

“STUDIES ON VARIABILITY OF *Rhizoctonia solani* Kuhn AND MANAGEMENT OF SHEATH BLIGHT OF RICE”

Ph.D. THESIS

By

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Certificate-I

This is to certify that the thesis entitled "**Studies on variability of *Rhizoctonia solani* Kuhn and management of Sheath Blight of Rice**" submitted in partial fulfillment of the requirements of the degree of **Doctor of Philosophy** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur is a record of the bonafied research work carried out by NITIN KUMAR TOORRAY under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

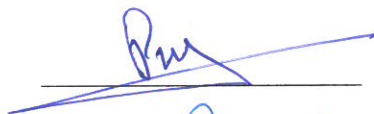
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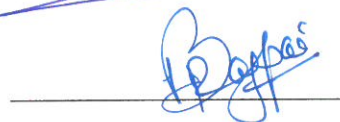

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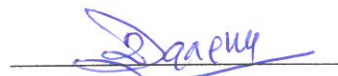
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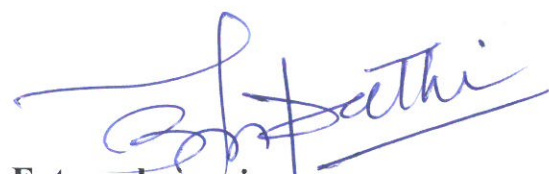
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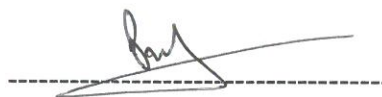
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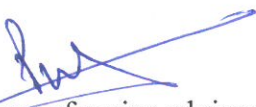
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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
%	Percent
viz.	Namely
SEm±	Standard error of means
DAI	Days After Inoculation
DAS	Day After Sowing
DAT	Day After Transplanting
Fig.	Figure
<i>i.e.</i>	That is
Mt	Metric tone
L	Liter
ppm	Part per million
PDA	Potato dextrose agar
Gm	Gram
T	Treatment
CV	Cultivar
Trt.	Treatments
EC	Emulsifiable concentration
WP	Wettable powder
µg	Micro gram
CD	Critical difference
Cm	Centimeter
<i>et al.</i>	And other
ha	Hectare
m ha	Million hectare
No.	Number
BOD	Biological oxygen demand
Kg	Kilogram
/	Per, also means and ar
ml	Milliliter
Gm	Gram
DS	Disease severity
DI	Disease incidence
PDI	Percent Disease Index
CG	Chhattisgarh

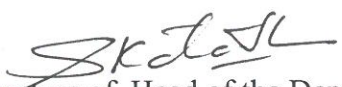
THESIS ABSTRACT

- a) Title of the thesis : "Studies on variability of *Rhizoctonia solani* Kuhn and management of Sheath Blight of Rice"
- b) Full name of the student : Nitin Kumar Toorray
- c) Major subject : Plant Pathology
- d) Name and address of the major advisor : Dr. P. K. Tiwari, Professor, Department of Plant Pathology, CoA, IGKV, Raipur
- e) Degree to be awarded : Doctor of Philosophy in Agriculture (Plant Pathology)


Signature of major advisor


Signature of the student

Date:


Signature of Head of the Department

ABSTRACT

Rice sheath blight caused by *Rhizoctonia solani* is one of the main disease of rice in the Chhattisgarh region. In view of the severe loss of yield from sheath blight in rice cultivation, current research entitled "Studies on the variability of *Rhizoctonia solani* Kuhn and the management of sheath blight in rice" was carried out to evaluate and investigate the use of indigenous bioagents, Chemical stimulants, micronutrients, host resistance, use of conventional and non-conventional chemicals for the environmental friendly and effective treatment of sheath blight in rice. To conduct the above study, an intensive survey program was undertaken to determine the loss and status of sheath blight in the Chhattisgarh during the Kharif 2015-16. Samples infected with the disease were collected for systematic study of sheath blight symptoms in rice. The total number of fifty-eight isolates was confirmed by the proof of the Koch postulates and classified in the category as weakly aggressive, moderately aggressive and highly aggressive. The seven isolates were recorded as highly aggressive and the maximum PDI 98.15 was shown by the isolate no. RS57. The variability between the *R. solani* isolates in terms of morphology, mycelial growth pattern and cultural characteristics

was also recorded. The *R. solani* isolates RS1, RS2, RS3, RS4, RS5, RS12, RS19, RS34, RS50 and RS57 were recorded as fast growing isolates. The color of the fungal colony was varied from light brown to dark brown. The *R. solani* isolates took 5 to 15 days to form sclerotia. The color of the sclerotia varied from light brown to dark brown and most isolates produced smoothly structured sclerotia with a number of 13.22 to 78.0. The impact of sheath blight on seedling vigour index under pot study revealed that the susceptible variety Swarna and Mahamaya had the lowest germination and seedling vigour index as compared to healthy seedlings.

To study about screening of native bioagents, *Trichoderma* and *Pseudomonas* revealed that the bioagent isolates significantly reduced the mycelial growth of *R. solani* under *in vitro* study. The application of *Trichoderma* for the management of sheath blight in rice noted that foliar spray of Durg isolate reduced the sheath blight severity up to 24.85% and increased the yield. The ITK technique *i.e.* evaluation of the plant extracts and panchgavya in cold water, hot water and acetone solution *in vitro* observed that the garlic extract in cold and hot water effectively reduced the mycelial growth of *R. solani* where the panchgavya was effective in acetone solution. The study on sheath blight development under *Trichoderma* rich organic amendments revealed that the treatment of *Trichoderma* + neem cake + *R. solani* was restrict the sheath blight development PDI 78.12% over control treatment under pot study, increased the seedling vigour index (4202.89) with trichoderma spore count 5.05×10^5 cfu/g. To evaluate the slow disease developing varieties among total forty three entries, the entry no. IET No. RP-Patho-23, IET No. 25916, IET No. R-2302-387-1-277-1, IET No. R-2302-390-2-288-1, IET No. R-2302-396-3-301-1 and IET No. SUVT-324 were recorded as resistant entries as compared with susceptible check Rasi and Swarna.

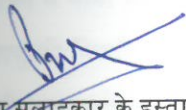
The resistant inducing chemicals *i.e.* salicylic acid, jasmonic acid, rose bengal and oxallic acid adversely reduced the mycelial growth of *R. solani* under *in vitro* whereas in pot study, the oxallic acid at 250µg/ml concentration strongly reduced the sheath blight PDI (33.34%) with 57.13 percent decrease over control treatment.

Effect of application of micronutrients under *in vitro* and pot study showed that the application of copper sulphate, zinc sulphate and silica at 500 ppm and *in vitro* significantly reduced the growth of *R. solani*. Whereas, in pot study, the mixing of copper sulphate in soil prior to transplanting effectively reduced the sheath blight PDI (38.34%) as compared to control treatment (55.56%) PDI. The evaluation of disease management practice combined with N fertilizer revealed that the susceptible variety + 1/2 RDN + three spray of hexaconazole reduced the sheath blight PDI (32.88%) as compared to control (75.93%).

The evaluation of new fungicides under *in vitro* noted that the combination fungicide Azoxystrobin 18.2% + Difenconazole 11.4% SC completely inhibited the mycelial growth of *R. solani*. This combination fungicide Azoxystrobin 18.2% + Difenconazole 11.4% SC @ 2.5 ml/lit significantly reduced the sheath blight PDI (22.87%) and increased the yield (4634.00kg/ha) under field conditions as compare to the control.

शोध ग्रन्थ सारांश

शोध ग्रन्थ का शीर्षक	: धान में <i>राइजोक्टोनिया सोलेनाई</i> कुहन की विविधता तथा पर्णच्छद अंगमारी रोग प्रबंधन पर अध्ययन।
विद्यार्थी का पूरा नाम	: नितिन कुमार तुरे
मुख्य विषय	: पादप रोग विज्ञान
मुख्य सलाहकार का नाम	: डॉ पी. के. तिवारी, मुख्य वैज्ञानिक, पादप रोग विज्ञान विभाग, कृषि महाविद्यालय, रायपुर ४९२०१२ (छ. ग.)
प्रदाय की जाने वाली उपाधि	: पी. एच. डी. पादप रोग विज्ञान


मुख्य सलाहकार के हस्ताक्षर


छात्र के हस्ताक्षर


विभागाध्यक्ष के हस्ताक्षर

सारांश

राइजोक्टोनिया सोलेनाई के कारण चावल की पर्णच्छद अंगमारी बीमारी छत्तीसगढ़ क्षेत्र के चावल किसानों के लिए एक प्रमुख बीमारी है। चावल की खेती में पर्णच्छद अंगमारी के कारण होने वाले गंभीर उपज नुकसान के मद्देनजर, वर्तमान शोध का शीर्षक "धान में *राइजोक्टोनिया सोलेनाई* कुहन की विविधता तथा पर्णच्छद अंगमारी रोग प्रबंधन पर अध्ययन" है, जिसका देशी जैव उर्वरकों के उपयोग, रोग प्रतिरोधकता उत्तेजित करने वाले रसायन, सूक्ष्म पोषक तत्वों का उपयोग, धीमी रोग प्रतिरोधी किस्मों, चावल में पर्णच्छद अंगमारी के प्रभावी उपचार के लिए पर्यावरण के अनुकूल पारंपरिक और गैर-पारंपरिक रसायनों के उपयोग का मूल्यांकन और जांच करने के लिए किया गया था जिनका छत्तीसगढ़ के विभिन्न भागों से किसानों के खेतों में होने वाले बीमारी और नुकसान का अध्ययन करने के लिए खरीफ 2015-16 के दौरान गहन सर्वेक्षण कार्यक्रम किया गया था। बीमारी से संक्रमित नमूनों को पर्णच्छद अंगमारी के लक्षणों को रोग संबंधी अध्ययन करने के लिए व्यवस्थित रूप से एकत्र किया गया था। कोच पोस्चुलेट्स से साबित हुए अन्ठावन प्रभेदों की कुल संख्या को कमजोर, मध्यम आक्रामक, आक्रामक और अत्यधिक आक्रामक की श्रेणी में विभक्त किया गया है। इनमें से सात प्रभेदों को अत्यधिक आक्रामक के रूप में दर्ज किया गया था और प्रभेद RS57 द्वारा अधिकतम 98.15 प्रतिशत पी. डी. आई. पाया गया। आर. *सोलेनाई* प्रभेदों के बीच आकारिकी लक्षणों में विविधता जैसे कवकजाल की बनावट भी दर्ज किए गए थे। कवकजालीय वृद्धि के अध्ययन से पता चला है कि आर. *सोलेनाई* के आरएस 1, आरएस 2, आरएस 3, आरएस 4, आरएस 5, आरएस 12, आरएस 19, आरएस 34, आरएस 50 और आरएस 57 तेजी से कवकीय वृद्धि करने वाले प्रभेद हैं। कवक

अध्ययन से पता चला है कि रोग सहिष्णु किस्म स्वर्णा और महामाया के रोगी बीजों को उगाने पर रोगी पौधों में सबसे कम अंकुरण और पौध ओज सूचकांक था।

प्रयोगशाला में अध्ययन से पाया गया कि मूल स्थानक जैव नियंत्रकों ट्राइकोडर्मा और स्यूडोमोनास प्रभेदों ने *आर. सोलेनाई* के कवकजालीय वृद्धि को घटाया। चावल में पर्णच्छद अंगमारी के प्रबंधन के लिए ट्राइकोडर्मा के पर्णिय छिड़काव के परिणामों से पता चला कि दुर्ग प्रभेद के पर्णिय छिड़काव ने पर्णच्छद अंगमारी बीमारी को 24.85% तक कम कर पैदावार में वृद्धि की। स्वदेशी तकनीकी ज्ञान (आई. टी. के.) तकनीक के प्रयोगशाला में ठंडे पानी, गर्म पानी और एसीटोन के घोल में पौधों के अर्क और पंचगव्य के अनुप्रयोग से पता चला है कि ठंडे और गर्म पानी में लहसुन के अर्क ने *आर. सोलेनाई* की कवकजालीय वृद्धि को कम कर दिया जबकि पंचगव्य सिर्फ एसीटोन के घोल में प्रभावी था। गमलों में ट्राइकोडर्मा से समृद्ध जैविक संशोधकों के पर्णच्छद अंगमारी बीमारी विकास व उपचार के अध्ययन से पाया गया कि ट्राइकोडर्मा + नीम खली + *आर. सोलेनाई* से उपचार द्वारा पर्णच्छद अंगमारी सघनता नियंत्रण 78.12% तक था जबकि ट्राइकोडर्मा बीजाणु की गिनती 5.05×10^5 cfu/g के साथ अंकुर शक्ति सूचकांक (4202.89) तक बढ़ी। कुल सैतालीस प्रविष्टियों में से धीमी गति से रोग विकसित होने वाली किस्मों का मूल्यांकन करने पर, प्रविष्टि संख्या IET No. RP-Patho-23, IET No. 25916, IET No. R-2302-387-1-277-1, IET No. R-2302-390-2-288-1, IET No. R-2302 -396-3-301-1 और IET No. SUVT-324 को रोग सहिष्णु प्रजाति रासी और स्वर्णा से तुलना करने पर रोग प्रतिरोधी प्रविष्टियों की श्रेणी में दर्ज किया गया।

प्रयोगशाला अध्ययन के तहत रोग प्रतिरोधकता उत्तेजित करने वाले रसायन जैसे सैलिसिलिक एसिड, जैस्मोनिक एसिड, रोज बेंगल और ऑक्सालोएसिटिक एसिड के प्रभावों द्वारा *आर. सोलेनाई* के कवकजालीय विकास पर प्रतिकूल प्रभाव डाला। गमलों के धान पौधों में प्रयोग अध्ययन के परिणामस्वरूप ऑक्सालोएसिटिक एसिड ने 250g/ml सान्द्रण पर पर्णच्छद अंगमारी बीमारी (33.34% पीडीआई) को अनुपचारित (57.13% पीडीआई) की तुलना में कम कर दिया।

प्रयोगशाला में अध्ययन के तहत सूक्ष्म पोषक तत्वों जैसे कॉपर सल्फेट, जिंक सल्फेट और सिलिका के 500 पीपीएम पर उपयोग से *आर. सोलेनाई* के विकास में काफी कमी आई जबकि गमलों में अध्ययन के तहत सभी सूक्ष्म पोषक तत्वों के बीच, मृदा में कॉपर सल्फेट को रोपाई के पूर्व मिश्रित करने से पर्णच्छद अंगमारी बीमारी (38.34% पीडीआई) को अनुपचारित (55.56% पीडीआई) की तुलना में प्रभावी रूप से नियंत्रित किया। नत्रजन उर्वरक की विभिन्न मात्रा के साथ मिश्रित रोग प्रबंधन विधि के मूल्यांकन से पता चला कि रोग सहनशील किस्म + 1/2 आर.डी.एन. + हेक्साकोनाजोल के तीन छिड़काव ने पर्णच्छद अंगमारी बीमारी (32.88% पीडीआई) को अनुपचारित (75.93% पीडीआई) की तुलना में रोक दिया। प्रयोगशाला में नए कवकनाशक उत्पादों के मूल्यांकन द्वारा उल्लेखित है कि मिश्रित कवकनाशी एज़ोक्सिस्ट्रोबिन 18.2% + डाईफेन्कोनकोनाज़ोल 11.4% एस. सी. ने *आर. सोलेनाई* के कवकजालीय वृद्धि को पूरी तरह से बाधित किया। प्रक्षेत्र अध्ययन में उक्त संयोजन कवकनाशी Azoxystrobin 18.2% + Difenoconazole 11.4% SC @ 2.5 मिली / लीटर ने पर्णच्छद अंगमारी बीमारी (22.87% पीडीआई) को काफी कम कर दिया। उक्त उपचार द्वारा अनुपचारित नियंत्रण की तुलना में उपज (4634.00kg/हेक्टेयर) बढ़ गई।

CHAPTER – I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food crop of over half of the world's population, and is also widely cultivated across the world, making it possibly the most valuable plant on earth (Shimamoto, 1995; Goff, 1999). It provides 20 percent of the world's supply of dietary energy followed by maize and wheat. Rice grows in at least 114 countries and more than 50 have a capacity of 100,000 tons or more per year. The production of rice to be adept by 2020 is 128 Mt. to feed the growing population in India. This crop also suffers due to number of diseases accounting for severe losses. Of the several factors known to destabilize rice yields, pests and diseases account for 30-40 percent crop losses. Most parts of the country regularly encounter complete crop failure due to epidemics of pests and diseases. In Chhattisgarh, rice production is comparatively smaller than the national average production. A lot of fungal, bacterial, nematode, and viral diseases are attacked on rice. Serious incidences of diseases such as blast, sheath blight and bacterial blight have been reported from rice growing areas in Chhattisgarh regions.

Sheath blight is one of India's widespread and harmful rice diseases. Rice sheath blight disease is causing significant loss, particularly in areas where high yielding varieties are cultivated. *Rhizoctonia solani* (Perfect stage-*Thanatephorus cucumeris*) which causes rice sheath blight in both soil and water borne.

Miyake (1910) stated that the sheath blight disease was first reported from Japan, and stated that the casual organism was *Sclerotia irregular*. Subsequently this disease was recorded from various global rice-growing regions, and particularly from major rice-growing countries. The presence of sheath blight disease in rice from several parts of India and beyond has been confirmed by workers of different parts of India. Butler made reference to the Indian disease as early as 1918. The presence of this disease has been confirmed by Andhra Pradesh, Assam, Jammu and Cashmir, Kerala, Tamil Nadu (Anonymous, 1971), Orissa and West Bengal (Das, 1970), Madhya Pradesh (Anonymous, 1975; Verma *et al.*, 1979).

Older plants are very susceptible to disease. Five to six week old sheaths to the leaf are highly sensitive. Ogoshi (1975) deliberately characterized the genus *Rhizoctonia* as: Branching near the distal end of cells in young, vegetative hyphae at right angle, Formation of a septum in near the point of origin in the branches, Constriction of the branch at its origin, Dolipore septum (present), No clamp connection, no conidium except the moniloid cells, no rind and medulla differentiated sclerotia. The primary inoculum of rice sheath blight was mostly of sclerotia float on the water surface after puddling. In addition to basidiospores, sclerotia of *T. cucumeris* and mycelium in plant debris were also designated as a source of infection.

It has a wide range of hosts including cultivated crops, weed plants and various family of horticulture crops. Both seedlings and adult plants are equally affected but when the disease occurs in seedlings, mortality is much greater. The initial symptoms usually develop as lesions on sheaths of lower leaves close to the waterline, when plants are in the growth stage of late tillering or nearly internode elongation typically these lesions develop as oval to elliptical, green gray, just below the leaf collar, water soaked spots about 1/4 inch wide and 1/2 to 1/4 inch in length. The disease has been named as “sheath blight” because of primary infection on leaf sheath. High doses of nitrogen fertilizers, intensive cultivation of modern high yielding variety, early maturation, high tillering rice varieties with double farming leads to increased severity of diseases, eventually yield losses of about 50% were recorded in Japan, Vietnam, South Korea, Taiwan, China, USA and India (Anonymous, 1988). Several workers reported, yield loss ranging from 20-50% in highly susceptible cultivars (Lee and Rush, 1983; Rajan and Naidu, 1986; Mizuta, 1956; and Hori, 1969). Ou (1972) also reported a grain yield loss of 25 per cent due to sheath blight. The disease is common in areas where there is high temperature (30 ± 32 °C) and relative humidity (> 95 percent) and in intensive cultivation areas.

The pathogen can exist in the soil as a mycelium or a sclerotia. The fungus generates generally long septate mycelium cells that are hyaline when young, yellowish brown when old. It releases a large number of sclerotia, they are irregular, globose or hemispheric, flattened at the base, white when young, and

turn brown or dark brown when older. Sclerotia is made up of small mycelial masses. Specific sclerotia have a diameter of 1–6 mm. Large sclerotia is considerably more virulent than smaller ones. Sclerotia spreads by irrigation water.

Awareness of the pathogenicity and aggressiveness nature of each pathogenic microbe is necessary not only to understand the expression of symptoms, but also contribute to the sheath blight disease control programme. Similar symptoms on rice sheaths are caused by a variety of fungal species and often difficult to distinguish by visual observation (Matsumoto 2003). Several researchers have observed differences in the length of the lesion among different isolates of *Rhizoctonia solani* (Sneh *et al.* 1996; Vidhyasekaran *et al.* 1997; Chaijuckam *et al.* 2010). However, the pathogen's soil-borne nature and the sustained persistence of its sclerotia complicate the chemical regulation of this disease.

The systematic search of higher plants for antifungal activity has shown that plant have the ability to impede spore germination and mycelia development in many fungal species. The antifungal activity used for systematic search of higher plants has shown in many fungal species, plants have the capacity to disrupt spore germination and mycelial growth. The antifungal and antibacterial properties of plant extracts particularly neem derivatives and to some extent panchgavya used as the integration of technologies to manage sheath blight of rice. The disease is controlled by one of chemical fungicide altering cultural practices, and restricted with biological control.

There are indications that pre-inoculation with the avirulent strain or other similar species can be induced in host resistance (Goodman, 1980; Kuc, 1983) or treatment with various non-conventional chemicals that can induce resistance (Wain and Carter, 1972; Sinha, 1988; Lazarovtis, 1988). Induction of resistance at rice plant to *R. solani* using non-conventional chemicals have reported (Sarkar and Sinha 1988, Manibhushanrao *et al.*, 1990)

Since, the resistant or tolerant sources to sheath blight are not available, it is important to monitor the new fungicidal molecule or drug to handle the disease effectively to prevent resistance developments in pathogen and reduce the fungicidal residues for ecological sustainability. Essential management aspect is

the judicious use of chemical control which is measures to combat sheath blight. Grasela *et al.* (1990) also mentioned that, many issues were still to be solved for most antimicrobial chemicals used in antimicrobial therapies.

The shortage of suitable and robust field-resistant varieties was primarily responsible for the cultivation of high yielding but susceptible varieties to this disease in most areas of the country and also in Chhattisgarh State. Since, sheath blight disease is the most prevalent in this state, and its recurrence is rising year after year, efforts to control this disease are focused. There is little scope for breeding for sheath blight resistance as no commercial rice cultivar was found to have resistant donor rates (Roy, 1993). Most of the prominent varieties under cultivation are susceptible in most parts of the country, particularly in the Chhattisgarh region.

A more sustainable approach for sheath blight management in rice with less reliance on synthetic fungicides, greater use of natural fungicides such as strobilurins and biological agents like *Trichoderma spp.*, *Pseudomonas spp.*, *Gliocladium spp.*, *Bacillus spp.* to restrict disease (Singh *et al.*, 2019).

Integrated disease control approach provide more sustainability-related vigilance. This approach mainly indicate the resistance of the host plant, cultural practices, eco-friendly methods, *i.e.* by using botanicals and bio-pesticides *etc.* application of chemical molecules needed to manage the disease. Looking to the above figure and facts, an attempt was made through this investigation to study the different methods contributing for the effective management of sheath blight of rice. Therefore, in this context, the present study entitled –“**Studies on variability of *Rhizoctonia solani* Kuhn and management of Sheath Blight of Rice**”with the following objectives:

- 1) Isolation, purification, identification, pathogenicity test of causal agent and symptomatology of disease.
- 2) Variability and cultural studies of *Rhizoctonia solani* Kuhn.
- 3) Integration of technologies to manage sheath blight of rice.
- 4) To assess effectiveness of stimulants, conventional and non conventional chemicals imparts resistance against sheath blight.
- 5) Screening of germplasm lines/varieties against sheath blight of rice.

CHAPTER-II

REVIEW OF LITERATURE

This chapter contains the literature relevant to the present thesis entitled “**Studies on variability of *Rhizoctonia solani* Kuhn and management of Sheath Blight of Rice**”

2.1 Study of survey, symptoms, isolation, purification, causal organism and pathogenecity test of sheath blight pathogen:

2.1.1. Survey:

Sheath blight disease has continued to endanger rice farmers and cultural-economic status in India and around the world since 1901. Sheath blight prevalence has been reported in most of the world's rice growing countries such as Bangladesh, China, Colombia, Germany, Indonesia, Japan, Korea, Malaysia, Moscow, Netherlands, Philippines, Senegal, Sri Lanka, Thailand, Trinidad, Tobago and Vietnam (Dasgupta, 1992). Butler (1918) had first described the occurrence of sheath blight disease in India. Paracer and Chahal (1963) from Gurdaspur, Punjab prepared the first detailed study of sheath blight in India. Subsequently the accident of this disease was reported from other locations of Punjab (Kohli, 1966), Uttar Pradesh (Singh and Pavgi, 1969) and from West Bengal (Amin *et al.*, 1974). Prabhat (1969) first observed the occurrence of sheath blight at Regional Agriculture Research Station, Pattambi in Kerala district Palakkad. Surveys conducted by Gokulapalan (1981) in rice fields of Vellayani, Karmana, Adoor and Kayamkulam of Kerala state revealed that besides rice, *R. solani* could infect a number of common weeds and on crops like Groundnut and Daincha grown in rice fallows. In Japan in 1901, sheath blight disease was first mentioned by Yano (Wei, 1934). Rice sheath blight was considered an internationally important disease, especially in the 1960s with the advent of high yielding varieties (Lee and Rush, 1983). Data gathered from the production-oriented survey over the past twenty-two years (1990-2011) related to sheath blight disease in rice and the studies indicated that sheath blight incidence and severity

were moderate before 2000. Yet in the last twelve years (2001-2012) the disease has spread rapidly in terms of both incidence and severity. At present, it is a major production constraint in the states of Punjab, Haryana, Eastern Uttar Pradesh, Uttarakhand, Bihar, Odisha, West Bengal, Chhattisgarh, Telangana, Andhra Pradesh and Tamil Nadu.

Swain *et al.*, (2005) was carried out an experiment on five isolates of *R. solani*, taking from various agro-climate zones. *R. solani* (S1) obtained from Bhubaneswar was found to be the most virulent to produce, and longer the length of the lesion and higher the overall sclerotic material in *R. solani*, S2 and S5 are much less virulent to isolate.

Xiao *et al.* (2008) Collected 55 *R. solani* samples from 5 distinctive areas of rice. After isolation and purification of fungus, the ability of pathogenicity and the molecular genetic variations were identified. Analysis of pathogenicity identification from leaves under *In vitro* shows a significant difference in pathogenicity among the strains.

Prasad V.R. (2014) was interviewed from August to September (2013) in ten rice growing areas in the Thrissur district. The incidence of sheath blight disease has been recorded in two of the farmer's most vulnerable popular varieties, namely Uma (MO-16) and Jyothi (PTB-39). The percent disease incidence (PDI) and percentage disease severity (PDS) at ten rice growing locations in the Thrissur district were found to be between 24.53 and 51.95 and between 44.76 and 85.53. The signs start below the waterline and extend upwards. At or near these lesions, they formed sclerotia that were removed early. Large greenish-gray lesions with brown edges were also found on leaf layers. Under favorable conditions, the disease spread very quickly to the surrounding farmers and caused the death of entire plants.

The 25 isolates of *Rhizoctonia solani* that cause sheath blight in rice have been collected from different countries. The population in *R. solani* was very different, which was enormously noticeable in the form of shading and surface of the state, number and size of sclerotia, time required for the arrangement of sclerotia and, furthermore, the location and type of development of the sclerotia in the colony. A total of 80 PCR groups were distinguished between 25 limits by *R.*

solani and the amount of alleles per locus varied from 1 to 7. Most of the elevated PCR objects were obtained with the basics OPW-13 and OPA-04, while the fewest PCR items were acquired with preliminary UBC-310 and OPB-08. There was only one monomorphic band that was present in the related primer UBC-373. The similarity coefficients among the *R. solani* population were between 0.53 and 0.94. An isolate from *R. solani* from Uttar Pradesh (RS-16) and another isolate from Punjab (RS-1) were most closely related. The *R. solani* isolates (RS-11 & RS-12) and (RS-20 & RS-21), all belonging to Uttar Pradesh, were genetically the closest to each other (Singh *et al.*, 2015).

2.1.2 The symptoms:

Ou *et al.* (1973) reported that the disease typically occurs during the tillering stage; it generally produces spots on the leaf sheath. The spots first appear as ellipsoid or ovoid, somewhat circular, greenish white, varying in length from 1-3 cm. The spot middle is turned grayish white with a brown margins.

Rush and Lee (1992) showed that sheath blight symptoms occur when the plants mature with later planting or early extension of the internode. The first symptoms are small, elongated or ellipsoidal, greenish-gray, water-soaked spots about 1 cm long that appear on the leaf sheath near the waterline. Under favorable conditions, i.e. With low sunshine, an air humidity close to 95% and a high temperature (28-32 ° C), the infection from runner hyphae spreads quickly to the upper parts of the plant, including the leaf blades and neighboring plants. When signs appear for the first time, sclerotia develops superficially on or near infected tissue and is closely related and can quickly detach from the plant when mature.

Rangaswami and Mahadevan (1998) reported that typically the plants are damaged when the sheaths of the leaves are discolored or above water level.

Sheath blight of rice was first reported from by Miyake (1910) in Japan. Subsequently, this disease was reported from different rice growing regions, general and particularly from major rice growing countries like Philippines (Reinking, 1918), Shri Lanka (Park and Bertus, 1932), China (Wei, 1934), Taiwan (Chen *et al.*, 1961), Bangladesh (Talukdar, 1968), Burma, Indonesia, Iran, Korea, Liberia and Thailand (Anonymous, 1975). Verma *et al.* (1979) reported that From

Madhya Pradesh. Widespread occurrence of the sheath blight of rice was also reported from Uttar Pradesh (Singh and Pavagi, 1969); Andhra Pradesh, Assam, Jammu and Kashmir, Kerala, Tamil Nadu (Anonymous, 1971); Madhya Pradesh (Anonymous, 1975); Orissa and West Bengal (Das, 1970).

Lee and Rush (1983) concluded that the lesions on the leaf sheath appeared as thin, oblong, greenish-gray patches and soaked in water. When lesions grew, the border of dark purple color to the center became bleached.

Kannaiyan (1987) noticed oval, unpredictably prolonged and enormous injuries on the leaf sheath and here and there reaching out to whole leaf cutting edge. Groth *et al.* (1991) gave a concise description of the symptoms of rice sheath blight disease.

