EPIDEMIOLOGY AND MANAGEMENT OF LEAF SCALD OF RICE

THESIS

By

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(A-2009-30-33)

Submitted to

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Since my birth to adulthood, you were there with me...

To bolster in all highs n lows of my life, you were there with me...,

Dear PAPA & MUMMY,

I really owe all my success to you and thank you for shaping my future fabulously.

Dedicated to the Most Cherished Persons of my life.....

My Parents and Brother

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CERTIFICATE – I

This is to certify that the thesis entitled **"Epidemiology and management of leaf scald of rice"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the discipline of **Plant Pathology** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Harish Kumar (Admission No. A-2009-30-33)** son of **Sh. Amar Nath Sharma** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

(Dr. S.K. Rana)
Major Advisor

Place: Palampur
Dated: 22 October, 2011

CERTIFICATE- II

This is to certify that the thesis entitled **"Epidemiology and management of leaf scald of rice"** submitted by **Harish Kumar (Admission No. A-2009-30-33)** son of **Sh. Amar Nath Sharma** to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Plant Pathology** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

19.11.11

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Dated: 22 October, 2011

(Harish Kumar)

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LIST OF ABBREVIATIONS USED

Sr. No.	Abbreviation	Meaning
1	*et al.*	et alii (and others)
2	*i.e.*	Id est (that is)
3	*viz.*	vi delicet (namely)
4	*vis-à-vis*	(in comparison with)
5	p.	Page
6	pp.	Pages
7	°C	Degree Celsius
8	g	Gram
9	kg	Kilogram
10	Mt.	Metric tones
11	/	Per
12	%	Per cent
13	Fig.	Figure
14	cm	Centimeter
15	mg	Milligram
16	mm	Millimeter
17	hr	Hour(s)
18	ml	Milliliter
19	q	Quintal
20	ha	Hectare

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ABSTRACT

Field surveys conducted in different districts during *kharif* 2010 established leaf scald (*Rhynchosporium oryzae*) to be an important disease of rice in Himachal Pradesh, with maximum incidence and severity in district Mandi and minimum in Chamba. Pathogen was found to grow and sporulate best at temperature 25-30°C and pH 7. At RH > 70 per cent the disease incidence and severity were high however significantly high at RH 100 per cent. The weather parameters were found to affect inception and establishment of disease and apparent rate of infection. *In vitro* studies on the efficacy of nine fungicides against *R. oryzae* revealed that among systemic fungicides, Tilt 25 EC and Contaf 5EC at 5 and 10 ppm were best providing cent per cent inhibition of mycelial growth whereas SAAF 75 WP among coordinated and Dithane M-45 among non- systemic fungicides exhibited same results at 5 and 200 ppm respectively. Vitavax 200 was found most effective in reducing the seed born infection and gave maximum disease control (20.42 %), when used as seed treatment. The foliar application of Tilt 25 EC (0.1 %) provided maximum disease control (54.02 %) and yield gain (38.49 %) followed by Beam (0.1 and 0.05 %), SAAF (0.25 %), Contaf (0.1 %), Tilt (0.05 %) and Contaf (0.05 %) with three sprays at 15 days interval starting from the first appearance of leaf scald symptoms in the field. Among non systemic fungicides Dithane Z-78 and Dithane M-45 at 0.25 per cent concentration provided disease control of 21.49 and 18.68 per cent and yield gain of 15.15 and 19.70 per cent respectively. Out of 100 rice genotypes evaluated against leaf scald none was found to be completely resistant. Under *in vivo* conditions three genotypes *viz.* IR 71703-57-3-1, IR 70554-48-1-2-YN1-1 and IRBB 60 showed moderately resistant reaction whereas only two *viz.* IR 71703-57-3-1 and IR 70554-48-1-2-YN1-1qualified this category *in vitro*.

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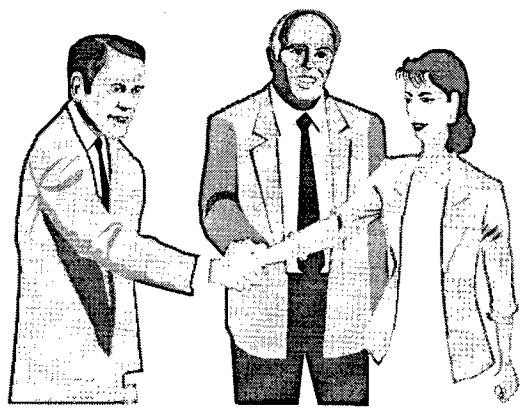


INTRODUCTION

1. INTRODUCTION

Rice (*Oryza sativa*) is the most important cereal crop and a primary food source for half of the world's population. Almost one fourth of the calories consumed by the entire world population come from rice alone. More than 90 per cent of world's rice is grown and consumed in Asia where 60 per cent of earth's population lives (Subudhi *et al.* 2006). Rice is planted over 156 million hectares annually *i.e.* 11 per cent of the world's cultivated land, with the production of 644 million tonnes (FAO 2006).

In India, where agriculture is the "culture of people", rice is the integral part of their life. The country stands at first rank in terms of acreage under paddy (41.85 million hectare) and second with respect to paddy production (89.13 million tonnes) (Anonymous 2010). Today, the rice production scenario is changing rapidly in different agroclimatic regions with the change in farming situations in the country. The crop suffers from the attack of various diseases caused by diverse type of pathogens. The diseases of rice are estimated to cause annually about 10 per cent losses in rice production (Padmnabhan 1959). About 43 fungal diseases are found to be associated with rice (Padhi and Gangopadhyay 1988) which contribute to the major part of total losses.

Rice leaf scald is caused by the fungal pathogen *Rhynchosporium oryzae* (Hashioka & Yokogi) synonym *Microdochium oryzae* (Hashioka & Yokogi) Samuels & I.C. synonym *Gerlachia oryzae* (Hashioka & Yokogi) W. Gams teleomorph *Monographella albescens* (Thüm) Parkinson, Sivanesan and Booth. It is a disease found virtually all over the rice growing regions of the world (International Mycological Institute 1996). Under favourable climatic and cultural conditions, *R. oryzae* can pose a serious threat to rice production and is often ranked in the first three or four fungal constraints for a region, along with blast (*Magnaporthe grisea*), sheath blight (*Rhizoctonia* spp.) and brown spot (*Helminthosporium* oryzae) (Jones *et al.* 1991; Alam *et al.* 1985; Cuevas-Perez

and Gaona 1988; Prabhu and Sitarama-Prabhu 1989). Incidence of leaf scald infection in an area can reach high levels under favourable conditions resulting in significant loss of yield, as 23.4 per cent yield reduction has been reported in India by Srinivasan (1981).

The disease was first described by Hashioka and Ikegami in 1955 although it occurred much earlier in Japan. In Bangladesh the disease has been found to cause 30 per cent yield losses. In India leaf scald of rice was first reported from Kerala (Shanmughom *et al.* 1973) and now it is gradually becoming widespread in different parts of the country. The disease usually occurs late in the season on mature leaves and is favored by wet weather, high nitrogen fertilization and close spacing. The wounded leaves, infected seeds and crop stubbles serve as the source of infection (IRRI 2011).

In Himachal Pradesh also rice is one of the important cereal crops next to wheat and maize on area basis. The crop is cultivated from foot hill plains to an altitude of 2290 m above mean sea level covering an area of 78.6 thousand hectares with the total production of 121.5 thousand tonnes during 2007-08 (Anonymous 2008). However, compared to national average (21.3 q/Ha), the production of crop in the state is only 15.5 q /ha, which is quite low due to the attack of diseases and pests, irregular rains, low nutrient use efficiency, cloudy weather and short growing season.

In the state, the leaf scald of rice was first recorded in 1989-90 during *kharif* season (Anonymous 1990) and from 1999-2000 it is reported to occur with low to moderate (5-30%) severity on regular basis in the state (Anonymous 2007). The incidence of disease attains a high level under favorable climatic conditions *i.e.* continuous and excessive rains during cropping season.

Despite the wide geographical distribution, the leaf scald of rice has been the topic of remarkably little research, being overshadowed by the more damaging rice blast. However, as blast-resistant rice varieties have been developed and being used around the world, leaf scald, a near-ubiquitous disease can become a severe problem under favorable conditions. In light of this,

attention needs to be given to understand the epidemiology of the disease and development of the management strategies. Since no work has been done on any aspect of this disease in Himachal Pradesh, the present studies were conducted with the following objectives:

i. To know the status of leaf scald of rice in Himachal Pradesh
ii. To study the epidemiological components of disease
iii. Management through host resistance and chemicals

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

A sufficient literature is available on the basic aspects of leaf scald of rice caused by *Rhynchosporium oryzae* Hashioka and Yokogi. The relevant literature pertaining to different aspects of present study has briefly been reviewed for guidance and planning of investigations under the following headings:-

2.1 Prevalence and distribution

2.2 Infection process

2.3 Cultural characteristics

2.4 Epidemiology

2.5 Disease management

2.5.1 Chemical management

2.5.2 Disease resistance

2.1 Prevalence and distribution

Leaf scald of rice incited by *Rhynchosporium oryzae* (= *Gerlachia oryzae*) is a common disease in almost all the rice growing countries. It was first described by Hashioka and Ikegami (1955) from Japan. Although it was reported as early as 1951 in Japan as brown leaf blight or 'Kassyokubagarebyo' but Hashioka and Ikegami (1955) called it leaf scald or 'Kumogata-byo' meaning cloud appearance disease, on the basis of specific symptoms of zonate lesions (Gangopadhyay 1983). Afterwards it was found to cause coleoptiles decay with red brown infection and root rot in Costa Rica (De Gutierrez 1960). Further reports started pouring from Elsalvador, Guatemala, Thailand, West Africa, USA, Bangladesh, Sierra Leone and Indonesia (Bakr and Miah 1975; Rao *et al.* 1977; Raymundo 1979). In 1962 and 1973 leaf scald became a severe problem in Guatemala and Louisiana respectively. In 1967, the disease was found in epidemic form in Japan (Matsumoto and Wakimoto 1977). It was confirmed from Brunei in 1974 (Peregrine *et al.* 1974). In Bangladesh the disease has been

found to cause yield losses up to 30 per cent (Bakr and Miah 1975). More than 1000 hectares of rice crop were affected by leaf scald in 1976 December- March crop in Indonasia (Rao *et al.* 1977).

In India, the disease was first time reported in 1970 from Kerala (Shanmughom *et al.* 1973). In Maharashtra, the disease was first observed in September 1970 at Karjat (District Kolava) and Lonavla (District Pune) and later on from hilly areas of Nasik and Kohlapur, having cool climate by D'Souza and Venkataparamanan (1976). It was found that high-yielding varieties were readily susceptible to the leaf scald. From Madhya Pradesh disease was first reported in the monsoon season of 1972 in the disease screening nursery grown under heavily fertilized conditions (200 kg N and 60 kg P_2O_5/ha) (Verma and Agrawal 1975). In Orissa the disease was noticed at Regional Research Station, Chiplima during 1973-1974 in the experimental plots of All India Co-ordinated Rice Improvement Project (Das 1976). The disease has also been reported from North Eastern states *viz.* West Bengal (Mukharjee 1977), Assam (Roy 1977) and Manipur (Singh 1977).

The disease was initially observed in 1977 samba season in Tanjore district of Tamil Nadu. During 1978 thaladi season, the disease was seen in all the raised cultivars while in 1979 thaladi season, its incidence was severe (up to grade 8) in the culture AS2887. Disease was found to cause no yield losses in AS2887 up to grade 4, while at disease grade 8 the losses were maximum *i.e.* 23.4 per cent (Srinivasan 1981). During a monitoring tour in February 1981, Satyanarayana and Reddy (1981) observed that many rice varieties in Regional Rice Research Station, Nellore, were affected by leaf scald disease. In Karnataka the disease was first time observed in October 1982 from Kodaku district on 'Intan' rice which was very susceptible to the disease and had lesions covering more than 50 per cent of the leaf area.

In different rice growing areas of Himachal Pradesh also leaf scald is emerging as a major problem. In the state the disease was first recorded in 1989-90 during *kharif* season (Anonymous 1990) and from 1999-2000 it has been

reported to occur with low to moderate (5-30%) severity on regular basis (Anonymous 2007). The incidence/severity of disease has been found to attain a high level if continuous and excessive rains are received during the cropping season.

2.2 Infection process

Conidia are transmitted by water-splash and germinate on the host surface. Singh and Gupta(1983a)have shown that rice leaf exudates and extracts stimulate conidial germination and germ-tube growth. Interestingly, this stimulation was found to be pronounced more with extracts from susceptible and opposed by resistant rice cultivars. The germ-tubes that emerge from conidia often anastomose (Naito 1982; Ou 1985). Naito (1982) further reported that infection by anastomosis complexes was significantly more successful than infection originating from solitary conidia.

Once the conidia have germinated, hyphae start to spread over the leaf surface. The leading edges of hyphae often run parallel to the longitudinal contours of the leaf surface and lateral branches develop from these exploratory hyphae. When stomata are encountered, the hyphae form swollen appressorial infection structures and penetrate the host through the stomatal apertures. Behind the leading edge of the lesion, the mycelium continues to develop forming a complex mass of inter-connected hyphae in which no preferred orientation can be discerned (Turner and Black 2001).

Although stomatal penetration is the most frequent method of infection, *R. oryzae* is also capable of direct penetration of host tissues. Naito (1982) found that this happens particularly in tissues lacking the heavy deposits of cuticular wax common on leaf surface. On the other hand observations by Turner and Black (2001) have confirmed that direct penetration can occur even into leaves with heavily-waxed cuticles, notably *via* bulliform cells, although stomatal penetration still remains the predominant method of entry.

Once the host leaf has been penetrated, the hyphae ramify between the mesophyll cells. This penetration and intercellular ramification begins in the

green region of the leaf ahead of the expanding necrotic zone. Some penetration of the mesophyll cells occurs (Naito, 1982) as the intercellular network develops and the leaf tissues start dying. Phenolic compounds are deposited and it becomes difficult to distinguish the fungal material present in this necrotic zone. Viable hyphae do persist and perithecia are formed in this necrotic zone (Turner and Black 2001).

The symptoms in the form of oblong or diamond shaped, water soaked lesions more or less restricted by veins, later developing into large ellipsoid or oblong olive areas encircled by dark brown narrow bands accompanied by light brown halos and zonation appear mostly near the tips, but sometimes start at the margins or other parts of the blade. On the leaf sheath and the young inflorescence, only browning occurs (Ou 1985). *R. oryzae* has also been shown to infect the leaf sheath (Singh 1989), seeds (Thomas 1984; Mia *et al.* 1985), spikelets and panicles (Ribeiro 1983). The disease has also been reported to cause decay of coleoptiles, with red brown infection, root rot, and a head blight causing considerable sterility, flower deformation and glume discolouration in Costa Rica (De Gutierrez 1960).

R. oryzae grown in liquid medium (potato dextrose broth supplemented with aqueous rice extract), produces one or more toxic compounds causing chlorosis, wilting and necrosis in rice plants (Turner and Black 2001; Singh and Gupta (1983a). This toxicity was found to be specific to rice plants and may comprise an important mechanism contributing to the successful invasion of the host by the pathogen. It has been demonstrated that conidia held in aqueous suspension for 48 hours can also release one or more host-specific toxic compounds into the water (Turner & Black 1996) and these compounds are dependent on light for their activity (Noor Azman 1994). Elucidation of the conditions for maximum toxin(s) production and its/their nature, however, was hampered by the loss of virulence in the pathogen and attenuation of toxin production during maintenance of the pathogen in culture (Turner and Black 2001).

2.3 Cultural characteristics

Before undertaking the study of any pathogen one must have the knowledge about its morphology, behavior and cultural characteristics. Some of the workers have studied the morphology of *R. oryzae* and tried to trace its characteristics. Parkinson (1980) has given the detailed characters of the fungus which can be described into the following cultural types:

a) Moderate aerial mycelia with deep orange, slimy conidia.
b) Deep pink, thick carpet of fluffy mycelia with orange, slimy conidia.
c) White mycelia with pink tinge, with a raised centre having none to few conidia.
d) Diffuse mycelia with abundant conidia production in orange slime.

Conidia are 6-15 x 3-4.5 µm, borne on short conidiophores, either singly or in clusters, elliptical with pointed ends slightly curved (bow or new moon shaped), occasionally 2-celled, single celled when young, hyaline under microscope.

Optimum growth of *R. oryzae* takes place at 24-28°C. It has tendency to form sector and in case of sector formation it produces only sterile hyphae. Pigmentation and conidial production are hampered on exposing to light. Conidial production is maximum at low glucose-peptone ratio (0.25 per cent glucose). Suitable media for culture of the fungus are lima bean, PDA, polished rice agar, oat meal agar, glucose peptone and synthetic medium (Modified Tanaka medium B) with KNO_3-20g, KH_2PO_4- 1g, $CaCl_2$, - 0.5g, $FeSO_4$ - 0.1g, $MnSO_4$ – 0.0075g, $CuSO_4$ – 0.002g, $ZnCl_2$ – 0.006g, $(NH_4)_6Mo_7O_{24}$ – 0.0075g, Biotine- 0.075g, Thiamine- 1.0g in 1.0 L water and Difco agar 29g (Gangopadhyay 1983). Thomas (1981) also made some studies on media for culturing *R. oryzae, in vitro* and isolated the fungus on PDA as well as Sucrose agar (SA) pH 7 and Peptone agar (PA) pH 5 successfully. However on transfer from SA or PA, the fungus was not able to sustain on PDA. In addition to other 4 media tested, V-8 vegetable juice agar (VA) pH 4.3 was most suitable for maintaining a good growth and abundant sporulation of fungus.

