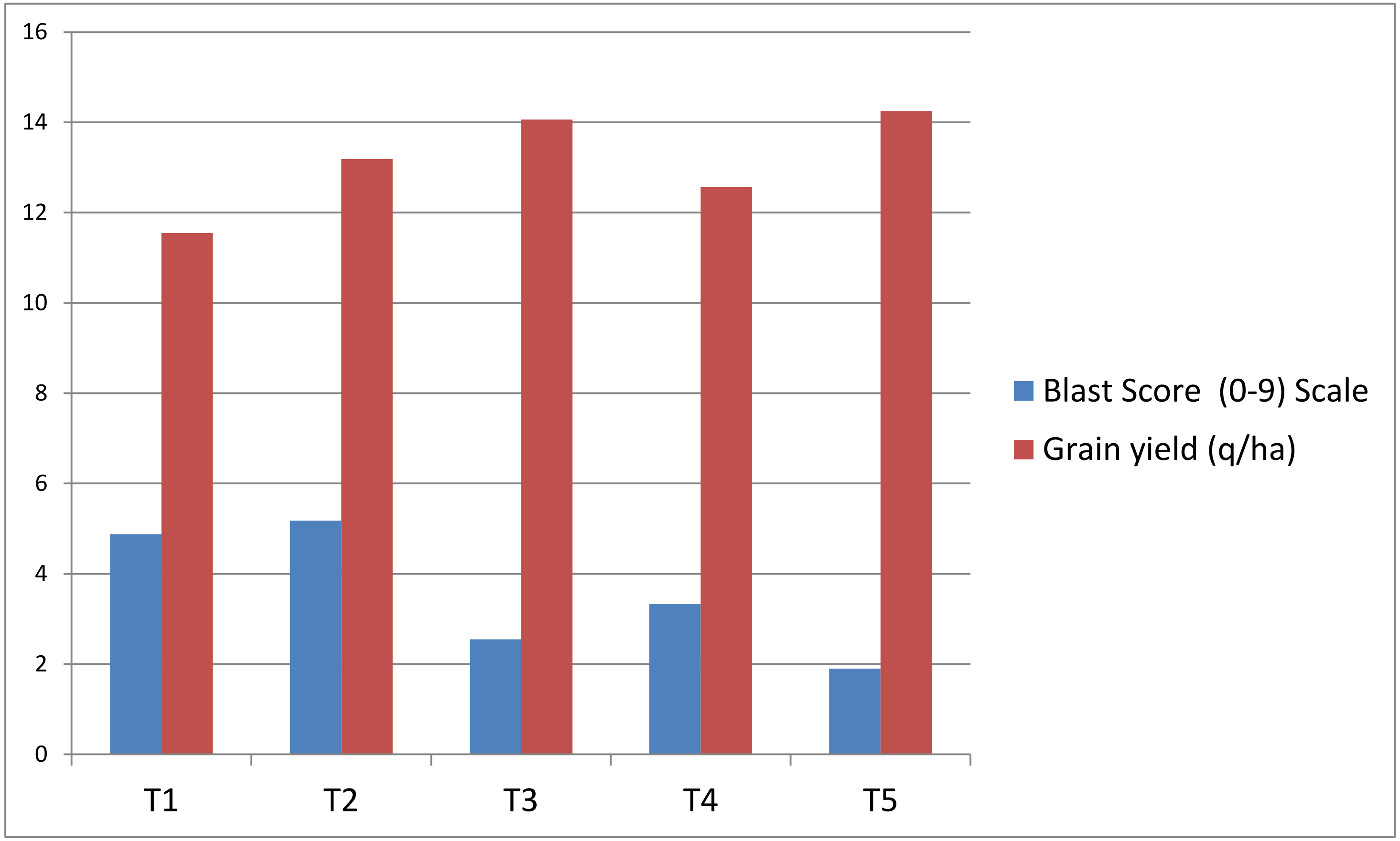


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Fig 4: Evaluation of grain yield and Blast score (0-9) by using bio- agents and chemicals.