Yu (1975) reported that the outer portion of the leaves became affected and slowly spread into the inner sheath. Sheath blight lesion occurs more rapidly over the sheath of the leaf, rather than over the sheath. The length of the lesion decreases in height when heading faster than at booting, and at tillering point. It was quicker than the upper leaves at booting the production on lower leaf sheaths, but reverses the heading stage at the rice plants. Because of primary infection on the leaf sheath, the disease was called 'sheath blight.'

Ou (1985) revealed that sheath blight causes leaf spots. The spots were originally ellipsoid or ovoid, somewhat oval, greenish-grey and varied in length from 1 to 3 cm. Sclerotia is produced at or near these sites, but has been easily removed. Based on the habitat, fungal mycelium may extend and disperse to a substantial distance on the surface of the leaf sheaths.

Reissig *et al.* (1986) concluded that Sheath blight occurs when the sclerotia *R. solani* found in the soil rises to the surface of the water and attaches to the rice base. During the planting period, when the rice roof was tight and the relative humidity was very high, the infection was typically the most serious and provided a good environment for the horizontal and vertical spread of diseases.

Singh *et al.* (1988) reported that the pathogen usually affected the bladder of the leaf and the sheath of the leaf, but the symptoms of fungal mycelium were

also chaffy, dull, and gray-brown in the panicles that formed. Various white and brown sclerotia were observed on diseased panicles.

Rangaswami and Mahadevan (1999) concluded that the pathogen caused spots or lesions mainly on the leaf sheath and extended to the leaf blades. The spots were initially greenish-gray, ellipsoidal or ovoid and about 1 cm long. They then become 2 or 3 cm long and gray-white with brown edges. Brown sclerotia were developed in the early stages and these lesions could easily be removed. The fungal mycelium expanded to other sheaths and leaf blades under moist conditions. Ultimately, the entire sheath and the affected leaf rot easily from the plant.

Rajput (2016) examined some areas in the north of Karnataka and the harvest eventually succumbed to ligament sheath and leaf blight. This led to the hypothesis that growth and sclerotic production could vary between different isolates from different parts of northern Karnatak.

Singh *et al.* (1988) reported that sheath blight symptoms were reflected on the panicle. They also observed that the leaf sheath and leaf blade were affected by this disease and, in extreme cases, symptoms appeared when panicles developed that were chaffy, gray-brown, and matted with mycelium.

Dasgupta (1992) described symptoms such as water-soaked spherical or elongated, ellipsoid, egg-shaped or sometimes irregularly elongated (3 cm x 1 cm) and discolored lesions that later develop into clear lesions with a light green-gray or white center. Finally, 4-5 of these lesions merge and girdle the entire envelope of the leaf, stalk and boot, as well as the flag leaf, while the tillers of the circle dry.

Saksena (1973) observed that the symptoms of the pathogen on the leaf were similar to those of the sugarcane banded sclerotial disease and this disease was thus referred to as 'banded blight.' During the banded blight cycle the flag leaf and panicle infection stopped the normal appearance and widening of skin.

Saksena and chaubey, (1972) concluded that the copper colored transverse bands are produced in leaf. This type of symptom is popularly called as 'banded blight'.

Anonymous (1988) examined crops, herbs and other seeds of family horticulture. Both seedlings and mature plants are affected in a similar way, but if

the disease occurs in seedlings, mortality is much higher. These lesions usually develop directly under the leaf collar as oval to elliptical, green-gray, water-soaked spots about ¼ inch wide and ½ to ¼ inch long. The loss of yield due to this disease is given as 5.20 to 50 percent depending on the environmental conditions, the harvest stages in which the disease occurs, and the varieties used. This disease is endemic in areas where the temperature ($30 \pm 32^{\circ}\text{C}$) and the relative humidity (> 95%) are high and the cultivation is intensive. Significant grain loss due to vaginal decay has been reported when susceptible varieties have been grown. High doses of nitrogenous fertilizers, intensive cultivation of modern high-yielding varieties, early-maturing rice varieties with high tillering and double cultivation lead to a higher severity of the disease. Finally, yield losses of around 50% were reported in Japan, Vietnam, South Korea, Taiwan, China, USA and India.

2.1.3 The causal organism:

The genus *Rhizoctonia* was first depicted by De Candolle in 1815 for the violet root rot organism. Parmeter (1970) portrayed that *Rhizoctonia* was accounted for by Julius Kuhn on infected potato tubers in 1858.

Hashioka (1970), Kozaka (1970) and Ou (1985) concluded that the nomenclature and scientific characterization of the sheath blight.

The sheath blight pathogen, now generally referred as *Rhizoctonia solani* Kühn and the perfect state (teleomorph) *Thanatephorus cucumeris* (Frank) Donk. The teleomorph of the pathogen, *Thanatephorus cucumeris*, belong to the family Ceratobasidiaceae of order Tulasnellales in the form class Hymenomycetes, sub-class Holobasidiomycetidae of class Basidiomycetes. The anamorph, *Rhizoctonia solani*, belong to the class Deuteromycotina, form class Deutromycetes and order Aganomycetales (Dasgupta, 1992). The taxonomy and nomenclature of *Thanatephorus cucumeris* (Frank) Donk was discussed by Talbot (1970). Talbot placed the genus *Thanatephorus cucumeris* in the family Tulasnellaceae in the order Tulasnellales and recommended that sub class Heterobasidio mycetidae and Homobasidio mycecidae should no longer be recognized. The perfect stage *Thanatephorus cucumeris* was known under different names and includes familiar names like *Hypochnus cucumeris*, *Hypochnus solani*, *Corticium solani*, *Corticium microsclerotia* (*Rhizoctonia microsclerotia*) and *Pellicularia filamentosa*. Other

possible synonyms are *Corticium sasakii* and *Corticium aerolatum*. *Thanatephorus praticolus* (Kotila) Flintje which were earlier considered as distinct species have also been included in *Thanatephorus cucumeris* by Talbot (1965). The pathogen for the sheath blight was found to be different from *R. solani* complex focused on cultural background, pathogenicity, symptomatology (Exner, 1953) and compatibility (Ogoshi, 1975). Comparative studies on mycelial and sclerotial characters of basidial (teleomorph) and anamorph of *Corticium solani*. *C. microsclerotia* and *C. sasakii* led to the conclusion that these disease did not differ significantly as distinct species and considered as forma specialis of *Pellicularia filamentosa* (Pat.) Rogers, a synonym of *T. cucumeris* (Frank) Donk. An additional *f.sp. timsii* was created to have four strains *f.sp. sasakii*, *f.sp. microsclerotia*, *f.sp. solani* and *f.sp. timsii*.

Sneh *et al.* (1991) classified the *Rhizoctonia solani* has been done on the basis of hyphal and cultural, morphology, nuclear condition, hyphal anastomosis and morphology of teleomorphs.

Ogoshi (1975) elaborate the character of genus *Rhizoctonia* as: (a) branching of small, vegetative hyphae at the distal end of cells at the right angle (b) development of a septum in the branch at the point of origin (c) constriction of branches at the point of origin (d) no clamp connection (e) no conidium, except for moniloid cells (f) sclerotia not separated in rind and medulla (g) no rhizomorph.

Ou (1985) reported that the sclerotia was established near the spots and after six days could easily be removed. The mycelium of the fungus may grow over the surface of the sheaths of the leaf, and may spread over a considerable distance (numerous cm) within 24 hours.

Duggar (1915) described details about the morphology and growth habit of the fungus and showed that the young hyphae branches tended to grow and were included at the point of union with the main hyphae. It has also been said that the *R. sclerotial* condition is commonly known as a fungus. *R. solani* Khun, as sclerotia develops abundantly on the affected sheath and rice leaf lamina.

Fredericksen *et al.* (1938) measured the sclerotia of *R. solani* and recorded the size (diameter) in the range from 1 to 7 mm. There are three types of sclerotia;

Namely, the smallest size is host sclerotia, the middle size is bottom sclerotia, and the largest size is laboratory sclerotia (Gangopadhyay and Chakrabarthy, 1979).

2.1.4 Isolation, purification and pathogenicity:

Saxena (1997) concluded from the pathogenicity point of view that three signs were significant. Isolates can cause various types of diseases and symptoms in the first group, isolates can vary aggressively in the second group, and the isolate range in the third group can vary from low to massive high. A comparison with 200 *R. solani* isolates from 59 crop plants shows that isolates belong to certain classes due to their physical, pathogenic and saprophytic ability.

Basu and Gupta (1992) found a significant correlation between sclerotic size and pathogenicity in isolates obtained from rice plants infected with sheath blight. Large sclerotic isolates are far more virulent than those with or without reduced sclerotia.

Sneh *et al.*, (1991) studied on the classification of *Rhizoctonia solani* on the basis of hyphal and cultural, nuclear condition, hyphal anastomosis and morphology of teleomorphs.

Sriram *et al.* (1997) found that Pathogenic variations in seven rice sheath blight pathogen isolates (*Rhizoctonia solani*), obtained during 1994 in seven major rice growing areas of South India. The isolate, obtained from Thiruvananthapuram (RS7) was extremely virulent.

Yang *et al.* (2008) tested 49 *R. solani* Isolates collected from 15 counties and classified AG-1 IA, AG-Bb and AG-4 isolates as being extremely pathogenic at the rice heading level while AG-1 IC and AG-1 IB isolates were moderately pathogenic and non-pathogenic, comparatively.

San Aye and Masaru Matsumoto (2012) were investigated at the *Rhizoctonia* rice complex in the rice growing region of Myanmar. The main goal of this research is to analyze the variety response of rice to the *Rhizoctonia* complex and to distinguish the effects of rice responses on these pathogens. Myanmar rice varieties, namely Manawthukha, Shwethweyin, Sinthwelatt and Yezinlonth, were used with three isolates of each variety to inoculate *Rhizoctonia solani*, *Rhizoctonia oryzae* and *Rhizoctonia oryzae-sativae*. The symptoms of

Rhizoctonia-growing organisms differ in the size and color of the lesions. A variation in the length of the lesion was found between different varieties of isolate rice varieties.

Mishra *et al.* (2014) examined 22 isolates of *Rhizoctonia solani*, with ten samples of rice and maize obtained, and two samples of green gram were examined for their natural, morphological and pathogenic variability. The appearance of the isolate colony was thin, slightly fluffy, fluffy cotton and even in cotton. The remaining isolates were light brown and had a small color of the three radial growth rates, *i.e.* Fast, medium and slow, twelve isolates had medium growth. In terms of color, the sclerotia of the isolates is gray, dark brown, and black and develops into a central, sub-centered, peripheral, scattered, and irregular shape.

Parmeter and Whitney (1970) and Ogoshi (1985) described cultural and pathogenicity studies listed indicate that *R. solani* Kuhn (teleomorph-*Thanatephorus cucumeris* (Frank) donk is the fungus that causes aerial sheath blight and durian dieback, as the isolates observed, showed indistinguishable characteristics.

Basu and Gupta (1992) were found positive correlation of sclerotia size and pathogenicity in isolates of rice infected with sheath blight. Smaller isolates of the sclerotia is much less virulent than those with large sclerotia.

Guttierrez *et al.* (1997) reported that infected plant tissue is cut into 5 cm pieces and washed to remove adhering organic matter in tap water and blotted to dry out. Instead, small samples of plant tissue (0.5 cm long) are collected from the lesions and transferred to an isolation medium, which can be either (*e.g.* alkaline water agar) or selective (*e.g.* modified Ko & Hora) medium. Because the R isolation was effective, alkaline water agar medium offers a faster way to isolate the fungus than other general media.

Mosaddeque *et al.* (2008) conducted an experiment on an infected sheath of a rice plant that was washed with tap water to remove the external contents. The shells were cut into small pieces with the HgCl₂ solution (0.001%) and sterilized in 30 seconds. After surface sterilization, the small pieces were washed three times

in sterile water and placed on the PDA plates for incubation at room temperature for 7 days to produce the pathogen. The culture was examined under a microscope and transferred to other petri dishes which retained PDA by the hyphal tip method. Both tests were performed in the laminar airflow chamber.

Xiao *et al.* (2008) collected fifty-five *R. solani* samples of rice collected from five distinct ecological zones. The fungus was collected, purified, and the propensity to pathogenicity and their variations were analysed. Pathogenicity identification from leaves under *in vitro* found that the pathogenicity of the strains was significantly different.

Singh (2012) reported on the study of the vertical and horizontal spread of sheath blight in six types of rice, namely. Swarna, Pusa Basmati 1, Pusa 1121, Tetep, Vikramarya and Pankaj when inoculated with Kapurthala (RS-1), Neu-Delhi (RS-2) and Moga- (RS-3) isolates in field / pot experiments. When inoculated with isolate RS-1 and isolate RS-2, Swarna was found to be the most susceptible, with the maximum relative lesion height (RLH) and Tetep being the most resistant. Pusa Basmati 1 and Pusa 1121 were either susceptible or moderately susceptible. Vikramarya and Pankaj were either resistant or moderately resistant. Isolate RS-1 was found to be the most virulent, the 47.8%, 39.1%, 33%, 13.6%, 14% and 20.4% RLH in the varieties Swarna, Pusa Basmati1, Pusa1121, Tetep, Vikramarya and Pankaj, followed by the Isolate RS2 production of 36.6%, 33.2%, 26.9%, 6.5%, 12.8% and 14.8% RLH produced on the varieties Pusa Basmati1, Swarna, Pusa1121, Tetep, Vikramarya or Pankaj. The incubation period for the three isolates varied from 4 to 7 days. Isolate RS-1 was found to be the most virulent, while isolate RS-3 was the least virulent of the three isolates. The horizontal spread was also maximal with isolate RS-1, followed by isolate RS-2 and isolate RS-3.

Susheela and Reddy (2013) classified thirty five isolates into different virulent groups. Among the 35 test isolates, 17 isolates were highly virulent (> 70% DI), 14 were virulent (60-70% DI), 2 isolates viz. , MCP, FZB were moderately virulent (50-60% DI) and the remaining isolates (MTU-w, JDP-w) were least virulent (≤ 50 %) on IR-50, a test variety used in the study.

Gangopadhyay and Chakrabarti (1982) concluded *R. solani* has a diverse range of hosts and inoculated plants belonging to more than 32 plant families and 188 genera. The alternate hosts help set the inoculum load in the soil to allow quorum to cause endemic and epidemic proportion of the disease in rice.

Prasad, V.R. (2014) investigated that the infected parts of the sheath, stem and leaf, which show typical symptoms of sheath blight, were collected in ten different locations in the Thrissur district. The pathogenicity of ten isolates of *R. solani* was demonstrated by inoculation under *in vivo* conditions on rice plants of a highly sensitive variety, Jyothi (PTB-39), at the maximum planting stage. The actively growing culture of *R. solani* was inoculated by placing it between the husk and the stem of the rice plant and, after sprinkling water, covered with polyethylene to produce moisture for the development of the disease, and the plants were grown at room temperature ($26 \pm 2^{\circ}\text{C}$) incubated C). The first symptoms were found on the third day of inoculation as small, water-soaked spots on both isolates. Characteristic symptoms are circular to ovoid, irregular, water-soaked larger lesions, which all isolates developed within seven to ten days.

Samples of diseased rice sheath were collected in the districts of Davangere, Mandya, Mysore, Raichur, Shivamoga, Tumkuru and Uttara Kannada in Karnataka during the Kharif (August and September) 2014 and 2015. Isolations were made from 20 samples infected with *R. solani* and identified and used for this study. For the sake of simplicity, the isolates were designated RS-K-1 to RS-K-20. The pathogenicity of all isolates was determined using the Typha-Bits inoculation method (Bhaktavatsalam, 1978) on a 40-day-old susceptible rice variety TN-1. Four to five Typha stem parts populated with fungal mycelia and sclerotia are placed between the tillers in the central area of the hill, 5-10 cm above the waterline, and then tied to a rubber band to maintain the high humidity in the microclimate. Plants that are not inoculated serve as support under greenhouse conditions. The inoculated plants are kept in a humid chamber for 4-5 days in greenhouse experiments for rapid pathogen growth. Symptom development was routinely observed in the inoculated plants. The re-isolation was carried out from infected plant parts and thus followed the Koch postulates in contrast to the original cultures. The pathogenic variability of the test isolates was assessed by

inoculating the test isolates on one-month-old plants of the susceptible rice variety TN-1 using the Typha bit inoculation method (Bhaktavatsalam *et al.*, 1978). Koch postulates for all isolates were demonstrated by Typha bit inoculation method on a 60 day old susceptible strain TN-1. All isolates were able to produce typical symptoms of sheath blight after three days of inoculation. The fungus was reisolated and purified by hyphal culture on water agar (2%) found.

Prasad *et al.* (2014) reported that the pathogenicity of eight *R. solani* isolates was carried out on a susceptible strain TN-1. Isolates RS-K-5 and RS-K-4 were the first to cause symptoms, and isolate RS-K-7 took seven days to show symptoms. The size of the lesion varied from 0.15 to 3.15 cm. Isolate RS-K-12 produced a maximum (33.86) relative lesion length and a minimum (17.26) through isolate RS-K-16. Based on the percentage incidence of diseases, all isolates were classified as highly virulent ($\geq 50\%$) (Manjunatha. O., 2016).

Chien and Chung (1963) reported 300 isolates of *R. solani* from Taiwan and inoculated on 16 rice cultivars. Based on pathogenicity, the isolates were classified in to seven cultural types and six physiological races.

Parmeter *et al.* (1969) composed four groups of *R. solani*, namely AG1, AG2, AG3 and AG4, genetically isolated and unable to share nuclear power due to non-fusion between isolates of different groups.

Tu *et al.* (1979) studied many strains from Taiwan and noted that the strains with less aerial mycelium were more pathogenic.

Yu (1975) stated that sclerotia from rich media were highly pathogenic. Floating and sinking sclerotia may have different roles in pathogenicity due to variation in membrane of permeability as proposed for *Macrophomina phaseolina* (Gangopadhyay and Chakrabarthy, 1979).

Hyakumachi *et al.* (1988) revealed *R. solani* as a complex pathogen having great variation among the isolates, in terms of mycelial colour, zonation, type and number of sclerotia and pathogenicity.

Singh *et al.* (2002) characterized 46 isolates from two fields of Dehradun and Nagina in Uttar Pradesh based on their cultural and morphological properties, their anastomotic behavior, their aggressiveness and their randomly amplified

polymorphic DNA (RAPD). All isolates were multinuclear and had the typical properties of *R. solani*. They all had a place on AG-1IA, although they showed either an anastomosis response of type 2 (contradicting combination) or 3 (perfect combination), with the analyzer islette having a place on AG-1IA. In fact, even morphologically divergent isolets showed 3 types of anastomosis reactions. The population of *R. solani* was very different in terms of the above attributes. The hereditary variety was associated with the appropriation of the islette in various climatic conditions. This can lead to impairment and pathogenic inconsistency, which is evident from the bundling of the lion's share of Dehradun and Nagina in subgroups I and II.

2.1.5 Mass multiplication:

Paracer and Chahal (1963) assessed that the stems of 35- to 40-day-old rice plants were cut into approximately 2 cm pieces and filled up to a third in 500 ml Erlenmeyer flasks. 10 ml (1%) peptone + sucrose (1: 1) solution was applied to each flask and the flasks were autoclaved at 15 pounds per square inch within 30 minutes. Mycelial disks with a diameter of 5 mm, which were cut off from the edge of a 48-hour old culture, were inoculated into the flask and incubated at $28 \pm 2^\circ \text{C}$. for up to 15 days in order to achieve maximum growth of the fungal and sclerotic formation. For artificial inoculation, the rice plants were taken for inoculation at the maximum tillering point.

Bhaktavatsalam *et al.* (1978) worked to increase the mass of sheath blight fungi that cause infection and suggest that standard Typha parts are cut and sterilized in an autoclave and inoculated with *Rhizoctonia solani*. The material is put wet to multiply the fungus. The bits were used for artificial inoculation when the fungal mat had completely covered the typha bits.

2.1.6 Source for survival of inoculums:

Ou (1987) reported that the primary inoculum of sheath blight was mainly sclerotic swimmers after puddling on the water surface. Basidiospores of *T. cucumeris* and mycelium in plant remains were also considered to be a source of infection. Mycelia can serve as an inoculum in tropics without losing their

viability, as dry, humid conditions prevail throughout the year with short intervals between growing seasons.

2.1.7 The infection and survival:

Chien (1979) has noticed the sheath blight disease shown spread everywhere the rice is grown. Sheath blight incidence was seen as a major problem in rice production in some countries, such as India, Sri Lanka, China, Taiwan and Japan.

Paracer and Chahal (1963) reported this disease first time from Gurdaspur area of Punjab (India). Widespread occurrence of rice sheath blight from Uttar Pradesh was also recorded (Singh and Pavagi, 1969); Andhra Pradesh, Assam, Jammu and Kashmir, Kerala, Tamil Nadu (Anonymous, 1971), Madhya Pradesh (Anonymous, 1975), Orissa and West Bengal (Das, 1970).

The fungus could infect at any growth stage in rice crop (Tu *et al.*, 1979; Kamjaipai and Giotgong, 1971). While all stages were equally susceptible, the damage was more serious on young plants (Valdez, 1955). Mycelium in the infected tissue was reported to survive as long as sclerotia under upland conditions (Anonymous, 1972). The disease was reported to be most important in upland rice than lowland rice (Anonymous, 1973).

Ou (1973) was found that sclerotia survived for one or two years. Specifically, soil composition may also affect the occurrence of disease because this is related to the moisture content.

Varma *et al.*, (1978) was reported, sheath blight more pervasive in upland fields and less compelling in light clay soil than clay loam and loam soil in Japan.

Mukherjee (1978) observed that sclerotia in soil act as the primary source of inoculum.

Roy (1984-1986) described weed hosts play a major role in pathogen perpetuation, and soil sclerotia survival has also been greatly affected by soil moisture content, and fewer than two months have established that survival in water-logged soil has been adverse.

Lakshmanan and Nair (1986) also reported that, sclerotia lost its viability in 60-90 days in water-logged soil.

Yield loss ranging from 20-50% in highly susceptible cultivars was reported by several workers (Mizuta, 1956, Hori 1967, Lee and Rush, 1983, Rajan and Naidu, 1986 and Chahal *et al.*, 2003).

Kozaka (1970) was reported yield loss is 30-40% in case of severe infected sheath leaf and leaf blade. Yield loss of 25% was observed when the disease extended up to flag leaf (Hori and Anraku, 1971). According to Lee and Rush (1983) losses occurred between 20 to 50%, when all sheaths were infected.

Rajan (1987) reported yield losses ranging from 5.2 to 50%, crop stages at which the disease occurs crop practices and cultivars used, depending on environmental conditions. The IRRI (2001) rice disease survey showed a production loss of 0.9% and 0.8% respectively due to sheath blight in Japan and Korea.

Naidu (1989) inoculated eight varieties with *R. solani* using stem tap method and scored for yield. In the Phalguna and Mansui strains, reductions in grain yield ranged from 49 to 69.1%.

Liao *et al.* (1997) noted that due to loss of sheath blight yield was 1.97 times that of rice blast. The effects, when seeds are harvested from infected plants, may be found in next generation crops. The sheath blight also increases lower internode resistance to crack, resulting in reduced lodging resistance. Loss of yield from sheath blight in rice depends on the degree and spread of the infection. In Arkansas, sheath blight was found to occur in 50-66% of the rice fields, resulting in yield declines of 5-15% in 2001 (Anonymous *et al.*, 2005). In Japan, approximately 1.2 to 1.9 lakh hectares were confirmed to be infected with sheath blight, resulting in a loss of 24,000 to 38,000 tons of rice annually (NIAS, Japan, 1954). In Philippines, losses due to sheath blight varied from 30 to 40% and reported up to 100% in endemic areas (Ou, 1985). A modest estimate of losses in India alone due to sheath blight was up to 54.3% (Roy, 1993). Losses in crop production due to sheath blight ranged from 1% to 50% and it's depended on inoculum, crop growth, environmental status and varietal resistance (Groth *et al.*, 1991; Marchetti and Bollich, 1991). Yield losses of 5-10% have been estimated from tropical low land rice in Asia (Savary *et al.*, 2000). According to Kumar *et al.*

(2009), Sheath blight is one of the most economically troubling rice diseases causing yield losses of up to 25%.

Liao *et al.* (1997) found that the yield from sheath blight loss was 1.97 times that of rice. The effects of harvesting seeds from infected plants can occur on next generation plants. The disease also increases the lower internode resistance to crack, which leads to a reduced resistance to lodging. The loss of yield from sheath blight in rice depends on the degree and spread of the infection. In Arkansas, vaginal decay was found in 50-66% of the rice fields, which led to a drop in yields of 5-15% in 2001 (Anonymous *et al.*, 2005). In Japan it has been confirmed that approximately 1.2 to 1.9 lakh hectares are infected with sheath blight, resulting in a loss of 24,000 to 38,000 tons of rice per year (NIAS, Japan, 1954). In the Philippines, losses ranged from 30 to 40% and up to 100% have been reported in endemic areas (Ou, 1985). A modest estimate of losses due to sheath blight in India alone was up to 54.3% (Roy, 1993). The losses in plant production were between 1% and 50% and depended on the inoculum, plant growth, environmental status and variety resistance (Groth *et al.*, 1991; Marchetti and Bollich, 1991). Yield losses of 5-10% have been estimated from tropical lowland rice in Asia (Savary *et al.*, 2000). According to Kumar *et al.* (2009), sheath blight is one of the most economically problematic rice diseases, causing yield losses of up to 25%.

2.2 Cultural and morphological variation in *R. solani* isolates of different rice growing areas of Chhattisgarh:

Meyer (1965) reported some *R. solani* isolates may lacking the sclerotia and therefore the lack of sclerotia in these cultural conditions does not exclude *R. solani* mycelium necessarily. The diameters of the sclerotia in Group 2 ranged from 1.13-2.03 mm and 1.5-2.03 mm.

Burpee *et al* (1980) had categorized across the same three classes. Growth rates of diameters after 24, 48 and 72 h were observed. The isolates were fast, medium, and slow, divided into 3 groups. Ten isolates covered the entire plate (90 mm) in 48h but even after 72 h RS-22 isolate did not cover the plate. Rapid and medium-growing isolates were more pathogenic than isolates with slow growth.

Anderson (1982) clearly distinguished the sclerotia were colour. That diameter of *R. solani* was also reported by Dath (1985) and IRRI (1986) sclerotia ranged from 1 to 3 mm.

Sinha and Ghufra (1988) concluded that more variations among isolates of *R. solani* and colour of mycelium and size, colour, number and form of sclerotia.

Singh *et al.*, (1990) has *R. solani* Isolates from group AG-1 collected from five different endemic sheath blight sites, namely Assam, Andhra Pradesh, Tamil Nadu and Andaman, India, having distinct natural morphological characteristics.

Singh *et al.* (2002) were formed Sclerotia in aerial mycelium in 9 isolates and on the surface of the mycelium in all isolates except RS-22.

Hoa (1994) reported that varied sclerotial color, brown, light brown and salmon. Sclerotia texture was categorized into two smooth, rough classes. 12 isolates in rough category and the remaining 12 isolates in the smooth category were grouped into the rough category. The isolates were divided into six groups, ranging from 0.85-3.05 mm depending on the sclerotia thicknesses.

Sunder *et al* (2003) defined the shades of brown, light brown, dark brown and yellowish gray. The decolorations of the growth media are mainly due to the production of pigments by the pathogen.

Basu *et al* (2004) found no correlation between the mycelial growth of an isolate and its on-host virulence. He also stated that the sclerotial diameter varied from 0.23 to 1.91 mm, and found abundance and size of sclerotia defining the virulence of an isolate.

Shahjahan *et al.* (1987) found that the growth rate and the virulence of the fungus were interdependent.

Lal M. and Kandhari Janki (2009) were found that the morphological variability of 25 isolates from various rice growing areas has been reported. The colony size, color and sclerotia type (central, peripheral, or scattered), location (aerial or surface) and texture (smooth or rough) varied in these isolates.

Cultural and morphological variation in *R. solani* have been reported by various workers viz. Singh *et al.*, (1999), Panja *et al.*, (2011) etc.

Meena *et al.* (2001) examined the morphological and cultural properties of *R. solani* isolates from Madurai, Melur, Coimbatore, Trichy and Arumbanur from the state of Tamil Nadu in relation to their virulence on rice. Of the five isolates from *R. solani* that were tested for virulence, the Madurai isolate was the most virulent by exerting the maximum lesion level of 66.4 percent on rice plants when artificially inoculated. Among the isolates from *R. solani*, the mycelial and sclerotial features differed greatly. The Madurai isolate developed faster, developed a dark brown mycelium and produced larger and dark brown sclerotia, while the Trichy isolate produced small, light brown sclerotia. Madurai found isolation to be the highest number and scale of sclerotia. Potato dextrose agar medium supported high mycelial growth and sclerotic development, while limited mycelial growth and sclerotic development were observed in the dox medium in Czapek.

Basu *et al.* (2004) collected sheath blight infected rice samples from various locations in West Bengal, namely R1 (Mashuri: Burdwan, Dist), R-2 (IR 36), R-3 (IR 50), R-5 (Jaya: all) from Chinsurah Dist. Hooghly), R-7 (Saket 4: Pandua, Dist. Hooghly), R9 (Pankaj Arambagh Dist. Hooghly), R-11 (IR 36: Howrah Dist.) And R-12 (Jaya, Bhangar Dist.)). Air growth was abundant (R-12) to abundant (R-1, R-5, R-7, R-9 and R-11) in most isolates. It was moderate in R-2 and sparse in R-3. The growth was suppressed in all isolates and varied from woolly (R-1, R-2, R-3 and R-9) to cotton (R-5, R-7, R-11 and R-12). The colony color ranged from creamy (R-5 and R-7) to light brown (R-1, R-2, R-3, R-9, R-11 and R-12). Sclerotia were not differentiated in isolates R-3 and R-5. Sclerotial production was poor in isolates R-1 and R-7, adequate in R-12, and good in R-2, R-9, and R-11. The sclerotial size was largest in R-9 and smallest in isolate R-2. The severity of the disease was lowest in seedlings inoculated with isolates R-3 and R-5 and highest in seedlings inoculated with isolates R-9 and R-11. The hyphae width of isolates R-2 and R-7 averaged 5.0 and 5.9 mm, respectively. The width of other isolates averaged between 6.4 and 7.5 mm. No anastomosis occurred between isolates R1-R2, R2-R3 and R3-R9. Between R1-R3, R1-R5, R1-R12, R2-R5, R2-R9, R2-R12, R3-R7, R3-R11, R5-R9, R5-R11, R7-R11 and R9-R12, hyphal Tip attraction and adherence was observed, but no fusion occurred.