Manandhar (1998) studied the effect of light, temperature, and water potential on growth and sporulation of *R. oryzae*. He found that radial growth and conidial production was higher on potato-sucrose-salt agar (PSSA) than malt extract agar, nutrient agar, PDA, potato sucrose agar (PSA) and V8 juice agar. Radial growth on PSSA was 8.5 mm/day with production of 3 x 10^6 conidia/cm^2/ day at 21°C. Radial growth and conidial production was more in dark at 25 to 30°C, than under 12 hour light and dark cycle at 21°C. The fungus grew faster when the water potential (ψ) was adjusted to −0.14 to −1.0 MPa with sucrose or KCl than with NaCl. The radial growth in sucrose-, KCl- or NaCl-amended media increased as ψ_s decreased from −0.14 to −0.53 MPa and incubation temperature increased from 15 to 30°C; and declined with decrease in ψ_s from −4.83 to −5.3 MPa in sucrose and −8.23 to −8.81 MPa in KCl or NaCl. Conidial production on ψ_s −0.14 to −2.07 MPa in sucrose was two-fold higher than KCl and four-fold higher than NaCl. It increased steadily with decreased ψ_s from −1.0 to −1.2 MPa at 25 or 30° C in sucrose, however, decreased at ψ_s from −0.25 to −0.7 MPa and then increased at −1.8 MPa in KCl or NaCl. Conidia are formed on ageing cultures in orange-pink gelatinous patches; particularly if the medium is supplemented with an aqueous extract of rice leaves however, prolonged maintenance *in vitro* results in attenuation of the isolate's pathogenicity and sporulation capacity (Turner and Black 1996).

The perfect stage of *R. oryzae* was revised as *Monographella albescens* (Thum) by Parkinson *et al.* (1981). Spherical perithecia, dark brown in colour with spherical to pear shaped osteol and having set of eight ascospores per ascus develop within the mesophyll layer of infected leaves (Turner and Black 2001; Gangopadhyay 1983). Asci are cylindrical to club shaped and slightly curved (22-60 x 9-15µm) having obliquely uniseriate, sometimes biseriate, elliptical or fusoid, colourless, 3-4 septa , long slender ascospores (9-29 x 2.5-9 µm) with colourless paraphyses (Ou *et al.* 1978). Crill *et al.* (1979) succeeded in inducing perithecia formation in cultured isolates by crossing isolates on rice leaf sheaths placed on 1.7 per cent agar containing Sach's medium.

2.4 Epidemiology

The knowledge of epidemiology of a pathogen is an important key to devise the management practices that can reduce or eliminate the initial inoculum, slow down the infection rate and can even escape the disease. *R. oryzae* has been reported to cause seed infection and many workers have tried to find out the role of paddy seed as the primary source of inoculum. Sanchez *et al.* (1979) isolated *R. oryzae* from the infected seeds and found that it could survive up to 7 months at 20-35°C in both air-dried and sun-dried samples. The fungus was found widely seed-borne as out of 50 seed samples collected from 9 districts in Karnataka, 37 were infected with *R. oryzae* and infection ranging from 0.25 to 64 per cent (Mia and Safeeulla 1984). They further indicated the presence of fungus in all the parts of the seed and its deep seated nature indicated the survival for longer time within seed as the primary source of infection. Thomas (1984) reported that the pathogen did not survive in dry season (November - May) under field conditions but survived in harvested seeds stored at 26-28°C for a year. However Mia *et al.* (1985) found it to survive for 11 years at 5°C.

Mia *et al.* (1986) tested 103 grain samples of different varieties collected from 13 districts of Karnataka and found 80 samples infected with infection percentage ranging from 0.25 to 64.0. The average infection in husk, endosperm and embryo was 22.8, 19.6 and 10.4 per cent respectively. Singh and Gupta (1986) studied the role of various sources of perpetuation of leaf scald fungus and found that a low percentage of unsterilized seeds of the cultivar 'Cheena 1' yielded the pathogen within the first three months of collection of samples. Conidia and mycelia of the fungus remained viable in air dried infected leaves kept in paper bags at 20-30°C for 4-6 months but not at 35°C. On infected leaves buried at different soil depths, the conidia remained viable for four months, while the stroma remained viable at 5 to 10 cm for at least 8 months. However, at surface soil and at a depth of 15 cm the stroma did not remain viable beyond 5 months.

Manandhar (1999) observed that the survival of *R. oryzae* decreased over time in seed lots stored at 10°C and 40 per cent relative humidity. He obtained highest frequency of *R. oryzae* in the endosperm and lemma, intermediate in the basal glumes and palea, and least in the embryo of seeds of IR 36, IR42 AND IR 46.

Alternate hosts are another potential source of inoculum for this disease. Several host species have been identified amongst graminaceous weeds commonly found around the margins of rice fields for example *Echinocloa crus-galli* (Singh and Gupta 1981); *Oryza perennis, Echinocloa crus-galli* and *Brachiaria mutica* (Das 1994). The transmissibility of *R. oryzae* between these potential hosts and cultivated rice as well as phenotypic and genetic similarities between isolates found on rice and non-rice hosts would require further investigation.

Plants supplied with 30-40 kg N/ha and with 150 kg N/ha were affected by the disease in Indonesia (Rao *et al.* 1977). Heavy rainfall of 600 mm/month and temperature of 24-30°C are highly conductive for disease development (Gangopadhyay 1983). The incidence and severity remain unaffected with closer or wider spacing (Virmani and Sumo 1978). Late sowing can also escape the disease in some regions (Verma and Agrawal 1975).

2.5 Disease management

2.5.1 Chemical management

Chemical management is one of the oldest methods of disease management in aerial, seed and soil borne diseases. Evaluation of *in vitro* efficacy against a particular pathogen is the primary step in the use of fungicides. Further the field evaluation confirms the true efficacy of fungicide for the control of disease in the field.

Under *in vitro* conditions Singh and Gupta (1984) studied the fungicidal and fungistatic effect of ten protective and systemic fungicides on spore germination of *R. oryzae* and observed that at lower concentrations, test fungicides were fungistatic while at higher concentrations they were fungicidal.

Difolatan and Sanspor were fungistatic and fungicidal at much lower concentrations of 0.02 and 1ppm (in terms of active ingredient) respectively. The fungistatic and fungicidal concentrations of Cuman L and Captan were also much lower than others. The values of fungicidal concentrations were several times higher than those of the fungistatic concentrations. The difference in fungistaitc and fungicidal concentrations varied from about 50 times (Difolatan and Sanspor) to about 4-5 times (Blitox-50 and Calixin). Dithane M-45, Bavistin and Blitox-50 were fungistatic at 5, 7 and 40 ppm while fungicidal at 40, 50 and 150 ppm respectively. Das (1995a) evaluated *in vitro* efficacy of nine commercial fungicides *viz.* Bavistin (carbendazim), Kitazin (IBP), Blitox-50 (copper oxychloride), Kavach (Chlorothalonil), Foltaf (Captafol), Dithane M-45 (Mencozeb), Hinosan (Ediphenphos), Topsin-M (Thiophanate methyl) and Cuman-L (Ziram) against *R. oryzae* and observed maximum inhibition of 100 per cent mycelial growth with Bavistin, Kitazin, Topsin-M and Hinosan at 50 ppm followed by Foltof at 100 ppm, Cuman-L at 200 ppm and Blitox-50 and Dithan M-45 at 500 ppm.

Under field conditions also Singh and Gupta (1982) evaluated nine fungicides with two sprays at an interval of two weeks and found that all the test fungicides reduced the incidence and severity of leaf scald significantly and increased yields compared to control. Of these fungicides, Difolatan (captafol) and Dithane M-45, sprayed @ 1600 and 1560 ppm (in terms of active ingredient) were more effective than all other test fungicides. They also studied the persistence of these fungicides in rice leaves and found that Blitox-50 (copper oxychloride), Difolatan and Dithane M-45 had relatively longer persistence. Mia *et al.* (1985) have reported Bavistin and Topsin M to be effective in eliminating the seed borne infection of *R. oryzae* at much lower doses *i.e.*7-10 ppm. Das (1995b) also evaluated some fungicides against leaf scald in the field and recorded lowest disease index with Topsin-M (0.1%) sprays which gave 56.8% disease control. It was followed by Bavistin (0.1%), Hinosan (0.1%) and Kitazin (0.1%) with 46.8, 45.1 and 44.4 per cent disease control respectively. The

highest grain yield of 42.4 q/ha was also obtained with Topsin-M sprayes followed by Hinosan, Bavistin, and Kitazin. Kumbhar and Savant (1998) tested the relative efficacy of 6 fungicides *viz.* Carbendazim (0.1%), Captafol (0.25%), Triforine (0.2%), Edifenphos (0.1%), Captan (0.25%) and Copper oxychloride (0.25%) against leaf scald under field conditions and found Carbendazim and Captafol to be most effective in reducing the incidence to an extent of 81.68 and 76.14 per cent respectively with only two sprays at 15 days interval. The per cent increase in yield was also maximum with Carbendazim (56.71%) followed by Captafol and Dithianon.

2.5.2 Host resistance

Use of disease resistant varieties is an economic and effective measure of disease management. In a number of regions where leaf scald is a significant constraint to rice production, screening of cultivars for resistance has been introduced. This has been done through field-trials usually using the International Rice Research Institute (IRRI) standard evaluation system to determine relative disease severity. The proportion of tested rice lines showing high levels of resistance, according to these standards, has often been disappointingly low. For example out of 1209 test materials constituting the disease screening nursery, Verma and Agrawal (1975) found only 19 entries showing low infection of leaf scald under natural conditions.

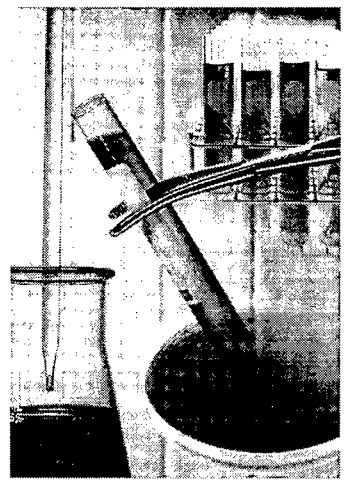
Singh (1975) screened the breeding material of All India Coordinated Rice Improvement Project for reaction to leaf scald and among the popular high yielding varieties found IR 22, Palman 579 and Pusa 2-33 to be resistant whereas IR 8, Jaya and IR 24 susceptible ones. Some of the varieties resistant to bacterial leaf blight such as BJ 1, Lacrosse-Zenith-Nira and IR 127-8-10, were also resistant to this disease. Das (1976) reported 5 varieties *viz.* Tkm 6, C 633, C1977, C3249 and RP 79-13 as resistant and 33 as moderately resistant from 437 entries. During the screening of rice varieties to bacterial leaf blight by clip-inoculation method, the fungus was also seen to establish the infection through clipped area (D'Souza and Venkataramanan 1976). Shamprakash (1977) also

evaluated some rice varieties against leaf scald and found that IR 26, MTU 20, IET 2254 and 3232 were highly resistant while Jaya, Annapurna, IR 22 and Kakatheya were highly susceptible. In a varietal screening programme initiated in 1980, 589 varieties were evaluated against leaf scald and of these 24 were found resistant and others were moderately resistant to susceptible. While during 1981, 152 cultivars were tested and only 2 *viz.* Paro white and Pokhareli masino were found resistant (Verma and Singh 1982).

At BCKV Kalyani, West Bengal, Singh and Gupta(1983a)screened 46 rice cultivars against leaf scald under natural infection and 11 through artificial inoculation and found that under both the conditions none was completely resistant but the high yielding cultivars IR 20, Ratna, indigenous 'Dular' and some other cultivars *viz.* IET 2859, Pankaj, Begunbibhi, NL 1281, ARC 10603 and IR 2071-875-2-3-4 had a fare level of resistance. They also observed that the rate of spread of disease was much lower in the resistant cultivars than the susceptible ones like Cheena 1 and Jaya. Pandurangegowda *et al.* (1983) tested 20 rice cultivars for resistance to leaf scald and found VL8, 5742 (Imp. Sabarmati/Sona), 6903 (RP5-32/Pankaj), 7150 (PTB 10/N136-19) Pankaj, Rasi (TN1/Co 29), Jaya (TN1/T141), KMS5914 (Sona/Mahsuri) and Intan to be resistant ones. Saifulla (1993a) found only one entry out of 490 accessions showing resistance to leaf scald at Karnal. Saifulla (1993b) also reported an accession showing relatively high levels of resistance to both scald and blast.

Efforts have also been made in other countries to find out the resistance sources for leaf scald of rice. In Brazil Faria and Prabhu (1980) developed a simple and uniform method for screening rice cultivars for resistance to *R. oryzae* under glasshouse conditions. They inoculated leaves of 30 days old rice plants grown in plastic trays with 6-7 days old mycelial disks, incubated them under moist conditions for 96 hours and measured the lesion extension from the point of inoculation as an indicator of resistance. Of the 40 local and introduced rice cultivars screened, 21 showed relative resistance to one isolate of *R. oryzae*. Ribeiro (1983) reported that the incidence of severe scald disease episodes has

increased with the introduction of semi-dwarf rice varieties in Brazil. Under lowland conditions in Indonesia, Rahamma (1986) found 10 out of 100 cultivars showing good resistance to leaf scald. Bonman *et al.* (1990) screened 288 rice accessions for resistance to *R. oryzae*, using an *in vitro* method and found that there was a continuum from low to high levels of resistance and none of the accession showed complete resistance to the pathogen.



MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigations entitled "Epidemiology and management of leaf scald of rice" were carried out at Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. All the laboratory and green-house experiments were conducted in the Department of Plant Pathology. Field Experiments were conducted at Rice and Wheat Research Centre (RWRC), Malan. The pot experiments were conducted in completely randomized and field experiments in randomized block designs. All the trials except evaluation of rice germplasm were carried out using susceptible variety "Kasturi" with the recommended package of practices.

3.1 Sterilization of glass/plastic wares

'Borosil' brand glass wares like test tubes, Petri plates, conical flasks, beakers and measuring cylinders etc. were dipped in chromic acid mixture (sodium dichromate 75g, distilled water 500 ml and concentrated sulfuric acid 500ml) overnight and washed with running tap water for 10 minutes and thrice in distilled water before use and sterilized in hot air oven at 160°C for 1 hour. Plastic wares were sterilized with 5 per cent ethyl alcohol or 2 per cent Sodium Hypochlorite. Growth media were sterilized in autoclave at 15 psi pressure for 20 minutes (Pandit 2010).

3.2 Collection and maintenance of disease material

Rice leaves with characteristic symptoms of leaf scald were collected during 2009-10 crop season from the experimental farm of RWRC, Malan where the disease was prevalent in severe form. The samples were placed between blotting sheets, dried and then preserved in brown paper envelops after proper labeling. Disease samples were also collected while conducting survey and surveillance tours in different parts of the state during the year 2010-2011 and studied under microscope to confirm the presence of pathogen.

3.3 Isolation and maintenance of pathogen

Small leaf bits of 2-3 mm size were cut from the junction of diseased and healthy tissue with the help of sterilized scalpel, surface sterilized by dipping in 0.1 per cent mercuric chloride solution for 30 seconds and washed thrice with sterilized distilled water. These bits were placed on sterilized filter paper to soak free water and then plated on potato dextrose agar medium (pH-6) in Petri plates under aseptic conditions and incubated at 25±1°C. After 48 hours Petri plates were observed for growth of mycelium from bits. The bits giving growth of light pink to whitish mycelium were selected for subculturing the pathogen. The mycelium along with some medium from the edge of the developing colony was taken with the sterilized inoculation needle and placed in the PDA slants and incubated at 25±1°C. After 7 days, the sporulating cultures were further purified by single spore isolation technique and the pure culture was maintained on PDA slants for further experiments. Stock cultures were subcultured regularly at an interval of 15-20 days. Unless otherwise stated, 7 days old cultures were used in all the experiments.

3.4 Pathogenicity Test

Pathogenicity test was performed on susceptible basmati rice cultivar 'Kasturi' to confirm the pathogenic nature and identity of the isolated fungus *i.e. Rhynchosporium oryzae*. The rice leaves exhibiting characteristic scald symptoms were collected from the fields of RWRC Malan and observed under microscope to confirm the presence of pathogen. Isolation was taken from these samples as described under section 3.3 and cultural characteristics were recorded and compared with literature.

3.4.1 Preparation of inoculum

Twelve days old sporulating culture of *R. oryzae* grown on PDA was taken to prepare spore suspension. Spores were harvested by adding small amount of sterile water to the culture slants and gently rubbing them with inoculation needle. The resultant spore suspension was filtered through double layer of muslin cloth to remove mycelial fragments. The spore concentration was fixed at 1×10^6 conidia/ml using haemocytometer and used as standard inoculum for inoculation.

3.4.2 Raising of seedlings and inoculation

Soil collected from the field area of Department of Plant Pathology, CSK HPKV Palampur was mixed uniformly with FYM @ 200g/kg of soil and then sterilized with formalin (40%) @ 25 ml formalin diluted in 100 ml of water for 20 kg of soil. Treated soil was covered with polythene sheet and kept as such for 7 days and then exposed for aeration before filling the pots. The plastic pots of 6" diameter were surface sterilized with 5 per cent ethyl alcohol and filled with sterilized soil. The seeds of susceptible variety ' Kasturi' were sown @ 7 seeds/pot and sprinkled with water. After sowing the pots were kept in growth chamber and watered frequently. The germination and further growth of seedlings was monitored regularly.

Two months old plants were then artificially inoculated with the prepared spore suspension (1 x 10^6 conidia/ml) using atomizer. Inoculated plants were shifted to green house and kept in the humidity chamber. The humidity was maintained above 90 per cent using fogger. Pots were watered regularly and observed daily for the appearance of disease symptoms. The pathogen was re-isolated from infected plants and identification was confirmed by microscopic examination.

3.5 Status and distribution of disease

Systematic surveys were conducted in different rice growing areas of Himachal Pradesh during September-October, 2010. From each visited location, 25 tillers were selected randomly and leaf scald incidence and severity were calculated on all the leaves of these tillers as mentioned under section 3.6. The disease samples collected from each surveyed location were also examined under microscope in laboratory to confirm the presence of pathogen.