4.5: Field evaluation of pearl millet materials against blast diseases

One hundred lines of pearl millet evaluated against blast to find out the resistance sources among them. Data presented in table 11 showed that eighteen lines *viz.,* 97111-A × 15045, RBR- 216, 96222 – A, 96666 – A, 02555 – A, 93333 – A, 05333-A, 97111- A, 81-A1 × RBR 186, 96222 B, RVBH 18-36, GHB-732, PRO AGRO-9444, GHB-558, RHB-177, GHB- 538, 86M01 and MPMH- 17 found completely free from blast affection and showed highly resistant reaction against the disease. Twenty lines *viz.,* 81-A1 × RBR 269, 81-A1 × RBR 259, 81-A1 × RBR161, 81-A1 × RBR 281, 81-A1 × RBR 214, 81-A1 × RBR 246, 81-A5 × RBR 211, 81-A5 × RBR 289, 81-A5 × RBR 214, 81-A5 × RBR 269, 81-A5 × RBR 286, 81-A5 × RBR 281, 98444 B, 81-A5 × RBR 183, 81-A5 × RBR 15045, 81-A5 × RBR 15581, 81-A5 × RBR 220, RVBH 18-38, RVBH18-40, RBR 220 were showed resistant reaction against blast disease, while fourteen lines *viz.,* RBR- 236, RBR- 193, RBR- 192, 86M86, 15083, KAVERY SUPER BOSS, KBH-108, 81-A5 × RBR 296, RVBH18-39, 81-A1 × RBR 211, 81-A1 × RBR 261, 81-A1 × RBR 262, 81-A5 × RBR 181 and RVBH18-41 were exhibited moderately resistant reaction against the disease. Thirty one lines *viz.,* 96222-A × RBR-186, 96222-A × RBR-281, 02555-A × RBR-309, 02555-A × 15045, 15081, RBR- 190, GHB-744, 93333-A × RBR-214, RBR- 189, RBR- 224, 98444-A × RBR-246, 02555-A × RBR-186, RBR-188, RHB-173, 96222-A × RBR-160, 05333-A × RBR-186, 02555-A × RBR-302, 02555-A × 15581, 98555-A × RBR-246, 98555-A × RBR-281, 15090, 15493, RBR- 229, 98444-A × RBR-160, 97111-A × RBR-306, 96222-A × RBR-220, 05333-A × 15042, 15514, 93333-A × RBR-186, 02555-A × RBR-295 and 98555-A × RBR-309 found moderately susceptible against blast. Remaining seventeen lines *viz.,* 97111-A × 15042, 05333-A × RBR-220, 15071, RBR- 159, 02555-A × RBR-220, RBR- 195, 97111-A × RBR-214, 98555 – A, 05333-A × RBR-296, 97111-A × RBR-186, 15072, RBR- 305, 15076, 97111-A × RBR-202, RBR- 191, RBR- 194 and RBR- 196 showed susceptible against blast disease.

Table 11: Screening of pearl millet materials against blast disease.

S. No.	Cultivars	PDI	Reaction
1	98444-A × RBR-246	42.22 (40.52)	Moderately susceptible
2	98444-A × RBR-160	51.11 (45.63)	Moderately susceptible
3	96222-A × RBR-160	48.88 (44.36)	Moderately susceptible
4	96222-A × RBR-186	37.77 (37.92)	Moderately susceptible
5	97111-A × RBR-306	51.11 (45.63)	Moderately susceptible
6	97111-A × 15045	0.00 (0.00)	Highly resistant
7	97111-A × 15042	57.77 (49.47)	Susceptible
8	96222-A × RBR-220	51.11 (45.63)	Moderately susceptible
9	96222-A × RBR-281	37.77 (37.92)	Moderately susceptible
10	02555-A × RBR-186	42.22 (40.52)	Moderately susceptible
11	02555-A × RBR-220	62.22 (52.07)	Susceptible
12	93333-A × RBR-186	55.55 (48.19)	Moderately susceptible
13	93333-A × RBR-214	40.00(39.23)	Moderately susceptible
14	05333-A × RBR-186	48.88 (44.36)	Moderately susceptible
15	05333-A × RBR-220	59.99 (50.76)	Susceptible
16	05333-A × RBR-296	71.10 (57.48)	Susceptible
17	97111-A × RBR-202	75.55 (60.36)	Susceptible
18	97111-A × RBR-214	64.44 (53.39)	Susceptible
19	02555-A × RBR-295	55.55 (48.19)	Moderately susceptible
20	02555-A × RBR-302	48.88 (44.36)	Moderately susceptible
21	02555-A × RBR-309	37.77 (37.92)	Moderately susceptible
22	02555-A × 15045	37.77 (37.92)	Moderately susceptible
23	02555-A × 15581	48.88 (44.36)	Moderately susceptible
24	98555-A × RBR-246	48.88 (44.36)	Moderately susceptible
25	98555-A × RBR-281	48.88 (44.36)	Moderately susceptible
26	98555-A × RBR-309	55.55 (48.19)	Moderately susceptible
27	05333-A × 15042	51.11 (45.63)	Moderately susceptible