Guleria *et al.* (2007) collected 19 *R. solani* separates from different Punjab districts and examined their morphological and pathological properties. The majority of isolates were fast breeders with raised and fluffy colonies and 9.6 μ m hyphae, although the moderate growth rate showed four. The sclerotic number per 5 mm culture slice of the test isolates was in the range from 2.1 to 11.2 mm; their thickness went individually from 1.31 to 2.08 mm. Overall, the sclerotial color was light yellow-brown, with the exception of two isolates, most of which were spread across the colony. The molecular characterization of genetic diversity in test isolates was tested using ISSR and RAPD markers, which were analyzed using UPGMA. Some of the isolates that are unique to the host type indicate grouping.

Kumar *et al.* (2008) examined the morphology and virulence of 25 *R. solani* isolates from different regions of Uttar Pradesh (India), including Azamgarh, Basti and Faizabad. Most isolates were fast growers with dark brown mycelium and medium-sized macrosized sclerotia with an average weight between 0.04 and 0.82 mg. Some isolates had a cream-colored mycelium that was distributed with sclerotia near the inoculation stage. The virulence diversity of the isolates was examined in ten rice varieties under *in vivo* and found that in the majority of the isolates the side effects occurred after 48 hours of immunization, but in some different deactivations an infection occurred after 96 hours of inoculation. The severity of the disease was assessed using the Area Under Disease Progress Curve (AUDPC) based on the length of the lesion and found that a large number of the separates were moderately virulent, some highly virulent and some less virulent.

Lal and Kandhari (2009) examined the morphological variation, namely, Colony size, mycelial development, color and sclerotic formation (central, peripheral or scattered), position (air or surface) and sclerotic texture (smooth or rough) among the 25 isolates of *R. solani* were obtained from various rice growing areas.

Jayaprakashvel and Mathivanan (2012) studied Morphological and pathological variants of 236 isolates of *R. solani* in South Indian. Causing blight of rice sheath gathered from 45 sites. Sclerotial characteristics such as color, scale, and shape and distribution pattern were varied among the isolates. majority of *R.*

solani isolates were fast growers and achieved full mycelial growth within two days, and the development of sclerotial structures was observed within four days of incubation. Selected 10 *R. solani* isolates showed major pathogenic differences on three distinct rice cultivars.

Jayaprakashvel and Mathivanan (2012) examined morphological and pathological variants of 236 isolates from *R. solani* in southern India. Causes blight of the rice sheath, which was collected in 45 places. The sclerotial properties such as color, scale, shape and distribution pattern were varied among the isolates. The majority of the *R. solani* isolates grew rapidly and achieved complete mycelial growth within two days, and the development of sclerotial structures was observed within four days after the incubation. Selected 10 *R. solani* isolates showed large pathogenic differences in three different types of rice.

Kuiry *et al.* (2013) collected 67 *R. solani* isolates, rice, maize, sugar cane, beans, cabbage, spotted pumpkins, watermelons, potatoes and beans from various agro-ecological regions in West Bengal (WB). Cultural and morphological features showed significant differences between the *R. solani* isolates. The cultural and morphological analysis of the WB rice isolates shows that the difference between the isolates does not correspond to their origin. Morphological features based on *R. solani* isolates can be conveniently isolated from *Oryzae sativae*. The number of sclerotia, the hyphae length, the sclerotic weight and the pathogen growth rate are important morphological indicators for the differentiation.

Mishra *et al.* (2014), who were examined on 22 *Rhizoctonia solani* isolates from rice (10), maize (10) and green grams (2), were examined for their diversity in terms of social, morphological and pathogenic properties. At the three fast, medium, and moderate development rates, twelve isolates developed as a medium with development completed within 72 hours, eight isolates developed rapidly (48 hours), and two isolates developed gradually (96 hours or more). The sclerotic isolates were colored light gray, gray, dark brown and black and formed a fragmented, irregular, central, subcentric, peripheral ring. Most isolates developed a high number of sclerotia in the range of 40 to 60 within 3 to 10 days. Cross-infectivity of the borders in each of the three hosts, their pathogenicity being the variability. Four rice isolates, two corn isolates, and green gram isolates were seen

as increasing and had a higher disease frequency that could be used for safe rearing projects for their respective hosts.

Manjunath, O. (2016) examined the cultural and morphological variation in *R. solani* with regard to the important basic factors for the identification and variability of the fungus, the colonial color, the colony texture as well as the colony diameter and the growth rate, and found a considerable variation between the isolated. 15 days after the inoculation, observations were made on the variability of the sclerotic properties such as sclerotic color, development site, production pattern. The twenty-five isolates, two were red, nine were sand yellow, and four were light brown in color. *R. solani* isolates were divided into three categories. The composition of the colony *R. solani* is limited to an exceptionally thick surface, for example to a pleasant level and a somewhat fragile improvement in the mycelia. Considering the example of sclerotial creation, the *R. solani* dislocations were divided into five groups, namely. mounted inside, lower ring, middle ring, edge ring and distributed accumulation. Of the twenty separates, nine isolates emitted nectar, while eleven did not. The weight of the sclerotia varies between 8.75 mg and 18.50 mg. while the number of sclerotia ranged from 67 to 618 for each disc.

Najeeb *et al.* (2017) examined the cultural and morphological variability and identification of the population from anastomosis that causes rice sheath blight in Kashmir. Twenty-seven *R. solani* isolates were observed, obtained from different locations in five districts of the Kashmir Valley. The isolates belonged to five classes of culture and morphology, classified as A, B, C, D and E, based on the pattern of mycelium color and growth rates. The isolate Shb-4, Shb-6, Shb-10, Shb-14, Shb-18 and Shb-24 belonged to group A, while group B for isolating Shb-3, Shb-5, Shb-9, Shb -12, belonged. Shb-13, Shb-15, Shb-16, Shb-20, Shb-22 and Shb-23. Group C consisted of isolates Shb-7, Shb-11, Shb-21 and Shb-25 and isolates Shb-1, Shb-8, Shb-17, Shb-27 and Shb-2, Shb-19 and Shb, respectively - 26. There was no correlation between morphological groups and isolate classification according to anastomosis, since all isolates belonged only to a subclass of anastomosis based on the study of hyphal anastomosis and its pathogenic response to rice, corn, soybeans and wheat.

Yaduman *et al.* (2019) studies morphological and pathological variability of 24 isolates of *R. solani*, collected from various location of Prayagraj (U.P.) that growth of *R. solani* was observed in different colours like, light yellow, whitish yellow, pale yellow, light cream yellow, yellow and cream yellow. Growth of this pathogen was good and very fast as in some isolates. Sclerotia were found mostly thin and their colours were brown, dark brown as well as blackish brown. Different distribution patterns were observed in sclerotia production viz., central, peripheral and scattered. Number of sclerotia was ranged between 53.67-164.00 and sclerotia weight was ranged between 0.116-0.373 g. Maximum numbers of affected/dead tillers (6.33), number of lesions (9.0), mean lesion length (19.0 cm) and relative lesion height (45.37 cm) was recorded with RS_U22, RS_U49, RS_U7 and RS_U22, respectively.

2.3 Evaluation of aggressiveness of different isolates of *R. solani* :

Saxena (1997) reported that three characters were significant. In the first group isolates can cause different types of diseases and symptoms, in the second group the state of aggressiveness can differ and in the third group the host between the isolates can shift from limited to very far.

Sriram *et al.* (1997) investigated pathogenic variations in seven isolates of the *R. solani* rice sheath rot that had been collected in seven large rice growing areas in southern India since 1994. The isolate was collected from Thiruvananthapuram (RS7) and was highly aggressive.

Singh *et al.* (2002) described 46 limited isolates in Uttar Pradesh from two fields of Dehradun and Nagina, depending on their cultural and morphological properties, their behavior during anastomosis and their aggressiveness. The population of *R. solani* was extremely different in terms of the above attributes. The aggressiveness and genetic variation of the strain was associated with the appropriation of dislocations in different climates, as the atmosphere could affect pathogenic variability, which is evident when most of the isolates from Dehradun and Nagina are individually bundled in subclusters I and II.

Kipsumbai and Kiptui P. (2015) investigated that *R. solani*'s rice isolates were tested for aggressiveness in six rice genotypes, and the Mahalanobis D2 study

was used to further assess these limits, and two significant classes were observed. Of all *R. solani*, about 20 percent of the isolates were considered to be highly aggressive. Cross infectivity studies showed that *R. solani* isolates were pathogenic transversals. A significant correlation between the *R. solani* isolates, which were partly related to the aggressiveness of the observed isolates.

Swain *et al.* (2005) found that among five isolates from different agroclimatic areas, the separate *R. solani* (S1) collected from Bhubaneswar was most virulent, resulting in a longer lesion length, generally a larger number of sclerotia. The isolate of *R. solani* S5 and S2 was considered to be moderately less virulent.

Yang *et al.* (2008) tested 49 isolates from *R. solani* from 15 counties and identified the isolates from AG-1 IA, AG-Bb and AG-4 were highly pathogenic on rice, while isolates from AG-1 IC and AG-1 IB were moderately pathogenic or not pathogenic. Souza *et al.* (2007) found cross-pathogenic isolates in rice and soybeans in Brazil, while Biswas and Samajpati (2007) reported that both rice and wheat were infected with *R. solani* when artificially inoculated.

San Aye Seint and Matsumoto Masaru (2012) found that the *Rhizoctonia* rice complex was found in Myanmar's rice development areas. This study is important in order to examine the variety reaction of rice to the complex *rhizoctonia* and to differentiate the symptom expression of rice reactions to these pathogens. Myanmar rice varieties, namely Manawthukha, Shwethweyin, Sinthwelatt and Yezinlon, were used to inoculate *Rhizoctonia solani*, *Rhizoctonia oryzae* and *Rhizoctonia oryzae-sativae* with three isolates. The symptoms caused by each *Rhizoctonia* species were characterized by the size and color of the lesion. A variation in the length of the lesion was observed between different combinations of isolate rice varieties.

Adhipathi *et al.* (2013) reported that the detection of susceptible and resistant rice genotypes against sheath blight disease and virulence / aggressiveness, along with the pathogens caused by *Rhizoctonia solani* Kuhn (Teleomorph: *Thanatephorus cucumeris*), is one of the most harmful soil-borne diseases. 12 *R. solani* isolates were collected and characterized in 10 different types of rice, based on morphological and sclerotial properties and variety of

virulence / aggressiveness. The progression and extent of the disease was assessed using the AUDPC value based on the duration of the lesion specified in DAI 4, 8, 12 and 16. The evaluation based on AUDPC values of 10 rice varieties showed that Sarju-52 was extremely resistant (19.91), whereas Jaya (21.87), UPR-2005-38 (23.97) and IET- 15182 (23.16) showed moderately resistant disease responses in most isolates tested; The susceptible variety Pusa Basmati-1 (46.57) showed highly susceptible disease reactions. Among these, some isolates were high and moderately aggressive, while most isolates were less aggressive. The identified resistant (Sarju-52) and susceptible (Pusa Basmati-1) is the potential source of rice-resistant strains for breeding programs.

Hu *et al.* (2010) found that *R. solani* was the most aggressive and common among 186 rhizoctonia, like fungal strains isolated in China, while Lore *et al.* (2015) observed that *R. solani* and *R. oryzae sativae*, which are available in different parts of India. Mixed inoculation of the Rhizoctonia genus has been found to exacerbate the severity of the disease.

Lalitha and Vineeta (2018), who examined for sheath blight, received 50 samples from different parts of the pathogenic variability of Eastern UP in different rice varieties, i.e. Vulnerable rice variety Pusa Basmati-1 (PB-1) and a moderately resistant Tetep variety. The total of 50 isolates was divided into four groups as weakly virulent (WV), moderately virulent (MV), virulent (V) and Highly virulent (HV), which corresponds to 30, 46, 20 and 4% of the isolates. Most isolates were moderately virulent in susceptible (PB-1), while the majority of isolates in moderately resistant (Tetep) to weakly virulent (88%).

Singh *et al.* (2002) mentioned 46 isolates collected in Uttar Pradesh from two fields of Dehradun and Nagina based on their cultural and morphological properties, anastomotic activity and aggressiveness. All of them belonged to AG-1IA, although they showed either type 2 (incompatible fusion) or 3 (compatible fusion) anastomosis reactions with the AG-1IA tester isolate. The population of *R. solani* was very different in terms of the above characteristics. The genetic variation was related to the distribution of isolates in different climatic regions, which influenced the pathogenic variability that was evident from Dehradun and Nagam isolates I and II.

2.4 Screening of native isolates of *Trichoderma* spp and *Pseudomonas fluorescence* against *Rhizoctonia solani* in vitro:

Ogura and Akai (1965), Hashioka and Fukita (1969) have investigated the antagonistic effects of microorganisms such as *Trichoderma*, *Gliocladium* and *Accremonium* in attempts to combat the disease. The comparative antagonistic ability of biological control agents against *R. solani* f. sp.sasaki and the probable mode of antagonism were examined for volatile antibiotics, non-volatile diffusible antibiotics, mycoparasitism and hydrolytic enzymes such as chitinase, β 1,3-glucanases and proteases (Dennis and Webster, 1971bc, Well *et al.*) 1972 and Elad *et al.* , 1982).

Roy (1977) observed that *Trichoderma virid* is effective as a biocontrol organism against *R. solani* and found that when *R. solani* was cultured in combination with *T. viride*, the former damaged mycelial growth and sclerotial germination.

Gokulapalan and Nair (1984) investigated that *T. viride* and *Aspergillus niger* inhibit the linear growth of *R. solani*, while other bacterial isolates reduced sclerotic germination.

Kumar and Marimuthu (1994) tested this trichoderma sp. with *Rhizoctonia solani* in double cultures and found that *T. viride* was the most antagonistic, followed by *T. harzianum* and *T. longibrachiatum*.

Van Loon *et al.* (1988) reported that all plants have active defense mechanisms against pathogen attack. The mechanism fails when the plant is infected with a virulent pathogen because the pathogens avoid the resistance response or the activation of defense response.

Das *et al.* (1995) found that application of *T. viride* in *Rhizoctonia solani* inoculated soil caused sheath blight infection and the accelerated growth and yield of rice plants, as well as the observed growth and incidence of disease in 22-day rice cv plants decreased in two seasons ('ahu'). and 'sali'). IR50 inoculated with 2% *T. harzianum* inoculation with 7 days before, 7 days after or simultaneously with 2% *R. solani*. *T. harzianum* greatly reduced the infection in both seasons; and the incidence of the disease was also significantly lower than when it occurred. *T.*

harzianum was administered 7 days before *R. solani* than when administered concurrently or 7 days after inoculation with *R. solani* in the first ("ahu") season.

Das *et al.* (1998) found that *trichoderma viride* is more effective than *Bacillus subtilis* in reducing rice infection with sheath blight. Glow in the dark *pseudomonas* additionally carried out the ISR against various fungal, bacterial and viral infections (Maurhofer *et al.*, 1994 and Lin *et al.*, 1995).

Krishnamurthy and Gnanamanickam (1997) showed that the *pseudomonad* strains expressing cloudy properties survived endophytically when embedded in the rice strain, thereby inducing systemic resistance and increasing salicylic acid levels. This resulted in an 18% reduction in sheath blight and a 21-29% reduction in the greenhouse trial. A correlation was found between the production of volatile antibiotics *in vitro* and the growth of *Rhizoctonia solani*. Three fungal antagonists, *Gliocladium virens*, *Trichoderma harzianum* and *T. viride*, were evaluated against *Thanatephorus cucumeris*, which caused sheath blight in the laboratory due to the dual culture technique. The results show that all fungal antagonists inhibited mycelial growth and sclerotial production of the pathogen. The local isolates of *G. virens* were most effective, with maximal inhibition of mycelial growth (83.45%) and sclerotic production (91.0%) recorded, followed by *T. harzianum* (75.9%), *T. viride* (75.0%) and Pantnagar isolates from *G. virens* (53.7%) (Dubey, 1998).

The influence of seed treatment of rice with two antagonistic fungi. *T. harzianum* and *T. viride* and found that the seeds treated with *T. harzianum* and *T. viride* showed a significant reduction in causing infection and increased grain yield, and among these, *T. harzianum* was more effective than *T. viride* in reducing the infection and increased yield (Das and Hazarika, 2000).

Kharakrang *et al.* (2002) reported that the use of *Trichoderma harzianum* either as seed treatment or as soil inoculation has proven that they are able to promote the growth parameters and thus significantly reduce the incidence of the disease.

Tang-ZiaBin *et al.* (2002), which were examined on PDA plates, the inhibition rate of 13 (antagonistic mycetes of *T. aureoviride*) was highest and reached 52.54%. The control effect of the fungal isolates mixture in the field was 32.25% and had a good effect on the seed rate.

Das *et al.* (1998) tested that the use of *trichoderma viride* and *Bacillus subtilis* as seed treatment reduced the infection by *R. solani*, while *T. viride* reduced the infection more effectively than *B. subtilis*.

Ramanathan *et al.* (2002) examined 27 *Pseudomonas fluorescens* strains *in vitro* for their inhibitory effect on the mycelium growth of the Ragi explosion fungus *Magnaporthe grisea*. The promising tribes namely, PF1, FP2, FP7, PFKO2 and FP1 were investigated for their influence on the seedling energy of Ragi plants as well as for the ISR against *M. grisea*. The exercises with expanded chitinase, glucanase, peroxidase and phenylalanine ammonialase were observed in Ragi plants that were treated with the PF1 strain up to four days after treatment.

Nandakumar *et al.* (2002) have shown the antifungal activity of the *P. fluorescens* strains PF1, FP7 and PB2 against the pathogen causing the rice sheath blight, *R. solani* [*Thanatephorus cucumeris*], and reports that bacterial strains produce the antibiotic 2, 4 diacetylphloroglucinol-produced iron chelate siderophor, Hydrogen cyanide, lytic enzymes such as chitinase and beta-1,3-glucanase in culture and induced chitinase in plants. The production of antibiotics, antifungals, bacterial lytic enzymes and the induction of plant chitinase correlated with the antifungal activity against treated *R. solani* sclerotia.

Mishra and Sinha (2002) examined rice seeds that were treated with three fungal antagonists (*T. harzianum*, *G. virens* and *Aspergillus niger*) and a bacterial antagonist (*Pseudomonas fluorescens*). Treating seeds with organic control agents has led to high germ levels and improved plant growth. The greatest increase in germination was seen in *T. harzianum* (32%) at 500 g (106 Propagule/g), and *G. Virens* and *G. Niger* showed the greatest improvement in shoot length (39.2%) and root length (69.6%).

Kazempour *et al.* (2003) obtained good regulation of sheath blight, incited by *R. solani* and antagonists *T. harzianum* and *T. viride*, *G. virens*. The extent to which such antagonists regulate the disease has been as successful as carbendazim application.

Meena *et al.* (2003) took native isolates, namely, *Trichoderma harzianum*, *T. virides*, *Gliocladium virens*, *Pseudomonas fluorescens* and *Bacillus subtilis* were isolated from the rhizosphere soils of healthy maize plants that came from

taped fields to suppress leaf and sheath blight. The volatile activity of *T. harzianum* was successful in both the mycelial development and the sclerotic arrangement of *Rhizoctonia solani* f.sp. *sasakii*. *T. harzianum* caused over 80% inhibition and 33.50% sclerotic assembly, followed by *T. viride*, causing over 70% mycelium inhibition and sclerotic formation inhibition by 25.90%.

Nine isolates from *Trichoderma* sp. were tested for their ability to inhibit ground-based chickpea fungal pathogens, namely, *Rhizoctonia solani*, *S. rolfii*, *Fusarium oxysporum* f. sp. *Ciceri* under both *in vitro* and *in vivo* conditions. Laboratory testing of trichoderma isolates using a dual culture test, inverted plate technique and poison food technique showed that *T. harzianum*-PDBCTH 10 is more inhibitory to *Rhizoctonia solani* (Rudresh *et al.*, 2005).

Khan and Sinha (2006) examined the effects of *Trichoderma harzianum* and *T. virens* [*Gliocladium virens*] on their formulations, doses and times of use. During the Kharif seasons 2001 and 2002 in Pantnagar, Uttar Pradesh, India, the registered formulation of *T. harzianum* based on talc + CMC was most effective in reducing sheath blight (45.10%) and increasing yield (24.0%). The higher dosage of the blight of the biological control agents (8 g / liter) was superior in order to minimize lower doses. The use of biological antifungal agents 7 days before inoculation with *R. solani* resulted in a 67% reduction in disease compared to concomitant use.

Grosch *et al.* (2006) examined infectious fungi that were extracted from the ground and recognized *Trichoderma reesei* and *T. viride* as a potential bio-control against *R. solani*.

Chakravarthy and Nagamani (2007) investigated the antagonistic potential of 26 isolates against the pathogen *Rhizoctonia solani* Kuhn. *T. harzianum* (M10P) and *T. aureoviride* (TA1) were more aggressive than others. *T. koningii* (TK) and *T. longibrachiatum* (M1Ps) significantly reduced the formation of sclerotia in *R. solani*. All isolates showed an obstacle to the development and arrangement of sclerotia through the formation of non-predictable (diffusible) antimicrobial agents. Be that as it may, only 22 limit comparable exercises by also providing unstable remedies for infections. Isolates from *T. longibrachiatum* (M9Ms) and TL3 were the best at producing non-volatile and volatile antitoxins, respectively.

Kumawat *et al.* (2008) reported that Pre-application of bioagent spores prevents the plant from challenging *Drechslera oryzae*, showing a decrease in the incidence of paddy disease from 59.21% to 12.40%, and also indicates the amount of soluble protein and total phenol arising from the role of bioagent in the induction of paddy host defense.

Singh (2013) evaluated the diverse application strategies for *T. harzianum* and *P. fluorescens* -27, and their potential against sheath blight of rice under glasshouse conditions and found that most extreme decrease in disease severity (40.5%) and incidence (58.90%) was recorded when *T. harzianum* applied as a combined delivery system as seeding root tip + foliar spray, followed by same blend of *P. fluorescens* -27 in reducing disease severity (35.0%) and incidence (54.90%).

Trivedi and Sinha (1976) reported that the application of various fungal fluids was provided stimulate resistance against *Drechslera oryzae* in rice plants, while Smith and Metraux (1991) reported induction of systemic resistance by *Pseudomonas syringae* pv. *Syringae* against *Pyricularia oryzae* in rice.

Strains of *Pseudomonas fluorescens* have been observed to induce systemic resistance against sheath blight of rice (Karthiba, 2014). Application of different antagonistic bacteria like *P. fluorescens*, *P. putida* and *Bacillus subtilis* are known to substantially reduce sheath blight disease severity (Mew and Rosales, 1992; Krishnamurthy and Gnanamanickam, 1997; Laha and Venkataraman, 2001). Preparation of *Trichoderma asperellum* T-12 was highly effective against sheath blight (Chen *et al.*, 2015).

Nagaraju *et al.* (2002) studied on biological control agents like *P. fluorescens*, *T. harzianum* and *T. viride* applied for seed treatment, root dip and in transplanted rice that revealed that root + seed treatment with *P. fluorescens* was the most effective followed by root + seed treatment with *T. viride* but none of the biological control agents were found as effective as the chemical control treatment.

Singh and Sinha (2005) conducted a field trial in Uttaranchal, India, to compare the relative efficacy of potential *Pseudomonas fluorescens* isolates and commercial formulations against rice sheath blight. Leaf sprays with different

isolates of *fluorescent pseudomonas* in transplanted rice reduced overall severity and incidence. Pfr 1 (a rice rhizosphere isolate) was logically incredible to reduce infection and increase grain yield and 1000 grain weight. Pfr 5 was next found to be against the disease. Pfr 1 was found best compared to commercial formulations of biological control agents.

Pathak *et al.* (2004) conducted a greenhouse experiment using a rice. Pusa Basmati decides the effectiveness of the *Pseudomonas* strain GRP3 against *Rhizoctonia solani* by inducing systemic resistance. Treatments included: 1 g tricyclazole / liter; Seed bacterization by GRP3 (108 / ml); Immersion in the root (108 GRP3 / ml); and the untreated control. Seed bacterization, followed by immersion in the root (double treatment), showed a 46% infection with reduced lesion length. In 5%, treatments with GRP3 and tricyclazole showed a higher level of disease inhibition and induction of resistance to *R. solani* than the control. The correlation analysis recommended that the extended articulation of the peroxidase and phenol combination be controlled by the GRP3 treatment.

A massive accretion of phenol complexes (M.Piga *et al.*, 1997), PR proteins (Maurhofer *et al.*, 1994), peroxidase (Zdor and Anderson, 1992) and increased lignification of mRNA (Anderson and Guera, 1985) have been reported in Plants analyzed after treatment with plant growth-promoting rhizobacterial strains (PGPR). The fluorescent pseudomonas (Pf1 strain) could induce resistance to different pathogens in the same culture. , *Rhizoctonia solani* and *Xanthomonas oryzae* pv. *Oryzae* in rice (Vidhyasekaran *et al.*, 2001).

Vishwanathan and Samiyappan (2001) reported the formulation of *Pseudomonas* spp. isolated from sugarcane rhizosphere and talc. The efficient bacterial strains KKM1 (*Pseudomonas putida*) and VPT4 (*Pseudomonas fluorescens*). The potential of the *Pseudomonas fluorescens* strain to cause systemic resistance in the red rot-prone variety of CoC671 sugarcane. Bacterial stain treatment sets under germinal conditions induced a higher concentration of chitinase. The development of regulated chitinase is systematically emphasized.

Isolates of different strains of *P. fluorescens* from different areas of Kuttanad in the Alleppey region in Kerala for screening against the rice sheath disease (Surendran *et al.*, 2011).

Rabindran and Vidhyasekaran (1996) investigated *Pseudomonas fluorescens* with their inhibitory activity against *R. solani* isolated from the rhizosphere of different cultures. Some of the most successful strains were PFALR2, which was developed as an antibiotic-resistant strain and a bio-control formula based on peat was extremely active in the management of rice sheath blight. Seed treatment, seedling dip, soil treatment and leaf spray were tested for the successful dose of a peat formulation. A good prevention against diseases from rice sheath was also found by single use.

Ongoing studies show that a few strains of *Pseudomonas fluorescens* also serve as inducers to optimize resistance in plants (Van Peer *et al.*, 1991 and Chen *et al.*, 1993).

Nandakumar *et al.* (2001) reported that two *P. fluorescens* strains, namely PF1 and FP7, which inhibited *Rhizoctonia solani* mycelial growth and expanded the seedling power of rice plants under vitro conditions, were selected to study the ISR against *R. solani* in rice. The use of *Pseudomonas* strains against *R. solani* was proportional to that of the fungicide carbendazim commonly used in the field of treating the disease. *Pseudomonas* treatment of rice cv. IR 50 induced a SAR against *R. solani* as the movement of chitinase and peroxidase increased. Although a single use of a *Pseudomonas* strain was found in ISR, the joint application expanded the strength of ISR in rice plants through the entirety of the four techniques (seeds, roots, soil and leaves).

Surendran *et al.* (2011) Isolated various strains of *P. fluorescens* from different locations in Kuttanad in the Alleppey district of Kerala for screening for rice sheath blight disease and found a reduction in disease and increased growth parameters.

A more sustainable approach for Sheath blight management in rice with less reliance on synthetic fungicides, greater use of natural fungicides such as strobilurins and biological agents like *Trichoderma spp.*, *Pseudomonas spp.*, *Gliocladium spp.*, *Bacillus spp.* to restrict disease (Singh *et al.*, 2019).

2.5 Evaluation of ITK techniques viz. application of panchgavya and plant extracts against *R. solani* under *in vitro*:

Leaf extracts from some higher plants, namely. *Polyalthia longifolia*, *Parthenium hysterophorus*, *Cymbopogan sp.*, *Zingiber officinale*, *Curcuma longa* (Naidu and John, 1981), Piper betle and *Lawsonia inermis* (Tewari and Premalatha Dath, 1984) inhibited the growth of *Rhizoctonia solani* *in vitro*. Lemongrass oil (*Cymbopogan flexuosus*) even in a very low concentration (0.4 ppm) effectively inhibits the germination of sclerotia and inhibits mycelium growth (Devi *et al.*, 1982).

Shukla *et al.* (1990) observed the growth of *Rhizoctonia solani* *in vitro*, which was completely inhibited by *Ocimum canum* oil (0.2%), while *Citrus sinensis* oil in the same concentration reduced the growth by 85% and the growth of *Pinus roxburghii* by 75% .

Kotasthane and Lakpale (1994) reported that plant extracts that inhibited the pathogen to a lesser extent were *Dolichus lablab*, *Elichhornia crassipes*, *Cyperus rotendus*, *Sachharum spontanium*, *Triticum aestivum*, *Coccinia indius*, *Sorghum* and *Solanum melongena*. Extracts from rice, *Phalaris minor* and *Lycopersicon esculentum* have an effect on the germination of sclerotia, mycelium growth and the development of sclerotia.

Ansari (1995) tested some of the plant extracts against *Rhizoctonia solani*, the causative agent of rice sheath blight, and reported that *T. ammi* (seed) and *Ocimum* sp. (Leaf) extracts were fungicidal, while the extract from *Cymbopogon flexuosus*, *Mentha* sp., *Rauwolfia* sp., *Lawsonia inermis* and *Vitex trifolia* showed fungistatic activity.

Shivpuri *et al.* (1997) examined ten plant species (*Allium cepa*, *Allium sativum*, *Azadirachta indica*, *Calotropis procera*, *Datura stramonium*, *Ocimum sanctum*, *Polyalthia longifolia*, *Tagetes erecta*, *Vinca rosea* and *Withania somnifera*), which were used for ethaol extraction, and showed toxic properties against five pathogenic fungi (*Alternaria brassicola*, *Colletotrichum capsici*, *Fusarium oxysporum*, *Rhizoctonia solani* and *Sclerotinia sclerotiorum*) when

examined under laboratory conditions in two concentrations. The higher dose of fewer plant extracts was more selective.

Dubey (1998) observed that once separated extracts from 11 plants (leaf, root and seed) were screened *in vitro* at a concentration of 4% against *R. solani*, and tests showed that Moringa's root extract showed the maximum pathogen development (55.2%), followed by Ficus (48.2%) and Eclipta (44.8%) leaf extracts. The radial growth of the pathogen, which was reported in the Ficus and Eclipta leaf extracts, was significantly the same. Many extracts were Karanj egg, Tulsi and Akven root in the order of their dominance. No sclerotic formation was reported in all extracts, except for the ficus and eclipta leaves, where weak sclerotic formation was found.