3.6 Recording disease incidence and severity

The disease incidence was calculated by counting the number of diseased and healthy leaves from these selected tillers.

$$\text{Disease Incidence (\%)} = \frac{\text{Total number of diseased plants/leaves}}{\text{Total number of plants/leaves observed}} \times 100$$

The same leaves, used for recording incidence were also observed for disease severity. The disease severity was calculated using the following formula described by Habgood (1975).

$$\text{Disease severity (\%)} = \frac{\sum i \times 100}{\sum a}$$

Where '*a*' is the area of each leaf and '*i*' is the infection level in terms of lesion area. The measurement of the leaf was made according to the length-width method of the International Rice Research Institute (1971) which is as follows: *A* = *klw,* where '*k*' is the adjustment factor with a value of 0.75, '*l*' is the length and '*w*' is the width of leaf.

3.7 Epidemiological components of disease

3.7.1 Effect of temperature on growth and sporulation

Effect of five temperature regimes *viz.*, 15, 20, 25, 30 and 35°C on fungal growth and sporulation was studied. Five mm bits from the seven days old non sporulating culture of *R. oryzae* were transferred to potato dextrose agar medium in Petri plates (90 mm). After inoculation, the Petri plates were incubated at above mentioned temperatures, maintained in five different incubators. The continuous darkness was maintained in the incubators and further Petri plates were covered with the black chart paper. Each treatment was replicated four times.

The data on growth in terms of colony diameter (mm) was recorded after seven days of inoculation with the help of ruler. For the measurement of sporulation the plates were flooded with 10 ml of 0.05 per cent NaOCl, brushed with a flat-type hair brush and the resultant suspension was diluted in a known volume of 0.01 per cent Tween 20 solution. The number of conidia/cm^2 of the colony were counted with a haemocytometer (average of two counts) using a compound microscope. The number of conidia were calculated by using formula

(C X V)/ πr^2, where C = the number of conidia/ mL, V = the volume of the conidial suspension in ml, and πr^2= area of the colony in a cm^2 (Manandhar 1998).

3.7.2 Effect of pH on growth and sporulation

Effect of hydrogen ion concentration (pH) was also studied on growth and sporulation of pathogen. Six levels of pH *viz.* 4, 5, 6, 7, 8 and 9 were evaluated. The various levels of pH were adjusted in medium with the help of freshly prepared solutions of HCl (1N) and NaOH (1N). The pH adjusted media after sterilization were poured into 90 mm Petri plates under aseptic conditions with five replications for each pH level. The inoculation was done with 5 mm mycelial bits taken from seven days old culture of *R. oryzae* and then incubated at 25±1°C. The continuous darkness was maintained in the incubator and data on growth and sporulation were recorded after 7 days as described under section 3.7.1.

3.7.3 Effect of relative humidity on disease development under controlled conditions

The effect of relative humidity on disease development was studied under controlled conditions. A pot experiment was laid with three replications for each RH (%) level of 60, 70, 80, 90 and 100 per cent. The seedlings of susceptible variety 'Kasturi' were raised in 6" diameter pots as described under section 3.4.2 and two months old plants were then inoculated with freshly prepared spore suspension (described under 3.4.1) of standard spore strength (1 x 10^6 conidia/ml) of *R.* oryzae. Initially plants were kept under humidity chamber for 48 hours and humidity was maintained above 95 per cent by regular fogging of water to initiate the infection. After that plants were transferred to greenhouse and kept inside polythene chambers. The respective RH levels were maintained by regular fogging of water on plants in poly chambers and monitored using digital hygrometer.

Data on disease severity and number of lesions per leaf were recorded after 20 days of inoculation. The analysis of variance was done as per completely randomized design (CRD) at 5 per cent level of significance.

3.7.4 Effect of age of inoculum on spore count *vis-à-vis* pathogenicity of *R. oryzae*

An experiment was conducted to see the effect of age of inoculum on its pathogenicity. The isolated fungus was maintained in PDA slants at 25±1°C in the incubator. Each time the culture slants were picked up at pre-specified intervals of 15, 30, 60 and 90 days, studied for the presence of spores and then inoculated on two months old rice plants grown in six inch size pots (described under section 3.4.2) in triplicate. For inoculum preparation the fungal mycelium along with spores was homogenized in the homogenizer and suspension was filtered through muslin cloth. The filtrate was sprayed on plants grown in pots @ 50 ml for 3 pots and kept in the humidity chamber at high relative humidity (>95 %). The plants were frequently sprayed with water and regularly watered. The data on disease severity was recorded after 20 days of inoculation.

3.7.5 Role of weather variables in disease development

The relationship between climatic factors and disease development was studied under natural epiphytotic conditions during *kharif* 2010 at RWRC Malan. The data on weather variables *viz.* maximum minimum and average temperature (°C), relative humidity (%), rainfall (mm) and number of rainy days were obtained from the meteorological observatory of RWRC Malan. The weekly average of weather data was used except rainy days. For recording the disease development ten plants of susceptible variety "Kasturi" were tagged in the field. The disease severity was recorded on each plant from the first appearance of symptoms in the field, at weekly intervals. The apparent infection rate 'r' was also calculated as per the formula given by Vanderplank (1963)

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

Where; x_1 and x_2 are the proportion of disease tissue at dates t_1 and t_2 respectively.

3.8 Disease management

3.8.1 Fungicide evaluation

i. *In vitro* evaluation

Four systemic *viz.* Bavistin 50 WP (carbendazim), Beam 75 WP (tricyclazole) Contaf 5 EC (hexaconazole) and Tilt 25 EC (propiconazole), three non systemic *viz.* Blitiox 50 WP (copper-oxychloride), Dithane M-45 75 WP (mancozeb) and Dithane Z- 78 75 WP (zineb) and two coordinated fungicides *viz.* SAAF 75 WP (carbendazim 12 % + mancozeb 63 %) and Vitavax 200 75 WP (carboxin 37.5 % + thiram 37.5 %) were used to evaluate their *in vitro* efficacy against *R. oryzae.*

Poisoned food technique (Flack, 1907) was followed to assay the efficacy of fungicides. Double strength test concentrations of each fungicide were prepared in 50 ml sterilized distilled water and added individually to equal volume of double strength PDA to get desired concentrations *viz.,* 50, 100, 200, 250, 500 and 1000 ppm for non- systemic fungicides and 1, 2, 5, 10, 20 and 50 ppm for systemic and coordinated fungicides. PDA plates in triplicate, impregnated with each fungicide at desired concentrations were inoculated with 5 mm bit of 7 days old culture and incubated at 25±1°C. Petri plates having PDA devoid of any fungicide were inoculated and incubated in the similar way, served as control for comparison. Data on mycelial growth (mm) were recorded after 10 days when the fungus completely colonized the Petri plates kept as check and per cent growth inhibition over control was calculated for comparing the efficacy of each fungicidal concentration of different fungicides against the pathogen.

ii. *In vivo* evaluation

a) Effect of seed treatment with fungicides

Six selected fungicides *viz.* Bavistin 50 WP (carbendazim), Contaf 5 EC (hexaconazole), Tilt 25 EC (propiconazole), Vitavax 200 75 WP (carboxin 37.5 % + thiram 37.5 %), Dithane M-45 75 WP (mancozeb) and Thiram 75 WP were tested @ 2.5 g/Kg seed as dry seed dressers except Tilt and Contaf, which were used as wet treatments by dipping seed in 0.1 per cent solution for 6 hours to

check their efficacy against leaf scald in a field trial at RWRC Malan by using seed of susceptible variety 'Kasturi'. The trial was laid out in randomized block design with four replications by direct sown method. The data on disease severity and seed yield per plot were recorded. Per cent disease control and yield gain were also calculated.

b) Effect of fungicidal spray

Efficacy of sprays of different fungicidal concentrations was evaluated by conducting a field trial at RWRC Malan. The nursery of leaf scald susceptible cultivar "Kasturi" was grown in the raised beds. Thirty days old seedlings were transplanted in plots of 1m x 2.7m size (in five rows) in a randomized block design with three replications, during 2010 *kharif* season.

Four systemic *viz.* Bavistin 50 WP (carbendazim), Beam 75 WP (tricyclazole), Contaf 5 EC (hexaconazole) and Tilt 25 EC (propiconazole), three non systemic *viz.* Blitox 50 WP (copper-oxychloride), Dithane M-45 75 WP (mancozeb) and Dithane Z-78 75 WP (zineb) and two coordinated fungicides *viz.* SAAF 75 WP (carbendazim 12% + mancozeb 63%) and Vitavax 200 75 WP (carboxin 37.5 % + thiram 37.5 %) were evaluated with two concentrations for each fungicide. All the recommended package of practices for rice crop were followed. Three sprays of each fungicidal concentration were given at an interval of 15 days starting from the first appearance of disease symptoms in the field. The disease was assessed 20 days after final spraying. At random 20 tillers were selected per replication and disease severity was recorded as given under section 3.6. The grain yield was recorded after harvest and sun-drying of produce. Data was analysed statistically and percent disease control and yield gain were calculated.

3.8.2 Germplasm evaluation

i. *In vivo* evaluation

Hundred rice germplasm lines including some commercial varieties were evaluated for resistance against leaf scald under transplanted conditions at RWRC Malan during 2010 *kharif* season. Thirty days old seedlings of these lines

were transplanted in paired rows of 2 m length. These lines were fertilized with high dose of N 120 kg/ha in order to create better epiphytotic conditions. The rice leaves exhibiting symptoms and having sporulating lesions in the adjoining early planted crop were taken and ground in the grinder. The extract was filtered through muslin cloth to obtain conidial suspension. The leaves of first three plants in each row were clipped and inoculated with this conidial suspension to increase the inoculum load in the field. The data on disease severity were recorded when most of the lines approached maturity *i.e.* at growth stage 8 (dough stage). The per cent disease index (PDI) was also calculated by using the following formula given by McKinney (1923):

$$\text{PDI (\%)} = \frac{\text{Sum of all the disease ratings X 100}}{\text{Total number of ratings X maximum infection score examined}}$$

The ratings were done on 0-9 scale as per IRRI (1988) Standard Evaluation System for Rice.

Scale for evaluating leaf scald of rice:

Scale	Code	Severity and prominent lesion type
0	HR	No incidence
1	R	Very small apical lesion having less than 1 per cent area of leaf
3	MR	Apical lesion covering 1-5 per cent leaf area
5	MS	Apical lesions with some marginal lesions affecting 6-25 per cent leaf area
7	S	Apical and marginal lesions covering 26-50 per cent leaf area
9	HS	Apical and marginal lesions affecting more than 50 per cent leaf area

ii. *In vitro* evaluation

The same rice germplasm was also screened under controlled greenhouse conditions. The potting mixture was prepared as described under section 3.4.2 and filled in the trays of 30 x 30 x 15 cm size. Five seeds of each entry were sown in the holes made in soil equidistant from each other in trays. Then after trays were marked, sprinkled with water and kept in the growth chamber for germination. After the germination of all the entries, the trays were shifted to green house. Watering of plants was done regularly twice a day in the morning and evening.

Forty five days old plants were then inoculated with the standard spore suspension (1 x 10^6 conidia/ml) of *R. oryzae* and kept under polythene chambers. Relative humidity in the chambers was maintained above 95 per cent by regular spray of water. After 20 days of inoculation data were recorded on disease severity using standard scale, PDI values were calculated and entries were classified as HR, R, MR, MS, S and HS according to the standard scale of IRRI (1988).

3.9 Statistical analysis

All the data obtained from the field, laboratory and green house experiments were subjected to analysis of variance. Before analysis the data were transformed wherever found necessary (Gomez and Gomez 1984). Disease progress data were correlated with meteorological parameters and simple correlation was calculated as per the standard statistical procedures (Panse and Sukhatme, 1984).

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The present investigations entitled "Epidemiology and management of leaf scald of rice" were undertaken with a view to know the status and distribution of disease in the state, its epidemiology and to device the management practices through host resistance and chemicals.

The results obtained on various aspects are described under the following subheadings:

4.1 Pathogenicity test

4.2 Status and distribution of disease in Himachal Pradesh

4.3 Epidemiological components of the disease

4.3.1 *In vitro* studies

4.3.2 *In vivo* studies

4.4 Disease management

4.4.1 Chemical management

4.4.2 Host resistance

4.1 Pathogenicity test

The fungus isolated from the rice leaves exhibiting characteristic scald symptoms, was found to be pathogenic and exhibited similar symptoms when inoculated on a susceptible variety 'Kasturi' under controlled conditions. Establishment of Koch's postulates proved that the isolated fungus was the real cause for the scald symptoms (Plate 1) obtained on the infected leaves from which was obtained. Further study of cultural characteristics and microscopic observations revealed that the pathogen was *Rhynchosporium oryzae* Hashioka and Yokogi.

A lot of variation was observed in the morphology of cultures isolated/obtained from same place. On the basis of morphology and sporulation behavior of colonies the cultures were grouped into three categories (Table 4.1and Plate 2).

Table 4.1 Groups of *R. oryzae* cultures on the basis of their morphology

S. No.	Group	Characteristics
1.	A	Abundant fluffy mycelial growth usually light pink to pinkish white with conidia produced in a deep orange colored slime. The conidial masses were of various patterns and wherever formed there was no mycelial growth.
2.	B	Moderate aerial usually pink to light pink mycelium with sparse conidial production in orange slime masses.
3.	C	Diffuse mycelial growth with abundant, uniform conidial production in orange slime. The whole colony appeared orange to dark orange in colour. No aerial mycelial growth observed and after about 7 days the Petri dish was found to be covered with conidia deposited in the orange slime.

The cultures falling in group A in the present studies were almost similar to the cultures placed in group 'A' by Parkinson (1980). These were very irregular in sporulation and sometimes did not sporulate at all. If sporulation occurred, it was found to start after 4-5 days in the culture. This type of culture was found to loose sporulation capacity and light pinkish tinge (pigmentation) of mycelium with subsequent subculturing but the mycelium remained fluffy. The Group B and C cultures were found to be nearly similar to the cultures described under Group C and D by Parkinson (1980). On subsequent subculturing both the culture types were found to exhibit slow radial mycelial growth, forming thick dark orange mycelial mat and decrease in sporulation capacity appeared similar to Group B described by Prakinson (1980) except that it had no aerial mycelium. The sector formation as recorded by Parkinson (1980) was also observed in all the three groups in the present studies. The Group 'C' culture was uniform in growth and sporulation therefore selected and maintained in PDA slants for further studies.

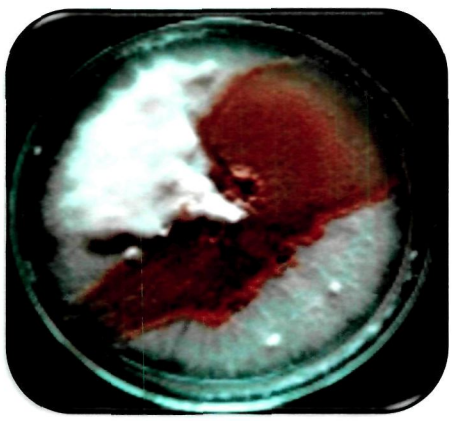
a. Leaf scald in field

b. Leaf scald through artificial inoculation *in vitro*

c. Through clip inoculation

d. Characteristic zonation

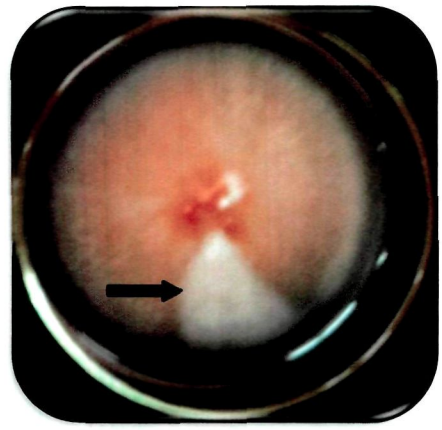
Plate 1. Leaf scald symptoms



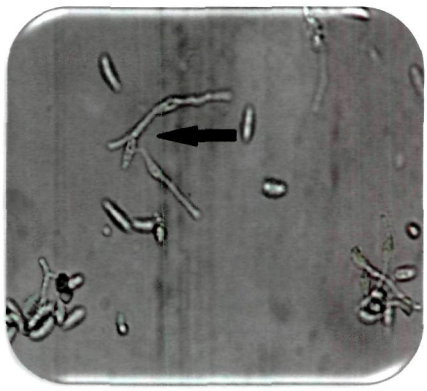
GROUP 'A'

GROUP 'B'

GROUP 'C'



Sector formation



Anastomosis complex

Conidia in culture

Plate 2. Cultural variation in *R. oryzae*

The microscopic observations showed that the conidia present on host tissue were bow to sickle shaped, hyaline, have mostly 1septum rarely 2 and no septum in young ones and had dimensions 6-15 x 3-4.5 µm corresponding closely to the description of species by Hashioka and Ikegami (1955). The conidia in culture were also hyaline, sickle to oblong, borne on conidiophores either singly or in clusters with more or less round ends. While purifying the culture through single spore technique the germinating conidia on water agar were found to form anastomosis complex between germtubes as described by Naito (1982), the another character of *R. oryzae* (Plate 2).

4.2 Status and distribution of disease in Himachal Pradesh

To assess the status and distribution of leaf scald in the state, extensive field surveys were conducted in different rice growing areas of districts Kangra, Chamba, Kullu, Mandi, Una, Bilaspur, Hamirpur, Sirmour and Solan during *kharif* 2010 (September-October). The survey of 33 locations in 9 districts (Figure 1) revealed that disease was prevalent in all the localities with incidence varying from 9 to 68.25 per cent and severity between 6.30 to 37.65 per cent (Table 4.2 and Figure 2). An overall incidence of 33.30 per cent and severity 17.93 per cent were recorded in the state during *kharif* 2010. Among the surveyed locations, maximum incidence and severity was at Bhambla in Mandi district *i.e.* 68.25 and 37.65 per cent, respectively. The figures were also comparable for both incidence and severity from Dhaulakuan, Jahu, Malan, Chakkar and Majra (Table 4.2). The district wise average incidence and severity showed maximum disease in Mandi and Hamirpur districts *i.e.* 48.20-48.56 per cent disease incidence and 27.88-28.29 per cent disease severity whereas it was minimum in Chamba and Una districts having disease incidence 10-15.35 per cent and severity 6.65-9.71 per cent.