28	97111-A × RBR-186	71.10 (57.48)	Susceptible
29	15071	59.99 (50.76)	Susceptible
30	15072	71.10 (57.48)	Susceptible
31	15076	71.11 (57.48)	Susceptible
32	15081	37.77 (37.92)	Moderately susceptible
33	15083	28.89 (32.51)	Moderately resistant
34	15090	48.88 (44.36)	Moderately susceptible
35	15493	48.88 (44.36)	Moderately susceptible
36	15514	51.11 (45.63)	Moderately susceptible
37	RBR- 188	46.66 (43.09)	Moderately susceptible
38	RBR- 189	40.00 (39.23)	Moderately susceptible
39	RBR- 190	37.77 (37.92)	Moderately susceptible
40	RBR- 191	75.55 (60.36)	Susceptible
41	RBR- 194	75.55 (60.36)	Susceptible
42	RBR- 195	62.22 (52.07)	Susceptible
43	RBR- 196	77.77 (61.87)	Susceptible
44	RBR- 193	26.66 (31.09)	Moderately resistant
45	RBR- 192	26.66 (31.09)	Moderately resistant
46	RBR- 236	25.21 (30.14)	Moderately resistant
47	RBR- 159	59.99 (50.76)	Susceptible
48	RBR- 224	40.00 (39.23)	Moderately susceptible
49	RBR- 229	48.88 (44.36)	Moderately susceptible
50	RBR- 305	71.10 (57.48)	Susceptible
51	RBR- 216	0.00 (0.00)	Highly resistant
52	96222 - A	0.00 (0.00)	Highly resistant
53	96666 - A	0.00 (0.00)	Highly resistant
54	02555 - A	0.00 (0.00)	Highly resistant
55	93333 - A	0.00 (0.00)	Highly resistant
56	05333- A	0.00 (0.00)	Highly resistant

57	97111- A	0.00 (0.00)	Highly resistant
58	98555 – A	64.44 (54.29)	Susceptible
59	81-A1 × RBR 269	8.33 (16.78)	Resistant
60	81-A1 × RBR 211	31.11 (33.9)	Moderately resistant
61	81-A1 × RBR 259	6.11 (14.31)	Resistant
62	81-A1 × RBR 161	8.33 (16.78)	Resistant
63	81-A1 × RBR 281	10.00 (18.43)	Resistant
64	81-A1 × RBR 261	31.66 (34.24)	Moderately resistant
65	81-A1 × RBR 214	11.11 (19.47)	Resistant
66	81-A1 × RBR 246	7.22 (15.59)	Resistant
67	81-A1 × RBR 186	0.00 (0.00)	Highly resistant
68	RBR 220	11.11 (19.47)	Resistant
69	81-A1 × RBR 262	31.66 (34.24)	Moderately resistant
70	81-A5 × RBR 296	30.55 (33.56)	Moderately resistant
71	81-A5 × RBR 214	9.44 (17.90)	Resistant
72	81-A5 × RBR 289	8.33 (16.78)	Resistant
73	81-A5 × RBR 211	11.11 (19.47)	Resistant
74	81-A5 × RBR 269	7.22 (15.59)	Resistant
75	81-A5 × RBR 186	11.11 (19.47)	Resistant
76	81-A5 × RBR 281	5.00 (12.92)	Resistant
77	81-A5 × RBR 181	32.22 (34.58)	Moderately resistant
78	98444 B	9.44 (17.9)	Resistant
79	81-A5 × RBR 183	6.67 (14.96)	Resistant
80	81-A5 × RBR 15045	6.67 (14.96)	Resistant
81	81-A5 × RBR 15581	9.44 (17.90)	Resistant
82	96222 B	0.00 (0.00)	Highly resistant
83	81-A5 × RBR 220	9.44 (17.90)	Resistant
84	RVBH 18-36	0.00 (0.00)	Highly resistant
85	RVBH 18-38	11.11 (14.06)	Resistant