Kandhari and Singh (2000) worked on the eight environmentally friendly plants and their extraction was *in vitro* against *Rhizoctonia solani* (*Ocimum basilicum*, *Citrus reticulata*, *Syzygium aromaticum*, *Jasminum officinale*, *Tagetes tenuifolia*, *T. erecta*, *Pyrus pashia* and *Gladiolus sp.*). The benzene and acetone extracts from *T. tenuifolia* as well as the hexane and acetone extracts from *T. erecta* also showed a complete inhibition of mycelium growth at higher concentrations (1000 ppm).

Reddy and Sudhakar (2002) reported that aspirin is highly effective in inhibiting mycelial development and sclerotic production (100%), followed by extraction of *Allium sativum* (61.8%), *Azadirachta indica* (24.9%) and *Allium cepa* (19, 3%). In plants treated with potassium chloride, an absolute reduction in disease (21.5%) was observed when aspirin (20.10%) and *Allium sativum* (17.2%) were distributed 24 hours before the inoculation. Neem fungicide and neemark were found to be the most suitable for treating sheath blight among the formulations tested by Neem.

Panchgavya's antifungal potential against *R. solani*, *S. rolfsii*, *F. solani*, *S. sclerotiorum* and *Phytophthora colocasiae*, and advocated that the mycelium pieces immersed in Panchgavya for 6 hours completely suppressed *R. solani* and mycelial growth other pathogens caused growth inhibition between 88.1 and 92.3 percent (Sugha, 2005).

Dogra (2006) observed Panchgavya antifungal activity against major soil pathogens, namely. *F. solani f.sp. pisi*, *F. oxysporum f.sp. pisi*, *R. solani*, *S. solfsii* and *S. sclerotiorum*. Mycelium parts that have been immersed in Panchgavya for 12 hours have an inhibition of more than 90% *F. oxysporum* with *f.sp. pisi* inhibition in 100% of *Olivesii*, *S. sclerotiorum*, with *R. solani*.

Salam *et al.* (2009), which were examined on medicinal plant leaf extracts, showed a significant decrease in the incidence and time of diseases when used in a concentration of 10%. The severity of the disease varied between 30 and 55, 22 and 36 and 34 and 50% in samples of cold water, hot water and acetone, respectively. Due to plant extracts in this sample, no sclerotia, reduced mycelium growth and reduced incidence of disease were observed.

Joseph and Sankarganesh (2011) examined the effects of antifungal Panchgavya and cow urine against the pathogens born in the soil.

Prasad V.R. (2014) examined various liquid organic formulations, namely, Panchagavya, Dasagavya and Jeevamrutha and tested *in vitro* and showed that Jeevamrutha showed a maximum inhibition of 85.18% at 10% concentration, which is equivalent to Jeevamrutha was 20% (79.62). Panchagavya was closest with 3 and 2% with inhibitions of 80.73% and 76.29%, respectively.

Meena *et al.* (2000) tested plant extracts (10%) against the sheath blight of rice (*Rhizoctonia solani* Kuhn.) Under *in vitro* conditions. Sclerotic germination was assessed by placing a drop of the plant extract in the cavity of the cavity sled and adding sclerotia to the extracts. Among the plant extracts tested, *Pithacolobium dulce* and *Prosopis juliflora* (Sws.) DC showed a high inhibition of mycelial growth, sclerotial number, sclerotial dry weight and sclerotial germination of *R. solani*. Onion extract from *Allium sativum* (10%) and leaf extract from *P. juliflora* (10%) significantly reduced sheath blight disease under greenhouse conditions.

Muralidharan *et al.* (2003) reported that the majority of the various herbal products reduced disease incidence and improved crop yields. The degree of disease reduction and the increase in yield was more pronounced.

Raja *et al.* (2005) found that animal urine treatments were significantly superior to fungicides and reduced sheath blight intensity and grain yield. Among

the 10% concentrations, buffalo urine spray treatments showed the lowest intensity and high grain yield, followed by 10% concentrations of cow urine and sheep urine.

Sehajpal *et al.* (2009) investigated the antifungal effects of 44 plant extracts and 8 vegetable oils against the *Rhizoctonia solani* pathogen. Out of 44 plants tested, 36 plant extracts showed different levels of antimicrobial activity at different concentrations against the pathogen, while eight plant extracts, i.e. *Abrus precatorious*, *Acacia auriculiformis*, *Bougainvillea glabra*, *Convolvulus arvensis*, *Hibiscus rosa-sinensis*, *Morus alba*, *Thevatia peruviana* and *Withania somnifera* had no effect. Among all plant extracts, *A. sativum* showed even at the lowest concentration, i.e. 100 ppm, strong fungitoxicity with a relative size of the inhibition of 2.0 mm against the pathogen *R. solani*.

Srinivas *et al.* (2014) tested the thirteen plant extracts and found that garlic extract (10%) was the most effective in inhibiting the growth of *R. solani*, followed by Calotropis (10%). Thorn apple leaf extract (10%) was found to be the least effective at inhibiting *Rhizoctonia solani* growth.

Shrishti *et al.* (2014) examined ten essential oils, i.e. peppermint, eucalyptus, wild mint, Van-Tulsi, lemon tulsi, lemongrass, clove, citronella, patchouli and khus at concentrations of 100, 200, 300, 400 and 500 ppm against *Rhizoctonia solani* using poisoned food technique. This investigation found that Van-tulsi's essential oil was significantly effective against *Rhizoctonia solani* mycelium growth, followed by lemongrass, clove, citronella and eucalyptus.

Divya *et al.* (2014) investigated the antifungal effects of 13 plant extracts, namely *Aloe barbadensis*, *Cymbopogon citrate*, *Datura inoxia*, *Datura stramonium*, *Hibiscus rosa sinensis*, *Ipomea carnea*, *Nerium indica*, *Nyctanthes arbortristis* and *Parthenium hysterophorus* against *Rhizoctonia solani* Kuhn, causative agent of the sheath blight of rice. Many of the plants screened have found significant antifungal effects against *Rhizoctonia solani* in all plants, and only one plant, *Saraca asoca*, has completely prevented the growth of the pathogen. The effective plant extract concentration that inhibits the growth of mycelium formation was 100%.

2.6 Impact of sheath blight on seedlings and plant vigour:

Seshu *et al.* (1987) have shown that the seed power is an essential quality parameter and differs from the germination capacity. The decrease in germination has also been associated with a decrease in vigour and can be due to many reasons, including a seed infection with microorganisms.

Parsaud (2009) found that seeds grown from infected spotted seeds greatly reduced the length of the root and the seedling vigour index compared to plants grown from healthy seeds. Seeds from infected panicles showed a decrease in seed germination of 19.87% and 15.39% compared to seeds from healthy plants under greenhouse and field conditions. Pant 4 was significantly superior in terms of seed germination, root length, shoot length and seedling vigour index compared to cv. swama under greenhouse and field conditions.

Nanda and Chaudhary (1972) conducted studies in tropical Asia, where rice is grown mainly during the monsoon season. The strength of the seedlings was measured on the basis of their shoot and root length. It was significantly larger for normal seeds than for spotted seeds and had a higher percentage of germination (98%) and a faster pace for normal seeds than for spotted seeds (<90%). It was concluded that blight is an undesirable character that is observed in early rice growing and should be preferred for growing in the dry season.

Anselme (1987) suggested that germination, strength, and rest are important parameters in the study of bacterial, fungal, and viral infections. Abnormal and diseased seeds in a batch of seeds showed poor seed quality. Various forms of diseases that cause the organism mainly affected seed health (International Seed Testing Association, ISTA, 1985).

Ou (1985) and Neergard (1979) observed during the experiment and included that the various fungi are pathogenic and seed-borne.

Binesh and Torabi (1985) reported that the manner in which sheath blight was transmitted by seeds and the seed samples from infected rice fields were obtained and tested at harvest time showed infection with *Rhizoctonia solani* from 21.70 to 39.10% in September and 9.90 to 19.30% was infected in May, at the same time as the second cultivation. *R. solani* killed 0-5% of the seedlings when

infected seeds were sown in sterile soil, and 6.20-11.70% of the living plants showed signs of sheath blight.

Roy (1989) reported that the source of seed-borne sheath blight infection in rice is a small percentage of the spikelets of cv. Pusa 2-21 were infected with *Rhizoctonia solani* when they came into contact with infested soil. The fungus from infected seeds from cv. IR 8 did not penetrate the developing panicles. It is concluded that a seed-borne infection occurs through direct contact with contaminated soil.

Velazhahan (1991) found that in all seven cultivars examined, rice sheath blight pathogen culture filtrates had a clear inhibitory effect on germination and also reduced the shoot and root lengths of the seedlings.

Fakir *et al.* (2002) concluded that seed-borne diseases are a major cause of crop loss. The infected seeds often do not germinate, the disease spreads from seed to seedling and from seedling to 26 ascending plants.

Acharya *et al.* (2004) had conducted studies to determine the type and intensity of seed infection and germination of seeds from plants infected with *Rhizoctonia solani* and the health of the seedlings growing from these seeds. 40.50% *R. solani* was isolated from spotted seeds while 36% was isolated from spotted seeds with surface sterilization. Artificially inoculated seeds gave *R. solani*, but only 10% of the surface sterilized seeds were made *R. solani*. Artificial inoculation affected seed germination and 19.2% of the plants showed symptoms of the disease. However, sterilizing the surface of the seeded seed reduced the harmful effects on seed germination.

Mathur *et al.* (2004) collected 20 rice seed samples from the Tangail district in Bangladesh in two different growing seasons, which were of extremely poor quality and showed a germination between 60 and 77% (average 66%). All samples contained many discolored and spotted seeds, their frequency was between 7 and 15%. When such seeds were removed manually, the clean seeds showed a remarkable increase in germination to 82-93% (87% on average). In addition, seedlings developed from such clean seeds showed improved seedling vitality, were greener and appeared to be much healthier. The discolored and spotted seeds were attacked by fungi such as *Alternaria padwickii*, *Bipolaris*

oryzae, *Fusarium moniliforme*, *Sarocladium oryzae* and *R. solani*. In addition, symptoms have been observed in seedlings grown from such seeds.

Zhang *et al.* (2007) reported that seeds are an important and special resource for agriculture and a basis for agricultural growth. Improving seed quality is an important factor for high production, sustainability and competitiveness. Seedling vigour is the index used to calculate seed quality. Seed vigour tests are used by researchers to predict the emergence of seedlings under field conditions. In addition, *Curvularia* spp., *Alternaria* spp., *Sarocladium attenuatum*, *Bipolaris sorokiniana*, *R. solani*, etc. reduce commercial value.

2.7 Evaluation of antagonists and the effectiveness of application methods in the glasshouse:

Prasad and Reddi (2011) examined the comparative effectiveness of different isolates of *Trichoderma* spp. against *Rhizoctonia solani*, instigator of the sheath blight of rice. Three isolates from *Trichoderma* spp. were isolated and the inoculation of pathogen and leaf spray from bioagents and hexaconazole was carried out at 30 DAT and 60 DAT. Bioagents could effectively reduce the severity of the disease under greenhouse conditions.

Kumawat *et al.* (2008) reported that the prior use of bioagent spores protects the plant from an impairment of *Drechslera oryzae* infestation, reduces the severity of the disease of rice from 59.21% to 12.40% and also shows that the measure for Soluble protein and all of the phenol from Bioagent's movement showed inclusion in the paddy field have defense induction.

Triveidi and Sinha (1976) reported that the use of various fungal fluids in rice plants induced resistance to *Drechslera oryzae*, while Smith and Metraux (1991) reported systemic induction.

Van Loon *et al.* (1988) reported that all plants have active defense mechanisms against pathogens. The system fails when a virulent pathogen infects the plant because the pathogen prevents resistance reactions from being caused or suppressed, or defenses from being activated and the disease can worsen. Resistance induction is a condition to improve the protective potential generated by a plant, regardless of whether it is caused by certain chemicals, non-pathogens,

avirulent forms of pathogens or by virulent forms of pathogens in situations where the infection is blocked by environmental conditions, is approximately stimulated.

The few strains of *Pseudomonas fluorescens* also appear as resistance inducers in plants (Van Peer *et al.*, 1991 and Chen *et al.*, 1993).

Fluorescent pseudomonas work precisely against ISR against various diseases such as fungal, bacterial and viral diseases. (Maurhofer *et al.*, 1994 and Lin *et al.*, 1995).

Krishnamurthy and Gnanamanickam (1997) reported that pseudomonad strains containing incomplete genes survived endophytically when introduced into the rice strain and also caused systemic resistance by increasing salicylic acid levels to twice the original level. In a separate greenhouse trial, this suppressed sheath blight by 18% and suppressed travel explosion by 21-29%.

Vishwanathan and Samiyappan (2001) had for *Pseudomonas* spp. Isolated from the sugarcane rhizosphere and formulations based on talc. The successful bacterial strains KKM1 (*Pseudomonas putida*) and VPT4 (*Pseudomonas fluorescens*) induce a systemic resistance of the *Pseudomonas fluorescens* strain in the sugar cane variety CoC671, which is susceptible to red rot. Bacterial staining therapy sets under germinal conditions caused a greater aggregation of chitinase.

Ramanathan *et al.* (2002) examined the screening of 27 *Pseudomonas fluorescens* strains *in vitro* for their inhibitory effect on the mycelium growth of Ragi explosion fungi (*Magnaporthe grisea*). The promising tribes namely, PF1, FP2, FP7, PFKO2 and FP1 were examined for their effect on the seedling vigour of Ragi plants and on the induced systemic resistance (ISR) against *M. grisea*. All strains can promote *in vitro* plant growth and reduce the occurrence of Ragi blasts under greenhouse conditions. The increased activities of chitinase, glucanase, peroxidase and phenylalanine ammonialyase were observed up to four days after the intervention in Ragi plants treated with PF1 strain.

Massive accumulation of phenolic compounds (M. Piga *et al.*, 1997) of phytoalexin (Van Peer *et al.*, 1991), PR-Protein (Maurhofer *et al.*, 1994), peroxidase (Zdor and Anderson, 1992), increased lignification of mRNA (Anderson and Guera, 1985) have been reported in plants after treatment with

Rhizobacteria Promoting Plant Growth (PGPR) strains. Increasing the movement of the aforementioned substances in PGPR-treated plants may have either immediate or circulating capacity to suppress pathogen development in the host in the long run to protect plants from pathogenic microorganisms. The fluorescent pseudomonas (Pf1 strain) could induce resistance to various pathogens in a similar crop, *Rhizoctonia solani* and *Xanthomonas oryzae* pv. *Oryzae* in rice (Vidhya sekaran *et al.*, 2001).

Nandakumar *et al.* (2001) showed that two strains of *P. fluorescens*, namely, PF1 and FP7 were selected for the ISR against *R. solani*, which inhibited the mycelial development of *R. solani* and increased the seedling quality of *in vitro* rice plants. The use of *Pseudomonas* as a bacterial suspension or talc mixture by seed, root, soil and leaf application either alone or in combination (seed + root + soil + leaf) effectively reduced the severity of sheath blight, stimulated plant growth and ultimately increased yields under greenhouses or field conditions. The efficacy of *Pseudomonas* strains against *R. solani* was similar to the carbendazim fungicide that is commonly used in the field of disease reduction. *Pseudomonas* is treated with rice. Induction resistance was mediated, caused by an increased development of chitinase and peroxidase. Although ISR was the result of a single application of a *Pseudomonas* strain, the combined use of all four methods (seeds, roots, soil and leaves) improved the ISR longevity of rice plants.

Detection of the antifungal activity of the *P. fluorescens* strains PF1, FP7 and PB2 against the pathogen of the rice sheath rot; *R. solani* [*Thanatephorus cucumeris*] and concluded that bacterial strains produce the antibiotic 2,4-diacetylphloroglucinol, iron chelate siderophore, hydrogen cyanide, lytic enzymes such as chitinase and beta-1,3-glucanase in culture and induced chitinase in plants. The antibiotic improvement, the antifungal compound, the bacterial lytic chemicals and the plant chitinase were related to the antifungal activity against the induced induction of *R. solani* sclerotia (Nandakumar *et al.*, 2002).

Radjacommaré *et al.* (2004) examined two promising *Pseudomonas fluorescens* strains (PF1 and FP7) isolated from rhizospheric soil to assess their influence on seedling vigour and their ability to develop four rice varieties. Both strains of bacteria induced systemic resistance in rice résumés. IR 50, susceptible

to sheath blight. Plants treated with *Pseudomonas* showed a significantly greater increase in chitinase development than untreated control plants after inoculation with the pathogen.

Jayaraj *et al.* (2004) reported that the leaf application of the *Bacillus subtilis* strain AUBS1 under greenhouse conditions significantly reduced the disease of the rice sheath blight (*Oryza sativa* cv. IR 50). Treatment *B. subtilis* increases the activity of phenylalanine ammonia lyase (PAL) and peroxidase (PO) and the accumulation of pathogenesis-related protein (PR) in rice leaves. These defense reactions may help to limit *Rhizoctonia solani*.

Singh and Sinha (2005) conducted a field trial in Uttaranchal, India, to compare the relative efficacy of potential *Pseudomonas fluorescens* isolates and commercial formulations against rice sheath blight. Leaf sprays with unique fluorescent pseudomonas isolates significantly reduced the incidence and severity of the disease in transplanted plants.

2.8 Evaluation of *Trichoderma* organic amendments on disease development:

Rajan and Menon (1975) conducted a pot experiment with Annapurna rice grown in soil artificially infected with *Corticium sasakii*, to which 11 different organic oil cakes and waste products and 90 kg-N + 45 kg-P were added 15 days before the transplant + 45 kg-K / ha was added during the transplant. Plant height and disease severity tests showed that plant growth was superior to control in all treatments except the Mahua cake (without modification).

Kannaiyan and Prasad (1981) examined organic additives such as rice chaff, mustard cake, neem cake, sawdust and FYM, which were added to pots at 1%, and significantly reduced the infection with seedlings, and cake proved to be the most effective and reduced the seedling infection by *R. solani* in rice using neem cake.

Devi *et al.* (1982) concluded that there was a complete inhibition of mycelial development and germination of *R. solani* sclerotia with 0.4% *Cymbopogon flexuosus*öl.

Banerjee *et al.* (1989) concluded that oil from *Azadirachta indica* in a concentration of 5% inhibits the germination of sclerotia from *R. solani* isolated from rice.

Mishra and Tewari (1990) concluded that *Pongamia glabra* oil was extracted at a concentration of 5% that inhibited germination of the sclerotic pathogen causing the sheath blight.

Padma Kumari and Balakrishnan (1991) concluded that paddy shell is very promising as a supplement to the biological control of *R. solani*, while Glyricidia leaves, neem cake, Punna cake, fish waste and peanut cells are also effective.

Garg and Siddiqui (1992) reported that caryophyllene and eugenol were taken from the leaves of *Ocimum sanctum* and showed antifungal activity against *R. solani*.

Ganguly (1994) reported that water was extracted from leaves of *O. sanctum*, which had an antifungal activity against *R. solani*. The use of Subabul (*Leucaena leucocephala*) reduced the appearance of *R. solani* in the soil.

The *et al.* (1995) completed the use of *T. viride* in soil inoculated with *R. solani*, which reduces infection with sheath blight and improves the growth and yield of rice plants.

Sundarraaj *et al.* (1996) reported that plant extracts from *Allium sativum*, *Prosopis juliflora*, *Gymadropsis pentaphaylla*, *Leucosaspera* and Gingelly oil cake showed inhibition of the causative agent of sheath blight disease.

Das *et al.* (1996) also reported significant improvements in crop yield when antagonists were used to treat seeds. *T. harzianum* and *P. fluorescens* showed better results because the antagonist was best developed in the target niche by using a mixture of organic fertilizer to fight rice sheath blight disease and a greater antagonistic ability against *R. solani*.

Parsad *et al.* (1997) reported that the *R. solani* rice sheath fungus was grown in various combinations on a medium containing Neem, Gingelly and peanut cakes as well as *Crotalaria juncea*, *Calotropis gigantia* and *Phaseolus triobus* extracts. *Calotropis* restricted maximum fungal growth. An absolute slow down in growth of *R. solani* was found in medium containing neem cake.

Dubey (1998) came to the conclusion that the Til cake inhibits the maximum mycelium growth (86.30%), followed by Karanj (83.30%) and Neem cake (81.90%). The radial growth reported on the integrated medium of Til and Karanj cakes was statistically the same and the growth of Karanj cakes was the same as the growth of Neem cakes. The radial growth observed with the integrated medium in mahua and peanut cakes was also equivalent. Sclerotial production was not recorded in all oil cakes.

Meena and Muthusamy (1999) reported that 150 kg / ha neem cake was the most effective treatment compared to the control in reducing the incidence and severity of the sheath blight disease caused by *R. solani*. This was followed by FYM decomposed coconut pulp.

Bhagawati and Roy (2004) reported that successful sheath blight disease reduction was found when various organic additives, e.g. Kuhdung, rice straw in separate combinations with NPK, with *T.harzianum* and *T. viride* were used. The use of organic additives increased the antagonistic behavior of Trichoderma, especially in the presence of cow dung. In the modification combination of cow dung + rice straw + NPK, a maximum survival of trichoderma species was obtained together with that of minimal *R. solani*, which led to a minimal invasion of sheath blight with the highest plant growth and yield.

Tiwari and Singh (2005) concluded that inoculation with antagonists reduced disease severity and incidence, significantly improving crop yield and weight compared to soil treated with *T.harzianum*.

Several studies have shown that the use of silica and soil improvements with organic fertilizers such as Sesbania aculeata, Neembuchen and Calotropis alone and the combination with peanut cake, Akven, Neem extracts, Gingelly cake and Gliricidia maculata leaves is promising for sheath blight with a higher grain yield (Premlath Dath, 1990; Manibhushanrao and Baby, 1991; Prasad *et al.*, 1998; Rodriguez *et al.*, 2003; Kumar *et al.*, 2006).

The effect of integrating organic additives with fungal or bacterial antagonists (*Trichoderma harzianum* and *Pseudomonas fluorescens*), which were used as soil treatment, was evaluated against the disease of sheath blight caused by

Rhizoctonia solani in basmati rice under field conditions. Neem cake + *T. harzianum* proved to be the most effective treatment for reducing the incidence of the disease by up to 57.27% and the severity of the disease by 54.77%, followed by manure (FYM) + *T. harzianum*, which resulted in the reduction of Disease incidence increased to 53.77% and disease severity to 52.29%. Among all organic changes, the reduction in sheath blight with sawdust + *P. fluorescens* was the smallest with a disease incidence of 40.94% and a disease severity of 35.29%. The maximum increase in grain yield (39.44%) and rice weight of 1000 grains (29.19 g) was recorded with Neem cake + *T. harzianum* treatment followed by treatments FYM + *T. harzianum* and Pressmud + *T. harzianum*. The minimal increase in grain yield (9.76%) and 1000 grain weight (11.53%) was recorded with the Sawdust + *P. fluorescens* treatment (Mishra *et al.*, 2009).

Khoa *et al.* (2011) concluded that spraying leaves and soaking seeds from fresh or dry extracts of *Chromolaena odorata* leaves reduced sheath blight disease by up to 68% under controlled field conditions.

2.9 Evaluation of disease management practices combined with different doses of ‘N’ fertilizer:

Dev and Mary (1982) reported that the intensive use of nitrogen fertilizer increases the number of farmers / plants and this leads to an increase in the relative humidity of the plant's microclimate, which promotes sheath blight disease. The high indica strains are classified as very susceptible even under high nitrogen levels.

Slaton *et al.* (2003) reported that excessive nitrogen fertilizer use was observed to increase rice damage from sheath blight.

Kueh *et al.* (1985) reported that different levels of nitrogen fertilization did not affect infection. While the increase in nitrogen content increases the incidence of the disease proportionally, the increase in nitrogen content to 120 ppm no longer increases the incidence.

Anonymous (2009) reported that the integration of disease management practices such as the growing disease-specific resistant / moderately resistant or susceptible varieties with 100% or 2/3 RDN along with needs-based fungicidal

protection for fungal diseases such as blast and sheath blight and nitrogen management in the case of bacterial leaf blight are promising when it comes to checking the severity / incidence of the disease and improving grain yield.

Jagat Janni (2011) investigated that the assessment of disease management practices in combination with different doses of nitrogen fertilizer and observed the significant decrease in severity of sheath blight and the increase in yield in resistant varieties, as well as the 100% recommended dose of nitrogen fertilizer with different doses of hexaconazole effective Practice.

2.10 Evaluation of chemical stimulants in imparting resistance such as salicylic acid, Jasmonic acid, Rose Bengal and oxallic acid:

Dempsey and Klessing (1995) reported that salicylic acid plays an important role as a signal for disease resistance and for the development of systemically acquired resistance, and it appeared to transduce this signal by inhibiting catalase activity and generating an elevated level of active oxygen species. Induction of resistance by treating different plants with different non-conventional chemicals has been reported to induce resistance to a variety of pathogens, and the effect appeared to be largely mediated by the host (Wain and Carter, 1972; Sinha, 1984; Lazarovits, 1988); and in the case of inducing resistance of rice plants to *R. solani* by using non-conventional chemicals, Sarkar and Sinha (1989) and Manibhushanrao *et al.* (1990) reports.

Xiao *et al.* (1996) reported that when the seedling roots were soaked in salicylic acid, the MDA content and membrane permeability decreased, but PAL production, chlorophyll content, and IUA increased. It is concluded that exogenous salicylic acid can increase resistance to sheath blight in rice.

Rice seedlings had the highest salicylic acid content among all plants tested for salicylic acid content. In order to investigate the role of salicylic acid in the resistance to rice diseases, the rice grade - M-201 salicylic acid level after inoculation with bacteria and fungal pathogens was examined and it was found that the second leaf of rice seedlings had a slightly lower salicylic acid level than any other younger leaf (Silverman *et al.*, 1995).

Studies on the effect of leaf application on certain resistant inducing chemicals, namely acibenzolar, NAA, salicylic acid and jasmonic acid, on controlling the incidence of sheath blight disease in IR-50 rice showed the improved efficacy of salicylic acid over other chemically induced systemic substances. Tobacco, radish and arubidiopsis resistance to pathogens have been reported by root or soil level SA treatment (Enedi *et al.*, 1992 Leeman *et al.*, 1995 and Van Loon and Antoni 1982).

Meyer and Hofte (1997) have been found to reduce the incidence of sheath blight disease, and this may indicate salicylic acid-induced systemic resistance of rice plants to *Rhizoctonia solani*.

Toal and Jones (1999) reported that the use of chemicals that induce systemic resistance together with biocontrol agents would be the appropriate alternative strategy to improve the management of sheath blight disease in rice. Various chemicals, namely salicylic acid, acetylsalicylic acid, jasmonic acid and oxalic acid, have been shown to induce resistance in crops.

Bhattacharya and Roy (2001) examined the field performance of some successful chemicals that cause resistance to *R. solani* and found that sodium selenite, zinc sulfate, lithium sulfate, calcium nitrate, sodium fluoride and iron chloride were most effective in reducing the length of the lesion and the number of sheath blight lesions in cut rice leaves and standing plants. At their effective concentrations, these chemicals showed no *in vitro* fungioxicity.

Dantre *et al.* (2003) examined the effectiveness of 15 non-conventional chemicals in inducing resistance to sheath blight disease in susceptible varieties. The use of acetylsalicylic acid, aminoisobutyric acid, indole acetic acid, DL- β -amino-n-butyric acid and salicylic acid resulted in lesion-free leaves on cut rice leaves after 72 hours of inoculation with pathogens, although these chemicals were directly toxic to *R. solani* was not observed on artificial media been.

Wei Dong *et al.* (2003) examined the resistance to *R. solani* induced by benzothiozole (BTH) and found that *in vitro* there was no inhibitory effect on the mycelium of *R. solani* and a significantly reduced lesion length of the infection of

the sheath blight disease in the detached leaves compared to untreated controls were observed.

Of the 3 resistant inducing chemicals (salicylic acid, gibberellic acid and Rose Bengal) tested at 25, 50, 100 and 200 µg / ml, the disease severity was found to be at all levels and salicylic acid in general compared to control was significantly reduced especially among the chemicals examined (Salam, 2007).

Usharani *et al.* (2013) found that after sowing rice seeds, four resistance-inducing chemicals, namely acibenzolar, naphthalene acetic acid, jasmonic acid and salicylic acid in an amount of 0.075 and 0.1 percent, were sprayed individually on the 15th DAS one day before exposure *Rhizoctonia solani* with rice plants. The observations were recorded one week after exposure to *Rhizoctonia solani* sheath blight in rice. Leaf application to a certain resistance inducing chemical, namely acibenzolar, NAA, salicylic acid and jasmonic acid, to control sheath blight disease in IR-50 rice indicated the improved efficacy of salicylic acid over other chemically induced systemic resistances to pathogens by SA treatment Root or soil. The present study discovered that salicylic acid reduces the incidence of sheath blight in IR-50 rice and may be an indication of the increased systemic resistance of rice plants to *Rhizoctonia solani* induced by salicylic acid. The results included the effectiveness of salicylic acid in reducing the incidence of blight by 19.10 percent and 28.12 percent at concentrations of 0.10 and 0.075 percent, respectively.

Bhattacharya and Roy (1998) showed that the use of various chemicals as phytoalexin inducers in rice plants is effective against the sheath blight disease of rice.

Kandhari and Gupta (2003) conducted an experiment to test the effectiveness of the fungicides GFT-10 (S-methyls, s-diphenylphosphorothioate), Folicur (tebuconazole) and three chemicals resistant to sheath blight in rice (see Pusa Basmati-1) under controlled conditions. Di-potassium hydrogen phosphate resulted in the highest reduction in disease among resistance-inducing chemicals and also confirmed that all chemicals used as a foliar spray reduced the occurrence of sheath blight disease.

Certain chemicals such as salicylic acid, gamma-amino-butyric acid and chitosan, used as seed treatment and/or foliar spray, have been found to induce resistance in rice plants and significantly reduce the severity of sheath blight disease (Laha *et al.*, 1997; Dantre and Rathi, 2007; Liu *et al.*, 2012).

2.11 Evaluation of silicon, copper and zinc applications on sheath blight disease severity on rice:

Kannaiyan and Prasad (1979) reported that two leaf sprays (10 days apart) of seven micronutrients at a concentration of 0.5% reduce the infection of *Rhizoctonia solani* and increase the grain yield of the ADT 31 variety. Good results have been obtained with borax, copper sulfate. Iron sulfate and zinc sulfate.