Rice is cultivated in the state from foot hills to an altitude of 2290 m above mean sea level under varied agroclimatic conditions for the crop. For this reason, different types of rice varieties (improved, local and hybrid) suitable for different agroclimatic conditions are grown in the state following different

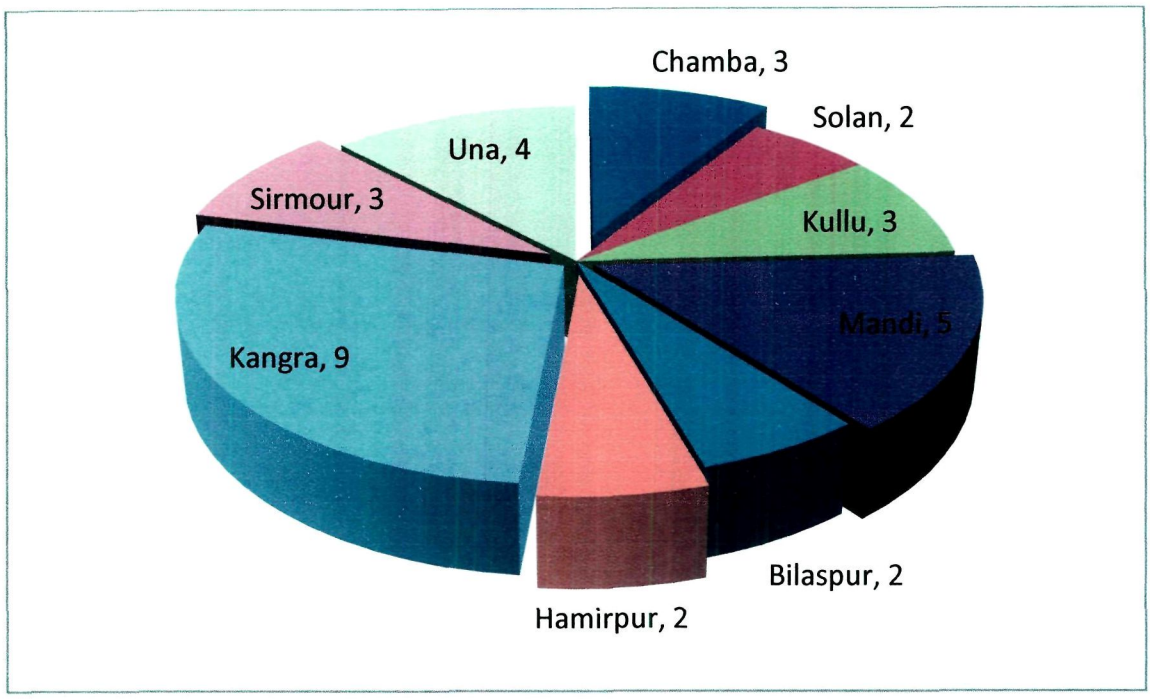


Figure 1. Locations surveyed in each district in H.P.

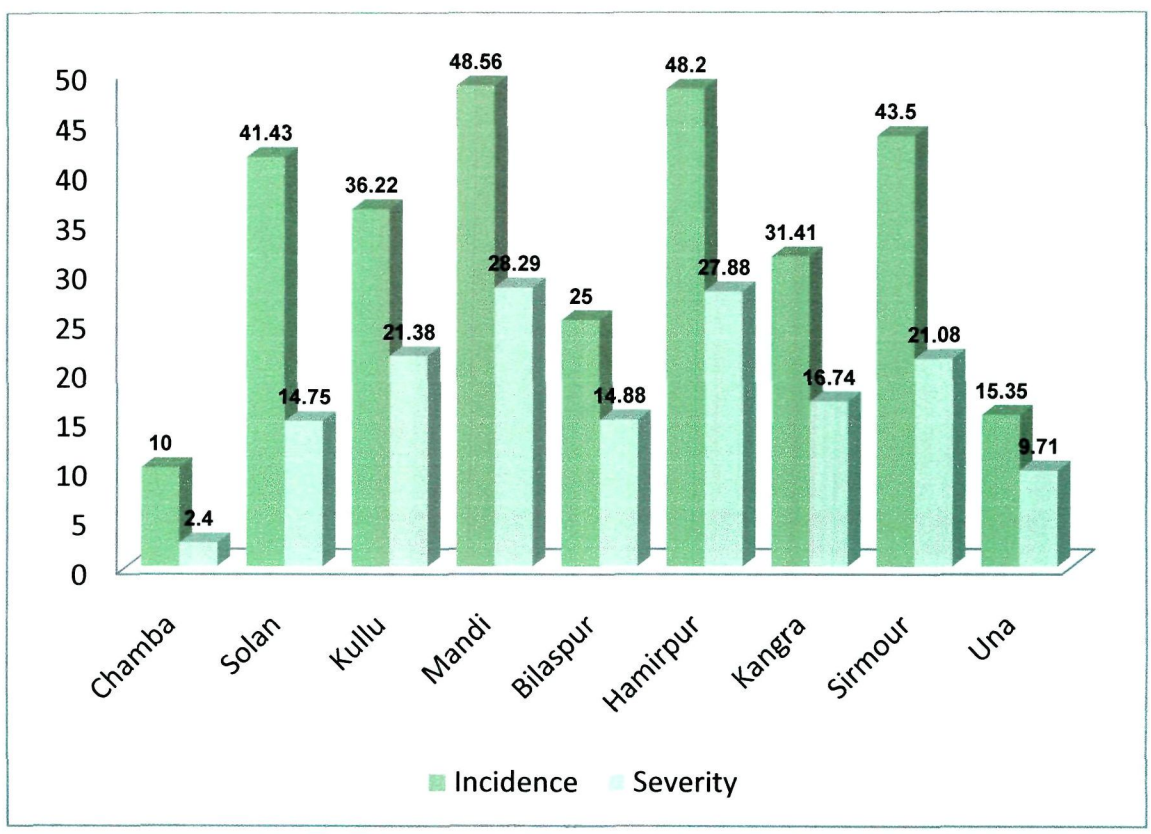


Figure 2. Leaf scald incidence and severity in districts of H.P.

Table 4.2 Status and distribution of leaf scald in different rice growing areas of Himachal Pradesh

District/Locality	DI (%)	Av DI (%)	DS (%)	Av DS (%)
Chamba				
Sihunta	10.00	10.00	06.65	06.65
Kamla	09.00		06.30	
Daintha Har	11.00		07.00	
Solan				
Nalagarh	42.35	41.43	14.50	14.75
Baddi	40.50		15.00	
Kullu				
Sohil	30.35	36.22	22.40	21.38
Hamser	42.05		20.95	
Shamshi	36.25		20.79	
Mandi				
Bhambla	68.25	48.56	37.65	28.29
Chakkar	56.00		35.00	
Nag Chala	46.25		20.25	
Nagvain	33.50		22.50	
Chauntra	38.80		26.05	
Bilaspur				
Shahtalai	26.00	25.00	14.75	14.88
Ghumarwain	24.00		15.00	
Hamirpur				
Jahu	62.00	48.20	34.25	27.88
Ladror	34.40		21.50	
Kangra				
Palampur	10.40	31.41	03.65	16.74
Sapdi	26.20		08.50	
Takipur	20.35		07.50	
Dorian	35.65		20.55	
Samloti	36.20		28.35	
Thural	20.45		08.50	
Malan	60.50		28.65	
Mahakaal	40.45		27.00	
Shahpur	32.50		18.00	
Sirmour				
Dhaulakuan	65.50	43.5	26.00	21.08
Majra	50.00		30.75	
Kala Amb	15.00		06.50	
Una				
Jankor	10.00	15.35	03.25	09.71
Haroli	20.45		16.50	
Nandpur	15.45		07.90	
Basal	15.50		11.20	
Average		33.30		17.93

Av = average, DI = disease incidence, DS = disease severity

cultivation methods (direct sown or transplanted). This might be the reason for variation in the leaf scald incidence and severity from one place to another. In addition plant spacing and varietal status also exhibited variation in disease scenario in various areas. However contrary to it Virmani and Sumo (1978) have earlier reported that leaf scald incidence and severity remains unaffected with closer or wider spacing. It is thus clear from the above observations that leaf scald is an important disease of all rice growing areas of Himachal Pradesh especially in the Mandi, Hamirpur, Sirmour, Kullu, Solan and Kangra districts. The results are comparable with the earlier reports (Anonymous 1989-90 and Anonymous 2007).

4.3 Epidemiological components of the disease

4.3.1 *In vitro* studies

I. Effect of temperature on growth and sporulation of *R. oryzae*

Temperature is one of the important factors for the growth and sporulation of fungi, so the mycelial growth (mm) and number of spores per cm^2 of the colony in relation to different temperatures were studied under *in vitro* conditions and the results are presented in Table 4.3. The growth of fungus increased steadily from 15 to 30°C and inhibited completely at 35°C (Plate 3a). It is evident from the data that after 7 days of inoculation the maximum mycelial growth of 77.75 mm occurred at 30°C but statistically was at par with growth at 25°C. The similar trend was observed for the sporulation of fungus. The highest sporulation (2.975 x $10^4/cm^2$) was observed at 30°C which was at par with 25°C and there was no sporulation at 35°C. This showed that the fungus required a little higher temperature for its growth under cultural conditions.

The present findings are corroborated by the findings of Manandhar (1998) who found that radial growth and conidial production was greater in the dark at 25 or 30°C, than under 12 hour cycle of light and dark at 21°C. Parkinson (1980) obtained optimum growth of *R. oryzae* between 24-28°C. Shamprakash (1977) has also obtained maximum growth of leaf scald pathogen at 25°C however the temperature range for growth varied from 15 to 35°C.

Table 4.3 Effect of temperature on growth and sporulation of *R.oryzae*

S. No.	Temperature (°C)	Radial growth (mm)	Sporulation per cm^2
1	15	09.88	0.1175×10^4
2	20	63.00	0.9125×10^4
3	25	75.25	2.9×10^4
4	30	77.75	2.975×10^4
5	35	00.00	0.0×10^4
CD (5%)		7.53	0.665×10^4

*mean of four replications

II. Effect of hydrogen ion concentration (pH) on growth and sporulation of *R. oryzae*

Hydrogen ion concentration (pH) is also an important factor determining the growth and sporulation of a fungus. An experiment was conducted to find out the optimum pH for the growth of *R. oryzae* on PDA at 25°C. Different pH levels ranging from 4.0 to 9.0 were tested with five replications each. The data on mycelial growth (mm) and sporulation (spores/cm^2) is presented in Table 4.4.

The pathogen showed increase in mycelial growth from acidic to neutral pH and then decrease towards alkaline pH (Plate 3b). The growth was maximum at pH 7 (67.4 mm) and minimum at pH 4 (34.9 mm). In a similar way sporulation was also maximum at neutral pH and which decreased towards alkaline pH. It was least at pH 4 (0.89×10^4 spores/cm^2) and highest at pH 7 (4.66×10^4

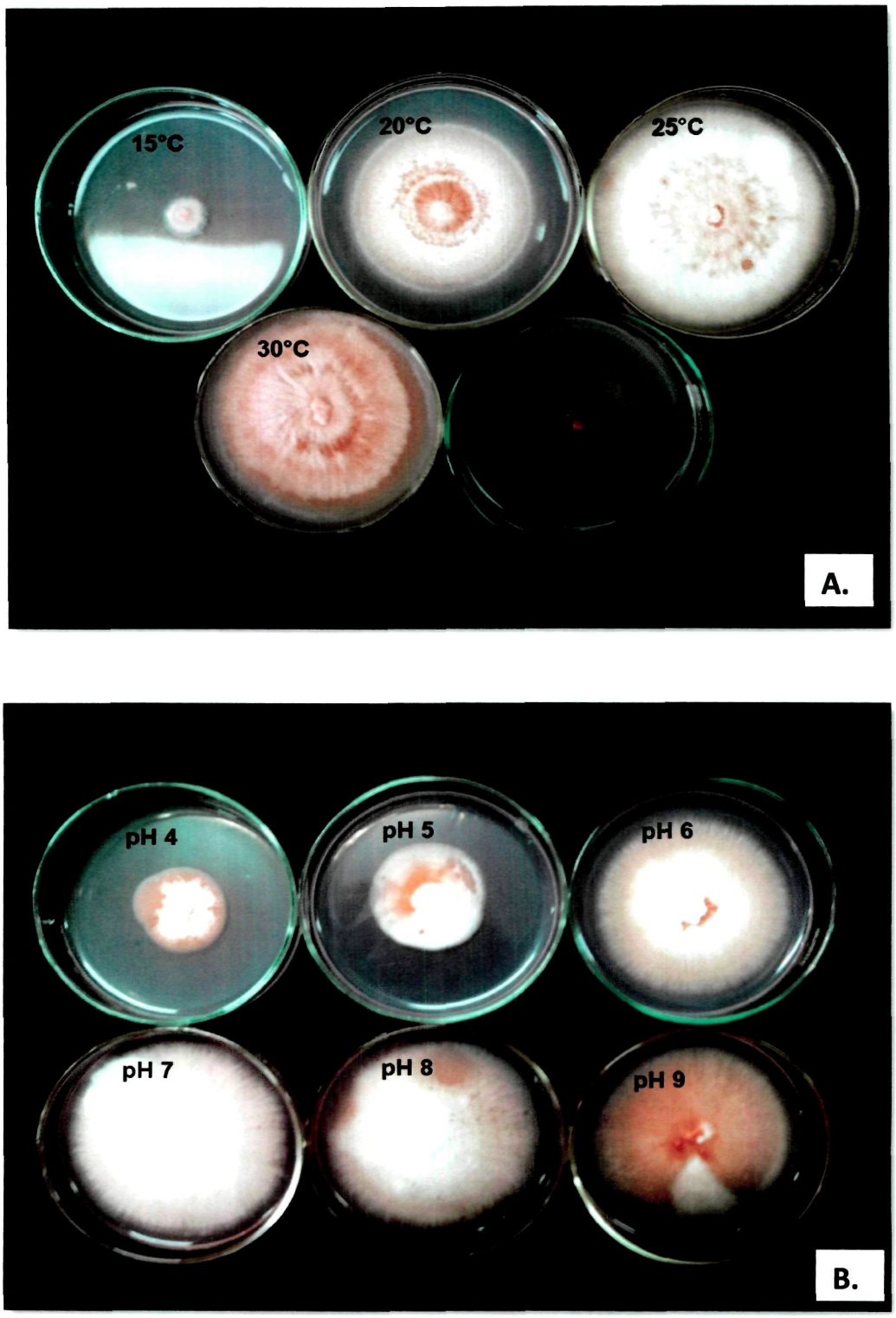


Plate 3. **Effect of temperature (A) and pH (B) on growth and sporulation of *R. oryzae***

spores/cm^2). This indicated that the pathogen could grow and sporulate best on neutral pH. However contrary to these observations Shamprakash (1977) has reported that *R. oryzae* could grow under wide range of hydrogen ion concentration and 4.2 to 6.2 being the best. Another pathogen of rice *Cercospora oryzae* causing narrow brown leaf spot produced abundant conidia at pH 5.7 – 7.1 and temperature 25-28°C on rice Straw decoction agar medium (Gangopadhyay 1983).

Table 4.4 Effect of hydrogen ion concentration (pH) on growth and sporulation of *R. oryzae*

S. No.	pH	Radial growth (mm)*	Sporulation per cm^2 *
1	4	34.9	0.89 x 10^4
2	5	45.8	1.74 x 10^4
3	6	58.9	3.42 x 10^4
4	7	67.4	4.66 x 10^4
5	8	59.3	2.78 x 10^4
6	9	51.8	2.22 x 10^4
CD (5%)		7.17	0.684 x 10^4

*mean of five replications

III. Effect of relative humidity on disease development under controlled conditions

An experiment was conducted to know the effect of relative humidity on incidence and severity of rice leaf scald in controlled conditions using a susceptible cultivar 'Kasturi'. The data were recorded after 20 days of inoculation and presented in Table 4.5. It is clear from the data that both incidence and

severity increased gradually with the increase in relative humidity (RH) from 60 to 100 per cent. The lesions per leaf (2.07 lesions/leaf) and severity (31.33 per cent) were highest at 100 per cent RH. Though the lesions per leaf were statistically at par, at 70, 80, 90 and 100 per cent RH. The severity at RH 80, 90 and 100 per cent were also at par. It shows that RH above 80 per cent is conducive for development of disease.

Table 4.5 Effect of relative humidity on disease development under controlled conditions

S. No.	Relative humidity (%)	Lesions per leaf*	Disease severity (%)*
1	60	0.40	07.77
		(1.18)	(2.86)
2	70	1.73	16.50
		(1.65)	(4.15)
3	80	1.73	23.33
		(1.65)	(4.89)
4	90	1.77	28.17
		(1.66)	(5.36)
5	100	2.07	31.33
		(1.75)	(5.66)
CD (5%)		0.20	1.42

Values in parentheses are square root transformed means
*mean of three replications

It is well known that humid conditions favor the disease development in most of the cases. Wet conditions are not only essential for the germination of any fungal spore, but also govern the further growth and development of pathogen on its host. Rafei and Ou (1979) in their studies on the effect of relative humidity on rice blast (*Pyricularia oryzae*) found an increasing trend in the number of lesions per leaf when the inoculated seedlings were exposed to 50 to 95 per cent relative humidity. In the present studies also the lesions per leaf and

severity gradually increased with increase in RH. In rice blast the high humidity not only influences the spore germination and infection but also increases the sporulation and dissemination of conidia (Hashioka 1943; Hemmi and Imura 1939; Kuribayashi and Ichkabwra 1952).