86	RVBH18-39	30.55 (32.14)	Moderately resistant
87	RVBH18-40	7.22 (15.59)	Resistant
88	RVBH18-41	32.22 (33.21)	Moderately resistant
89	KAVERY SUPER BOSS	28.89 (32.51)	Moderately resistant
90	86M86	26.66 (31.09)	Moderately resistant
91	KBH-108	28.89 (32.51)	Moderately resistant
92	GHB-732	0.00 (0.00)	Highly resistant
93	GHB-744	37.77 (37.92)	Moderately susceptible
94	RHB-173	48.88 (44.34)	Moderately susceptible
95	PRO AGRO-9444	0.00 (0.00)	Highly resistant
96	GHB-558	0.00 (0.00)	Highly resistant
97	RHB-177	0.00 (0.00)	Highly resistant
98	GHB- 538	0.00 (0.00)	Highly resistant
99	86M01	0.00 (0.00)	Highly resistant
100	MPMH- 17	0.00 (0.00)	Highly resistant

4.6: Screening of pearl millet promising hybrids against blast disease.

A field experiment was conducted at Research Farm, College of Agriculture, Gwalior during *Kharif* season of 2019-20 for screening of Thirty promising hybrids of pearl millet against blast. Out of thirty promising hybrids, none of the promising hybrids found was found highly resistant against the disease. Seven promising hybrids *viz,* HHB 272, JBV 3,, Pratap, Super 27, 86M86, Pioneer 86M90, and Pusa Comp. 383 showed resistant reaction against the disease. Nine promising hybrids *viz,* MPMH 21, AHB 1269, Krishna 9119, Pioneer 86M84, NBH 20, Vardan bajra hybrid, NBH 21, JK26Gold, and JVB 2 were found moderately resistant against the blast, while ten promising hybrids *viz.,* AHB 1200, Raj 171, KAVERI SUPER BOSS, ICMV 155, RHB 173, Pusa Comp. 612, 86M01,PROAGRO 9450, ABV 04, JBV 4, and exhibited moderately susceptible reaction against the disease, while remaining promising hybrids four *viz .,* Dhanya7888, Pusa composite 383, NBH 4903, HHB 67 Improved and ICMV 221 were found susceptible against the disease.

Table 12: Screening of pearl millet promising hybrids against blast

S.No.	Promising hybrids	PDI	Reaction
1	HHB 272	11.11 (19.47)	Resistant
2	MPMH 21	27.78 (31.43)	Moderately resistant
3	HHB 67 Improved	66.66 (55.83)	Susceptible
4	AHB 1269	22.22 (28.12)	Moderately resistant
5	AHB 1200	33.33 (35.26)	Moderately susceptible
6	86M01	44.44 (41.81)	Moderately susceptible
7	86M86	11.11 (19.43)	Resistant
8	Pusa composite 383	11.11 (19.47)	Resistant
9	Krishna 9119	22.22 (28.12)	Moderately resistant
10	Pioneer 86M90	11.11 (19.43)	Resistant
11	Super 27	11.11 (19.49)	Resistant
12	Pioneer 86M84	22.22 (28.16)	Moderately resistant
13	NBH 20	27.78 (31.82)	Moderately resistant

14	Vardan bajra hybrid	27.78 (31.87)	Moderately resistant
15	NBH 21	27.78 (31.77)	Moderately resistant
16	KAVERI SUPER BOSS	50.00 (45.00)	Moderately susceptible
17	JK26Gold	22.22 (28.12)	Moderately resistant
18	PROAGRO 9450	44.44 (41.81)	Moderately susceptible
19	NBH 4903	66.66 (54.73)	Susceptible
20	Raj 171	44.44 (41.83)	Moderately susceptible
21	ICMV 221	61.11 (51.49)	Susceptible
22	Dhanyaan 7888	61.11 (51.42)	Susceptible
23	Pratap	11.11 (19.47)	Resistant
24	ICMV 155	44.44 (41.83)	Moderately susceptible
25	Pusa Comp. 612	38.89 (38.56)	Moderately susceptible
26	ABV 04	38.89 (38.55)	Moderately susceptible
27	JBV 2	22.22 (28.18)	Moderately resistant
28	JBV 3	11.11 (19.45)	Resistant
29	JBV 4	38.89 (38.54)	Moderately susceptible
30	RHB 173	33.33 (35.26)	Moderately susceptible
SEm±		2.75	
C.D. at 5 %		7.94	