Lakpale (1992) concluded that the drastic reduction in *Rhizoctonia solani* mycelium growth in boron and zinc supplemented the media. The formation of sclerotia was completely inhibited by both elements.

Zinc (Zn) is essential for a few biochemical processes in the rice plant, e.g. B. cytochrome and nucleotide amalgamation, auxin metabolism, chlorophyll production, enzyme activation and membrane integrity (IRRI, 2000).

Marchner (1995) found that copper (Cu) fertilization reduced the incidence of a variety of bacterial and fungal diseases related to cell wall integrity and plant lignification. Copper plays a crucial role in the formation of chlorophyll and the increase in yields (Heitholt *et al.* 2002).

Somani (2008) reported that micronutrient deficits deteriorate dramatically due to intensive harvesting, loss of fertile top soil, and nutrients from surface runoff.

Datnoff *et al.* (2005) concluded that the disease management approach concentrated here is to manipulate the cultural practices of resistance to host plants and apply micronutrients to disease management.

The effectiveness of micronutrients against sheath blight disease was very good against macronutrients (Bhattacharya *et al.*, 2001, Ganguli *et al.*, 2003 and Salam *et al.*, 2010).

Korndorfer and Lepsch (2001) examined the effects of silicone on the yield in connection with the deposition under the leaf epidermis, which contribute to the

physical defense mechanism. decreases the ability to accommodate, increases the ability to photosynthesis and reduces the loss of perspiration.

Bhattacharya and Roy (2001) investigated the field performance of some chemicals against *R. solani* and found that sodium selenite, zinc sulfate, lithium sulfate, calcium nitrate, sodium fluoride and iron chloride most effectively reduced the disease length and lesion number of the sheath blight disease in rice. These chemicals showed no *in vitro* fungitoxicity at appropriate concentrations.

Ganguli and Sinha (2003) examined the effect of a dilute solution of seven metal salts on the occurrence of rice sheath blight disease in pots and fields and reported that copper chloride, barium sulfate, iron chloride, lithium sulfate and zinc sulfate had a moderate to strong effect. The lower concentration (10–4 M) had a strong influence on the symptoms of the disease, which led to a reduction in the severity of the disease by 41.4 to 65.5%.

The use of silicon fertilizer not only increases rice yield, but also reduces fungal diseases in rice (Rodrigues and Datnoff, 2005 and Wang Meiqin, 2005).

Khaing *et al.* (2014) investigated that the use of micronutrients that reduced the incidence and incidence of sheath blight disease affected varieties. Silicon fertilization was significantly more effective in minimizing the loss of yield due to sheath blight disease compared to Cu and Zn treatments.

Khaing *et al.* (2014) showed that the micronutrients reduced the incidence and severity of sheath blight. The study was carried out to compare rice varieties MR219 and MR253 against sheath blight disease and micronutrient applications and to determine the influence of the disease on rice yield. The epidemics of sheath blight disease in pots were triggered in April 2013 by inoculation at the stage of maximum tillering under greenhouse conditions. Silica gel, copper sulfate and zinc sulfate were applied to the soil at a rate of 360 g, 0.30 g, 0.45 g per 15 kg of soil before planting. Inoculation significantly increased the severity and incidence of sheath blight disease, resulting in 11% loss of yield for the moderately resistant variety MR219 and 50% for the moderately susceptible variety MR253. The use of micronutrients reduced the incidence and severity of sheath blight regardless of the

variety. Fertilization with Si, Cu and Zn treatments was effective for both strains to minimize the loss of yield due to sheath blight disease.

Numerous studies (Korayemm A.M., 1993; Nand R., 1996; Sagwal *et al.* 1994, Selvi S., 1995) have been carried out with Zn applications in rice plants in order to increase the grain yield. Zn has been found to increase the phenol content of plants and reduce the severity of rice blight (Singh *et al.*, 2010).

2.12 Efficacy of new molecules in the management of sheath

blight:

Saksena and Choubey (1972) argued that chemical treatment is the only viable technique available for effectively treating sheath blight disease without resistant varieties. The chemical substances Vitavax, Benlate (Benomyl), Agrosan G.N., Ceresan, Aretan, Karathane, Thiram, Dithan Z-78 (Zineb) and Brassicol completely inhibited the growth of *R. solani*.

Chien and Chu (1973) reported that benomyl was effective against sheath blight disease. Carbendazim is the best fungicide for sheath blight disease. (Roy and Saikia, 1976; Kannaiyan and Prasad, 1982, 1983; Rajan and Alexander, 1988).

Roy *et al.* (1974) came to the conclusion that Benlate can inhibit *Rhizoctonia solani* efficiently.

Kannaiyan and Prasad (1976) reported the fungicides, namely. Benomyl (Benlate) W. P., Brassicol, Edifenophos, IBP (Kitazin) ES, Dithan D-14 E. C., Demosan (Chloroneb) and Deconil completely inhibited the growth of the fungus.

Roy and Sakia (1976) showed that Benomyl and Mancozeb effectively reduced the sheath blight disease.

Iwasa (1978) showed that 30 ppm antibiotic, i.e. H. Validamycin, which effectively controlled the disease.

Kanniayan and Prasad (1979) reported that soil application of edifenphos, kitazin and carboxin can completely inhibit sclerotic germination and inactivate *R. solani*'s mycelium.

Lakshmanan *et al.* (1980) concluded that Vitavax was superior both in reducing the severity of infection and in the percentage of infected hills reported by

Bavistin and Hinosan.

Viswanathan and Mariappan (1980) reported the effects of fungicides such as carbendazim (Bavistin), carboxin (Vitavax) and Iprobephos (Kitazin) in combating sheath blight in prophylactic and therapeutic use. Similarly, they found that wetting the soil with carbendazim, carboxin, wet Cerasan, and PCNB13 also controlled this disease by reducing the inoculum on the ground.

Dev (1980) revealed that the soil fungicides Thiram and Quintozen were used before planting in the soil (20 kg / ha) to kill sclerotia in the soil.

Mathai *et al.* (1981) reported that Edifenphos best reduced the disease and increased yields compared to the other chemicals.

Dath *et al.* (1983) tested various biocides to control sheath blight and found that Bavistin, Derosal, MBC and Validamycin were the best fungicides to fight the disease.

Herman *et al.* (1984) concluded that the field test in Indonesia Rovrol (Iprodione) controlled sheath blight in rice and increased yields.

Das and Panda (1984) showed that carbendazim in a concentration of 1000 µg / ml completely killed the sclerotia of the causative agent of sheath blight. Treatment with carbendazim resulted in the loss of sclerotial viability of a rice plant infected with *R. solani* (Roy and Saikia, 1976).

The nature of validamycin and its activity against rice sheath rot has been described by Yamamoto (1985) and Uyeda *et al.* (1988). Validamycin at 45 g / ha gave excellent results in Thailand (Arunyanart *et al.*, 1986).

Jones *et al.* (1987) concluded that the use of propiconazole significantly reduced the severity of the disease and increased the yield.

Torabi and Binesh (1987) reported that iprodione + carbendazim, benomyl and validamycin reduced disease and increased yield when compared to mepronil, zineb, carboxin + thiram and edifenphos, which were less effective. A decrease in the severity of the disease and an increase in the yield could be achieved with the use of propiconazole (Jones *et al.*, 1987).

Borthakur and Addy (1989) reported that rice sheath blight can be better treated with a leaf spray of carbendazim.

Izadyar and Baradaran (1989) reported that five fungicide effects against sheath blight in Iran and improved yields with IBP, validamycin and iprodione treatments were also reported.

Shukla *et al.* (1990) reported that carbendazim was the most effective in reducing mycelial growth, sclerotic formation and germination, and lesions caused by sheath blight.

Vanitha and Thangamani Naryanswamy (1992) reported that Iprobephos and carbendazim completely inhibited the mycelial growth and sclerotial germination of *Rhizoctonia solani*. In the field trials they conducted in Coimbatore, all fungicides, namely hexaconazole, penicuron, propiconazole, cyproconazole and bitertenol, were superior to the control in reducing the disease.

Izadyar and Baradaran (1993) reported that Iprobephos, Mepronil, Validamycin and Iprodione + Carbendazim increase the yield, which could be due to combinatorial effects. *In vitro* toxicity study with Captafol, Edifenphos and Carbendazim (fungicides) and Monocrotophos, Quinalphos and HCH (insecticide) against *R. solani* (causative agent of sheath blight) and Nilaparvatha lugens (brown plant hopper). There was no synergism in the insecticidal effects with low doses of Quinalphos in combination with different dosages of fungicides. The insecticides with fungicides have shown antagonistic activity at higher fungicide levels.

Mai *et al.* (1993) reported that validamycin and benomyl + copper sulfate were commonly used to control sheath blight disease.

In his excellent work on the effects of pesticides on *Rhizoctonia* spp. (Kataria and Gisi, 1996) has been referred to an exhaustive list of chemicals used to treat diseases caused by *Rhizoctonia* in various cultures, including rice.

Haque (1997) reported that the fungicides thifluzamide, Contaf, Fluquin, Conazol, Baynate, Hinosan, Octave and Cu-Hydroxide significantly reduced the severity of the disease.

Kumar *et al.* (1997) reported that epoxiconazole (as opus) was most effective in reducing sheath blight disease, followed by thiophanate-methyl (as Baynate) and cyproconazole (as Atemi) and thiophanate-methyl (as tilt). They

found that Propineb (as Antracol) and Prochloraz (as Octave) controlled the disease but had little effect on crop yield.

Tiwari (1997) tested carbendazim (as Bavistin), benomyl, hexaconazole (as Contaf), Mancozeb (as Dithane M-45), Ediphenfos (as Hinosan) and thiophanate methyl (as Topsin-M) for the control of *Rhizoctonia solani* in the paddy field, in MP, India. The maximum diseases were controlled by hexaconazole, followed by edifenphos and the least control by mancozeb.

Use of carbendazim and iprodione (Izadyar and Baradaran, 1989); Epoxiconazole (Kumar *et al.*, 1997); Difenconazole and validamycin (Saha, 2003; Kandhari, 2007); Metominostrobin (Ichiba *et al.*, 2000); Thifluzamide and hexaconazole (Sunder *et al.*, 2003); Propiconazole and tebuconazole (Mian *et al.*, 2004) as well as penicuron and azoxystrobin (Goswami *et al.*, 2012) were highly effective in controlling disease and protecting yield. In addition, the combination of fungicidal formulations such as Carbendazim + Mancozeb (Prasad *et al.*, 2006); Propiconazole + difenconazole (Kandhari, 2007); Carbendazim + epoxiconazole (Saha, 2003) and carbendazim 25% + flusilazole 12.5% SE (Goswami *et al.*, 2012) proved to be very promising for sheath blight disease.

Akter *et al.* (2001) tested six fungicides and found that Contaf 5EC (hexaconazole) best reduced percent relative lesion height, percent disease index (PDI), and tiller infection in rice (see Swarna).

Hossain and Mia (2001) reported the efficacy of four fungicides, namely Amicozim50wp (Carbendazim), Bavistin 50wp, Shincar 50wp and Tilt 250EC, and two additional rates of Kali-Murat (MP), ie 20 and 40 kg / ha against sheath blight disease of rice. The best treatment for disease reduction and increased yield was discovered when leaf spray with tilt (0.1%) was used in addition to 40 kg / ha of Kali-Murat.

Sharma (2002) reported that validamycin can be used as a prophylactic treatment for sheath blight disease in affected areas.

Tiwari *et al.* (2002) used 7 fungicides to control sheath blight disease in rice and reported that carbendazim + epoxiconazole (0.2%), hexaconazole (0.2%),

epoxiconazole (0.24%) and propiconazole (0.2%) Controlled disease severity significantly more effectively than other fungicides.

Ali *et al.* (2002) concluded that treatment with Mancozeb, Copperoxychloride, Captan and Contaf reduced the incidence of sheath blight disease. Three sprays with Bavistin (0.1%) and Mancozeb (0.1%) + semen treatment significantly reduced the incidence of the disease.

Reddy and Krishnaiah (2003) reported that imidacloprid in combination with hexaconazole effectively reduced the incidence of sheath blight disease and BPH.

Chahal *et al.* (2003) reported that propiconazole (0.1%) edifenphos (0.1%), iprodin (0.3%), carboxin (0.2%) and carbendazim effectively controlled sheath blight disease.

Saha (2003) reported that sheath blight disease was lowest when difenoconazole was used (28.3%), followed by validamycin (29%) and epoxyconazole + carbendazim (33%).

Singh and Sinha (2004) reported that Contaf was able to reduce the severity of infection and the grain yield and the 1000-grain weight to 23.5%, 60.9%, 34.2 g / plant and 29.3, respectively g versus 74.7%, 95.6% and 24.4 g increase / plant and 25.5 in control.

Slaton *et al.* (2003) showed that strobilurins in general and azoxystrobin in particular were found to be very efficient in both reducing disease and increasing yield. Azoxystrobin at 0.17 kg / ha and flutolanil at 0.56 kg / ha in the middle of the boot and a heading of 50-70% dramatically reduced the frequency and severity of the disease (Groth and Bond, 2007).

Kandhari (2007) reported that seven fungicides and three plant substances in different concentrations were tested under field conditions against the sheath blight of rice of the Pusa Basmati-1 variety. All fungicides and plant substances have been found to be effective. Armure 30EC (propiconazole + difenconazole) with 1.0 ml / l was the most effective for fungicides and showed the lowest disease incidence of 31.3% compared to 77.9% in the control, while Achook had the lowest incidence of botanicals 65.1% compared to 82.9% showed control.

Bavistin, which was used as the standard fungicide at 1000 ppm, was most effective and showed a disease incidence of only 8.4%.

Bhanu *et al.* (2007) conducted field studies to determine the effectiveness and co-toxicity of certain insecticides, fungicides and their combinations against the occurrence of plant breeders and sheath blight in rice. The results showed that the insecticides imidachloprid and thiamethoxam individually decreased Planthopper formation, while sheath blight was reduced by the fungicides validamycin and propiconazole.

Sundravadana *et al.* (2007) reported that the optimal azoxystrobin rate to combat sheath blight was 125 g / ha.

A newly formulated mixture of azoxystrobin and propiconazole called Quilt Xcel TM was highly effective in combating sheath blight and protecting rice yield and milling quality (Parsons *et al.*, 2009).

Mukherjee *et al.* (2009) conducted field trials to test the compatibility of insecticides (imidacloprid and thiamethoxam) and two fungicides (propiconazole and validamycin) as a tank mix in insecticide and fungicide combinations against sheath blight in rice. All insecticide and fungicide applications were successful against the mixed population of BPH and WBPH insect and sheath blight. These blending drugs did not have an adverse effect on natural enemies and registered for better crop yields. (i.e. up to 37% higher than the untreated control).

Fungicide has successfully fought rice fungus diseases. Studies have shown that pathogenic ability can increase tolerance to a certain chemical increase with continued use over time (Brent and Hollomon 1998; Zhang *et al.*, 2009).

Bag (2009) tested a combination of two systemic fungicides for sheath blight disease, e.g. Trifloxystrobin 25% + tebuconazole 50% at 75 WG - the most effective means of reducing the severity of the disease compared to the control (37.61%), but at the level of the commercial antifungal antibiotic compound Validamycin 3L (38.30%). However, the percentage of grain yield was higher (0.6 t / ha) in the plot treated with trifloxystrobin 25% + tebuconazole 50% 75WG compared to with validamycin 3L (0.57 t / ha) than in trifloxystrobin 25% +

tebuconazole 50% 75WG in treated parcel 50% higher yield than untreated (control).

Swamy *et al.* (2009) evaluated the effectiveness of Filia 52.5 SE (400 g tricyclazole + 125 g propiconazole; 1.5, 2.0 and 2.5 ml / liter) and Nativo75 WG (25% trifloxystrobin + 50.0% tebuconazole; 0.4 g / liter). and hexaconazole (Contaf 5 EC; 2.0 ml / liter), validamycin (Rhizocin 3L; 2.5 ml / liter) and propiconazole (Tilt 25 EC; 1.0 ml / liter) as tests for those caused by rice *Rhizoctonia solani* sheath blight (see IR 64)). The fungicides were sprayed 50, 65 and 80 days after planting. All fungicides reduced the incidence of the disease compared to the control. The reduction in the severity of sheath blight ranged from 22 to 31%. Under the new formulations, Filia 52.5 SE and Nativo 75 WG were equally effective in reducing sheath blight (25% control). Among the control fungicides, Contaf 5 EC was highly effective (31% control) and this fungicide gave the highest yield (5322 kg / ha).

Singh *et al.* (2010) concluded that hexaconazole and diniconazole reduced the disease severity by approximately 70% and improved grain yield at the same time.

Prasanna Kumar *et al.* (2012) reported that thifluzamide was tested for its effectiveness against sheath blight in three seasons by a new group of carboxynilide fungicides.

The strobilurins in general and azoxystrobin in particular (Slaton *et al.*, 2003) have proven to be very effective both in reducing sheath blight disease and in increasing yield. Azoxystrobin with 0.17 kg a.i./ha and flutolanil with 0.56 kg a.i./ha in the middle of the boot and a heading of 50 to 70 percent significantly reduced the severity of the disease (Groth and Bond, 2007). Azoxystrobin was more effective than flutolanil in reducing yield loss. An azoxystrobin, which was applied to the middle bootate with 0.17 kg a.i./ha, and a leaf application with 125 g / ha inhibited the disease (Groth, 2008). In field trials, kresoxim-methyl 40% + hexaconazole 8% at 0.1% (Lore *et al.*, 2012), azoxystrobin followed by trifloxystrobin 25% + tebuconazole 50% (Agarwal and Sunder, 2013a), azoxystrobin and metominostrobin followed by tricyclazole + Propiconazole (Lore and Hunjan, 2012) and picoxystrobin 25% SC at 1.2 ml per liter also used

picoxystrobin + propiconazole 20% SC (2.0-2.5 ml / l) (Krishnam Raju and Bhuvaneswari, 2013), Azoxystrobin, pencycuron and hexaconazole at 112, 280 and 50 g ai / ha (Ranjan Nath *et al.*, 2005) were highly effective in combating diseases.

Bhuvaneswari and Raju (2012) reported that the new combination of fungicide azoxystrobin 18.2% and difenoconazole 11.4% SC was tested in field conditions against the rice sheath disease. The combined fungicide at 1.25 ml / l and 1.0 ml / l was found to be effective against sheath blight, with the lowest disease incidence recorded at 9.36% and 16.43%, respectively. Similarly, disease severity of 17.19% and 21.37% under 72.09% and 78.21% was found in the untreated control. Hexaconazole 5% EC was also effective and showed an incidence and disease severity of 23.09% and 31.06%, respectively. Azoxystrobin 23 SC alone was also found to be effective, with incidence and severity of sheath blight of 27.06% and 32.89%.

Johnson *et al.* (2013) examined the efficacy of hexaconazole 5 SC greenhouse and field conditions against sheath blight disease. Hexaconazole 5 SC in various doses, namely 500, 1000, 1500 and 2000 ml ha⁻¹, reduced the incidence of sheath blight disorders in all three field trials where hexaconazole was superior to 2000 ml ha⁻¹ and reported the lowest incidence in 3, 5.73 and 11.33% respectively in the first, second and third studies. In the second and third trial, maximum yields of 3000 and 2800 kg per ha were also recorded.

Jagadeeshwar *et al.* (2014) found that the four main fungal diseases of rice blast (*Pyricularia oryzae* Cav.), sheath blight (*Rhizoctonia solani*) and sheath rot (*Sarocladium oryzae*). The loss of grain yield due to these diseases is between 15 and 35%. Five fungicides, namely Metaminostrobin 20 SC, Metiram 70WDG, Captan 70% + Heaxaconazole (5%) 75 WP, Hexaconazole 5 SC and Tricyclazol 75 WP, were evaluated against a major rice disease using rice HR 12.

Several experiments have shown that strobilurin-based molecules such as azoxystrobin, trifloxystrobin and metominostrobin treat the disease effectively and in an environmentally friendly manner than other commercially available fungicides (Bag *et al.* 2016).

Laxmikant *et al.* (2017) evaluated the seven fungicides, e.g. B. Tropiconazole 25 EC, hexaconazole 5 EC, copper oxychloride 77 EP, chlorothalonil 75 WP, carbendazim 75 WP, thifluzamide 24 SC and azoxystrobin 23 SC, where they were evaluated for their effectiveness against sheath blight of rice. Among all the fungicides tested, Propiconazol 25 EC and Azoxystrobin 23 SC appeared to be the best management tool, reducing the incidence of sheath blight by 58.9% and 58.3%.

Pramesh *et al.* (2017) reported that the combination fungicide azoxystrobin 11% + tebuconazole 18.3% w / w SC at 1000 ml / ha was found to be effective against sheath blight disease, with the lowest percentage disease index (PDI) of 10.93 was recorded.

For Sheath blight management in rice with less reliance on synthetic fungicides, greater use of natural fungicides such as strobilurins is more sustainable approach to restrict disease (Singh *et al.*, 2019).

2.13. Identification of the slow disease developing varieties for sheath blight:

Mizuta (1956) estimated the yield was decreased up to 20% when the disease developed up to flag leaf, and Hori (1969) reported yield loss of 25% when the disease spreads to uppermost flag leaves. Ou (1972) likewise revealed a grain yield loss of 25 percent because of sheath blight.

Kozaka (1961) found no significant differences in reaction among cultivars tested at 40-50 days old.

Wild rice *Oryza barthii* (Swain and Dath, 1976) and *Oryza rufipogon* (Kannaiyan and Prasad, 1978) were found to be resistant against sheath blight pathogen *R. solani*.

Naidu (1983) recorded damages at panicle initiation stage from Andhra Pradesh district of Godawari because of sheath blight.

Few cultivars lines and wild rice species were reported to be resistant by different workers. Varieties like Kataktara DA-2 (IRRI, 1972), BR-430-51-2, BR-57-49-6 (Manian and Manibhushanr Rao, 1979), KRC346, KRC355, RP1057-3

(Reddy *et al.*, 1981), PTB-33, Sinna Sivappa and CR57-11-2 (Gangopadhyay and Mishra, 1984), IET8748 (Dev and Mary, 1985), IR-8, IR-42, IR-32 (Iboton, 1985), CR-1014 and T141 (Premalatha Dath, 1985) and Tetep, IET-4699, Jawa-14 (Guo *et al.*, 1985) were reported to be resistant. Siani and Raina (1985) also reported 15 varieties as resistant from their evaluation trials.

Kang *et al.* (1965) found that all the 155 cultivars tested produced lesions when inoculated. Few cultivars/breeding lines and wild rice species were reported to be resistant by different workers. Varieties like Kataktara DA-2 (IRRI, 1972), BR-430-51-2, BR-57-49-6 (Manian and Manibhushan Rao, 1979), MO-5 (Balakrishnan *et al.*, 1981), KRC346, KRC355, RP1057-3 (Reddy *et al.*, 1981), PTB-33, Sinna Sivappa and CR57-11-2 (Gangopadhyay and Mishra, 1984), IET8748 (Dev and Mary, 1985), IR-8, IR-42, IR-32 (Iboton, 1985), CR-1014 and T141 (Premalatha Dath, 1985) and Tetep, IET-4699, Jawa-14 (Guo *et al.*, 1985) were reported to be resistant.

Rajan *et al.* (1979) tested 52 rice varieties none were found to be resistant against rice sheath blight. Similarly, none of the commercial rice cultivars in Taiwan have been shown to be resistant to this disease, although some have demonstrated moderate resistance from the tall population (Teng and Hsu, 1979).

Vidhyasekaran (1981) worked out of 46 cultivars inoculated with *Corticium sasakii*, Pankaj, Tedukan and Mashuri were resistant while Ratna, Padma, Co25, Vaigai, Thiruveni, GEB24, ASD4, ASD8, Sabarmathi and Basumathi were moderately resistant to disease development. 15 varieties as resistant from their evaluation trials (Siani and Raina, 1985).

Dath (1985) suggested, in rating the response of rice cultivars against sheath blight. To assess the cultivars, she utilized 6 measures and expressed that CR1014 and T-141 resistant than other selective variety assessed.

Ahn *et al.* (1986) also proposed new scale to determine resistance of rice sheath blight disease. A scale was based on the connection between severity and loss of yield.

Wasano and Hirota (1986) reported that among 210 *Oryza sativa* varieties from 13 countries were found to be resistant, with the majority of Nepal and

Vietnamese cultivars. Among the Japanese varieties, which were taller with longer panicles, larger internodes and leaf sheaths, found resistant. Significant differences in resistance to disease development when inoculated at the booting and heading stages were also recorded.

Kim *et al.* (1987) Genotypes Gayabyo and SR9713-543 showed less disease among 200 genotypes evaluated artificially with race K2.

Panda (1989) found that the 91 cultivars tested against natural infection by *R. solani*, 14 were resistant and 28 were moderately resistant, while the others were moderate to highly susceptible. Few cultivars/breeding lines and wild rice species were reported to be resistant by different workers including varieties like kataktara DA-2 (IRRI, 1972), BR-4-30-51-2, BR57-49-6 (Manian and Manibhushan Rao, 1979), MO-5 (Balakrishnan *et al.*, 1981), KRC 346, KRC355, RP1057-3 (Reddy *et al.*, 1981), PTB-33, Sinna Sivappa and CR57-11-2 (Gangopadhyay and Mishra, 1984), IET-8748 (Dev and Mary, 1985), IR-8, IR-42, IR-32 (Iboton, 1985), CR-1014 and T-141 (Premalatha Dath, 1985) and Tetep, IET-4699, Jawa14 (Guo *et al.*, 1985) were reported to be resistant.

Hashiba and Ijiri (1989) provided a method for estimating loss of yields due to sheath blight. This system was based on the ratio of height of the lesions caused by *Rhizoctonia solani* to the height of the plant (X, vertical disease development) and percentage of the number of diseased hills. Loss of yield from fully ripened grains was expressed as

$$L = (41.31X - 826.2) A/100$$

Where, X = Vertical development of the disease

A = Horizontal development of the disease

Naidu (1989) reported that the grain yield losses due to sheath blight varied from 4.90% in Phalguna to 69.10% in Mansuri and straw yield losses from 1.20% (IR 42) to 28.80% (Laxmi). Disease score was highest in Laxmi variety.

Sing (1990) revealed that the fungus causes grain yield losses of up to 20% when the disease progresses before the flag leaf stage. The deficit was closely linked to a number of hills.

Marchetti and Bollich (1991) conducted 5-year study evaluating the correlation between symptom expression and disease resulted in sheath blight yield losses and found a high correlation between disease index (DI) and percentage yield loss, $r_2 = 0.74$. The DI is estimated from visual assessments of the percentage harvest area at specified disease severity levels. The DIs ranged from 1.7 to maximum 9 in 7 cultivars and 5 years. A regression line used for yield loss calculation was:

$$Y (\text{loss}) = -1.8 + 5.1x (\text{DI})$$

Basu and Sengupta (1992) reported that reduction in grain yield due to this disease was proportionate to degree of disease resistance.

Guo-Chongjion and Chen-Zhiyi (1992) observed that The lesion from the top of the fourth leaf ($\text{DI} < 40$) did not significantly affect the yield of moderately resistant cultivars but the yield declined considerably as the lesion expanded from the top to the third leaf.

Fan *et al.* (1992) gave a simulation model for sheath blight prediction and management based on experimental data collected during the period 1985-90. The model is focused on submodels, rice development, and initial infection with *R. solani*, AG-1 sclerotia, management of fungicidal disease and optimum decision taking. This model will forecast the risk of disease epidemics, the degree of injury and disease control under various environmental conditions.

Li *et al.* (1992) gave a simulation model for optimizing and management of rice sheath blight and considered SIMOMRSB to be satisfactory when evaluated and addressed the practical application of dynamic programming to determine yield loss.

Genotypes Gayabyo and SR9713-54-3 indicated less predictable diseases among 200 genotypes misleadingly with Race K2 (Kim *et al.*, 1987). Among 40 varieties (Lakpale, 1992); 25 varieties (Haque 1997); and 22 varieties (Sharma 2002) tested under artificial inoculated condition under Chhattisgarh conditions, none of the varieties demonstrated safe response to sheath blight.

Suparyono and Nuryanto (1991) revealed that at Inoculation at maximum tillering and primordial stages shows a major decrease in early and long-lived

crops, becoming the. Several workers conducted varietal tests for *R. solani* resistance. Genotype progressed early appear to fail rather than those of late stages.

Lakpale (1992) concluded that the 40 varieties tested under artificial inoculated condition, none was found resistant to sheath blight.

Sharma and Teng (1996) worked on cultivars IR72 and IR42 inoculated with *Rhizoctonia solani* grown on a rice grain hull mixture at tillering, panicle initiation, booting and flowering stages during the 1989 dry season and reported that yield ranged from 3.8-5.6 t/ha in IR42 and 3.7-5.6 t/ha in IR72. In both cultivars inoculation at flowering resulted in the lowest yield and accounted for highest yield loss.

Genja *et al.* (1996) reported that the main factor related with yield reduction due to *Rhizoctonia solani* were an expansion in the quantity of contracted and unfilled grain and a reduction in 1000 grain weight. Sheath blight additionally diminished the percent of entire rice and increased that of powdery rice. Yielding rate was increased and firmly identified with the disease index at the yellow ripeness stage.

Haque (1997) reported that none of the tested varieties showed resistant reaction, though early varieties suffered more than late duration under Chhattisgarh conditions.

Reddy *et al.* (1997) also Studied 457 breeding lines of rice for sheath blight tolerance, and observed that PNR15336 and PNR82096 had disease resistance.

Among 40 varieties (Lakpale, 1992); 25 varieties (Haque, 1997); and 22 varieties (Sharma, 2002) tested under artificial inoculated condition under Chhattisgarh conditions, none of the varieties showed resistant reaction to sheath blight.

Haque (1997) reported that the early varieties suffered more than late duration; while Sharma (2002) reported that out of all the varieties studied, dwarf varieties showed more disease severity as compared to semi-dwarf and tall varieties. Similar findings was reported by Bhaktavatsalam *et al.* (1978) when 50 varieties were tested, none of the varieties tested showed resistant reaction.

Reddy *et al.* (1997) also evaluated 457 breeding lines of rice resistance to sheath blight and found that PNR15335 and PNR82096 were possessing resistance to the development.

Chen *et al.* (2000) made preliminary research on origins of rice sheath blight resistance. Highly significant difference was noted among the lines in the sheath blight resistance. However, the findings showed that sheath blight resistance was an heritable trait. Most of the source had the same resistance, both from China and from the United States.