IV. Effect of age of inoculum on spore count *vis-à-vis* pathogenicity of *R. oryzae*

An experiment was conducted to know the effect of age of pathogen on its pathogenicity under *in vitro* conditions. The data on effect of age of inoculum on incidence and severity of *R.* oryzae is given in Table 4.6.

It is evident from the data that there was a sharp decline in the number of spores per cm^2 at each time interval. The highest spore count (3.5983×10^4 spores/cm^2) was recorded in the 15 days old culture and least (0.1367×10^2) in the 90 days old culture. A comparable decline was also observed in the respective leaf scald incidence and severity. Both the incidence and severity, were significantly higher *i.e.* 25.55 and 22.58 per cent respectively in the plants inoculated with 15 days old culture than others.

Table 4.6 Effect of age of inoculum on spore count *vis-à-vis* pathogenicity of *R. oryzae*

S. No.	Inoculum age (days)	Number of spores per cm^2	Disease incidence (%)*	Disease severity (%)*
1	15	3.5983×10^4	25.55	22.58
			(5.12)	(4.79)
2	30	7.2267×10^2	7.28	05.50
			(3.45)	(3.16)
3	60	0.3033×10^2	00.50	00.67
			(1.45)	(1.55)
4	90	0.1367×10^2	00.00	00.00
			(1.00)	(1.00)
CD (5%)			1.03	1.29

Values in parentheses are square root transformed means
*mean of three replications

It was also observed that two months old culture of *R. oryzae* induced negligible disease while three months old culture failed to induce any disease on susceptible cultivar "Kasturi". The loss of virulence in the test isolate of *R.* oryzae may be due to the fact that it is a weak pathogen (IRRI 2011) and may failed to cause any disease with low inoculum load. The fungus is known to lose its pathogenicity, virulence and ability to sporulate with the time. From the trends followed by disease incidence and severity in the present studies, it can further be concluded that the pathogen loses its pathogenicity sharply after one month. Turner and Black (1996 and 2001) have also reported that prolonged *in vitro* maintenance results in attenuation of *R. oryzae* isolate's pathogenicity, sporulation capacity, virulence and toxin production, thus confirm our observations on loss of virulence.

4.3.2 *In vivo studies*

I. Effect of weather components on the development of leaf scald under natural conditions

In this experiment an attempt has been made to relate the development of leaf scald with the meteorological variables using simple correlation. The progress of disease in relation to weather factors over a period of 8 weeks is shown in the Figure 3. Weekly weather data along with respective disease severity values, apparent infection rate 'r' and correlations derived thereof are given in Table 4.7.

From the data it is clear that leaf scald would have started appearing in the paddy fields in the second fortnight of August and progressed gradually with a high apparent infection rate 'r' (0.2281units/day) in the first week of September as all the weather parameters like minimum, maximum and mean temperature, relative humidity, rainfall and rainy days were optimum for the disease development. After 10^{th} September the disease still progressed but with a low apparent infection rate 'r' (0.05392-0.0688 units/day) as factors like RH and rainfall governing the spread and development of disease, sharply decreased after first week of September. In the second fortnight of October the disease

Table 4.7 Correlation of disease with different weather parameters

S. No.	Week	Av DS (%)	'r' (x/day)	Temp max (°C)	Temp min (°C)	Av temp (°C)	RH (%)	Rainfall (mm)	Rainy days
1	27 Aug - 02 Sep, 2010	02.00	-	30.09	22.24	26.16	66.50	24.27	3
2	03 Sep - 09 Sep, 2010	09.17	0.2281	28.07	20.31	24.19	68.00	21.87	7
3	10 Sep - 16 Sep, 2010	13.33	0.0602	26.2	19.11	22.66	66.14	17.73	3
4	17 Sep - 23 Sep, 2010	18.33	0.0539	26.56	18.93	22.74	61.07	00.30	2
5	24 Sep - 30 Sep, 2010	26.67	0.0688	29.63	17.46	23.54	53.00	00.00	0
6	01 Oct - 07 Oct, 2010	35.00	0.0560	28.09	15.61	21.85	44.79	00.40	1
7	08 Oct - 14 Oct, 2010	40.00	0.0305	28.37	15.01	21.69	46.71	00.03	1
8	15 Oct - 21 Oct, 2010	46.67	0.0388	27.11	15.69	21.40	48.14	5.29	2
	Correlation with DS			-0.1866	-0.9649	-0.8609	-0.9338	-0.7760	-0.5883
	Correlation with 'r'			-0.1266	0.2186	0.1217	0.3801	0.3148	0.7571

DS = disease severity, r = apparent infection rate, x = proportion of diseased area, temp = temperature Av = average, min = minimum, max = maximum, RH = relative humidity.

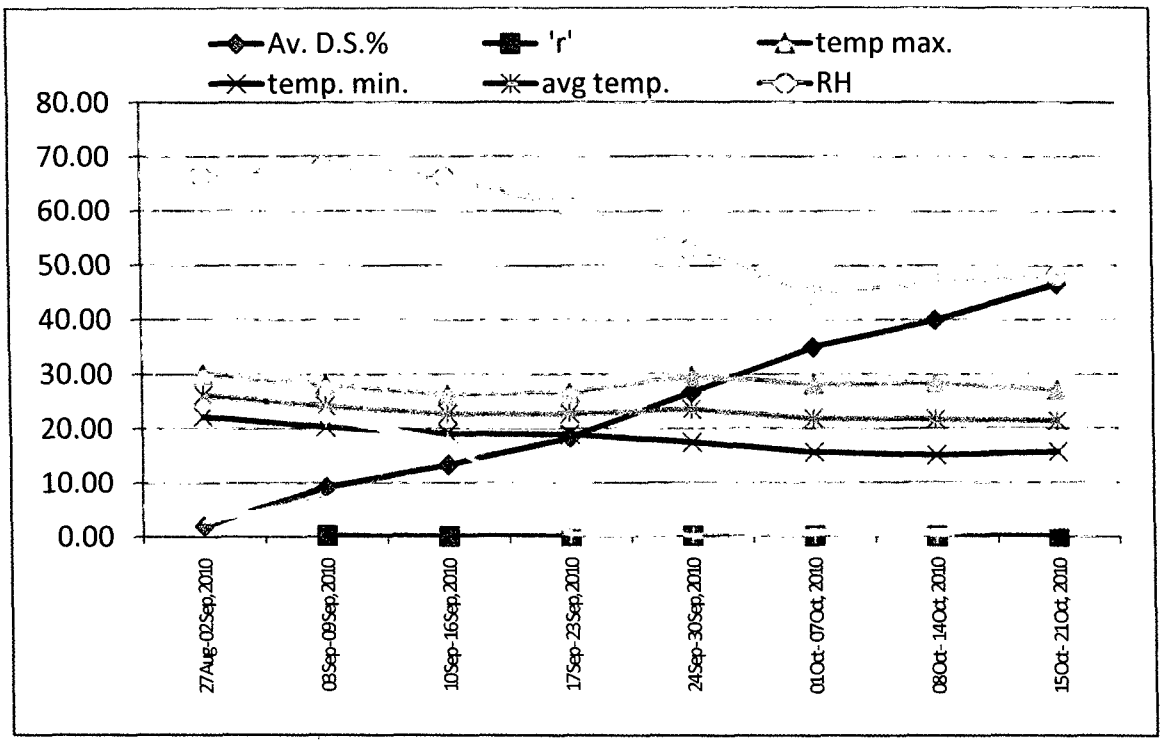


Figure 3. Effect of weather components on the development of leaf scald

progressed very slowly with the infection rate 'r' of only 0.0304-0.03881units/day due to the unfavourable climatic conditions. The correlation studies revealed that all the weather factors *viz.* minimum, maximum and mean temperature, relative humidity, rainfall and rainy days, had little effect on the disease thus negatively correlated with the disease severity. The highest negative correlation (-0.9649) was found with the minimum temperature whereas lowest (-0.1866) with the maximum temperature. Negative correlations between disease severity and individual weather parameters were obtained because the former continued to increase gradually during September-October (till third week of October) while the later decreased gradually from mid of September. It indicated that the pathogen caused infection and established well during second fortnight of August and first fortnight of September when climatic conditions were highly congenial for its establishment and development. The declining weather parameters had little effect on the progress of disease because the pathogen has already well established itself. However the apparent infection rate was positively correlated

with all the weather parameters except maximum temperature and the highest correlation of 0.7570 was found with the rainy days. Here the high correlation value of rainy days with the disease severity (%) can be combined with the fact that the dispersal of leaf scald pathogen *R. oryzae* occurs through water-splashes (Turner and Black 2001).

In case of rice blast, Asai *et al.* (1967) have found that rain, temperature, relative humidity of air, light and soil temperature are not significantly correlated with disease development under field conditions however, amount of dew, length of dew period and leaf area are significantly correlated with disease development.

4.4 Disease management

4.4.1 Chemical management

I. *In vitro* evaluation of fungicides

Nine fungicides, including four systemic, three non systemic and two coordinated were evaluated against *Rhynchosporium oryzae*. The systemic and coordinated fungicides *viz.* Bavistin 50 WP (carbendazim), Beam 75 WP (tricyclazole), Contaf 5 EC (hexaconazole), Tilt 25 EC (propiconazole), SAAF 75 WP (carbendazim 12% + mancozeb 63%) and Vitavax 200 75 WP (carboxin 37.5 % + thiram 37.5 %) were tested at 1, 2, 5, 10, 20 and 50 ppm and non-systemic *viz.* Blitox 50 WP (copper-oxychloride), Dithane M-45 75 WP (mancozeb) and Dithane Z-78 75 WP (zineb) at 50, 100, 200, 250, 500 and 1000 ppm. Data on mycelial growth and per cent inhibition are presented in Table 4.8 and 4.9.

The data revealed that all the fungicides, at different concentrations, inhibited the mycelial growth of *R. oryzae* to varying extents except Bavistin and Beam among systemic fungicides and Blitox and Dithane Z-78 among non systemic fungicides which failed to do so at 1 and 50 ppm respectively (Figure 4 and Plate 4). Amongst the systemic and coordinated fungicides, SAAF proved most effective at 1 ppm concentration, resulting in 11.50 mm of mycelial growth and 86.47 per cent inhibition followed by Tilt, Contaf and Vitavax 200.

Table 4.8 ***In vitro*** **efficacy of systemic and coordinated fungicides against** ***R. oryzae***

Fungicide	Mycelial growth(mm)*at different concentrations(ppm)						Mycelial inhibition(%)*at different concentrations(ppm)					
	1	2	5	10	20	50	1	2	5	10	20	50
Bavistin	85.00	75.50	73.00	55.75	26.00	0.00	00.00	11.18	14.12	34.41	69.41	100.00
							(00.00)	(19.31)	(22.06)	(35.90)	(56.40)	(89.96)
Beam	85.00	85.00	73.50	63.00	59.00	56.00	00.00	0.00	13.53	25.88	30.59	34.11
							(00.00)	(0.00)	(21.55)	(30.56)	(33.56)	(35.72)
Contaf	22.50	19.50	2.17	0.00	0.00	0.00	73.53	77.06	97.45	100.00	100.00	100.00
							(59.06)	(61.37)	(82.45)	(89.96)	(89.96)	(89.96)
Tilt	14.83	3.83	0.00	0.00	0.00	0.00	82.55	95.49	100.00	100.00	100.00	100.00
							(65.29)	(77.82)	(89.96)	(89.96)	(89.96)	(89.96)
SAAF**	11.50	4.50	0.00	0.00	0.00	0.00	86.47	94.71	100.00	100.00	100.00	100.00
							(68.54)	(76.79)	(89.96)	(89.96)	(89.96)	(89.96)
Vitavax	69.25	48.75	44.83	18.33	4.67	0.00	18.53	42.66	47.26	78.43	79.11	100.00
200**							(25.45)	(40.75)	(43.41)	(62.51)	(79.10)	(89.96)
Control	85.00	85.00	85.00	85.00	85.00	85.00	-	-	-	-	-	-
CD (5%)	4.021	3.360	2.988	4.531	3.798	.7265	3.5465	3.7798	5.1235	3.7702	7.397	0.5217

Figure in parentheses are arc sine transformed values

*Average of three replications.

** Coordinated fungicides

Table 4.9 ***In vitro*** **efficacy of non-systemic fungicides against** ***R. oryzae***

Fungicide	Mycelial growth(mm)*at different concentrations(ppm)						Mycelial inhibition(%)*at different concentrations(ppm)					
	50	**100**	**200**	**250**	**500**	**1000**	**50**	**100**	**200**	**250**	**500**	**1000**
Blitox	85.00	80.50	73.00	62.67	0.00	0.00	00.00	5.29	14.12	26.27	100.00	100.00
							(00.00)	(10.82)	(21.84)	(30.81)	(89.96)	(89.96)
Dithane M-45	80.33	53.67	0.00	0.00	0.00	0.00	5.49	36.86	100.00	100.00	100.00	100.00
							(13.54)	(37.32)	(89.96)	(89.96)	(89.96)	(89.96)
Dithane Z-78	85.00	76.50	69.83	55.50	0.00	0.00	00.00	10.00	17.84	34.71	100.00	100.00
							(00.00)	(18.04)	(24.76)	(36.06)	(89.96)	(89.96)
Control	85.00	85.00	85.00	85.00	85.00		-	-	-	-	-	-
CD (5%)	0.3344	9.0906	8.1036	4.5908	NS		0.4887	13.181	7.4010	3.3369	NS	

Figure in parentheses are arc sine transformed values
*Average of three replications.

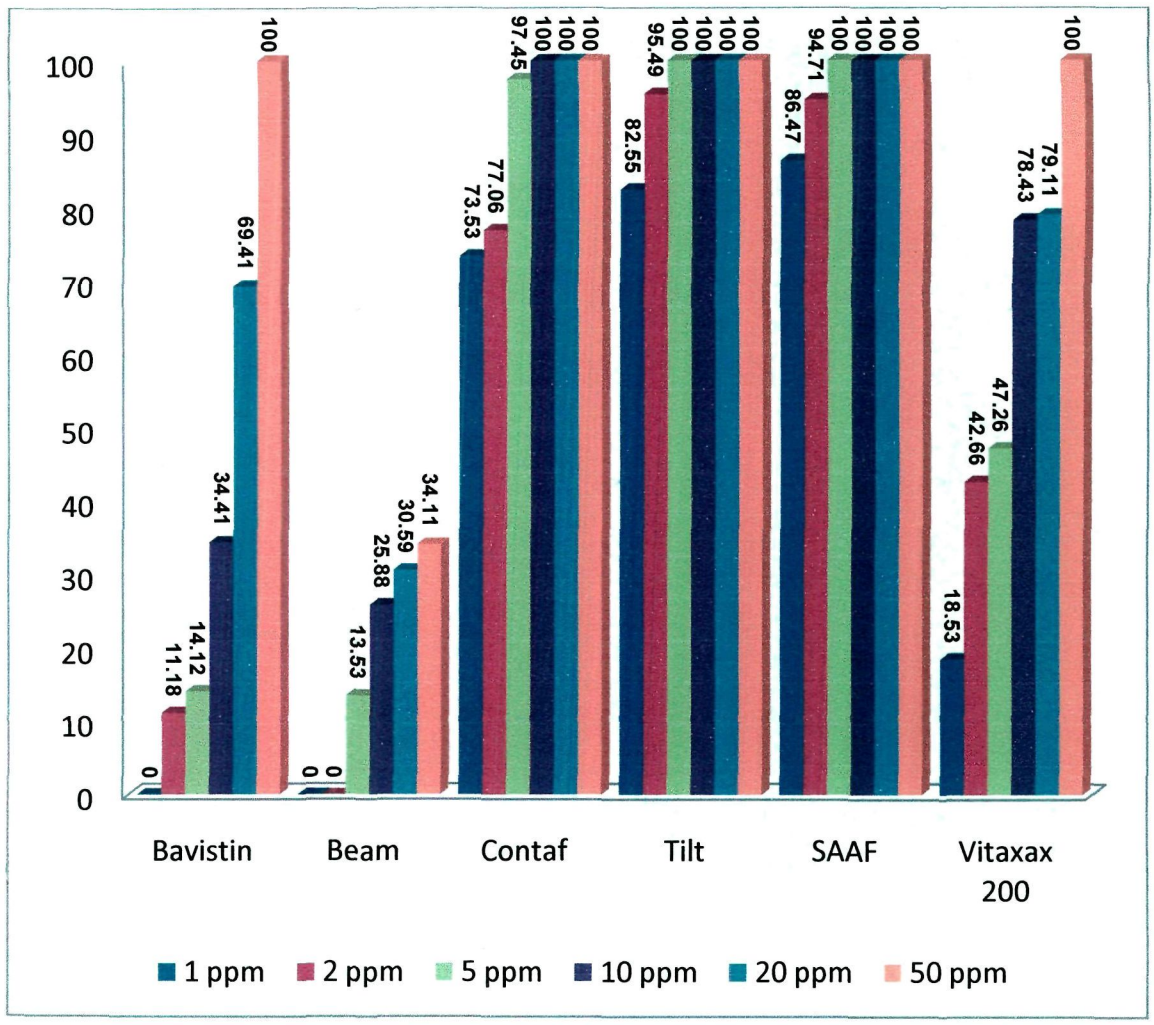


Figure 4. Per cent mycelial inhibition of *R. oryzae* by systemic and coordinated fungicides

At 2 ppm concentration Tilt was most effective resulting in 95.49 per cent mycelial inhibition followed by SAAF, Contaf, Vitavax 200 and Bavistin. At 5 ppm cent per cent inhibition of mycelial growth was given by SAAF and Tilt whereas, at 10 ppm Contaf became effective and gave complete inhibition. However, at 50 ppm, a complete inhibition of mycelial growth was obtained with all the systemic and coordinated fungicides except Beam which proved least effective.