Chapter-V
DISCUSSION

A well planned survey was conducted in major pearl millet cultivated districts of Madhya Pradesh to know the Per cent Disease index of blast. The overall blast PDI in all the three districts was 8.98 percent. Among all the villages, highest blast PDI was noticed in Surpura of Bhind district, while lowest PDI was recorded in Maharajpura village of Gwalior district. In Morena district, maximum blast PDI was recorded in Sainthara, while minimum disease PDI was recorded at Dimni. In Bhind district, highest blast PDI was noticed at Surpura, while lowest blast PDI was recorded at Phoop. In Gwalior district, maximum PDI of blast disease was noticed at Bhandoli, while least blast PDI was observed at Maharajpura.

Devda (2009) conducted a similar survey in major pearl millet growing districts *viz.,* Morena, Bhind, and Gwalior and recorded 5.5, 3.8, and 5.4 blast severity, respectively. The average blast severity at Morena, Bhind, and Gwalior, according to Yadav *et al*. (2012), was 11.53, 13.40, and 11.28 percent, respectively. During the Kharif 2012, Naik (2013) conducted a survey and found that the highest level of infection was in Koppal district, with a blast intensity of 76.1 percent, while the lowest was in Bijapur (31.1 percent). Kaurav *et. al.,* (2017) surveyed the blast severity; the block severity was ranged from 1 to 5.48% and 3.6 to 13.8% in 2015-16 and 2016-17 respectively. In 2015-16, the maximum blast severity was noticed in Morena, followed by Morar, Lahar, Seopur, Vijaypur, Shivpuri. During 2016-17, the maximum blast severity was recorded in Sabalgarh followed by Lahar, Joura, Ater, Morena, Ambha.

The biochemical constituents *viz.,* total soluble sugars and total phenols were analysed from blast infected leaf of pearl millet to know the effect of blast disease on total soluble sugars and total phenols. Total sugar gradually increased with increasing infection of blast in the leaf of pearl millet. Maximum total sugar was recorded in highest blast infection scored leaf (9), while minimum sugar content was noticed in blast infection free health leaf of pearl millet. The correlation coefficient between disease score and sugar content was found significantly positive (0.9724). It is clearly indicated that sugar content increased by infection of blast in pearl millet. Highly blast infected leaves of pearl millet had also significantly maximum quantity of total phenol as compared to healthy leaves of pearl millet. Correlation coefficient between blast score and total phenol was found significantly positive (0.9924), which was clearly indicated that the total phenol content increased gradually with increasing of blast infection in pearl millet leaf.

The Bio - chemical analysis shows that the Total sugars and non-reducing sugars declined with age and illness, the reducing sugar, a deficit was observed in all healthy leaves as compared too healthy leaves but the amount of sugar increased in all the diseased leaves Plant age and illness both decreased total phenols, according to Neeraj *et al.* (2010). Except for total phenol and proline levels, Hosagoudar (1997) found a drop in the primary metabolites of infected leaves when compared to healthy leaves. Infected leaves had a halving of soluble sugars. Reduced soluble sugars in diseased leaves suggest that metabolic activity in the leaves has decreased. According to Kumar (2005), resistant genotypes of barley had higher amounts of sugar and reducing sugar than susceptible genotypes throughout the year. Total sugar and reducing sugar were reduced in all genotypes due to leaf blight infection, but the degree of decrease was greater in susceptible genotypes than resistant genotypes. Bisen *et al.* (2015) looked at rice leaves with high levels of total phenol and soluble protein and found that they had a decreased illness incidence. There was a negative connection between total phenol and disease severity at various stages of development.