Sharma (2002) reported that twenty-two varieties tested under artificial inoculated conditions, None demonstrated resistant to donor levels. By comparison to semi-dwarf and small varieties, Dwarf varieties displayed greater disease severity in all the varieties examined.

Saha *et al.* (2002) screened 149 entries of NSN-1 during the 2000 Kharif (wet) season, at Bankura and Chinsurah, West Bengal, India; and reported the same finding *i.e.*, none of the test entries recorded resistant reaction to sheath blight disease either at Bankura or at Chinsurah. However, 11 and 17 entries showed moderate resistance to this disease at Bankura and Chinsurah, respectively.

Chahal *et al.* (2003) reported that sheath blight reduced grain filling by 32.30% in rice when diseased area of top three leaves was 54.30%. They found yield recorded was 18 gram per plant as compared to 35.9 gram per plant in well control, when all the leaves were infected and on artificial inoculations of rice cultivars, maximum disease severity was recorded in PR 103 (97%) with yield loss of 43.4%.

Goel and Lore (2004) studied on one hundred elite advanced breeding lines of rice in Hyderabad, Andhra Pradesh, India that were screened for resistant reactions to different rice diseases including sheath blight (*Rhizoctonia solani*); Only 4 lines (IET-14277, -16958, -17048 and -17159) were found to be moderately resistant toward sheath blight.

2.14 Screening of different entries / varieties against sheath blight resistance:

Wasano and Hirota (1986) reported that among 210 varieties of *Oryza sativa* from 13 countries, most of the cultivars from Nepal and Veitnam were found to be resistant. The Japanese varieties were taller with longer panicles, tended to be more resistant to larger internodes and leaf sheaths. Significant differences in disease resistance were also identified when the pathogens were inoculated during the booting & heading stages.

Panda (1989) found that out of 91 cultivars tested against natural infection by *Rhizoctonia solani*, 14 were resistant and 28 modestly resistant, the others moderate to profoundly susceptible.

Among 40 varieties (Lakpale, 1992) 25 varieties (Haque, 1997) and 22 varieties (Sharma, 2002) tested under Chhattisgarh conditions under artificial inoculation, none of these varieties showed resistant reaction to sheath blight. Haque (1997) reported that late varieties endured longer than late varieties; although Sharma (2002) were observed all dwarf varieties displayed greater disease intensity than semi-dwarf and tall varieties.

Saha *et al.* (2002) reported that 149 NSN-1 entries at Bankura and Chinsurah, West Bengal, India, during the 2000 kharif (wet) season; and finding, *i.e.*, none of the test entries reported a resistant reaction to sheath blight disease either at Bankura or Chinsurah. However, 11 and 17 entries At Bankura and Chinsurah respectively demonstrated moderate resistance to this disease.

Mosaddeque *et al.* (2008) evaluated under field and laboratory observed that 44 test entries of parental lines of rice with one susceptible (BR 11) and one resistant (BRRI dhan 29) were screened against sheath blight (*Rhizoctonia solani*) at maximum tillering and flowering stage in the field. The pathogenicity test was concentrated in the laboratory and observed ten lines were resistant, 31 were moderately resistant and 3 showed moderately susceptible reaction response at maximum tillering stage. At flowering stage just 2 lines were resistant, 24 were tolerably resistant and 18 lines were moderately susceptible.

Kumar *et al.* (2015) screened six parental genotypes of rice viz, FL 478, IW Ponni, BPT 5204, IR 64, RNR 57979 and TETEP along with the susceptible check, T (N) 1 against sheath blight resistance. TETEP exhibited resistant reaction to sheath blight with 5.75% mean RLH as against the highest mean RLH of 66.70% in T (N) 1 (susceptible check). The RNR 57979 and IR 64 parental lines showed moderately resistant and moderately susceptible reactions with a mean RLH of 21.35% and 31.80% respectively. The other parental lines viz, FL 478, IW Ponni and BPT 5204 showed susceptible reaction recording 47.60%, 49.55% and 46.70% mean RLH respectively.

Chandra *et al.* (2016) Tested 108 germplasms, screened in both natural and artificial inoculated conditions, none of the entries were observed as immune or resistant. Two entries Baigani black and Prasada registered moderately resistant reactions, 17 moderately susceptible and 27 noted resistant reactions.

Tejaswani (2016) reported that the F5 rice varieties obtained from the two crosses MTU 7029/PAU 3116-25-5-1 and MTU 7029/PAU 3140-126-1 has been screened against sheath blight using artificial inoculation typha leaf bit method followed by field screening using 0-9 scale of SES, 2014. Specific varieties of bacterial leaf blight were also screened using artificial leaf clipping method, and no varieties were detected resistant. 21 varieties displayed moderately resistance to sheath blight while only six varieties displayed moderately resistance to bacterial leaf blight.

CHAPTER –III

MATERIAL AND METHODS

The present studies entitled “**Studies on variability of *Rhizoctonia solani* Kuhn and management of Sheath Blight of Rice**” carried out at the SKS College of Agriculture and Research Station, Rajnandgaon and the Department of Plant Pathology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, (C.G.). In general all the material used and methods followed during the course of investigation are given below:

3.1 Materials:

All the *in vitro* and *in vivo* studies were conducted in the laboratory and fields of Department of Plant Pathology, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) and SKS College of Agriculture, Rajnandgaon. During the course of investigation, glasswares of Borosil and chemicals of standard grade (SD fine, Hi Media, Qualigens, Emarck etc.) were used.

3.1.1 Instruments used:

1. Autoclave for sterilization.
2. BOD incubator for incubation of the pathogen.
3. Compound and stereoscopic microscope for pathogen detection.
4. Hot air oven for sterilization of glasswares.
5. Forceps, scissors, cork borer & needle for inoculation.
6. Laminar Air Flow for isolation, purification & inoculation.
7. Spirit lamp for sterilization
8. Microwave oven for melting of media.
9. Electronic Digital Balance for weighing.
10. pH meter.
11. Micro pipette
12. Funnel etc.

3.1.2 Cleaning and sterilization of materials:

The glassware's were cleaned with detergent powder whenever needed and finally washed by cleaning solution, rinsed with tap water and/or distilled water.

The dried glassware's had been sterilized in a hot air oven at 180°C for 2 hour. During inoculation and purification the forceps and other metallic instruments were sterilized by dipping into alcohol and heating over the spirit lamp flame. Media sterilized by an autoclave at 1.02 kg /cm² in 20 minutes.

3.1.3 Media used:

Potato Dextrose Agar (Riker and Riker, 1936) with the following composition was prepared and used during *in vitro* studies:

Potato (peeled and sliced)	- 200 g
Dextrose	- 20 g
Agar	- 20 g
Distilled water	- 1000 ml
pH	- 6.0-7.0

3.1.4 Experimental site:

The field experiments were performed in the experimental area of the Department of Plant Pathology situated in the Research farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur and fields at Rajnandgaon (C.G.) during Kharif 2016 and 2017. In addition to area experiments, all *in vitro* studies were conducted in the Department of Plant Pathology Laboratory, SKS College of Agriculture and Research station, Rajnandgaon.

3.1.5 Statistical analysis:

The designs used in all field experiments and laboratory experiments were done by Randomized Block Design (RBD) and Complete Randomized Block Design (CRD) respectively.

3.1.6 Test variety:

The test variety “Swarna” susceptible for sheath blight disease of rice were grown under field and pot conditions for experimental studies.

Isolation, purification, identification, pathogenicity test of causal agent and symptomatology of disease:

3.2 Study of symptoms, collection, isolation, purification and pathogenicity test of the sheath blight pathogen:

3.2.1 Symptoms of sheath blight disease:

The initial signs typically develop as lesions on sheaths of lower leaves near the waterline while plants are in the growth stage of late tillering or nearly internodal elongation. These lesions usually grow as oval to elliptical, green gray, just below the leaf collar, water soaked spots about 1/4 inch wide and 1/2 to 1/4 inch long. The disease has been named as “sheath blight” because of primary infection on leaf sheath. The fungus attack the crop from tillering to heading stage and leaf blade symptoms also observed. The presence of several large lesions on leaf sheath causes death of whole leaf and in several causes all the leaves of a plant blighted. The infection spreads to inner sheath resulting death of entire plant. These types of symptoms are popularly called as banded blight. In the banded blight phase, the flag leaf and panicle infection prevented the normal emergence and expansion of the ears and caused poor filling of the grains.

3.2.2 Collection of disease samples:

The disease samples were collected from naturally infected rice plants from farmers field of district *i.e.* Rajnandgaon, Bemetara, Mahasamund, Balod, Raipur, Dhamtari, Kabirdham, Gariyaband, Durg, Kanker, Narainpur, Raigarh, Jaspur, Korea, Korba of Chhattisgarh during kharif 2015-2016 at maximum tillering stage of rice crop. The detail about the survey is presented under the table given:

Table 3.1 : Survey and collection of disease samples of sheath blight of rice from different locations of Chhattisgarh year kharif 2015 and 2016

S.No.	Crop stage	Village	Block	District	Variety	Cropping pattern
1	Maximum tillering stage	Mohad	Rajnandgaon	Rajnandgaon	Swarna	Rice-Wheat- Fellow
2	----do-----	Mohad	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Rice
3	----do-----	Mohad	Rajnandgaon	Rajnandgaon	Swarna	Rice- Wheat-Rice
4	----do-----	Jungleswer	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Fellow
5	----do-----	Jungleswer	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Fellow
6	----do-----	Jungleswer	Rajnandgaon	Rajnandgaon	Swarna	Rice-Wheat- Fellow
7	----do-----	Jungleswer	Rajnandgaon	Rajnandgaon	Mahamaya	Rice-Fellow- Fellow
8	----do-----	Somni	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Fellow
9	----do-----	Mokhala	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Fellow
10	----do-----	Dewada	Rajnandgaon	Rajnandgaon	Swarna	Rice-Gram- Fellow
11	----do-----	Kaketara	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Fellow
12	----do-----	Ratepayali	Dongergaon	Rajnandgaon	Swarna	Rice-Fellow- Fellow
13	----do-----	Ghumka	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Rice
14	----do-----	Odiya	Chhuikhadan	Rajnandgaon	Swarna	Rice-Gram- Fellow
15	----do-----	Odiya	Chhuikhadan	Rajnandgaon	Swarna	Rice-Fellow- Rice
16	----do-----	Haldi	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Fellow
17	----do-----	Haldi	Rajnandgaon	Rajnandgaon	Swarna	Rice-Gram- Fellow
18	----do-----	Haldi	Rajnandgaon	Rajnandgaon	Swarna	Rice
19	----do-----	Haldi	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Rice
20	----do-----	Chhichhanpatri	Ambagarh-chowki	Rajnandgaon	Swarna	Rice-Fellow- Fellow

S.No.	Crop stage	Village	Block	District	Variety	Cropping pattern
21	----do-----	Tolagaon	Khairagarh	Rajnandgaon	Swarna	Rice-Wheat- Fellow
22	----do-----	Kanhe	Ambagarh-chowki	Rajnandgaon	Swarna	Rice-Fellow- Fellow
23	----do-----	Dharmapur	Khairagarh	Rajnandgaon	Swarna	Rice-Fellow- Fellow
24	----do-----	Surgi	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Rice
25	----do-----	Surgi	Rajnandgaon	Rajnandgaon	Swarna	Rice-Wheat- Fellow
26	----do-----	Mohbhatta	Berla	Bemetara	Swarna	Rice-Fellow- Fellow
27	----do-----	Mahasamund	Mahasamund	Mahasamund	Swarna	Rice
28	----do-----	Saloni	Rajnandgaon	Rajnandgaon	Swarna	Rice-Gram- Fellow
29	----do-----	Saloni	Rajnandgaon	Rajnandgaon	Mahamaya	Rice-Fellow- Fellow
30	----do-----	Saloni	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Rice
31	----do-----	Khadgaon	Manpur	Rajnandgaon	Mahamaya	Rice-Fellow- Fellow
32	----do-----	Khadgaon	Manpur	Rajnandgaon	Swarna	Rice-Fellow- Fellow
33	----do-----	Sanesara	Dongergaon	Rajnandgaon	Swarna	Rice-Fellow- Fellow
34	----do-----	Gathala	Rajnandgaon	Rajnandgaon	Mahamaya	Rice-Wheat- Fellow
35	----do-----	Kumarda	Dongergaon	Rajnandgaon	Swarna	Rice-Gram- Fellow
36	----do-----	Muretitola	Ambagarh-chowki	Rajnandgaon	Swarna	Rice-Fellow- Rice
37	----do-----	Bhathasakri	Saja	Bemetara	Swarna	Rice-Fellow- Fellow
38	----do-----	Kutelikhurd	Chhuikhadan	Rajnandgaon	Swarna	Rice-Fellow- Fellow
39	----do-----	Jogidalli	Rajnandgaon	Rajnandgaon	Swarna	Rice-Fellow- Rice
40	----do-----	Matri	Dondilohara	Balod	Swarna	Rice-Fellow- Fellow
41	----do-----	Hirapur	Dharsiwa	Raipur	Swarna	Rice-Fellow- Fellow
42	----do-----	Dhamtari	Dhamtari	Dhamtari	Swarna	Rice-Fellow- Rice

S.No.	Crop stage	Village	Block	District	Variety	Cropping pattern
43	----do-----	Surajpura	Kawardha	Kabirdham	Swarna	Rice-Fellow- Fellow
44	----do-----	Nagdha	Nawagarh	Bemetara	Swarna	Rice-Fellow- Fellow
45	----do-----	Singhola	Khairagarh	Rajnandgaon	Swarna	Rice-Gram- Fellow
46	----do-----	Singhola	Khairagarh	Rajnandgaon	Mahamaya	Rice-Fellow- Rice
47	----do-----	Singhola	Khairagarh	Rajnandgaon	Swarna	Rice-Wheat- Fellow
48	----do-----	Kirwai	Fingeshwer	Gariyaband	Swarna	Rice-Fellow- Fellow
49	----do-----	Borsi	Durg	Durg	Swarna	Rice-Wheat- Fellow
50	----do-----	Pakhanjur	Kanker	Kanker	Swarna	Rice-gram- Fellow
51	----do-----	Narainpur	Narainpur	Narainpur	Swarna	Rice-Fellow- Fellow
52	----do-----	Lailunga	Raigarh	Raigarh	Swarna	Rice-Fellow- Fellow
53	----do-----	Jaspur	Jaspur	Jaspur	Swarna	Rice-Fellow- Rice
54	----do-----	Korea	Korea	Korea	Swarna	Rice-Gramm- Rice
55	----do-----	Utai	Durg	Durg	Swarna	Rice-Fellow- Fellow
56	----do-----	Pali	Katghora	Korba	Swarna	Rice-Fellow- Rice
57	----do-----	Kirwai	Fingeshwer	Gariyaband	Mahamaya	Rice-Fellow- Rice
58	----do-----	Kirwai	Fingeshwer	Gariyaband	Swarna	Rice-Gram- Fellow



Fig.3.1: Collection and isolation of sheath blight disease samples

3.2.3 Isolation of the pathogen:

The disease affected samples obtained from the different localities were separately washed thoroughly with tap water. Small portion of the infected parts containing healthy as well as diseased tissues were cut in to 0.5 cm pieces with the help of sterilized scalpel blade. These pieces were then surface sterilized with 1 percent sodium hypochlorite solution for 1 minute with 3 subsequent changes in sterilized water to remove traces of the chemical. The pieces were then transferred aseptically to petri dishes containing sterilized Potato Dextrose Agar (PDA) and incubated at $28\pm 2^{\circ}\text{C}$ under BOD incubator. The petri dishes were examined at regular time intervals for fungal growth radiating from the infected pieces and the 58 isolates were isolated.



Fig. 3.2: Plate No. 1.1 and 1.2 Pure culture of *R. solani*

3.2.4 Purification:

After supplementing with a pinch of streptomycin sulphate, about 20 ml of PDA medium was poured into each petri-dish to prevent bacterial contamination. One 8 mm mycelial disc from a freshly isolated culture was transferred aseptically to the solidified PDA in each petri dish by hyphal tip cut method. The dishes were incubated at $28\pm 2^{\circ}\text{C}$ in BOD incubator. Adequate numbers of sub culture transformation were separately made for further purification and all the collected

58 isolates were purified and confirmed to the current species concept of *R. solani* (Parmeter and Whitney, 1970) and maintained under deep freezer at -20°C .

3.2.5 Mass multiplication of inoculums:

Stems of 35-40 days old rice plants were cut in to pieces of about 2 cm size and filled in to 500 ml Erlenmeyer flasks up to one third. Flasks were autoclaved at 15 pound per square inch for 30 minutes. Mycelial discs of 5 mm diameter cut from the margin of 48 hrs old culture of the pathogen were inoculated into the flask and incubated at $28\pm 2^{\circ}\text{C}$ up to fifteen days for full growth of fungus and sclerotia formation. For artificial inoculation, rice plants at maximum tillering stage were taken for inoculation.



Fig.3.3: Mass multiplication of *R. solani*

3.2.6 Inoculation:

Rice stem bits (*Rhizoctonia solani* mycelium profusely grown) and sclerotia from 7-9 days old culture were used for inoculation of the rice plants at the maximum tillering stage in all the field experiments. The primary tillers of each hill were tagged and gently inoculated by punching and pushing into the sheath a single sclerotium or rice stem bit just $1\frac{1}{2}$ to $2\frac{1}{2}$ cm above the water surface level as per the sheath location. After 12 hours plants were examined for symptoms. The disease severity (lesion length) was assessed 21 days after inoculation.



Fig.3.4: Artificial Inoculation

3.2.7 Pathogenicity test of different isolates of sheath blight pathogen:

Pathogenicity test of the 58 isolates of sheath blight pathogen collected from different parts of Chhattisgarh were assessed through artificial inoculation on rice susceptible cultivar Swarna in the fields of Rajnandgaon during kharif 2016. The pathogenicity of the isolates was determined by rice stem bits inoculation method on 40-day-old susceptible rice cultivar Swarna. Four to five rice stem bits colonized with fungal mycelia (and sclerotia) are then placed in the central region of the hill, between the tillers, 5 to 10 cm above the soil. The inoculated plants were regularly observed to growth symptom. Re-isolation was made from contaminated sections of plants and thus supported Koch's postulates as opposed to original cultures.



Fig.3.5a Inoculation on rice sheath



Fig. 3.5b Development of symptoms



Fig. 3.6 Variation in lesion length



Fig.3.7 Diseased plant

Variability and cultural studies of *Rhizoctonia solani* Kuhn

3.3 Evaluation of aggressiveness of different isolates of *R. solani*:

Fifty eight isolates were assessed that was collected from different parts of Chhattisgarh, affected by sheath blight pathogen through artificial inoculation on rice cultivar swarna under pot condition. This experiment was conducted under pot condition in completely randomized design (CRD) with four replications during kharif 2016 and 2017. Artificial inoculation was done at the maximum rice tillering stage using mycelial block of 5-day-old culture. To study the aggressiveness, sclerotia rice and stem bits were inoculated in to rice plants for development of symptom, mycelial growth and sclerotial production to record aggressiveness of *R.*

solani isolates. Observations for disease initiation and lesion length were recorded regularly at 24 h interval after inoculation upto 3 weeks of the study period in kharif season. All the collected isolates were measured for aggressiveness based on the disease symptoms development, 24 hours incubation period after inoculation up to three weeks. Observation on the Lesion length, Relative lesion height, Percent disease severity and Percent Disease Index was recorded and also calculated. The control plants were not inoculated with sclerotia and they did not show any symptom.

3.3.1 Incubation period:

The experiment was conducted under pot condition to observe the incubation period of the different isolates of *R. solani* inoculated on rice cultivar Swarna. The data were recorded after 12 h of inoculation.

3.3.2 Lesion height:

The lesion height was recorded 21 days after inoculation of different isolates of *R. solani* on the rice cultivar.

3.3.3 Plant height:

The plant height was recorded 75 days after transplanting (DAT).

3.3.4 Relative Lesion Height:

The Relative Lesion Height (RLH) was recorded 21 days after inoculation (DAI) of different isolates of *R. solani* on the rice cultivar. The relative lesion height (cm) in each tiller was calculated by using the formula given by Sharma *et al.* (2013):

$$RLH = \text{Maximum height at which lesion appear} / \text{Plant height} \times 100.$$

3.3.5 Disease severity:

Each plot was observed in number of infected tiller and each tiller was observed plant height and symptoms length of sheath blight of rice. The disease development was recorded and disease severity was calculated as standard evaluation system (SES), IRRI (2014). Observations were recorded 21 days after inoculation and graded as per 0-9 SES scale. The sheath blight scale was as follows:

Table 3.2: Standard Evaluation System (SES), IRRI (2014)

Disease rating scale	Response	Description
0	Immune	No Infection
1	Highly Resistant	Vertical spread of the lesions up to 20% of plant height
3	Resistant	Vertical spread of the lesions up to 21-30% of plant height
5	Moderately Resistant	Vertical spread of the lesions up to 31-45% of plant height
7	Susceptible	Vertical spread of the lesions up to 46-65% of plant height
9	Highly Susceptible	Vertical spread of the lesions up to 66-100% of plant height

The disease severity was calculated as:

$$\text{Disease severity} = \frac{\text{Total lesion length}}{\text{Total length of sheath}} \times 100$$

3.3.6 Percent Disease Index (PDI)

PDI was calculated 21 days after inoculation by the formula given by Wheeler.

$$\text{PDI} = \frac{(\text{Sum of all ratings} \times 100)}{(\text{Total no. of observations} \times \text{Maximum rating scale})}$$

3.3.7 Categorization of Aggressiveness:

Aggressiveness of all the isolates of *R. solani* was categorized into 4 classes *i.e.* Weakly Aggressive (WA), Moderately Aggressive (MA), Aggressive (A) and Highly Aggressive (HA). PDI% (2-21)=WA; PDI% (22-43)=MA; PDI% 44-65%=A; PDI% (66-87)=HA.

3.4 Cultural and morphological variation in *R. solani* isolates of different rice growing areas of Chhattisgarh:

3.4.1 Determination of cultural and morphological variability

Cultural and morphological variation was determined by analyzing colour, growth pattern, and growth rate in the colony. This experiment was conducted under *in vitro* condition in completely randomized design (CRD) with five

replications during kharif 2016. For each replication, three plates were maintained. With the help of Munsel's Soil Color Map (Munsell Color Company, Inc. 1954), the color of the colony was calculated. Visual observation documented growth pattern based on growth of the aerial hyphae. Growing isolate's growth rate was measured, using plastic scale at 24 h, 48 h, 72 h and 96 h intervals. The systems proposed by Burpee *et al.* (1980) were followed for the categorization of colony and sclerotial characteristics. Cultural and morphological parameters of each isolate like colony colour, sclerotial colour, size and formation pattern was recorded after inoculation of *R. solani* on to the sterilized PDA in 90 mm Petri plates incubated at 28 ± 2 °C in B.O.D incubator after 15 days (Panja *et al.*, 2011). Single sclerotial cultures of all the isolates were cultured separately on PDA and master cultures of these isolates were maintained on PDA slants in test tubes at 10 ± 2 °C (Bolkan and Riberiro, 1985). The mycelial growth rate, however, was recorded after every 24 hours interval till the last Petri plate was completely colonized (96 hours). Five replications were maintained for each isolate.

3.4.2 Determination of Sclerotial characteristics

Sclerotial characteristics viz, colour, texture, number, size, time taken for initiation of sclerotia formation, pattern of production (central, peripheral and scattered) and location (Aerial-Sclerotia formed, on the aerial mycelium; Surface-Sclerotia formed on the surface mycelium; Embedded –Sclerotia formed on the substrate) of sclerotia were recorded. The diameter of the sclerotia was measured with the help of randomly harvested 20 sclerotia with the help of Digital Vernier Callipers (Mitutoyo Corp made in Japan). Sclerotia forming isolates were categorized as poor, 1-10 fair, 11-20 moderate, 21-40 good, 41- 60 very good and >60 as excellent. Single sclerotial cultures of all the isolates were cultured separately on PDA and master cultures of these isolates were maintained on PDA slants in test tubes at 10 ± 2 °C (Bolkan and Riberiro, 1985).

Integration of technologies to manage sheath blight of rice:

3.5 Screening of native isolates of *Trichoderma* spp and *Pseudomonas* fluorescence against *Rhizoctonia solani* under *in vitro*:

3.5.1 Production and inhibitory effect of volatile compounds of *Trichoderma* sp.:

Production and inhibitory effect of volatile compounds of *Trichoderma* isolates were tested against the *Rhizoctonia solani* by following the procedure of Dennis and Webster (1971b). *Trichoderma* isolates were isolated from various places of Rajnandgaon, Raipur and Durg district. Bottom of Petri plate containing *R. solani* culture disc were inoculated on PDA was inverted atop on the bottom of plate containing *Trichoderma* isolate culture disc on PDA. The assembly was sealed with cello tape. Control plate have *R. solani* in both, lower and upper plates. This experiment was conducted under *in vitro* condition in completely randomized design (CRD) with three replications during kharif 2016. For each replication, five plates were maintained. All the plates were incubated at 28 ± 2 °C in BOD incubator. Mycelial growth and number of sclerotia of *Rhizoctonia solani* was recorded seven days after inoculation.

3.5.1.1 Mycoparasitism of *Trichoderma* spp:

The antagonistic potential of the *Trichoderma* isolates against *Rhizoctonia solani* was tested by dual culture technique (Dennis and Webster, 1971c). Twenty milliliter of PDA was poured into sterile petri plates. Fungal antagonists were evaluated by inoculating the pathogen at one side of the petri plate and the antagonist inoculated at exactly opposite side of the same plate by leaving 3 to 4 cm gap. One control was maintained where in only test fungus was grown. Three replicated petri plates were maintained for each treatment. The plates were incubated at 28 ± 2 °C for 96 hours. (Rajput and Zacharia, 2017). The mycelial growth of the pathogen and antagonist in dual culture and control plates was measured seven days after inoculation.

3.5.1.2 Isolation of *Trichoderma harzianum*:

The soil samples randomly collected from rhizosphere soil of rice crop from farmer's fields at Raipur, Durg and Rajnandgaon districts. Ten gram of soil collected from each samples used for isolation of the *Trichoderma harzianum* following the serial dilutions and pour plate method.

3.5.1.3 Preparation of the serial dilutions for isolation:

Rhizosphere soil (10 g) was suspended in Erlenmeyer flask with 90 ml sterile distilled water. Suspension on vortex shaker was shaken for 10 minutes. One ml of the suspension from the first dilutions (10^{-1}) was transferred aseptically to a culture tube with 9 ml of sterile water, labelled as (10^{-2}) and the initial suspension was diluted to 100 times. This procedure was repeated till the original sample was diluted to 10^{-8} time (Mew and Rosales, 1986). For *Trichoderma harzianum*, sufficient dilutions in quantity of (1 ml) from the sample were put on Potato Dextrose Agar media to isolate single colonies by pour plate method.

3.5.1.4 Pour plate method

One ml of soil suspension was applied aseptically from aliquot dilutions (10^{-1} to 10^{-8}). For each petriplate twenty ml of sterilized, melted, and cooled medium were added and poured. For 24 hours, the petriplates were incubated at $28 \pm 2^\circ\text{C}$. Established individual colonies were marked and analyzed separately. For further purification and isolation the individual colonies were picked up and moved onto the surface of solidified petriplates. For 24 hours, the plates were incubated at $28^\circ\text{C} \pm 2^\circ\text{C}$. The pure cultures were stored in refrigerator at 4°C .

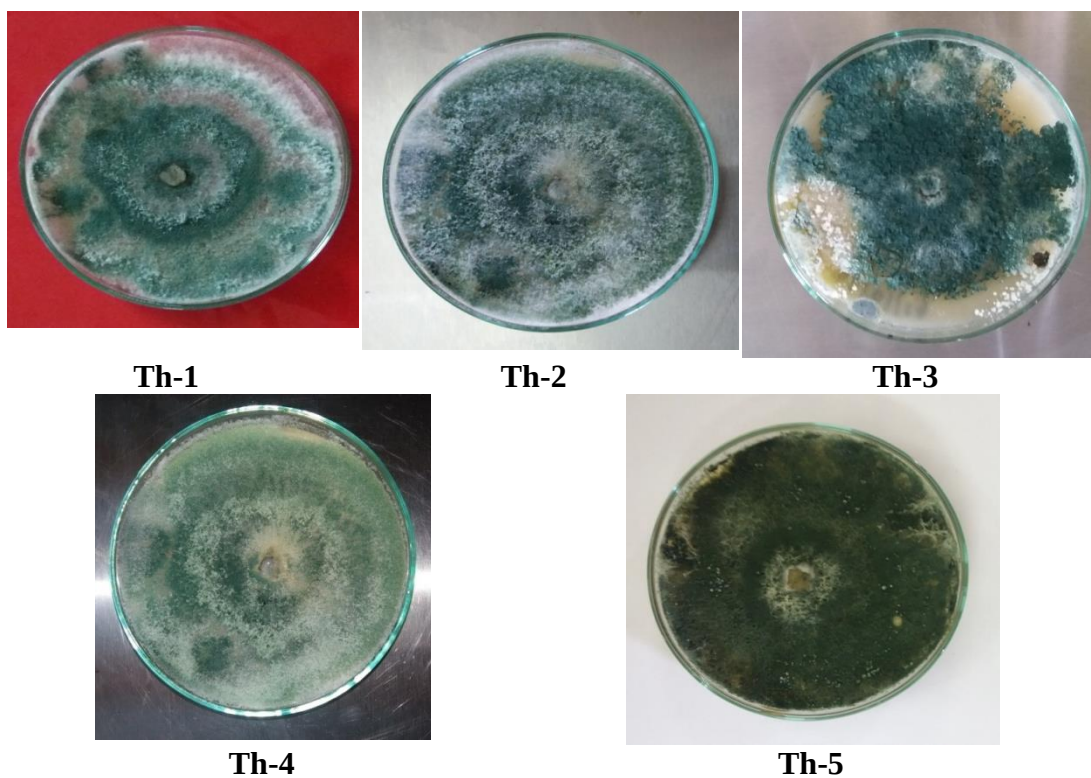


Fig.3.8: *Trichoderma* isolates collected from different locations of Chhattisgarh

3.5.2 Production and inhibitory effect of volatile compounds of *Pseudomonas* spp.:

Production and inhibitory effect of volatile compounds of *Pseudomonas* isolates were tested against the *Rhizoctonia solani*. This experiment was performed in complete randomized design (CRD) under *in vitro*, with three replications during the kharif 2016. Five plates were taken for each replication. All the plates had been incubated in BOD incubator at $28 \pm 20^\circ\text{C}$. Seven days after inoculation, mycelial growth and number of sclerotia of *Rhizoctonia solani* were recorded.