Among the non-systemic fungicides, only Dithane M-45 showed little mycelial inhibition (5.49 %) at the lowest tested concentration of 50 ppm. At 100 ppm, Dithane M-45 gave maximum inhibition of 36.86 per cent followed by

Dithane Z-78 and Blitox. The similar trend was observed at 200 and 250 ppm and Dithane M-45 did not allow the fungus to grow and resulted in the complete inhibition at both the concentrations. On increasing the concentration to 500 ppm, it was observed that all the three non-systemic fungicides caused complete per cent inhibition of growth (Figure 5 and Plate 5).

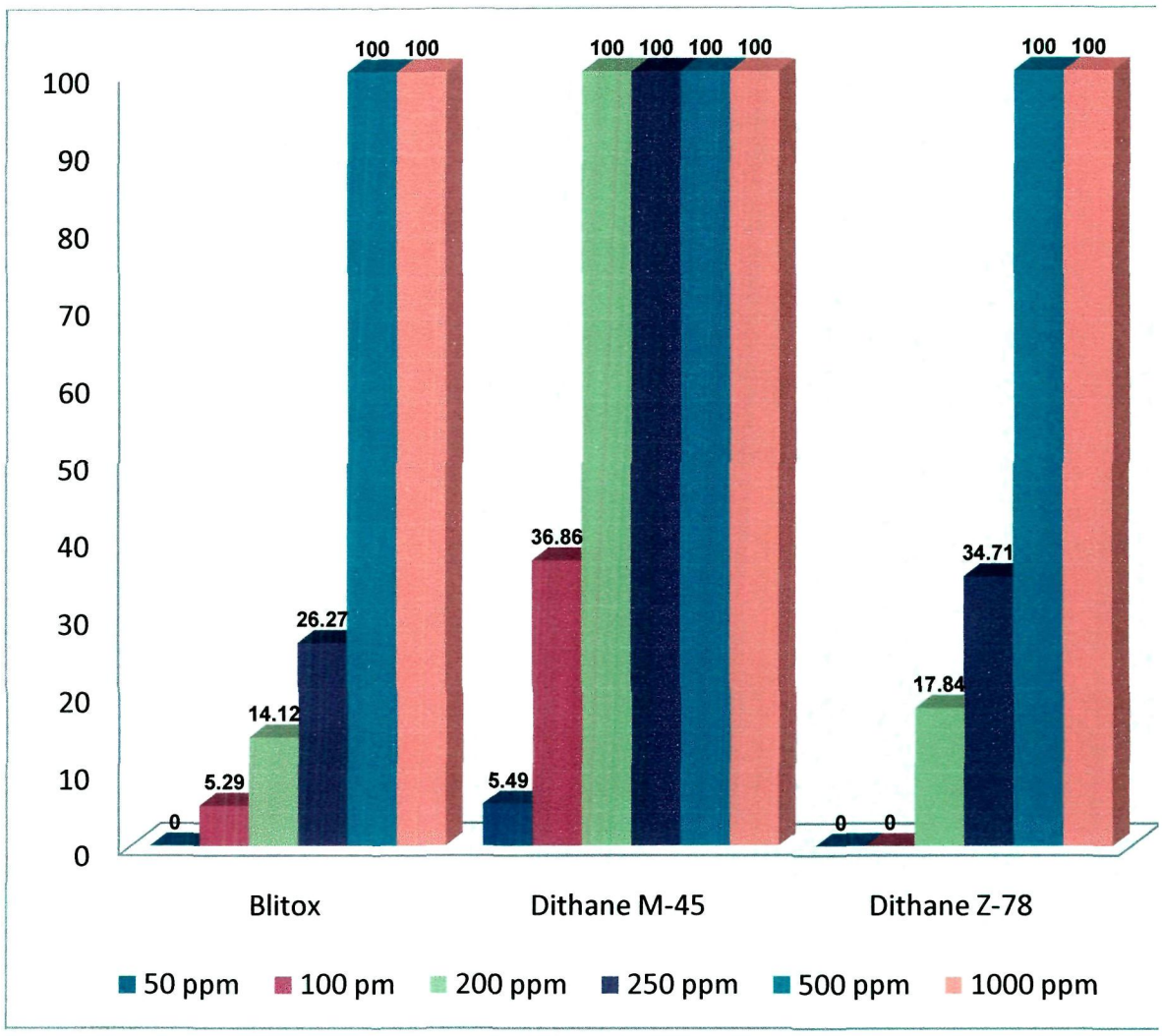
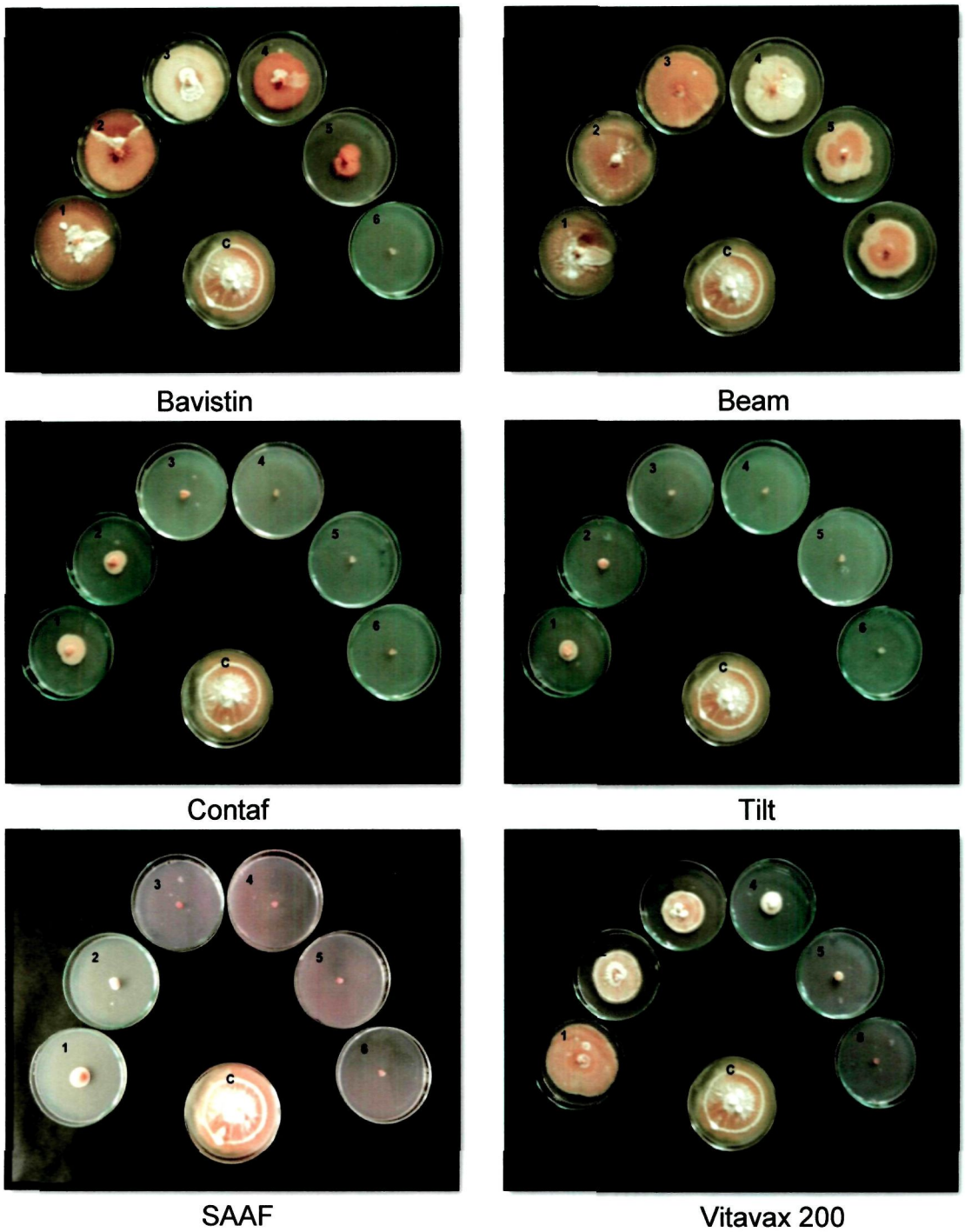
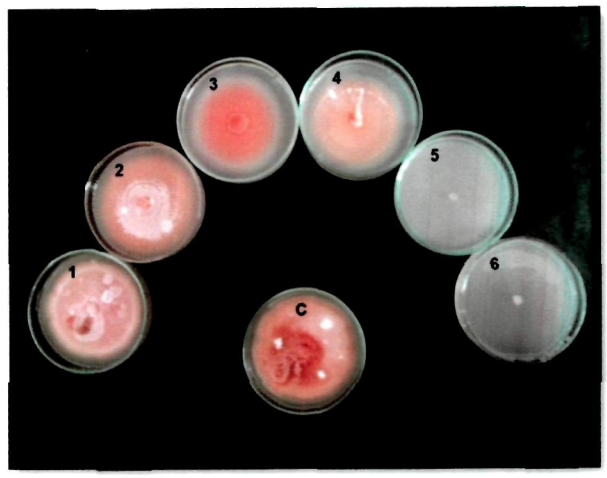


Figure 5. Per cent mycelial inhibition of *R. oryzae* by non-systemic fungicides

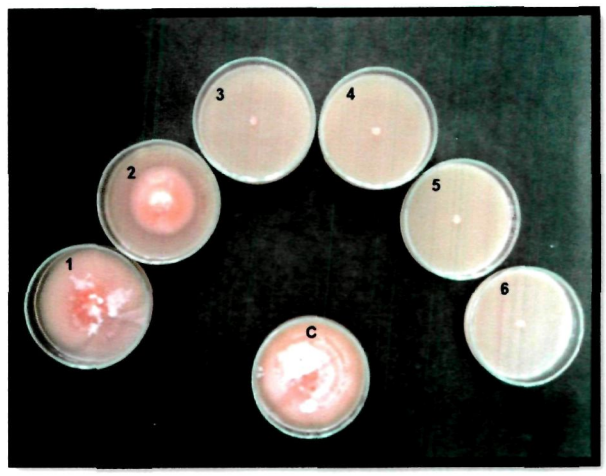


1 = 1 ppm, 2 = 2 ppm, 3 = 5 ppm, 4 = 10 ppm, 5 = 20 ppm, 6 = 50 ppm, C = Control.

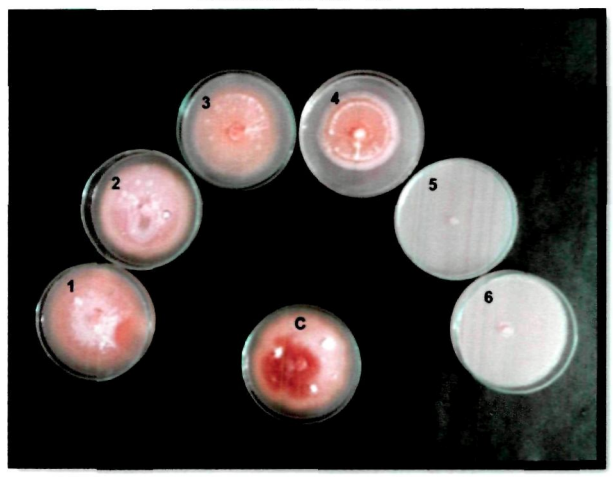
Plate 4. **Mycelial inhibition of *R. oryzae* by systemic and coordinated fungicides**



Blitox



Dithane M-45



Dithane Z-78

1 = 50 ppm, 2 = 100 ppm, 3 = 200 ppm, 4 = 250 ppm, 5 = 500 ppm, 6 = 1000 ppm, C = Control

Plate 5. Mycelial inhibition of R. oryzae by non-systemic fungicides

Of these nine fungicides Bavistin, Dithane M-45 and Blitox have earlier been evaluated by Das(1995a) against *R. oryzae* and obtained 100 per cent inhibition with 50 ppm of bavistin and 500 ppm of Dithane M-45 and Blitox. These three fungicides were also evaluated by Singh and Gupta (1984) for their fungistatic and fungicidal properties against *R. oryzae* and found that Dithane M-45, Bavistin, and Blitox were fungistatic at 5, 7 and 40 ppm respectively while fungicidal at 40, 50 and 150 ppm respectively showing Blitox to be the least effective. *In vitro* studies by Shamprakash (1977) have also shown Dithane M-45 and Benlate to be most effective against *R. oryzae.* So among systemics the triazole fungicides *viz.* Contaf and Tilt were found best while among coordinated and non systemics SAAF and Dithane M-45 were most effective respectively.

II. *In vivo* evaluation of fungicides

a. Effect of seed treatment with fungicides

Six fungicides *viz.* Bavistin 50 WP (carbendazim), Contaf 5 EC (hexaconazole), Tilt 25 EC (propiconazole), Vitavax 200 75 WP (carboxin 37.5 % + thiram 37.5 %), Dithane M-45 75 WP (mancozeb) and Thiram 75 WP were used as seed treatment against leaf scald and data on disease severity, disease control and yield gain is presented in Table 4.10.

Perusal of the data revealed that all the fungicides reduced the disease considerably ranging from 5.32 to 20.42 per cent except Bavistin which gave only 2.75 per cent disease reduction and proved least effective. The disease severity under different treatments ranged from 36.17 to 45.46 per cent. The minimum disease severity (36.17 %) and maximum disease control (20.42 %) was obtained with Vitavax 200 followed by Dithane M-45 and Tilt. The maximum yield gain of 5.36 per cent was obtained with Vitavax 200 and Tilt followed by Dithane M-45 and Contaf but the analysis of variance indicated that seed treatment with fungicides had insignificant effect on the grain yield of rice.

Table 4.10 Effect of seed treatment with fungicides on disease severity and grain yield

Fungicide	Dose (%)	Disease severity (%)*	Disease control (%)	Grain yield (q/ha)*	Yield gain (%)
Bavistin	0.25	44.21 (41.65)	2.75	44.17	0.00
Contaf	0.1	42.82 (40.85)	5.81	45.83	3.64
Tilt	0.1	40.53 (39.50)	10.85	46.67	5.36
Dithane M-45	0.25	39.95 (39.18)	12.13	45.83	3.64
Thiram	0.25	43.04 (40.98)	5.32	45.00	1.85
Vitavax 200	0.25	36.17 (39.50)	20.42	46.67	5.36
Control	-	45.46 (42.37)	-	44.17	-
CD (5%)		2.73		NS	

Figures in parentheses are arc sine transformed values
*Average of three replications.

R. oryzae has been reported to cause seed infection by many workers (Sanchez *et al.* 1979; Mia and Safeeulla 1984; Mia *et al.* 1985; Mia *et al.* 1986; Singh and Gupta 1986; Manandhar 1999). It has been isolated from all components/parts of infected seed of paddy with varying frequency (Mia *et al.* 1986; Manandhar 1999). The deep seated nature indicates the survival of *R. oryzae* for longer time within seed as the primary source of infection (Mia and Safeeulla 1984). Thus seed treatment is of great significance in reducing the primary infection in rice crop. The fungicides used in the present studies were found to reduce the disease severity in different treatments (Table 4.10) where

maximum disease control (20.42 %) was noticed in the Vitavax 200 treated seeds whereas it was least in Bavistin. The effect of seed treatment on seed yield was insignificant. The different fungicides reduced the disease by reducing the initial inoculum but at later stages due to the high inoculum load of *R. oryzae* in the field, it proved to be ineffective resulting in the insignificant yield gain over control.

b) Effect of fungicide sprays

Nine fungicideds including four systemic *viz.* Bavistin 50 WP (carbendazim), Beam 75 WP (tricyclazole), Contaf 5 EC (hexaconazole) and Tilt 25 EC (propiconazole), three non systemic *viz.* Blitox 50 WP (copper-oxychloride), Dithane M-45 75 WP (mancozeb) and Dithane Z-78 75 WP (zineb) and two coordinated fungicides *viz.* SAAF 75 WP (carbendazim 12 % + mancozeb 63 %) and Vitavax 200 75 WP (carboxin 37.5 % + thiram 37.5 %) were evaluated under field conditions by using leaf scald susceptible cultivar "Kasturi". Two concentrations of each fungicide were evaluated by giving three sprays at 15 days intervals starting from the first appearance of disease symptoms in the field. The data were recorded on disease severity and grain yield and presented in Table 4.11.

The disease severity in different treatments ranged from 19.08 to 41.50 per cent. The maximum disease control (54.02 %) was obtained with Tilt (0.1 %) followed by Beam (0.1 % and 0.05 %), SAAF (0.25 %), Contaf (0.1 %), Tilt (0.05 %) and Contaf (0.05 %) providing more than 40 per cent disease control. Amongst non-systemic fungicides Dithane Z-78 and Dithane M-45 at 0.25 per cent concentration provided disease control of 21.49 and 18.68 per cent respectively which were statistically at par with each other. Blitox (0.25 and 0.3 %) and Bavistin (0.05 %) were found least effective giving less than 15 per cent disease control.

All the treatments except Blitox (0.25 %) were found to enhance the yield levels ranging from 9.08 to 38.49 per cent. The maximum increase in grain yield (38.49 %) was obtained with Tilt (0.1 %) where as no increase in yield was obtained in case of Blitox (0.25 %).