An *in-vitro* experiment was conducted to evaluated ten homeopathic drugs at 500, 1500 and 2000 ppm against *Pyricularia grisea.* None of the homeopathic drugs completely inhibited the growth of *Pyricularia grisea* at 500 ppm, but Silecia and *Thuja occidentalis* at 1500 and 2000 ppm and *Arsenicum album* and *Ferrum metallicum* at 2000 ppm completely inhibited the growth of *Pyricularia grisea.*

Marcia *et al*., (2016) reported that Arsenicum album was significantly reduced the growth of *A. solani*. Alam *et al.* (2017) reported that Arsenicum album was significantly reduced the growth of *Colletotrichum gloeosporioides* followed by Selenium, Nux vomica, Belladonna and Calcarea fluorica. Rissato *et al.* (2016a) reported that Nosode

24 CH and Sulphur 36 CH and 48 CH completely inhibited the production of sclerotia. Toledo *et al*. (2016) reported that for mycelial growth of *Alternaria solani* in suppressed by Sulphur and Staphysagria 100CH compared to both controls. Rissato *et al*. (2018) conducted *In vitro* experiment and reported that the homeopathic drugs namely Phosphorus 12CH, Phosphorus 48CH and Calcarea carbonica 48CH significantly reduced the growth of *S. sclerotiorum*. According to Asha *et al*. (2014), *Thuja occidentalis* (Q, 30 C, 1 M, 10 M and 50 M) showed inhibitor and found effective against *Fusarium, Bipolaris, Exserohilum, Aspergillus flavus* and *Curvularia.*

A field experiment was carried out at Research Farm, College of Agriculture, Gwalior during *Kharif* season of 2019-20 for the management of pearl millet blast. Two spray with Trifloxystrobin+Tebuconazole @ 0.04% after 20 DAS & 35 DAS which was found significantly superiors over other treatments, while maximum disease severity was recorded in untreated control. Maximum grain yield also recorded in Trifloxystrobin + Tebuconazole @ 0.04% two sprays after 20 DAS & 35 DAS which was found at par with T3: spray with *P. fluorescens* @ 10g/liter after 20 DAS + Trifloxystrobin + Tebuconazole @ 0.04% after 35 days. Similar experiment was conducted by Patro *et al*. (2020) and reported that foliar application of *P. fluorescens* and Trifloxystrobin + Tebuconazole at 20 DAS and 35 DAS respectively was recorded minimum disease severity and found most effective against blast disease. The treatment also recorded highest grain and fodder yield.

Blast disease can be managed by foliar application of *P. fluorescens* for two times (Ramappa *et al.,* 2002). Kumar and Kumar (2011) reported that seed treatment with *Pseudomonas fluorescens* along with two foliar sprays with same bio-agent found most effective against blast disease of finger millet. According to Netam *et al.* (2016) foliar application of *P. fluorescens* was effectively managed the blast incidence. Foliar spray with Trifloxystrobin + Tebuconazole was found most effective reduced the blast disease in pearl millet with higher yield (Kaurav *et al.,* 2018). Sharma et.al., (2018) concluded that Tebuconazolee + Trifloxystrobin or propiconazole was significantly managed the blast disease with higher yields in pearl millet.

One hundred lines of pearl millet evaluated against blast to find out the resistance sources among them. Eighteen lines *viz.,* 97111-A × 15045, RBR- 216, 96222 – A, 96666 – A, 02555 – A, 93333 – A, 05333- A, 97111- A, 81-A1 × RBR 186, 96222 B, RVBH 18-36, GHB-732, PRO AGRO-9444, GHB-558, RHB-177, GHB- 538, 86M01 and MPMH- 17 found completely free from blast affection and showed highly resistant reaction against the disease. Twenty lines *viz.,* 97111-A × 15045, RBR- 216, 96222 – A, 96666 – A, 02555 – A, 93333 – A, 05333- A, 97111- A, 81-A1 × RBR 186, 96222 B, RVBH 18-36, GHB-732, PRO AGRO-9444, GHB-558, RHB-177, GHB- 538, 86M01 and MPMH- 17 were showed resistant reaction against blast disease. Remaining fourteen, Thirty one and seventeen lines were showed moderately resistant, moderately susceptible and susceptible reaction, respectively against blast disease.