3.5.2.1 Antagonism of *Pseudomonas fluorescens*:

The antagonistic potential of the *Pseudomonas fluorescens* isolates against *Rhizoctonia solani* was tested by dual culture technique. 20ml of sterile PDA medium was poured into petridishes under aseptic conditions and allowed to solidify. After solidification, 9mm culture disc obtained from the periphery of 10 day old culture of *R. solani* was inoculated 1.5 cm away from the edge of the petridish. Similarly, 2 day old bacterial antagonists was streaked (1cm long) at equidistance just opposite to the pathogenic culture. The control plates were inoculated by opposing the two discs of culture of *R. solani*. Three replicated petri plates were maintained for each treatment. The plates were incubated at $28 \pm 2^\circ\text{C}$. The growth of the pathogen and antagonist in dual culture and control plates was measured seven days after inoculation (Dannis and Webster, 1971). The per cent inhibition of mycelial growth was calculated by the following formula (Vincent, 1927):

$$\text{Per cent inhibition (I)} = \frac{C - T}{C} \times 100$$

Where,

I is the Inhibition per cent,

C is the radial growth in control

T is the radial growth in Treatment.

3.5.2.2 Isolation of *Pseudomonas fluorescens*:

The soil samples randomly collected from rhizosphere soil of rice crop from farmers fields at Raipur, Durg and Rajnandgaon districts. Ten gram of soil collected from each samples used for isolation of the *Pseudomonas fluorescens* following the serial dilutions and pour plate method.

3.5.2.3 Preparation of the serial dilutions for isolation:

Rhizosphere soil (10g) was suspended in 90 ml sterile distilled water in Erlenmeyer flask. The suspension was shaken for 10 minutes on vortex shaker. One ml of the suspension from the first dilutions (10^{-1}) was aseptically transferred to a culture tube having 9 ml of sterile water, marked as (10^{-2}) and thus diluting the original suspension to 100 times. This procedure was repeated till the original sample was diluted to 10^{-8} time (Mew and Rosales, 1986). Appropriate dilutions in quantity of (1 ml) from the sample were placed on Kings B medium (KBM) for *Pseudomonas fluorescens* to isolate single colonies by pour plate method.

3.5.2.4 The medium

King's B medium, a selective one (Kings *et al.*, 1954) was used for the isolation of *Pseudomonas fluorescens*. The composition of the medium was as follows:

Ingredients	Quantity
Protease peptone	20.0 g
Potassium sulphate	1.50 g
Magnesium sulphate	1.50 g
Glycerol	8.00 g
Agar-Agar	20.00 g
Cyclohexamide	75.00 g
Novobiocin	45.00 g
Penicillin	75.00 g
Distilled water	1000.00 g

All three antibiotics namely cyclohexamide, novobiocin and penicillin were dissolved in 3 ml of 90 per cent ethanol and added after autoclaving when medium was cooled to 45°C.

3.5.2.5 Pour plate method

One ml of soil suspension from aliquot dilutions (10^{-1} to 10^{-8}) were aseptically added. Twenty ml sterilized, melted and cooled medium was added and poured in each petriplate. The petriplates were incubated at $28 \pm 2^\circ\text{C}$ for 24 hours. The separate individual colonies with yellow-green and blue white pigments developed were marked and examined under UV light. The individual colonies were picked up with sterilized loop and transferred on to the surface of solidified KMB petriplates by streaking to make a series of parallel, non-overlapping streaks, for further purification and single colony isolation. The plates were incubated at

28°C $\pm$ 2°C for 24 hours. The single colonies developed separately at the last tip of the streaks were transferred to KMB slants to serve as pure culture and designated. The pure cultures were stored in refrigerator at 4°C.

3.6 Evaluation of ITK techniques viz. application of panchgavya and plant extracts against *R. solani* under *in vitro*:

In vitro, Panchgavya and leaf extract of different plants were evaluated for their antifungal activity against *Rhizoctonia solani*.

3.6.1 Comparative evaluation of plant extracts against *R. solani* under *in vitro* extrected in cold water, hot water and acetone

The fresh leaves of four plants namely, Neem (*Azactiracta indica*), Garlic (*Allium sativum*), Dhatura (*Dhatura stramonium*) and Lemmon grass (*Cymbopogan flexousus*) were collected. The selected fresh leaves of healthy plants were washed thoroughly with clean water and dried. About 10 g of dried plant leaves were grind using pestle and mortar by adding same proportion 10 ml of sterilized distilled water. The plant extract thus obtained by filtered through muslin cloth and was diluted by adding sterilized distilled water to get 10 per cent concentration and were thoroughly mixed in the melted Potato Dextros Agar medium.

3.6.1.1 Cold water:

Plant leaves were washed thoroughly with distilled water and crushed individually in a pastle and mortar in 1:1 ratio of distilled water. The extract was passed through a double layer of muslin cloth and then through the Whatman's filter paper No.1. This filtrate was considered as stock solution.

3.6.1.2 Hot water:

Every plant species extract was prepared by taking leaf tissues and distilled water in 1:1 ratio (w / v), boiled in water bath for 30 minutes, and extracted material was filtered through double-layer muslin cloth, and then filtrate was passed through Whatman's filter paper No.1. This filtrate was considered solution for stock (Salam, 2007).

3.6.1.3 Chemical :

Fresh leaves of plant species were washed thoroughly with distilled water and crushed in pastle and mortar with Acetone individually in 1:1 ratio (w/v).

Extract was passed through a double layer muslin cloth and then through Whatman's filter paper No.1. This filtrate was considered as stock solution.

The each plant extracts were mixed aseptically in melted PDA with 10% concentrations and then poured in sterilized petri plates. Sterile distilled water mixed in same dilutions in PDA was served as control. This experiment was conducted under *in vitro* condition in completely randomized design (CRD) with three replications during kharif 2016. For each replication, five plates were maintained. Each petri plate was inoculated with 48-72 hrs old sclerotia of *Rhizoctonia solani*. The inoculated plates were incubated at $28^{\circ}\text{C} \pm 2^{\circ}\text{C}$. The mycelial growth and sclerotial formation were recorded seven days after incubation. The percent inhibition of mycelia growth was calculated as per the following formula described by Vincent (1947).

$$\text{Inhibition (\%)} = \frac{C - T}{C} \times 100$$

Where,

C = Diameter of fungus colony (mm) in control plate,

T = Diameter of fungus colony (mm) in treated plate.

Efficacy of medicinal plant extracts extracted in various solvents against *R. solani* including Neem based formation was reported by various workers (Naidu and John, 1981; Ansari, 1995; Shivpuri *et al.* 1997; Dubey, 1998; Kandhari and Singh, 2000 and Reddy and Sudhakar, 2002).

3.6.2 Evaluation of panchagavya against *R. solani* under *in vitro*

The unique combination in appropriate quantity of five products of cow *i.e.* milk, curd, ghee, urine and fresh dung are used in the panchgavya. For making Panchgavya, thoroughly mix the required quantities of the ingredients (Cow dung = 1kg (fresh), Cow dung slurry = 4 kg, Cow urine = 3L, Cow milk = 2L (fresh), Curd = 2kg, Cow butter oil (ghee) = 1kg) and allow to ferment for 7 days with twice stirring per day (Ashlesha and Paul, 2014). The cow milk, curd and urine contains microorganisms, which are useful in many ways.

3.6.2.1 Cold water :

Panchgavya was prepared with cold water and passed through a double layer muslin cloth and then through Whatman's filter paper No.1. This filtrate was considered as stock solution.

3.6.2.2 Hot water :

Panchgavya was boiled in water bath for 30 minutes and filtered through double-layer muslin cloth, and then filtered through Whatman's filter paper No.1. This filtrate was known as a remedy for stocks.

3.6.2.3 Chemical :

Panchgavya was mixed with Acetone individually in 1:1 ratio (w/v). These solvent was passed through a double layer muslin cloth and then through Whatman's filter paper No.1. This filtrate was considered as stock solution.

The panchgavya was prepared by above methods was separately mixed aseptically in molten PDA to have final dilutions of 10% and then poured in sterilized petri plates. Sterile distilled water mixed in PDA was served as control. This experiment was conducted under *in vitro* condition in completely randomized design (CRD) with three replications during kharif 2016. For each replication, five plates were maintained. Each petri plate was inoculated with 48-72 hrs old sclerotia of *Rhizoctonia solani*. The inoculated plates were incubated at $28^{\circ}\text{C} \pm 2^{\circ}\text{C}$. The mycelial growth and sclerotial formation were recorded seven days after incubation. The percent inhibition of mycelia growth was calculated as per the following formula described by Vincent (1947).

Poisoned food technique (Sumangala and Patil, 2009) was employed to know the effect of leaf extracts and panchgavya against *R. solani*. Twenty ml of amended medium was poured in 90 mm sterilized petridishes and allowed to solidify. Mycelial disc of 5 mm from seven day old actively growing culture was inoculated at the centre of the petriplate and then incubated at $28 \pm 2^{\circ}\text{C}$ for 7 days. The medium mixed with equal amounts of purified sterilized water acted as control without any treatment (Rajput and Zacharia, 2017). For each drug, three replications were maintained and data reported at 96 hours after inoculation and measurement of inhibition per cent in mycelial development.

3.7 Impact of sheath blight on seedlings and plant vigour:

This trial was performed under both green house (pots) and field conditions. The treatments were healthy seeds (*i.e.* seed harvested from healthy plant panicle) and diseased seeds (*i.e.* seed harvested from plant panicles with a score of 7 to 9 diseases) in both test varieties (Swarna and Mahamaya).

3.7.1 Pot studies:

For each application, the 16 earthen pots of 12-inch height with 12-inch diameter were filled with 4 kg field soil and 100 seeds from each seed source of test varieties (Swarna and Mahamaya) were sown in each pot. A factorial CRD design had 4 treatments with 4 replications. This recorded the following observations:

3.7.1.1 Estimation of plant vigour index:

The germination percent was first recorded for each treatment / varieties. The growth of seedlings was measured at 30 days after sowing in terms of the seedling vigor index. They also measured the root and shoot length of individual seedlings. The shoot length was taken from ten randomly selected plants and measured from the shoot base to the uppermost tip of the leaf. To measure the root length first plant was carefully removed (when seedlings were 30 days of age, respectively), washed gently, completely spread and carefully put on clean transparent surface. The root length was measured from up to the longest tip. The seedling vigour index was calculated by using the formula described by Abdul Baki and Anderson (1973) :

Seedling vigour index = (mean root length + mean shoot length) × germination percent
Seedling vigour index in diseases seeds (T1) over healthy seeds (T2) were calculated.

3.7.2 Field studies:

There were 2 varieties (Swarna and Mahamaya), 4 treatments with 4 replications under field conditions in a factorial RBD. Twenty one day old seedlings of the Swarna and Mahamaya were separately transplanted in a plot size of $5 \times 2 \text{ m}^2$ with a spacing of 1m between replication to replication. Row to row and plant to plant spacing was $20 \times 15 \text{ cm}$. Fertilizer was applied @ N120: P50: K0 ha⁻¹. Fifty percent of N and total P were given as basal dose and remaining N applied in two split doses as top dressing at tillering and panicle initiation stage. The following observations were recorded:

3.7.2.1 Estimation of plant vigour index:

At first, the germination percent was recorded for each treatment/varieties. The germination percent was first recorded for each treatment / varieties. In terms

of the seedling vigor index, growth of seedlings was calculated at 30 days after sowing. Also measured the length of root and shoot of individual seedlings. The shoot length was taken from ten randomly selected plants and measured from the base of the shoot to the leaf's uppermost end. To measure the root length first plant was carefully removed (when seedlings were 30 days of age, respectively), washed gently, completely spread and carefully put on clean transparent surface. Root length was estimated up to the longest tip. The seedling vigour index was calculated by using the formula described by Abdul Baki and Anderson (1973).

Seedling vigour index = (mean root length + mean shoot length) × germination percent
Seedling vigor index in diseases seeds (T1) over healthy seeds (T2) were calculated.

3.7.3 Statistical analysis

The experimental data were analyzed using Factorial RBD and RBD designs wherever necessary. The skeleton of ANOVA for RBD is given below:-

Source of Variation	d.f.	S.S	M.S.	F.ratio
Replication	r-1	SSr	Vr	Vr/Ve
Treatments	n-1	SSt	Vt	Vt/Ve
Error	(n-1) (r-1)	SSe	Ve	
Total	(nr-1)			

Where,

r = Number of replications

n = number of treatments

nr = Total number of observation.

The skeleton of ANOVA for Factorial RBD is given below:-

Source of Variation	d.f.	S.S	M.S.	F.ratio
Replication	r-1	SSr	Vr	Vr/Ve
Treatments	ab-1	SSt	Vt	Vt/Ve
Factor a	a-1	SSa	Va	Va/Ve
Factor b	b-1	SSb	Vb	Vb/Ve
Interaction (a x b)	(a-1)(b-1)	SSab	Vab	Vab/Ve
Error	(r-1)(ab-1)	SSe	Ve	
Total	Rab-1			

Where,

r = Number of replications

a = Number of factor a

b = Number of factor b

ab = Number of treatments

rab = Total number of experimental units

3.8 Evaluation of antagonists and the effectiveness of application methods under pot conditions:

Three potential *Trichoderma* species were evaluated against sheath blight disease of paddy under pot conditions. The *Trichoderma* spp. Obtained/ isolated from three districts Rajnandgaon, Raipur and Durg of Chhattisgarh were compared for their efficacy with check fungicide hexaconazole for foliar sprays. This experiment was conducted under pot condition in completely randomized design (CRD) with three replications during kharif 2016 and 2017. The soil was filled in plastic pots of 30 cm. diameter. The soil in pots were fertilized with requisite quantities of NPK. 21 days old seedlings of susceptible rice variety swarna were transplanted in each pot and two hills/pot were maintained. Inoculation of sheath blight pathogen was done in two treatments *i.e.* at 30 days after transplanting and at 60 days after transplanting. Inoculation of susceptible rice plant was done by placing stem bits covered with mycelium and sclerotia of the pathogen at the centre of each hill above water level (Sudhakar, 1996). Rice stem bits of 2 cm were inoculated aseptically and allowed to overgrow with the pathogen. The inoculation of pathogen and foliar spray of bioagent was done at 30 DAT and 60 DAT. Among the three potential *Trichoderma* spp., highly effective species against sheath blight pathogen was evaluated. The disease severity was recorded 14 days after inoculation. Spores of bioagent were harvested from 10 day old culture grown on PDA with the help of a camel hair brush and the spores were then suspended in distilled water and the concentration was measured with a Haemocytometer to get a final count of about 2×10^9 spores/ml. The first spray of bioagent @ 2×10^9 spores/ml was given at the time of pathogen inoculation (30 DAT) until run-off occurred. Second spray was given at 30 days interval (60 DAT). At the time of second spray, second treatment (60 DAT) was done. All the inoculated plants were covered with polythene bags to maintain humidity for one week.

3.8.1 Disease Scoring:

The treatments imposed are as follows:

T1: Foliar application of potential *Trichoderma* sp. from Distt. Rajnandgaon after inoculation of pathogen *i.e.*, 30 DAT,

- T2: Foliar application of potential *Trichoderma* sp. from Distt. Rajnandgaonafter inoculation of pathogen *i.e.*, 60 DAT,
- T3: Foliar application of potential *Trichoderma* sp. from Distt. Raipurafter inoculation of pathogen *i.e.*, 30 DAT,
- T4: Foliar application of potential *Trichoderma* sp. from Distt. Raipurafter inoculation of pathogen *i.e.*, 60 DAT,
- T5: Foliar application of potential *Trichoderma* sp. from Distt. Durgafter inoculation of pathogen *i.e.*, 30 DAT,
- T6: Foliar application of potential *Trichoderma* sp. from Distt. Durgafter inoculation of pathogen *i.e.*, 60 DAT,
- T7: Foliar application of Hexaconazole @ 0.2% after inoculation of pathogen *i.e.*, 30 DAT,
- T8: Foliar application of Hexaconazole @ 0.2% after inoculation of pathogen *i.e.*, 60 DAT,
- T9: Inoculated control at 30 DAT,
- T10: Inoculated control at 60 DAT.

The number of days required for the development of first lesions was recorded after imposing the treatments. The number of infected tillers and the number of tillers in the hill were counted and the disease incidence percent was calculated. After harvesting, the grain yield was also recorded.

$$\text{Disease incidence \%} = \frac{\text{No. of infected tillers}}{\text{Total no. of tillers /hill}} \times 100$$

$$\text{Percent reduction in disease incidence} = \frac{\text{No. of infected tillers in control} - \text{No. of infected tillers in treatment}}{\text{No. of infected tillers in control}} \times 100$$

The observations on disease severity were recorded and analyze. All plants from each pot were harvested and threshed separately from which total yield per plant were recorded to know any inhibitory or stimulatory effect of the imposed treatments (Khan and Sinha, 2007). Wherever necessary the data were statistically analyzed (Gomez and Gomez, 1984). Three replications were maintained and following the CRD (Completely Randomized Design) for pot culture studies and population assessment.

3.9 Evaluation of *Trichoderma* rich organic amendments on disease development:

This study was conducted in pot condition with three replications of each treatment in CRD during kharif 2016 and 2017. The treatments were in all possible combination as follows: *Rhizoctonia solani* + Neem cake, *Rhizoctonia solani* + Mustard cake, *Rhizoctonia solani* + Karanj cake, *Rhizoctonia solani* + FYM, *Rhizoctonia solani* + Karanj cake + *T. harzianum*, *Rhizoctonia solani* + Neem cake + *T. harzianum*, *Rhizoctonia solani* + Mustard cake + *T. harzianum*, *Rhizoctonia solani* + FYM + *T. harzianum*, *Rhizoctonia solani* + *T. harzianum* and *Rhizoctonia solani* alone (control).

Twenty-one days old rice seedlings of test variety Swarna were transplanted in the previously amended earthen pots of 9" height and 8.5" diameter in size @ 4 seedlings per pot. Inoculum of *R. solani* was added to the pot soil @1% (w/w) and organic amendments @ 3% (w/w). Pot soil containing inoculum and organic amendments incubated for 7 days in glasshouse condition. Ten days old culture of *Trichoderma harzianum*, multiplied on PDA broth was added to the pot soil @ 0.5 % (v/w) as per treatment schedule. Normal agronomical practices were followed during the course of study. Observations were recorded for number of cfu/g of rhizosphere soil sample for *T. harzianum* spores (Sharma and Dureja, 2004) and % disease severity for sheath blight between maximum tillering and panicle initiation stage. Hundred seeds of susceptible variety 'swarna' were sown in a pot immediately after the addition of *T. harzianum* and in other treatments as well. Plant vigour index (Abdul-Baki and Anderson, 1973) was recorded.

3.10 Evaluation of disease management practices combined with different doses of 'N' fertilizer:

This experiment was conducted in Randomized Block Design during 2016 and 2017 under field condition with three replications of kharif. Twenty-one days test variety (Swarna) seedlings were transplanted into plots of 2x2 m² with a plot spacing of 1 m to plot and replication to replication. The spacing between plant to plant was 15 cm and row to row was 15 cm. Recommended dose of

fertilizer was applied @ $N_{120}P_{50}K_0$ /ha. Total P was given as first basal dose. There was 8 treatments including control with 3 replication were mentioned below:

- T1 :- Susceptible variety + $2/3^{rd}$ of Recommended dose of 'N' Fertilizer.
- T2 :- Susceptible variety + 100% Recommended dose of 'N' Fertilizer + A single spray of an effective fungicide like Hexaconazole (Contaf).
- T3 :- Susceptible variety + $2/3^{rd}$ of Recommended Dose of 'N' Fertilizer + A single spray of an effective fungicide.
- T4 :- Susceptible variety + 100% Recommended Dose of 'N' Fertilizer + Need based number of sprays of an effective Fungicide.
- T5 :- Susceptible variety + $2/3^{rd}$ of Recommended dose of 'N' Fertilizer + Need based number of sprays of an effective Fungicide.
- T6 :- Susceptible variety + $1/2$ of Recommended Dose of 'N' Fertilizer + A single spray of an effective Fungicide.
- T7 :- Susceptible variety + $1/2$ of Recommended Dose of 'N' Fertilizer + Need based number of sprays of an effective Fungicide.
- T8 :- Susceptible variety + 100% Recommended Dose of 'N' Fertilizer (Control).

At maximum tillering stage, plants of each plot were inoculated with *R. solani* inoculum profusely grown on rice stem bits for inoculation two hills were selected in each lines in each plot. In each treatments the recommended dose of N fertilizer were given in three split doses. First split dose of 'N' fertilizer was applied at the first appearance of the disease symptoms. Second split of N fertilizer were applied on 10th day after the first split and third split was also applied on 10th day after the second split of N fertilizer. To test the efficacy of disease management practices combined with different doses of N fertilizer a single spray of Hexaconazole 5 Sc (Contaf) was done in T3, T4 and T7 treatment at 15 DAI and total no. of three sprays of Hexaconazole 5 Sc (Contaf) were done in T5, T6 and T8 treated at 15, 30 and 40 DAI.

Observations for the disease development difference were taken at every 10th day interval of each spray. At random, tillers in each plot were assessed for disease severity by measuring the total lesion length and total sheath length. Grain

yield were also recorded and expressed in Kg/plot at 14% moisture. Disease severity (%) was calculated as:

$$\text{Disease severity (\%)} = \frac{\text{Total lesion length}}{\text{Total sheath length}} \times 100$$

Percent increase or decrease in disease severity over control was calculated as per the formula described by Vincent (1947):

$$I \text{ or } D = C - T / C \times 100$$

Where,

I or D = % increase or decrease over control

C = % disease severity in control

T = % disease severity in treatment

To assess effectiveness of stimulants, conventional and non conventional chemicals imparts resistance against sheath blight

3.11 Evaluation of chemical stimulants in imparting systemic resistance for the management of sheath blight disease of rice:

The application of systemic resistance inducing chemicals would be suitable alternative strategy to improve the sheath blight disease management in paddy (Usharani *et al*, 2013 and Toal and Jones, 1999). Defense signaling hormones such as salicylic acid, jasmonic acid, rose bengal and oxallic acid play important roles in activation of plant defense responses (Taheri & Monica, 2007).

The solutions of the Salicylic acid, Jasmonic acid, Rose Bengal and Oxallic acid were prepared in sterile distilled water by adding requisite quantities of chemicals viz. 25, 50, 100 and 250 µg/ml. This experiment was performed *in vitro* in complete randomized design in year 2016 and under pot condition in CRD design during kharif 2016 and 2017 with four replications. To investigate the effect of the chemicals on growth of *R. solani in vitro*, poisoned food technique (Grover and Moore, 1962) was followed with four replications and the development of sheath blight lesion *in vivo*, the standard method given by Bhattacharya and Roy (1998) was followed on a susceptible rice cultivar swarna. Seeds were surface sterilized by 70 % alcohol (1 min), followed by 0.1 % HgCl₂ (2 min), rinsed three times in sterile distilled water and dried over night at room temperature in the laboratory and grown in autoclaved soil + sand in pots. After

sixty days of sowing, solution of each chemical was then thoroughly sprayed on the foliage of plants as per treatment schedule separate with the help of automizer. To prepare a concentration of 25µg/ml (25µg/ml means 0.0025mg/ml), micropipette used in test tube through 25µl chemical in pipette. Then dilute it with 975µl (making a total volume of 1ml) of the water. Similarly do for 50 µg/ml, pipette out 50 µl of the chemical and then dilute it with 950 µl of the water. For preparation of 100 µg/ml, pipette out 100 µl of the chemical and then dilute it with 900 µl of the water. Similarly for 250 µg/ml, pipette out 250 µl of the chemical and then dilute it with 750 µl of the water. The treatment continued until both the surface of entire leaf sheath covered with minute droplets of the solution. Rice plant sprayed with sterile distilled water served as control. Inoculation by insertion of sclerotia in the sheath after 48 hrs of chemical sprays was done (Usharani *et al.*, 2013). Taken observations for mycelial growth and sclerotial formation seven days after inoculation and incubation (*in vitro*) and per cent disease severity (*in vivo*) was recorded 21 days after spaying of chemicals.

3.12 Evaluation of micronutrients *i.e.* Silicon, Copper and Zinc applications for management of sheath blight disease on rice:

Application of micronutrients as fertilizer can play an important role in the management of various fungal and bacterial diseases. Therefore, the study was undertaken to manage the rice sheath blight disease of rice by application of the micro nutrients in soil under flooded conditions. In the present investigation, the nutrients *i.e.* Cu as Copper sulphate, Zn as Zinc sulphate and Silicon as Silicon dioxide (SiO₂) were mixed into pot soil in required quantity. The experiment was carried out *in vitro* and pot conditions in completely randomized design (CRD) with four replications during the kharif seasons 2016 and 2017.

Under the study the rice seeds were soaked in water for 24 h and dried for another 24 h at room temperature to hasten germination. 100 pre-germinated healthy seeds were planted into plastic seedling boxes (22.6cm x 18.6cm x 6.9 cm). Twelve-day seedlings were carefully uprooted from the nursery tray and three rice seedlings were transplanted into well-prepared experimental pots (35 cm in diameter and 38 cm in depth) containing 15 kg of paddy soil and placed under glasshouse conditions. Plants were regularly watered everyday and kept under

flooded conditions until the end of the experiment. All the pots were applied nitrogen (N), phosphorus (P) and potassium (K) fertilizers according to the recommended rate. Applications of Nitrogen fertilizers (150 kg N ha⁻¹) as urea split into 3 times at 15 days after planting (DAP) (25%), 35 DAP (30%) and 55 DAP (45%). Phosphorus (90 kg P₂O₅ ha⁻¹) as rock phosphate and Potassium (150 kg K₂O ha⁻¹) as murate of potash applied at basal and at panicle initiation stage at 55 DAP.

3.12.1 Application of silicon, copper and zinc nutrients:

Granular silica gel with a minimum SiO₂ content of 95% and particle size ranging from (0.6-2 mm), Cu source as copper sulphate (CuSO₄.5H₂O) with 99% purity and Zn source as zinc sulphate (ZnSO₄.7 H₂O) were used in this study. Silica gel, copper sulphate and zinc sulphate were applied to the soil prior to planting at the rates of 360g, 0.30 g, 0.45g per 15 kg soil respectively, as compared to the inoculated and un-inoculated (control) treatment without incorporation of these supplements. There were no modifications were made to the pots to allow the drainage and the rice plants were kept under flooded conditions till the end of the experiment.

3.12.2 Disease assessment and yield determination:

The rice seedlings in each treated pot were inoculated with the well prepared seven days inoculum of *R. solani* in rice stem bits at maximum tillering stage. Diseased rice plants of pots were evaluated on 21 days of inoculation for sheath blight development and the disease intensity was determined by the Highest Relative Lesion Length (HRLH percent) using the scale of Standard Evaluation System for rice by International Rice Research Institute.

$$\text{Highest Relative Lesion Height (\%)} = \frac{(\text{Vertical height of uppermost lesion on sheath or stem})}{(\text{Plant height})} \times 100$$

At the same time, disease severity was recorded in SES scale IRRI (2014) and PDI were calculated with above formula. At maturity stage, grain yield was also recorded.

3.13 Efficacy of new fungicidal molecules for the management of sheath blight of rice:

The experiment was conducted in randomized block design under *in vivo* (field condition with four replications) and completely randomized design under *in vitro* with three replicaitons.

***In-vitro* efficacy of new molecules against *Rhizoctonia solani* :**

The poisoned food technique was employed for the evaluation of new fungicides *in vitro* for their inhibitory action against *R. solani*. Under the study, Six fungicides with different doses taken were Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @ 0.75 ml/lit, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @ 1.0 ml/lit, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @ 1.25 ml/lit, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @ 2.5 ml/lit, Azoxystrobin 23% SC (Amistar 25% SC) @ 1.0 ml/lit., Difenconazole 25% EC (Score 25% EC) @ 0.5 ml/lit., Kitazin 48% EC (Kitazin 48% EC) @ 2.0 ml/lit., Iprodione 25% + Carbendazim 25% WP (Quintal) @ 1.0 g/lit., Hexaconazole 5% EC (Contaf 5% EC) @ 2.0 ml/lit. and Control (Untreated). Each fungicide was dispensed and thoroughly mixed with potato dextrose agar medium in requisite quantity before pouring. Approximately 20 ml of PDA medium was poured in each petri plate for each fungicidal treatment. The PDA plates without fungicides were served as control. After solidification of the medium each petri dish was inoculated with 5 mm disc of 7 days old culture of *R. solani*. The plates were incubated at 28 ± 2 °C. Three replications were kept for each treatment along with untreated (control) treatment. The observation for mycelial growth were recorded at every 3 days intervals up to 30 days. The percent reduction of mycelial growth was calculated by using the above procedure.

Field studies:

The present investigation was undertaken to asses the efficacy of a new combination fungicide having Azoxystrobin 18.2% and Difenconazole 11.4% SC was tested in different doses of the new fungicides *i.e.* Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @ 0.75 ml/lit of water, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @ 1.0

ml/lit, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @ 1.25 ml/lit, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @ 2.5 ml/lit, Azoxystrobin 23% SC (Amistar 25% SC) @ 1.0 ml/lit., Difenconazole 25% EC (Score 25% EC)@ 0.5 ml/lit., Kitazin 48% EC (Kitazin 48% EC) @ 2.0 ml/lit., Iprodione 25% + Carbendazim 25% WP (Quintal)@ 1.0 g/lit., Hexaconazole 5% EC (Contaf 5% EC) @ 2.0 ml/lit. and Control (Untreated) under field conditions for the management of sheath blight disease and increases the yield of rice.