Table 4.11 Effect of fungicide sprays on leaf scald severity and grain yield

Fungicide	Dose (%)	Disease severity (%)*	Disease control (%)	Grain yield (q/ha)*	Yield gain (%)
Bavistin	0.05	37.08 (36.75)	13.66	44.44	9.08
	0.1	26.33 (30.83)	36.55	50.00	22.73
Beam	0.05	21.00 (27.20)	49.40	54.94	34.85
	0.1	20.50 (26.91)	50.60	54.94	34.85
Contaf	0.05	24.42 (29.39)	41.17	51.24	25.76
	0.1	23.58 (29.00)	43.17	53.09	30.30
Tilt	0.05	23.83 (29.18)	42.57	52.47	28.79
	0.1	19.08 (25.89)	54.02	56.42	38.49
Blitox	0.25	40.75 (39.65)	01.81	40.74	0.00
	0.3	36.50 (37.15)	12.05	45.68	12.12
Dithane M-45	0.2	34.67 (35.50)	16.47	45.68	12.12
	0.25	33.75 (35.50)	18.68	48.76	19.70
Dithane Z-78	0.2	35.17 (36.35)	15.26	46.30	13.64
	0.25	32.58 (34.78)	21.46	46.91	15.15
SAAF**	0.2	27.17 (31.39)	34.54	49.38	21.21
	0.25	22.42 (35.50)	45.98	53.70	31.82
Vitavax 200**	0.05	31.67 (33.95)	23.70	48.77	19.70
	0.1	27.08 (31.14)	34.74	49.38	21.21
Control	-	41.50 (40.07)	-	40.74	-
CD (5%)		5.25		2.58	

Figures in parentheses are arc sine transformed values

*Average of three replications.

**Coordinated fungicides

In the present studies the triazole fungicides *viz.* Tilt (0.05 and 0.1 %), Beam (0.05 and 0.1 %) and Contaf (0.1 %) have been found quite effective while Blitox (0.25 and 0.3 %) and Bavistin (0.05 %) were least effective. However the contradictory results have been reported by Das (1995b) who obtained highest disease control (56.8 %) and yield gain with Topsin M (0.1 %) followed by Bavistin (0.1%), Hinosan (0.1%) and Kitazin (0.1). Kumbhar and Savant (1998) also found carbendazim (0.1 %) and captafol (0.25 %) to be the most effective fungicides reducing the incidence to 81.68 and 76.14 per cent respectively with two sprays at 15 days interval from the appearance of first visual symptoms. They noticed maximum increase in yield with carbendazim (56.71%) followed by captafol (48.82%) and dithianon (41.74%). Among the non systemic fungicides Dithane Z-78 (0.25 %) and Dithane M-45 (0.25 %) have been found most effective. The similar results were also reported by Singh and Gupta (1982) who found Dithane M-45 and Difolatan (captafol) sprayed @ 1600 and 1560 ppm (in terms of active ingredient) more effective against leaf scald than other test fungicides.

4.4.2 Evaluation of varietal resistance against leaf scald

Planting resistant varieties is the most practical and effective method of managing diseases in cereals as the chemical control is uneconomic, cumbersome and hazardous to the environment. In the present studies 100 genotypes of rice were screened for their resistance under natural and artificial epipthytotic conditions at RWRC Malan and Department of Plant Pathology, CSK HPKV Palampur respectively. The disease was quite severe under both the natural as well as artificial epiphytotic conditions. Out of 100 genotypes none was found completely resistant under both the conditions (Table 4.12, 4.13 and 4.14) whereas three *viz.* IR 71703-57-3-1, IR 70554-48-1-2-YN1-1and IRBB 60 and two *viz.* IR 71703-57-3-1 and IR 70554-48-1-2-YN1-1 were moderately resistant under natural and artificial epiphytotic conditions respectively. The remaining genotypes were moderately susceptible, susceptible and highly susceptible.

Table 4.12 Evaluation of rice genotypes against leaf scald disease

S. No.	Rice genotypes	Disease severity (%)		Reaction		Per cent disease index (PDI)	
		In vitro	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*
1	China 988	39.50	36.10	S	S	52.14	50.00
2	Ram Jawain 100	58.00	38.80	HS	S	74.44	61.11
3	R 575	48.00	39.80	S	S	63.33	59.44
4	Achhoo	38.00	20.90	S	MS	54.29	47.78
5	Kalizhini (White)	62.00	42.50	HS	S	83.89	75.56
6	Kalizhini (Red)	46.50	33.55	S	S	51.67	63.89
7	Himalaya 1	53.50	35.05	HS	S	59.44	66.67
8	Himalaya 2	33.85	29.50	S	S	52.78	62.22
9	Himalaya 741	61.00	43.75	HS	S	77.78	74.44
10	Himalaya 2216	53.50	32.05	HS	S	69.44	65.56
11	RP 2421	56.50	44.60	HS	S	82.78	75.56
12	Palam Dhan 957	53.00	37.50	HS	S	78.89	71.67
13	HPR 2143	50.00	42.30	S	S	75.56	75.56
14	HPR 1068	45.00	23.60	S	MS	70.00	56.67
15	HPU 741 (Waxy)	48.50	27.55	S	S	63.89	60.56
16	Palampur Purple	57.00	38.00	HS	S	73.33	71.11
17	Koshihikari	49.00	45.00	S	S	74.50	73.33
18	Hinohikari	49.00	32.30	S	S	74.44	65.56
19	Naggar Dhan	37.50	33.15	S	S	57.78	45.67
20	Norin 10	29.50	15.55	S	MS	40.00	33.89

S. No.	Rice genotypes	Disease severity (%)		Reaction		Per cent disease index (PDI)	
		In vitro	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*
21	Bhrigu Dhan	60.00	51.35	HS	HS	76.67	69.78
22	VL Dhan 221	58.50	47.35	HS	S	75.00	65.56
23	HPR 1156	63.00	47.75	HS	S	80.00	78.89
24	HPR 894	51.50	49.25	HS	S	77.22	74.44
25	Vandana	57.50	46.00	HS	S	77889	72.89
26	IR 36	41.00	28.45	S	S	45.56	54.44
27	IR 64	43.50	15.75	S	MS	58.33	40.00
28	IR 74	49.30	45.50	S	S	70.56	68.89
29	Fukunishiki	10.50	07.55	MS	MS	50.64	47.14
30	HPR 1149	68.00	50.25	HS	HS	85.56	72.22
31	VL 25867-2-2	37.00	17.45	S	MS	62.86	42.78
32	IR 65564-44-5-1	23.00	17.05	MS	MS	52.86	42.86
33	Zenith	34.00	22.45	S	MS	37.78	50.00
34	HPR 2001	57.00	43.25	HS	S	73.33	68.89
35	HPR 2072	48.25	33.00	S	S	56.67	53.33
36	HPR 2167	33.00	19.90	S	MS	57.14	49.44
37	HPR 2328	41.50	36.05	S	S	76.11	67.22
38	IR 68544-29-2-1-3-1-Yn1	29.00	17.05	S	MS	41.43	43.33
39	HPR 2310	31.00	19.50	S	MS	54.44	46.11
40	HPR 2373	36.50	19.90	S	MS	62.14	47.22
41	IRBB 60	09.00	04.65	MS	MR	46.67	46.00

S. No.	Rice genotypes	Disease severity (%)		Reaction		Per cent disease index (PDI)	
		In vitro	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*
42	IRBB 21	28.00	09.30	S	MS	44.29	48.57
43	HPR 868	50.00	49.5	S	S	75.00	71.11
44	HPR842	53.00	48.00	HS	S	68.89	65.56
45	IR 71693-197-4-4	36.50	18.90	S	MS	62.14	42.78
46	IR 71703-57-3-1	03.50	02.20	MR	MR	38.00	35.00
47	HPR 2083	55.50	38.55	HS	S	71.67	70.56
48	HPR 2355	43.50	27.40	S	S	48.33	55.00
49	HPR 2362	45.00	42.90	S	S	70.00	69.44
50	Hassan Serai	47.00	39.00	S	S	72.22	67.78
51	Kasturi	45.00	26.30	S	S	60.00	56.67
52	T 23	16.15	08.50	MS	MS	41.00	38.57
53	Ranbir Bas	30.50	10.40	S	MS	43.57	36.43
54	Purple (Farmer Field)	28.50	17.65	S	MS	40.71	37.86
55	Sabarmati	32.50	16.35	S	MS	56.43	40.00
56	VL Dhan 61	42.50	19.05	S	MS	57.22	49.29
57	VL 81	58.00	38.30	HS	S	64.44	61.11
58	Vivek Dhan 82	52.00	37.55	HS	S	67.78	67.78
59	VL 93- 2767	52.00	36.50	HS	S	67.78	64.44
60	VL Dhan 85	63.00	46.75	HS	S	80.00	77.78
61	VL Dhan 207	42.50	27.05	S	S	57.22	55.00
62	VL 3400	60.00	43.55	HS	S	76.67	74.44

S. No.	Rice genotypes	Disease severity (%)		Reaction		Per cent disease index (PDI	
		In vitro	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*
63	VL 4561	56.50	39.50	HS	S	72.78	60.56
64	VL 30424	32.50	29.30	S	S	60.71	51.67
65	VL 30425	53.00	39.25	HS	S	58.89	72.22
66	SKAU 23	40.50	36.35	S	S	75.00	68.89
67	SKAU 27	59.00	48.50	HS	S	75.56	63.33
68	SKAU 105	51.00	33.25	HS	S	66.67	64.44
69	SKAU 356	53.50	51.00	HS	HS	82.44	79.44
70	SKAU 357	45.75	45.00	S	S	70.00	76.11
71	SKAU 382	51.00	24.10	HS	MS	77.78	58.89
72	Acc 19146 (Begmi)	49.50	30.95	S	S	65.00	56.67
73	Acc 19164	60.00	42.50	HS	S	76.67	73.33
74	Acc 19178	61.00	48.00	HS	S	87.78	75.56
75	Acc 19180	57.00	43.00	HS	S	73.33	75.56
76	Acc 19186	65.00	50.30	HS	HS	82.22	80.00
77	Acc 19197	67.50	50.75	HS	HS	79.00	82.78
78	Acc 19229	53.00	23.95	HS	MS	78.89	62.86
79	Acc 19243	53.50	45.75	HS	S	81.44	77.22
80	Acc 19283 (Sukara)	43.25	37.50	S	S	73.89	53.57
81	Megha Rice 1	49.25	28.00	S	S	77.22	42.14
82	Megha Rice 2	60.50	42.75	HS	S	77.22	75.00
83	Bhalvm 1	51.00	30.30	HS	S	76.67	64.44

S. No.	Rice genotypes	Disease severity (%)		Reaction		Per cent disease index (PDI)	
		In vitro	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*
84	Bhalvm 2	39.50	27.00	S	S	58.89	51.67
85	IR 70554-48-1-2-YN1-1	04.50	02.35	MR	MR	41.00	38.30
86	DHR-9	58.50	36.30	HS	S	65.00	62.78
87	HPR 2529-4	53.00	32.35	HS	S	58.89	62.22
88	HPR 2544	46.00	37.10	S	S	71.11	60.56
89	HPR 2555	54.00	40.10	HS	S	60.00	57.22
90	HPR 2557	39.50	18.60	S	MS	53.89	47.22
91	HPR 2559	44.50	29.25	S	S	59.44	59.44
92	HPR 2589	53.50	39.55	HS	S	69.44	68.33
93	HPR 2598	46.00	28.00	S	S	51.11	46.11
94	HPR 2603	39.50	19.85	S	MS	65.00	50.56
95	HPR 2614	52.00	39.55	HS	S	57.78	68.33
96	HPR 2617	58.50	39.25	HS	S	65.00	72.78
97	HPR 2618	45.00	38.25	S	S	50.00	71.67
98	HPR 2619	41.75	35.00	S	S	38.89	76.67
99	HPR 2620	42.50	43.75	S	S	47.22	77.78
100	HPR 2625 (DH(D)24)	29.00	18.10	S	MS	43.33	56.43

Table 4.13 Reaction of rice genotypes to *R. oryzae* under natural field conditions

Grade	Reaction	Number of genotypes	Genotypes
0	Highly resistant	0	
1	Resistant	0	
3	Moderately resistant	3	IR 71703-57-3-1, IR 70554-48-1-2-YN1-1and IRBB 60.
5	Moderately susceptible	24	Achhoo, HPR 1068, Norin 10, IR 64, Fukunishiki, VL 25867-2-2, IR 65564-44-5-1, Zenith, HPR 2167, IR 68544-29-2-1-3-1-Yn1, HPR 2310, HPR 2373, IRBB 21, IR 71693-197-4-4, T 23, Ranbir Bas, Purple (Farmer Field), Sabarmati, VL Dhan 61, SKAU 382, Acc 19229, HPR 2557, HPR 2603 and HPR 2625 (DH(D)24).
7	Susceptible	68	China 988, Ram Jawain 100, R 575, Kalizhini (White), Kalizhini (Red), Himalaya 1, Himalaya 2, Himalaya 741, Himalaya 2216, RP 2421, Palam Dhan 957, HPR 2143, HPU 741 (Waxy), Palampur Purple, Koshihikari, Hinohikari, Naggar Dhan, VL Dhan 221, HPR 1156, HPR 894, Vandana, IR 36, IR 74, HPR 2001, HPR 2072, HPR 2328, HPR 868, HPR842, HPR 2083, HPR 2355, HPR 2362, Hassan Serai, Kasturi, VL 81, Vivek Dhan 82, VL 93-2767, VL Dhan 85, VL Dhan 207, VL 3400, VL 4561, VL 30424, VL 30425, SKAU 23, SKAU 27, SKAU 105, SKAU 357, Acc 19146 (Begmi), Acc 19164, Acc 19178, Acc 19180, Acc 19243, Acc 19283 (Sukara), Megha Rice 1, Megha Rice 2, Bhalvm 1, Bhalvm 2, DHR-9, HPR 2529-4, HPR 2544, HPR 2555, HPR 2559, HPR 2589, HPR 2598, HPR 2614, HPR 2617, HPR 2618, HPR 2619 and HPR 2620.
9	Highly susceptible	05	Bhrigu Dhan, HPR 1149, SKAU 356, Acc 19186 and Acc 19197.

Table 4.14 Reaction of rice genotypes to *R. oryzae* under artificial epiphytotic conditions

Grade	Reaction	Number of genotypes	Genotypes
0	Highly resistant	0	
1	Resistant	0	
3	Moderately resistant	2	IR 71703-57-3-1 and IR 70554-48-1-2-YN1-1.
5	Moderately susceptible	4	IR 65564-44-5-1, IRBB 60, T 23, and Megha Rice 1.
7	Susceptible	51	China 988, R 575, Achhoo, Kalizhini (Red), Himalaya 2, HPR 2143, HPR 1068, HPU 741 (Waxy), Koshihikari, Hinohikari, Naggar Dhan, Norin 10, IR 36, IR 64, IR 74, Fukunishiki, VL 25867-2-2, Zenith, HPR 2072, HPR 2167, HPR 2328, IR 68544-29-2-1-3-1-Yn1, HPR 2310, HPR 2373, IRBB 21, HPR 868, IR 71693-197-4-4, HPR 2355, HPR 2362, Hassan Serai, Kasturi, Ranbir Bas, Purple (Farmer Field), Sabarmati, VL Dhan 61, VL Dhan 207, VL 30424, SKAU 23, SKAU 357, Acc 19146 (Begmi), Acc 19283 (Sukara), Bhalvm 2, HPR 2544, HPR 2557, HPR 2559, HPR 2598, HPR 2603, HPR 2618, HPR 2619, HPR 2620 and HPR 2625 (DH(D)24).
9	Highly susceptible	43	Ram Jawain 100, Kalizhini (White), Himalaya 1, Himalaya 741, Himalaya 2216, RP 2421, Palam Dhan 957, Palampur Purple, Bhrigu Dhan, VL Dhan 221, HPR 1156, HPR 894, Vandana, HPR 1149, HPR 2001, HPR842, HPR 2083, VL 81, Vivek Dhan 82, VL 93- 2767, VL Dhan 85, VL 3400, VL 4561, VL 30425, SKAU 27, SKAU 105, SKAU 356, SKAU 382, Acc 19164, Acc 19178, Acc 19180, Acc 19186, Acc 19197, Acc 19229, Acc 19243, Megha Rice 2, Bhalvm 1, DHR-9, HPR 2529-4, HPR 2555, HPR 2589, HPR 2614 and HPR 2617.