Another screening trial was conducted to evaluated thirty promising hybrids of pearl millet against blast. Out of thirty promising hybrids, none of the promising hybrids found was found highly resistant against the disease. Seven promising hybrids *viz.,* HHB 272, JBV 3, AHB 1269, JBV 2, 86M01, PROAGRO 9450 and Pusa Comp. 383 showed resistant reaction against the disease. Nine promising hybrids *viz.,* Super 27, Krishna 9119, AHB 1200, ICMV 221, 86M86, JK26Gold, Pioneer 86M90, NBH 20 and Vardan bajra hybrid were found moderately resistant against the blast. Ten and four promising hybrids showed moderately susceptible and susceptible reaction against the disease.

Kumar (2008) found two entries (MH 148 and MH149) completely free from blast infection. He also screened nineteen promising cultivars. Among nineteen cultivars, only one cultivar (GHB558) found absolutely free from blast. One entry (MH 1541) completely free from the infection of blast was reported by Devda (2009). Yadav *et al.* (2013) screened twenty five promising hybrids and varieties against blast. Out of twenty five cultivars, none of the cultivar was found free from the blast, however the minimum severity of 7.5% was recorded in PB 106, GHB-744, and GHB-732. Meena (2016) reported only four cultivars were found free from blast infection and were kept in the category of highly resistant. Six entries showed 2-3 rating and placed under resistant category. Parihar *et al.* (2019) evaluated fifty promising pearl millet hybrid and varieties against blast. The cultivars namely MPMH17, GHB538 and NHB5061 were found completely free from the blast infection.

Chapter-VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

6.1: SUMMARY

- A well planned survey was conducted in major pearl millet cultivated districts of Madhya Pradesh *viz.,* Morena, Bhind and Gwalior. During the year 2019-20, the overall blast PDI in all the three districts was 8.98 percent. Among all the villages, highest blast PDI was noticed in Surpura of Bhind district (13.44%), while lowest blast PDI was recorded in Maharajpura village of Gwalior district (5.59 %). In Morena district, maximum blast PDI was recorded in Sainthara (12.26%), while minimum blast PDI was recorded at Dimni (6.41 %). In Bhind district, highest blast PDI was noticed at Surpura (13.44%), while lowest blast PDI was recorded at Phoop (6.89 %). In Gwalior district, maximum PDI of blast disease was noticed at Bhandoli (12.11 %), while least PDI of blast disease was observed at Maharajpura (5.59 %).
- The quantity of total sugar gradually increased with increasing infection of blast in the leaf of pearl millet. Maximum total sugar (15.94 mg/g) was recorded in highest blast infection scored leaf (9), while minimum sugar content (14.54 mg/g) was noticed in blast infection free health leaf of pearl millet. The correlation coefficient between disease score and sugar content was found significantly positive (0.9724). It is clearly indicated that sugar content increased by infection of blast in pearl millet.
- Highly blast infected leaves of pearl millet had significantly maximum quantity of total phenol (5.24 mg/g) as compared to healthy leaves of pearl millet (4.15 mg/g). Correlation coefficient between blast score and total phenol was found significantly positive (0.9924), which was clearly indicated that the total phenol content increased gradually with increasing of blast infection in pearl millet leaf.
- An *in-vitro* experiments was conducted to evaluated ten homeopathic drugs *viz.,* Silecia, *Thuja occidentalis, Kali iodatum, Arsenicum album,* Belladona, *Ferrum metallicum, Carbo vegetabilis,* Sulphur, Sepia and *Natrum muriaticum* at 500, 1500 and 2000 ppm against *Pyricularia grisea.* Data presented in table 9 reveals that none of the homeopathic drugs completely inhibited the growth of *Pyricularia grisea* at 500 ppm, but Silecia and *Thuja occidentalis* at 1500 and 2000 ppm and

Arsenicum album and *Ferrum metallicum* at 2000 ppm completely inhibited the growth of *Pyricularia grisea.*