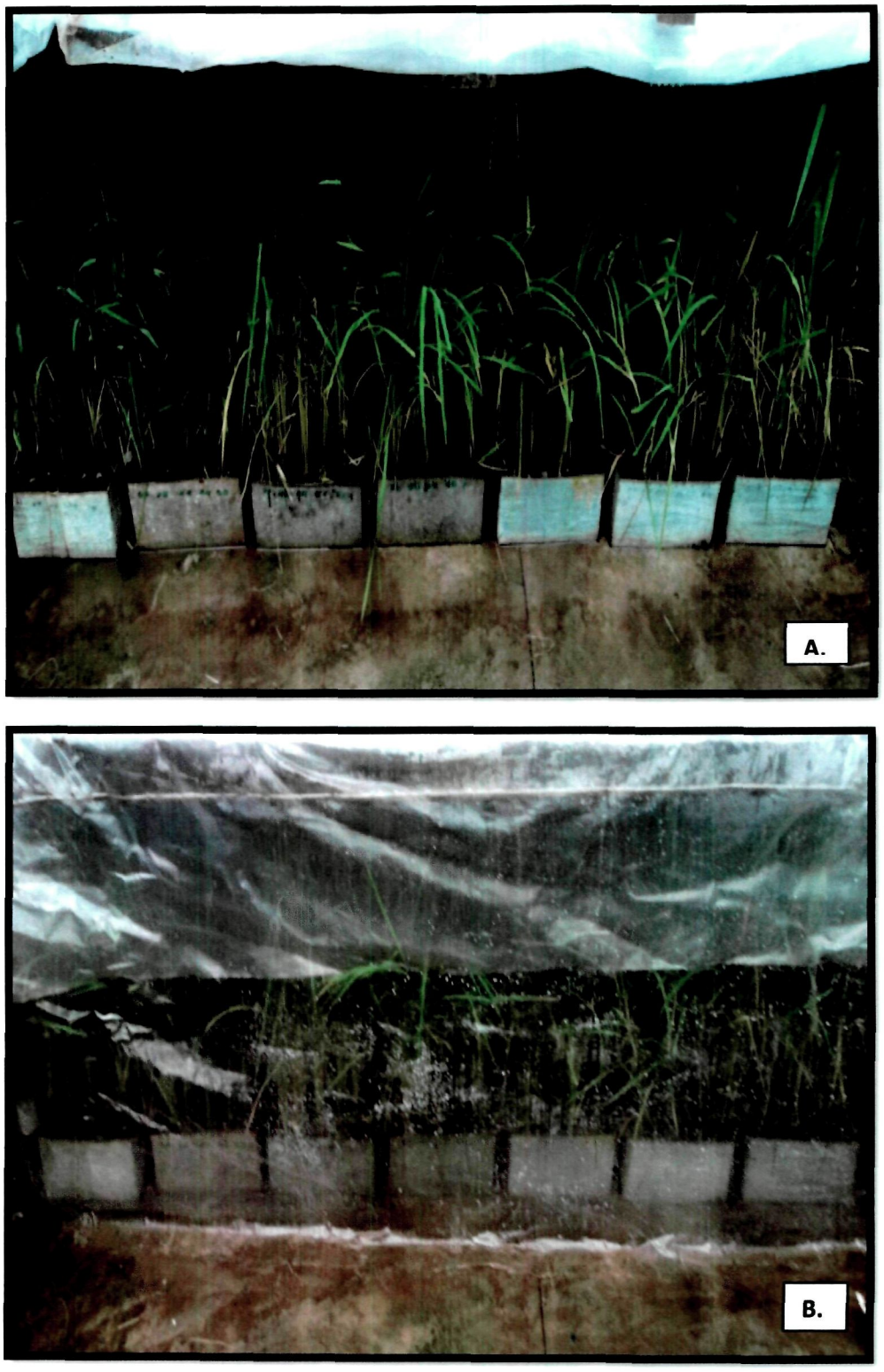


Plate 6. ***In vitro*** **evaluation of rice Germplasm against** ***R. oryzae;*** **A.** ***before and*** **B.** ***after artificial*** **inoculation.**

Many of the genotypes which were moderately susceptible and susceptible under field conditions proved susceptible and highly susceptible under artificial epiphytotic conditions except SKAU 382 and Acc 19229 which were moderately susceptible under field conditions proved highly susceptible under artificial conditions.

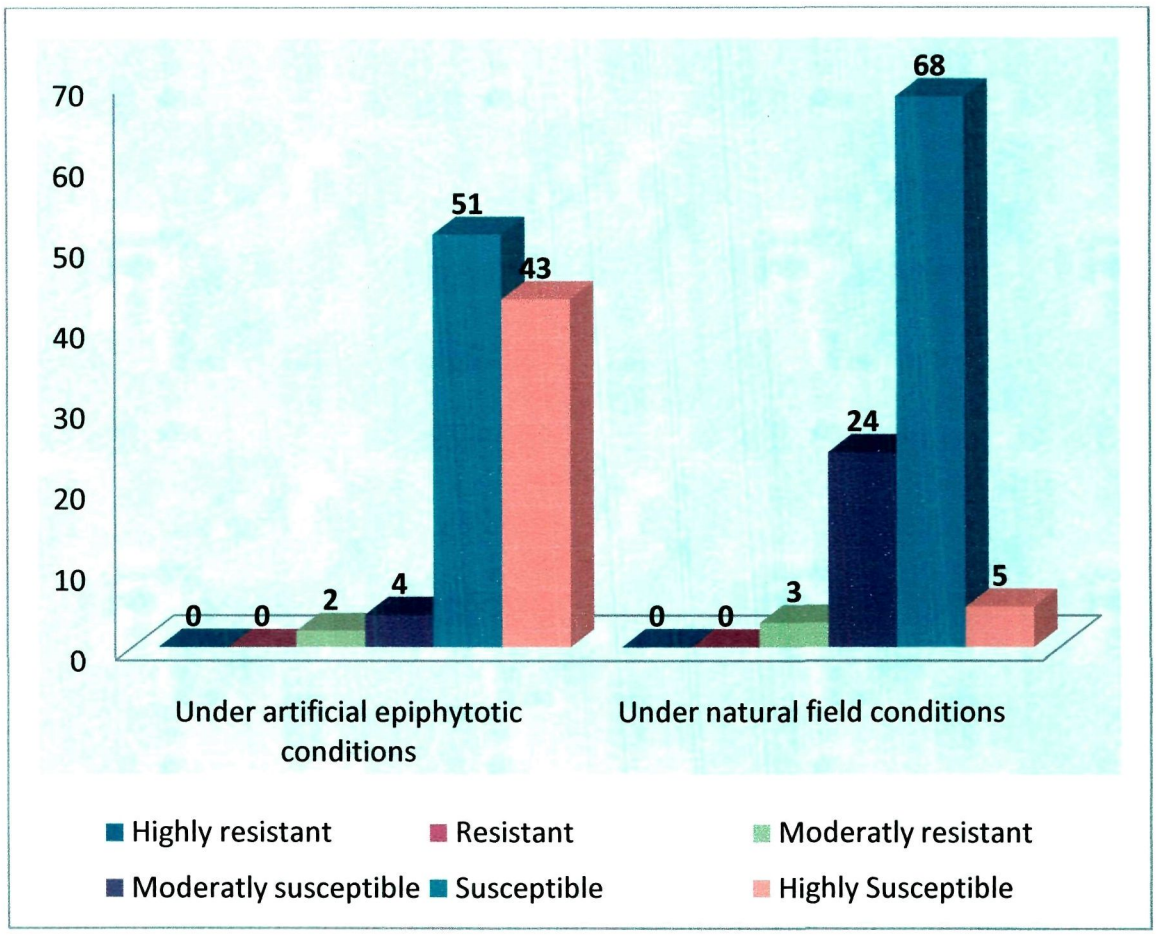
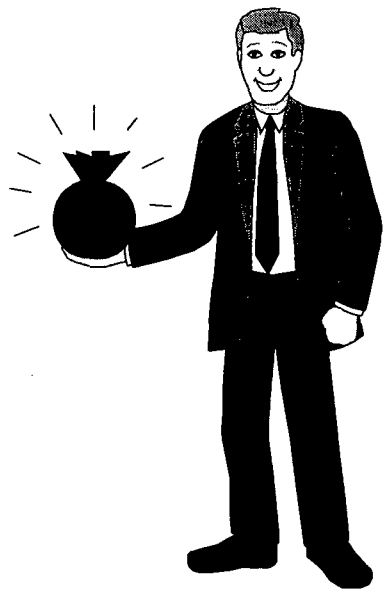


Figure 6. Reaction of rice genotypes to *R. oryzae* under artificial epiphytotic and natural field conditions

Similar trends have been reported by many workers such as Verma and Agrawal (1975), Das (1976) and Rahamma (1986) while screening rice germplasm against leaf scald. Very low proportion of varieties has been reported to possess resistance to leaf scald disease in different parts of the world (Verma and Agrawal 1975; Das 1976; Ribeiro 1983; Bonman *et al.* 1990). Verma and Agrawal (1972) found only 19 entries out of 1209 showing low infection of leaf

scald under natural conditions. Out of 437 entries, Das (1976) reported only 5 varieties *viz.* Tkm 6, C 633, C1977, C3249 and RP 79-13 to be resistant and 33 to be moderately resistant. Under lowland conditions in Indonesia, Rahamma (1986) found 10 out of 100 cultivars, showing good resistance to leaf scald. Bonman *et al.* (1990) screened 288 rice accessions for resistance to *R. oryzae*, using an *in vitro* method and found that there was a continuum from low to high levels of resistance with no accessions showing complete resistance to the pathogen.



SUMMARY AND CONCLUSIONS

5. SUMMARY AND CONCLUSIONS

5.1 Summery

Investigations on the 'Epidemiology and management of leaf scald of rice' were under taken to know the status and distribution of disease in the state, effect of different environmental factors on disease development along with management through host resistance and chemicals. The important findings are summarized below.

The leaf scald pathogen *Rhynchosporium oryzae* was isolated from the infected rice leaves exhibiting the scald symptoms on potato dextrose agar medium and pathogenicity was proved to verify the Koch's postulates.

Field surveys conducted during *kharif* 2010 in different districts of Himachal Pradesh established leaf scald (*R. oryzae*) to be an important upcoming disease of rice in the state. Disease was more severe at some locations like Bhambla, Jahu, Chakkar and Dhaulakuan. Amongst the districts the maximum disease was recorded in Mandi followed by Hamirpur, Sirmour, Kullu, Solan and Kangra. The overall leaf scald incidence and severity in the state, during 2010 were 34.82 and 18.12 per cent respectively.

The fungus grows at temperatures ranging from 15-30°C but the optimum temperature range for growth and sporulation was 25-30°C. pH range of 6-9 was found suitable for the growth of fungus, however, the maximum growth and sporulation was obtained at pH 7.

Relative humidity influenced the disease incidence and severity to a great extent. High incidence was observed at RH >70 per cent, however, it was significantly high at 100 per cent relative humidity. The disease severity was also high at 100% relatively humidity. It indicates that high relative humidity > 90 per cent not only provides free water for spore germination but also increases the growth of pathogen.

The *in vitro* studies on the effect of age of inoculum revealed that *R. oryzae* lost its pathogenicity after 3 months of storage of sporulating culture at

25±1°C and the infectivity of culture was least after 60 days of storage whereas three months old culture failed to induce any disease in leaf scald susceptible cultivar 'Kasturi'. The disease incidence and severity both were maximum in plants inoculated with 15 days old culture.

Negative correlations were obtained between disease severity and weather variables because the disease severity continued to increase gradually during September-October while the weather parameters decreased gradually from mid September. It indicated that the pathogen caused infection and established well during favorable period (mid August to mid September) and declining weather parameters later on had little effect on the progress of disease. However, the apparent infection rate was positively correlated with all the weather parameters except maximum temperature.

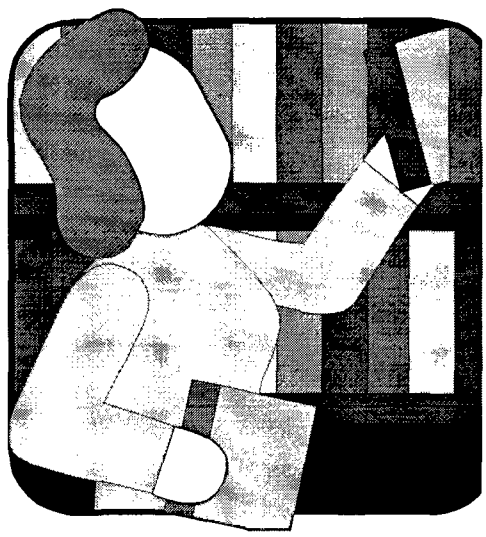
Tilt and SAAF, a systemic and coordinated fungicide respectively gave complete inhibition of mycelial growth at concentration as low as 5 ppm followed by Contaf at 10 ppm and Vitavax 200 at 50 ppm whereas Dithane M-45 a non systemic fungicide gave cent per cent inhibition at 200 ppm however all the non systemic fungicides gave complete inhibition at 500 ppm. Seed treatment helped in the reduction of seed borne inoculum as 20.42 per cent disease control was achieved with Vitavax 200. Other fungicides also reduced the seed born inoculum to some extent (2.75 -12.13 %) but the infection of crop at later stages diluted the effect of seed treatment. Therefore increase in yields with seed treatment, over the check was insignificant. Under field conditions, the sprays of triazole fungicides and coordinated fungicide SAAF were found more effective for leaf scald than those reported earlier. Tilt (0.1 %), was most effective giving 54.02 per cent disease control and followed by Beam (0.05 & 0.1 %), SAAF (0.25 %), Contaf (0.1 %), Tilt (0.05 %) and Contaf (0.05 %). Tilt (0.1 %) gave maximum yield gain of 38.49 per cent followed by beam (0.1 & 0.05 %), SAAF (0.25%) and Contaf (0.1%).

Out of 100 rice genotypes evaluated against leaf scald none was found to be completely resistant. High disease severity level was obtained under *in vitro*

than *in vivo* conditions. Under *in vivo* conditions three genotypes *viz.* IR 71703-57-3-1, IR 70554-48-1-2-YN1-1 and IRBB 60 were found moderately resistant whereas only two *viz.* IR 71703-57-3-1 and IR 70554-48-1-2-YN1-1qualified this category *in vitro*. It indicates that the reaction of different genotypes to leaf scald is highly influenced by the optimum conditions *i.e.* RH and temperature. If they prevail under natural conditions the disease can attain a severe level and cause huge losses.

5.2 Conclusions:

1. The fungus, isolated from the rice leaves exhibiting scald symptoms was found to be pathogenic and identified as *Rhynchosporium oryzae* Hashioka and Yokogi.
2. Leaf scald was prevalent in all the rice growing areas of Himachal Pradesh with maximum incidence and severity in Mandi and Hamirpur districts.
3. The fungus was found to grow and sporulate best at temperature 25-30°C, pH 7 and RH 80-100 per cent *in vitro* whereas, under natural conditions weather parameters were found to affect the inception of disease and apparent rate of infection.
4. Triazole fungicides *viz,* Tilt, Contaf and Beam among systemic, SAAF among coordinated fungicides and Carbamate fungicides *viz.* Dithane M-45 and Dithane Z-78 among non systemic alongwith Vitavax 200 as seed dresser were found most effective. Only two genotypes *viz.* IR 71703-57-3-1 and IR 70554-48-1-2-YN1-1 were found moderately resistant among 100 screened rice germplasm.



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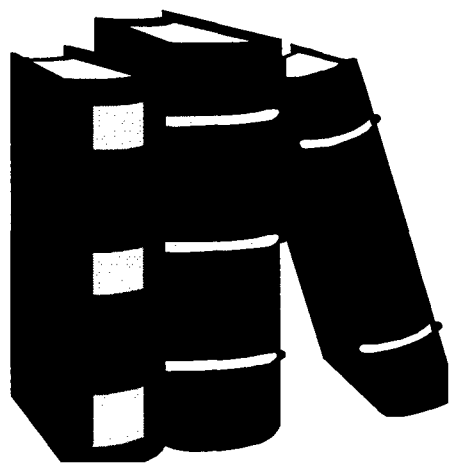

APPENDICES

Appendix-1

Composition of media used

Potato Dextrose Agar (PDA)

Peeled Potato	200.0 g
Dextrose	20.0 g
Agar	20.0 g
Streptomycin sulphate	200 ppm
Distilled Water	1000.0 ml

Potato Dextrose broth (PDA)

Peeled Potato	200 g
Dextrose	20.0 g
Streptomycin sulphate	200 ppm
Distilled Water	1000.0 ml

Potato Sucrose Salt Agar (PSSA)

Peeled Potato	300 g
Sucrose	20.0 g
Potassium Chloride	10.0 g
Agar	20.0 g
Streptomycin sulphate	200 ppm
Distilled water	1000 ml

Potato Sucrose Agar

Peeled Potato	200 g
Sucrose	20.0 g
Agar	20.0 g
Streptomycin sulphate	200 ppm
Distilled water	1000 ml

Appendix-II

Weather data at weekly interval during August-November 2010 at RWRC, Malan

	Week	Total rainfall (mm)	Temperature (^{0}C)		RH (%)	Rainy days
			Min.	Max.		
Aug. 2010	1.	218.7	21.8	29.8	28.3	5
	2.	168.1	21.7	30.6	69.7	4
	3.	198.4	21.2	29.0	68.6	3
	4.	333.3	20.8	26.7	70.6	6
	5.	158.1	21.9	30.4	66.0	2
Sep. 2010	1.	149.0	20.7	29.1	68.0	7
	2.	139.3	19.0	25.4	66.9	4
	3.	0.2	19.2	26.7	61.5	0
	4.	1.9	17.6	29.2	54.6	0
	5.	-	-	-	-	-
Oct. 2010	1.	NIL	15.8	28.2	46.2	0
	2.	3.0	14.9	28.2	46.3	1
	3.	1.8	16.0	28.5	47.7	-
	4.	35.2	12.1	23.7	44.1	1
	5.	-				
Nov. 2010	1.	NIL	12.2	24.2	44.6	0
	2.	NIL	11.5	27.0	43.45	0
	3.	NIL	10.4	25.6	42.3	0
	4.	NIL	10.1	23.9	43.6	0
	5.	NIL	9.0	23.5	42.6	0

Week considered from Monday to Sunday

Preparation of stock solution

Flow chart for preparing concentrations-

Fungicide: Propiconazole (Tilt 25EC) .....1.0 ml

Solvent: Water (sterilized) .....100 ml

Concentration of stock solution .....10,000 ppm

Stock solution (In ml)	Solvent: Water (sterilized) (In ml)	Concentrations (In ppm)
1.0ml	9.0 ml	1000 ppm-A
1.0ml of A	9.0 ml	100 ppm-B
5.0ml of B	5.0 ml	50 ppm-C
2.0ml of B	8.0 ml	20 ppm-D
1.0ml of B	9.0 ml	10 ppm-E
5.0ml of E	5.0 ml	5 ppm-F
4.0ml of E	6.0 ml	4 ppm-G
3.0ml of E	7.0 ml	3 ppm-H
2.0ml of E	8.0 ml	2 ppm-I
1.0ml of E	9.0 ml	1 ppm-J
5.0ml of J	5.0 ml	0.5 ppm-K
4.0ml of J	6.0 ml	0.4 ppm-L
3.0ml of J	7.0 ml	0.3 ppm-M
2.0ml of J	8.0 ml	0.2 ppm-N
1.0ml of J	9.0 ml	0.1 ppm-O

(Srivastava and Sexena 2008)

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10+2	March	2005	Jawahar Navodaya Vidyalaya, Pekhubela, Una	70.8	First
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M. Sc. Plant Pathology	Oct	2011	CSK HPKV, Palampur (HP)	72.9	First