- A field experiment was carried out at Research Farm, College of Agriculture, Gwalior during *Kharif* season of 2019-20 for the management of pearl millet blast. Five treatment combinations were evaluated against the blast. All the treatment significantly reduced the infection of blast. Minimum blast score was recorded in T5: Trifloxystrobin+Tebuconazole @ 0.04% 2 sprays after 20 DAS & 35 DAS (1.9) which was found significantly superiors over other treatments. Maximum grain yield of pearl millet was also recorded in T5: Trifloxystrobin + Tebuconazole @ 0.04% two sprays after 20 DAS & 35 DAS (14.25 q/ha) which was found at par with T3: spray with *P. fluorescens* @ 10g/liter after 20 DAS + Trifloxystrobin + Tebuconazole @ 0.04% after 35 days (14.06 q/ha).
- One hundred lines of pearl millet evaluated against blast to find out the resistance sources among them. Eighteen lines *viz.,* 97111-A × 15045, RBR- 216, 96222 – A, 96666 – A, 02555 – A, 93333 – A, 05333- A, 97111- A, 81-A1 × RBR 186, 96222 B, RVBH 18-36, GHB-732, PRO AGRO-9444, GHB-558, RHB-177, GHB- 538, 86M01 and MPMH- 17 found completely free from blast affection and showed highly resistant reaction against the disease. Twenty lines *viz.,* 81-A1 × RBR 269, 81-A1 × RBR 259, 81-A1 × RBR161, 81-A1 × RBR 281, 81-A1 × RBR 214, 81-A1 × RBR 246, 81-A5 × RBR 211, 81-A5 × RBR 289, 81-A5 × RBR 214, 81-A5 × RBR 269, 81-A5 × RBR 286, 81-A5 × RBR 281, 98444 B, 81-A5 × RBR 183, 81-A5 × RBR 15045, 81-A5 × RBR 15581, 81-A5 × RBR 220, RVBH 18-38, RVBH18-40, RBR 220 were showed resistant reaction against blast disease. Remaining fourteen, Thirty one and seventeen lines were showed moderately resistant, moderately susceptible and susceptible reaction, respectively against blast disease.
- Another screening trial was conducted to evaluated thirty promising hybrids of pear millet against blast. Out of thirty promising hybrids, none of the promising hybrids found was found highly resistant against the disease. Seven promising hybrids *viz.,* HHB 272, JBV 3, Pratap, Super 27, 86M86, Pioneer 86M90, and Pusa Comp. 383 showed resistant reaction against the disease. Nine promising hybrids *viz.,* MPMH 21, AHB 1269, Krishna 9119, Pioneer 86M84, NBH 20, Vardan bajra hybrid, NBH

21, JK26Gold, and JVB 2 were found moderately resistant against the blast. Ten and four promising hybrids showed moderately susceptible and susceptible reaction against the disease.

6.2 : CONCLUSION

- During the survey, the overall blast severity in all the three districts was 8.98 percent. Among all the villages, highest blast severity was noticed in Surpura of Bhind district (13.44%), while lowest severity was recorded in Maharajpura village of Gwalior district (5.59 %).
- The quantity of total sugar and total phenol gradually increased with increasing infection of blast in the leaf of pearl millet.
- Silecia and *Thuja occidentalis* at 1500 and 2000 ppm completely inhibited the growth of *Pyricularia grisea* and found most effective*.*
- Two foliar spray with Trifloxystrobin+Tebuconazole @ 0.04% after 20 DAS & 35 DAS (1.9) was found significantly superiors over other treatments.
- Eighteen lines *viz.,* 97111-A × 15045, RBR- 216, 96222 – A, 96666 – A, 02555 – A, 93333 – A, 05333- A, 97111- A, 81-A1 × RBR 186, 96222 B, RVBH 18-36, GHB-732, PRO AGRO-9444, GHB-558, RHB-177, GHB- 538, 86M01 and MPMH- 17 found completely free from blast affection
- Out of thirty promising hybrids, seven promising hybrids *viz.,* HHB 272, JBV 3, Pratap, Super 27, 86M86, Pioneer 86M90, and Pusa Comp. 383
- **6.3: SUGGESTIONS FOR FURTHER WORK**
- A disease survey and surveillance should be undertaken every year to evaluate whether there are any rhythmic changes in the disease's incidence in response to weather changes.
- It is required to assess genetic resistance in a variety of locations in order to determine the broad base of resistance.
- More number of genotype should be screened to find out the resistance source.
- Few homeopathy drugs are found effective against the pathogen under *In vitro* conditions. Effective homeopathy drugs *viz, silecia, Thuja occidentalis, Ferrum Metallicum, Arsenicum album* should also be used for further assess and compared with the recommended chemicals.

- The effective Blast resistant material should be utilized in crop improvement programme.
- Research work should be carried out on the cultural and genetic variability of the pathogen.

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