Fig.3.9: New molecules tested for sheath blight disease management

The trials were laid in a Randomized Block Design with 10 treatments and four replications. Twenty one days old seedlings of the test variety (Swarna) was transplanted in 5 x 2 Sq meter plots with a spacing of one meter between plot to plot and replication to replication. The fertilizer applied at the rate of N₁₂₀ P₅₀ K₀ kg/ha. There were 10 plots for 10 treatments including control (without any treatment) in each replication. At maximum tillering stage, per plot 25 hills were inoculated with 200g of seven days old *Rhizoctonia solani* inoculum profusely grown on rice stem bits. The mycelial mass and sclerotia developed on these stem bits were used directly by dropping in between the hills. The first fungicidal spray was applied at first appearance of symptom. The second spray was applied after 10th day from 1st spray. The data on the disease severity and per cent disease index were recorded. The per cent disease severity was recorded from the data collected from 25 hills in each replication in each treatment at 21 day of inoculation as per the Standard Evaluation System for rice (IRRI, 1996). The

disease severity data was transformed into arc sine values before statistical analysis. For measuring sheath blight disease, 0-9 disease rating scale developed by International Rice Research Institute (IRRI, 1996) was used. Disease severity was calculated as:

$$\text{Disease severity \%} = \frac{\text{Total lesion length}}{\text{Total sheath length}} \times 100$$

Further, the scored data was converted into per cent disease index (PDI) using formula given below:

$$\text{PDI} = \frac{(\text{Sum of the scores})}{(\text{Number of observation} \times \text{Highest number in rating scale})} \times 100$$

The grain yield was recorded from each gross plot at maturity of the crop and expressed as kg/ha.

Screening of germplasm lines/varieties against sheath blight of rice

3.14 Identification of the slow rice disease developing entries/screening of different entries against sheath blight resistance:

The experiment of identification of the resistant entries was conducted under field condition in bunded rice field under irrigated conditions during kharif 2016 and kharif 2017. One set of nineteen rice varieties were used for the identification of slow disease developing varieties against sheath blight disease. Nineteen rice varieties/ entries were transplanted in two rows and in one row ten plants were maintained. IET No.RP-Patho-23, IET No. 25916, IET No. 22240, IET No. 545191, IET No. 463893, IET No. 22017, IET No. R-2138-1037-1-415-1, IET No. 24367, IET No. 24451, IET No. 25033, IET No. 25520, IET No. 26351, IET No. 25991, IET No. 26103, IET No. 25979, IET No. 25924, IET No. 26267, IET No. 26394 and Rasi were grown in I.G.K.V., Raipur research field.

The experiment of screening of different entries/varieties against sheath blight resistance was conducted under field condition in bunded rice field and under irrigated conditions during *Kharif* 2016 and *kharif* 2017. Twenty four rice varieties/ entries *i.e.*, IET No.R-2302-396-3-301-1, IET No.VL-31289, IET No. Nidhi, IET No.RP-Patho-4, IET No.RP-Patho-6, IET No.UPL R1-7, IET No.R-1675-1844-2-1257-1, IET No.R-2302-386-1-275-1, IET No.R-2302-387-1-277-1, IET No.R-2302-390-2-288-1, IET No.R-1909-112-1-86-1, IET No.R-2034-147-

1-186-1, IET No. Jaldoobi, IET No. R-RGY-SI-13, IET No. R-1670-3975-1-485-1, IET No. SUVT-122, IET No. SUVT-230, IET No. SUVT-353, IET No. SUVT-362, IET No. SUVT-412, IET No. Badshah bhog-2, IET No. Sarai phool and swarna were transplanted in two rows and in one row ten plants were maintained for the resistance screening in I.G.K.V., Raipur Research field.

To conduct above experiments twenty one day old seedlings of each entries were transplanted in 2 rows of 2 meter length. 10 plants were transplanted in each row. Row to row and plant to plant spacing was 20 × 15 cm. Fertilizer was applied @ N₁₂₀: P₅₀: K₀ ha⁻¹. Fifty percent of N and total P were given as basal dose and remaining N applied in two split doses as top dressing at tillering and panicle initiation stage. Artificial inoculation was done at the maximum rice tillering stage by using mycelial block of 5-day-old culture of *R. solani*. Five plants were inoculated in each row. The disease development was recorded in each variety and percent disease severity was calculated as Standard Evaluation System (SES), IRRI (2014). Observations were recorded 30 days after inoculation and graded as per 0-9 SES scale. The sheath blight scale was as follows:

Table3.3: Standard Evaluation System (SES), IRRI (2014)

Disease rating scale	Response	Description
0	Immune	No Infection
1	Highly Resistant	Vertical spread of the lesions up to 20% of plant height
3	Resistant	Vertical spread of the lesions up to 21-30% of plant height
5	Moderately Resistant	Vertical spread of the lesions up to 31-45% of plant height
7	Susceptible	Vertical spread of the lesions up to 46-65% of plant height
9	Highly Susceptible	Vertical spread of the lesions up to 66-100% of plant height

The disease development was recorded in each variety and Percent Disease severity and Percent Disease Index was calculated as:

$$\text{Disease severity \%} = \frac{\text{Total lesion length}}{\text{Total length of sheath}} \times 100$$

CHAPTER-IV

RESULTS AND DISCUSSION

This chapter deals with the experimental results obtained during the course of investigation on- “**Studies on variability of *Rhizoctonia solani* Kuhn and management of Sheath Blight of Rice.**” The results were statistically analyzed as required by using the analysis of variance technique and the findings are given below. The results of the experiments have been thoroughly discussed and corroborated in the light of research work done by various workers earlier:

Isolation, purification, identification, pathogenicity test of causal agent and symptomatology of disease:

4.1 Symptoms, collection, isolation, purification and pathogenecity test of the sheath blight pathogen:

4.1.1 Survey

The extensive survey was done (presented in table 4.1) and the diseased samples were collected from 58 farmer fields from 41 locations of (Mohad, Jungleswer, Somni, Mokhala, Dewada, Kaketara, Ratepayali, Ghumka, Odiya, Haldi, Chhichhanpahri, Tolagaon, Kanhe, Dharmapur, Surgi, Mohbbhatta, Mahasamund, Saloni, Khadgaon, Sanesara, Gathala, Kumarda, Muretitola, Bhathasakri, Kutelikhurd, Jogidalli, Matri, Hirapur, Dhamtari, Surajpura, Nagdha, Singhola, Kirwai, Borsi, Pakhanjur, Narainpur, Lailunga, Jaspur, Korea, Utai and Pali) situated in fifteen districts *i.e.* Rajnandgaon, Bemetara, Mahasamund, Balod, Raipur, Dhamtari, Kabirdham, Gariyaband, Durg, Kanker, Narainpur, Raigarh, Jaspur, Korea, Korba of Chhattisgarh during kharif 2015-16 at maximum tillering stage of rice crop under natural conditions.

Table 4.1. : Survey and collection of *R. solani* isolates collected from different locations of Chhattisgarh in kharif year 2015-16 at maximum tillering stage of rice:

S.No	Village/ location	Block	District	Cropping pattern	Variety	Name of the Isolates	Pathogenic
1	Mohad	Rajnandgaon	Rajnandgaon	Rice-Wheat- Fellow	Swarna	RS1	+
2	Mohad	Rajnandgaon	Rajnandgaon	Rice-Fellow- Rice	Swarna	RS2	+
3	Mohad	Rajnandgaon	Rajnandgaon	Rice- Wheat-Rice	Swarna	RS3	+
4	Jungleswer	Rajnandgaon	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS4	+
5	Jungleswer	Rajnandgaon	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS5	+
6	Jungleswer	Rajnandgaon	Rajnandgaon	Rice-Wheat- Fellow	Swarna	RS6	+
7	Jungleswer	Rajnandgaon	Rajnandgaon	Rice-Fellow- Fellow	Mahamaya	RS7	+
8	Somni	Rajnandgaon	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS8	+
9	Mokhala	Rajnandgaon	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS9	+
10	Dewada	Rajnandgaon	Rajnandgaon	Rice-Gram- Fellow	Swarna	RS10	+
11	Kaketara	Rajnandgaon	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS11	+
12	Ratepayali	Dongergaon	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS12	+
13	Ghumka	Rajnandgaon	Rajnandgaon	Rice-Fellow- Rice	Swarna	RS13	+
14	Odiya	Chhuikhadan	Rajnandgaon	Rice-Gram- Fellow	Swarna	RS14	+
15	Odiya	Chhuikhadan	Rajnandgaon	Rice-Fellow- Rice	Swarna	RS15	+
16	Haldi	Rajnandgaon	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS16	+
17	Haldi	Rajnandgaon	Rajnandgaon	Rice-Gram- Fellow	Swarna	RS17	+
18	Haldi	Rajnandgaon	Rajnandgaon	Rice	Swarna	RS18	+
19	Haldi	Rajnandgaon	Rajnandgaon	Rice-Fellow- Rice	Swarna	RS19	+
20	Chhichhanpahari	Ambagarh-chowki	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS20	+
21	Tolagaon	Khairagarh	Rajnandgaon	Rice-Wheat- Fellow	Swarna	RS21	+
22	Kanhe	Ambagarh-chowki	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS22	+

S.No	Village/ location	Block	District	Cropping pattern	Variety	Name of the Isolates	Pathogenic
23	Dharmapur	Khairagarh	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS23	+
24	Surgi	Rajnandgaon	Rajnandgaon	Rice-Fellow- Rice	Swarna	RS24	+
25	Surgi	Rajnandgaon	Rajnandgaon	Rice-Wheat- Fellow	Swarna	RS25	+
26	Mohbhatta	Berla	Bemetara	Rice-Fellow- Fellow	Swarna	RS26	+
27	Mahasamund	Mahasamund	Mahasamund	Rice	Swarna	RS27	+
28	Saloni	Rajnandgaon	Rajnandgaon	Rice-Gram- Fellow	Swarna	RS28	+
29	Saloni	Rajnandgaon	Rajnandgaon	Rice-Fellow- Fellow	Mahamaya	RS29	+
30	Saloni	Rajnandgaon	Rajnandgaon	Rice-Fellow- Rice	Swarna	RS30	+
31	Khadgaon	Manpur	Rajnandgaon	Rice-Fellow- Fellow	Mahamaya	RS31	+
32	Khadgaon	Manpur	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS32	+
33	Sanesara	Dongergaon	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS 33	+
34	Gathala	Rajnandgaon	Rajnandgaon	Rice-Wheat- Fellow	Mahamaya	RS 34	+
35	Kumarda	Dongergaon	Rajnandgaon	Rice-Gram- Fellow	Swarna	RS 35	+
36	Muretitola	Ambagarh-chowki	Rajnandgaon	Rice-Fellow- Rice	Swarna	RS 36	+
37	Bhathasakri	Saja	Bemetara	Rice-Fellow- Fellow	Swarna	RS 37	+
38	Kutelikhurd	Chhuikhadan	Rajnandgaon	Rice-Fellow- Fellow	Swarna	RS 38	+
39	Jogidalli	Rajnandgaon	Rajnandgaon	Rice-Fellow- Rice	Swarna	RS 39	+
40	Matri	Dondilohara	Balod	Rice-Fellow- Fellow	Swarna	RS 40	+
41	Hirapur	Dharsiwa	Raipur	Rice-Fellow- Fellow	Swarna	RS 41	+
42	Dhamtari	Dhamtari	Dhamtari	Rice-Fellow- Rice	Swarna	RS 42	+
43	Surajpura	Kawardha	Kabirdham	Rice-Fellow- Fellow	Swarna	RS 43	+
44	Nagdha	Nawagarh	Bemetara	Rice-Fellow- Fellow	Swarna	RS 44	+
45	Singhola	Khairagarh	Rajnandgaon	Rice-Gram- Fellow	Swarna	RS 45	+
46	Singhola	Khairagarh	Rajnandgaon	Rice-Fellow- Rice	Mahamaya	RS 46	+

S.No	Village/ location	Block	District	Cropping pattern	Variety	Name of the Isolates	Pathogenic
47	Singhola	Khairagarh	Rajnandgaon	Rice-Wheat- Fellow	Swarna	RS 47	+
48	Kirwai	Fingeshwer	Gariyaband	Rice-Fellow- Fellow	Swarna	RS 48	+
49	Borsi	Durg	Durg	Rice-Wheat- Fellow	Swarna	RS 49	+
50	Pakhanjur	Kanker	Kanker	Rice-gram- Fellow	Swarna	RS 50	+
51	Narainpur	Narainpur	Narainpur	Rice-Fellow- Fellow	Swarna	RS 51	+
52	Lailunga	Raigarh	Raigarh	Rice-Fellow- Fellow	Swarna	RS 52	+
53	Jaspur	Jaspur	Jaspur	Rice-Fellow- Rice	Swarna	RS 53	+
54	Korea	Korea	Korea	Rice-Gramm- Rice	Swarna	RS 54	+
55	Utai	Durg	Durg	Rice-Fellow- Fellow	Swarna	RS 55	+
56	Pali	Katghora	Korba	Rice-Fellow- Rice	Swarna	RS 56	+
57	Kirwai	Fingeshwer	Gariyaband	Rice-Fellow- Rice	Mahamaya	RS 57	+
58	Kirwai	Fingeshwer	Gariyaband	Rice-Gram- Fellow	Swarna	RS 58	+

Related results in the agreement with Swain *et al.*(2005), Xiao *et al.* (2008) and Prasad, V.R. (2014) who surveyed and collected the samples of sheath blight disease at maximum rice tillering stage.

4.1.2 The symptoms of sheath blight disease:

The lesions occurred on sheaths and blades of leaves. The sheath blight fungus has an effect on the paddy crop from tillering to heading stage. All the isolates seen on leaf sheaths of lower leaves close to water level as water soaked lesions that are circular to oblong, ellipsoid, ovoid or even irregularly elongated (3x1cm) and discoloured have found the initial symptoms of sheath blight, which later is a subtle lesion with a pale greenish to a grayish white center with a narrow blackish to a dark brown margin (Fig.4.1 and 4.2). Finally, 3-5 these lesions extend upwards, coalesced and girdle the entire sheath of the leaf, culm, boot and flag leaf (Fig. 4.3 and 4.4). On or near these lesions, sclerotia were developed, and were easily detached. Several large lesions were found on the sheath of the leaf causes the death of the entire leaf and in severe causes all the leaves of a plant blighted and the encircled tiller dries. Owing to the primary infection on leaf sheath, the disease was called as “sheath blight”. The mycelium of the fungus may grow over the surface of the sheaths of the leaf and can spread within 24 hours for a considerable distance of several centimeters. The fungus spreads to the inside sheaths resulting in the death of whole plant, known as sheath blight symptom/disease. Throughout the stages of development, plants heavily infected in the early heading and grain filling growth stages produce poorly filled grains. This disease typically attacks when the leaf sheath is discolored at or above water line during tillering stage (Ou *et al.*,1973). Normally the disease produces spots on the sheath of the leaf. The spots are first seen as ellipsoid or ovoid, somewhat irregular, greenish grey, ranging from 1-3 cm in length. The spot centre is turned greyish white with a brown border. Prasad, V.R. (2014) reported similar symptoms of sheath blight who surveyed in rice fields, it initially appeared as greenish grey, ellipsoid or ovoid, water soaked irregular lesions of one to three cm long. The spot centre was greyish white with brown margins. The symptoms started near the water line and were spreading upwards. The sclerotia were developed on or near these lesions and were detached early on. Also found on leaf lamina were irregular greenish grey lesions with brown margins. The disease spread very quickly to neighboring tillers under favourable conditions, and caused death of entire plants.



Fig.4.1: Initial symptoms of sheath blight near water surface

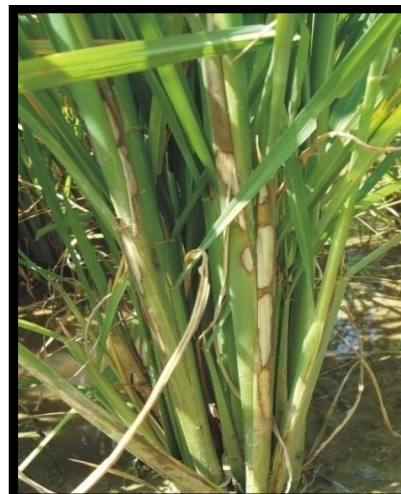


Fig.4.2: Irregular greyish white spots



Fig. 4.3 Development of banded blight disease



Fig.4.4: Sheath blight on panicle leaf and glum



Fig.4.5: Death of plants by severe infection of *R. solani*

4.1.3 The symptoms of banded blight disease:

Once humidity reaches 95% and temperature ranges from 29 to 32°C, infection spreads rapidly through runner hyphae that occurs on parts of the plant, including leaf blades, causing irregularly formed lesions with brown margins as bands. At times, copper coloured transverse bands are also formed on the leaf (Fig. 4.3). This disease generally referred to as banded blight. Outer leaves may fall off; plants may look yellow, and ultimately wilt. Saksena (1973) observed that the symptoms developed by the pathogen on the leaf were similar to those seen in the banded sclerotial disease of sugarcane and that this disease was named “banded blight”. In the banded blight phase, panicle and flag leaf infection prevented the normal emergence and expansion of the ears and caused poor filling of grains. Under favourable conditions, infection may spread to the culm, destroys all the leaves on the surface of the lesions and often on the inside of the sheath and on the culms; brownish silky wefts of mycelium are present. Such wefts produce brown or dark brown sclerotia, which eventually fall onto the bottom. It is the banded appearance and presence of the sclerotia that gives the name “banded sclerotial disease” caused by *R. solani* (Singh, 2005).

4.1.4 Isolation and purification of pathogen:

In the present study isolates were assigned code numbers such as RS1, where "RS" named *Rhizoctonia solani* and "1" denote the serial number of the isolate. Similarly, the other fifty-eight isolates were also referred to as RS1, RS2, RS3, RS4, RS5, RS6, RS7, RS8, RS9, RS10, RS11, RS12, RS13, RS14, RS15, RS16, RS17, RS18, RS19, RS20, RS21, RS22, RS23, RS24, RS25, RS26, RS27, RS28, RS29, RS30, RS31, RS32, RS33, RS34, RS35, RS36, RS37, RS38, RS39, RS40, RS41, RS42, RS43, RS44, RS45, RS46, RS47, RS48, RS49, RS50, RS51, RS52, RS53, RS54, RS55, RS56, RS57, RS58 were listed in Table No. 4.1. The sheath blight causing the *R. solani* pathogen was isolated and purified by a single hyphal tip / single sclerotial method. Cultures were kept in test tubes on sterile PDA slants maintained in 4°C to further investigate the variability. Similar results for isolation, purification and

identification have been reported by Leach and Garber (1970), Parmeter and Whitney (1970).

4.1.5 Systematic classification:

The causative agent of sheath blight, now commonly known as *R. solani* Kühn, and *Thanatephorus cucumeris* (Frank) Donk, a teleomorph (perfect stage). The teleomorph of the pathogen *Thanatephorus cucumeris* belongs to the family of the Ceratobasidiaceae of the order Tulasnellales in the form class Hymenomycetes, subclass Holobasidiomycetidae of the class Basidiomycetes. The anamorph *R. solani* comes under the class Deuteromycotina, form class Deutromycetes and order Aganomycetales (Dasgupta, 1992).

4.1.6 Identification of the test fungus:

The isolated fungus was then identified based on the following morphological properties. *R. solani* does not form vegetative spores and is present as a mycelium and sclerotia. The isolate had typical characteristics of *R. solani*: (I) It creates a shade of brown hyphae. (II) Branches at right angles beside the distal septum of the cell in young hyphae. (III) formation of a septum in the branch beside the point of origin, (IV) narrowing at the branch point, dolipore septum, (V) moniloid cells, (VI) undifferentiated sclerotia and (VII) absence of rhizomorphs (VIII) clamp connection absent. Undifferentiated Sclerotia, aggregations of thick-walled cells, small (1-4 mm diameter) irregularly shaped brown to black structures (Gutierrez *et al.* 1997). A similar result in identification was reported by Doman and Flentje (1970), Sherwood (1970).

4.1.7 Pathogenicity test:

After artificial inoculation with the susceptible Swarna variety, rules of Koch's postulates for fifty-eight isolates were described and the isolates were yet to confirmed. After 3 days of inoculation, all *R. solani* isolates showed their pathogenic potential and developed typical symptoms of the sheath blight in the susceptible Swarna variety as follows: Dark lesions were developed on the sheath near the water line. In the further growth phase of the infected plant, small sclerotia were developed.

The sclerotia seen as round and light brown to dark brown on the affected sheath. Sclerotia were also formed in the hollow leaf internodes at maturity. When opening the infected parts, the sclerotia was clearly visible. The fungus was isolated again and compared to the original *R. solani* culture to meet Koch's postulates. The symptoms produced were consistent with the authentic reports from previous workers about rice sheath blight (Ou, 1972, IRRI 1988 and Manjunatha, 2016).

Variability and cultural studies of *R. solani* Kuhn

4.2.1 Evaluation of Aggressiveness of different isolates of *Rizoctonia solani* in pot condition:

The pot culture experiment was conducted with various *R. solani* isolates collected from different rice growing regions of Chhattisgarh to determine its aggressiveness on susceptible rice cultivar Swarna in kharif 2016 and kharif 2017.

Fig.4.6: Aggressiveness test (pot condition) and variation in sheath blight disease symptoms

Highly aggressive isolates





Aggressive isolates



Moderately aggressive isolates**Weakly aggressive isolate**

In kharif 2016, the data shown in Table 4.2 and fig. 4.6 showed that the 58 isolates were divided into four groups: weakly aggressive (WA), moderately aggressive (MA), aggressive (A) and highly aggressive (HA). The majority of the isolates were weakly aggressive (21), followed by moderately aggressive (17), aggressive (12) and highly aggressive (8) against the susceptible Swarna variety of fifty-eight isolates. The results showed that the PDI was between 11.11% and 100% among all 58 isolates. The maximum PDI (100%) was recorded in isolate RS 3, followed by RS-57 (96.29%), RS 4 (94.44%) and RS-5 (92.59%), while isolates RS8, RS9, RS 20, RS22, RS23, RS32, RS33, RS35, RS36, RS37, RS44, RS48, RS 49 and RS 55 showed the lowest PDI value (11.11). Reviewing the data showed significant differences in the aggressiveness of the isolates. The isolates showed varied incubation period, lesion lengths, relative lesion heights, disease severity and percent disease index.

Table 4.2: Evaluation of Aggressiveness of different isolates of *Rizoctonia solani* under pot condition in kharif 2016:

Isolates	Incubation period	Lesion length (c.m.)			Relative Lesion Height (cm)	PDI (%)
		1 week	2 weeks	3 weeks		
RS 1	1.41	10.35	16.81	22.24	51.22	72.21
RS 2	1.24	8.32	16.59	23.73	53.95	77.77
RS 3	1.08	15.60	26.71	36.61	81.30	100.0
RS 4	1.16	10.85	21.89	32.29	71.75	94.44
RS 5	1.16	15.46	22.66	30.65	71.31	92.59
RS 6	1.24	4.81	9.67	17.45	44.54	55.56
RS 7	1.0	4.66	7.77	12.30	32.16	37.18
RS 8	8.0	0.0	2.35	5.23	16.86	11.11
RS 9	4.25	1.24	3.44	4.90	15.15	11.11
RS 10	1.0	5.86	11.18	17.12	38.83	55.56
RS 11	1.24	2.54	6.65	9.81	22.69	16.66
RS 12	2.0	7.52	15.08	24.64	53.24	77.77
RS 13	1.0	4.51	8.43	13.18	29.70	35.18
RS 14	1.08	6.59	12.56	18.62	40.30	55.56
RS 15	1.24	5.71	11.73	18.92	40.64	55.56
RS 16	1.08	5.21	11.35	18.22	40.73	51.84
RS 17	1.25	4.86	10.70	17.46	37.73	53.69
RS 18	3.0	2.96	6.77	11.56	25.33	31.47
RS 19	1.58	4.41	9.16	19.01	39.74	51.84

Isolates	Incubation period	Lesion length (c.m.)			Relative Lesion Height (cm)	PDI (%)
		1 week	2 weeks	3 weeks		
RS 20	1.0	3.47	5.50	7.94	17.54	11.11
RS 21	2.25	3.07	5.95	8.45	18.68	25.92
RS 22	1.08	1.96	3.89	5.91	10.16	11.11
RS 23	5.0	0.19	1.63	3.28	9.72	11.11
RS 24	3.0	0.91	4.86	8.07	17.42	12.96
RS 25	1.16	7.89	12.34	18.29	37.67	53.69
RS 26	1.41	4.89	8.09	12.14	26.68	31.37
RS 27	1.0	4.48	7.25	11.47	24.89	33.33
RS 28	3.50	2.15	7.13	11.81	26.94	29.62
RS 29	1.75	3.38	7.36	11.52	25.80	24.07
RS 30	2.50	3.42	7.22	12.99	28.02	33.33
RS 31	1.16	3.99	6.65	9.65	21.12	18.51
RS 32	4.66	0.37	2.69	4.08	10.57	11.11
RS 33	3.16	1.00	3.23	5.31	13.24	11.11
RS 34	1.0	11.83	20.35	29.35	59.90	80.55
RS 35	3.08	0.74	3.9	5.88	14.86	11.11
RS 36	4.58	0.26	2.21	3.59	10.37	11.11
RS 37	6.50	0.0	2.42	3.42	9.37	11.11
RS 38	3.08	2.06	4.23	6.51	15.83	12.96
RS 39	1.25	7.25	11.48	15.86	33.87	44.44
RS 40	1.0	4.25	8.41	12.87	28.33	33.33
RS 41	1.08	5.82	9.08	13.03	28.83	33.33
RS 42	1.24	4.78	8.40	11.93	25.84	33.33
RS 43	1.33	5.11	9.27	16.10	37.44	51.85
RS 44	3.50	0.96	1.91	2.87	8.74	11.11
RS 45	1.0	3.33	6.99	10.32	22.70	24.06
RS 46	3.33	1.58	4.62	6.79	16.41	16.67
RS 47	1.25	3.63	6.92	9.41	21.13	14.81
RS 48	3.25	1.69	4.54	6.98	16.64	11.11
RS 49	2.75	1.74	4.74	7.08	13.29	11.11
RS 50	1.0	9.74	16.68	24.02	45.54	61.11
RS 51	1.0	3.49	6.60	8.76	19.62	14.81
RS 52	1.33	3.95	7.26	10.97	24.75	29.62
RS 53	4.0	0.66	5.60	11.31	25.22	33.33
RS 54	1.25	3.03	5.96	10.06	22.63	22.21
RS 55	1.24	2.61	5.73	8.12	18.71	11.11
RS 56	3.24	2.22	7.21	9.36	22.66	20.36
RS 57	1.0	11.93	22.07	31.48	67.04	96.29
RS 58	1.08	4.92	11.08	17.22	39.93	57.39
Mean	2.10	4.49	8.84	13.42	30.09	36.44
CD					4.8283	8.1831
SEm					1.7298	2.9317

In Kharif 2017, the data shown in Table 4.3 and fig. 4.6 showed weak aggressiveness (WA), moderately aggressive (MA), aggressive (A) and high aggressiveness (HA) on susceptible variety Swarna. The majority of the isolates were weakly aggressive (25), followed by moderately aggressive (18), aggressive (9) and highly aggressive (6). The percent disease index was between 11.11% and 100%. Among all 58 isolates, a maximum PDI of 100% was recorded in isolates RS 57, followed by RS 5 (92.59%) and RS 3 (77.78%), while isolates RS8, RS9, RS20, RS 21, RS22, RS23, RS24, RS 27 RS 31, RS32, RS33, RS35, RS36, RS37, RS38, RS44, RS45, RS46, RS48, RS49 and RS51 showed the lowest PDI value (11.11). The isolates have different incubation period, lesion lengths, relative lesion heights, disease severity and percent disease index. The perusal of data showed significant differences in the aggressiveness of the isolates.

Table 4.3: Evaluation of Aggressiveness of different isolates of *Rizoctonia solani* under pot condition in kharif 2017:

Isolates	Incubation period	Lesion length (c.m.)			Relative Lesion Height (cm)	PDI (%)
		1 week	2 weeks	3 weeks		
RS 1	1.24	9.40	15.79	23.56	53.36	70.37
RS 2	1.08	6.64	13.97	25.31	51.32	72.22
RS 3	1.16	11.12	19.63	26.62	56.63	77.78
RS 4	1.0	9.30	15.31	21.38	46.62	55.56
RS 5	1.24	14.26	23.42	33.20	68.67	92.59
RS 6	1.0	7.56	13.76	19.04	41.94	55.56
RS 7	1.24	6.41	9.32	13.04	29.06	33.33
RS 8	1.08	3.40	5.59	7.06	17.60	11.11
RS 9	2.83	0.96	2.89	5.47	13.59	11.11
RS 10	1.0	8.13	11.85	16.34	35.33	50.0
RS 11	1.91	2.00	5.54	9.65	22.69	14.81
RS 12	1.16	4.42	8.19	14.19	31.31	35.18
RS 13	1.41	4.31	9.24	13.48	29.61	33.33
RS 14	1.0	6.42	11.33	16.98	36.02	50.0
RS 15	1.24	6.72	12.44	19.57	41.65	55.56
RS 16	1.49	5.33	9.70	14.58	32.28	40.74
RS 17	1.08	4.54	8.31	14.37	31.43	35.18
RS 18	1.83	4.99	7.63	14.53	32.13	38.88
RS 19	1.0	6.41	11.44	18.38	39.38	55.56
RS 20	1.0	4.15	6.56	7.52	17.11	11.11
RS 21	1.08	2.25	4.56	6.79	17.08	11.11

Isolates	Incubation period	Lesion length (c.m.)			Relative Lesion Height (cm)	PDI (%)
		1 week	2 weeks	3 weeks		
RS 22	1.50	2.83	4.76	6.85	17.60	11.11
RS 23	1.0	1.76	3.36	4.63	13.26	11.11
RS 24	2.0	2.56	5.62	7.98	18.81	11.11
RS 25	1.24	9.27	13.38	18.44	39.00	55.56
RS 26	1.0	4.11	8.26	12.51	27.13	33.33
RS 27	1.25	3.13	6.30	8.58	19.51	11.11
RS 28	1.24	4.47	8.16	11.42	24.63	31.47
RS 29	1.75	4.36	7.20	9.78	21.70	20.36
RS 30	1.25	6.30	10.01	12.81	29.92	35.18
RS 31	2.0	2.56	5.63	8.50	21.70	11.11
RS 32	1.0	2.31	3.69	4.73	15.23	11.11
RS 33	4.50	1.16	3.67	6.09	16.71	11.11
RS 34	2.08	4.95	9.27	16.89	37.57	51.85
RS 35	1.0	3.12	5.79	8.53	20.48	11.11
RS 36	2.14	2.07	3.09	3.55	11.71	11.11
RS 37	3.0	1.06	2.02	3.68	12.74	11.11
RS 38	2.25	2.16	4.38	6.25	17.08	11.11
RS 39	1.0	5.74	8.05	13.09	30.38	33.33
RS 40	1.24	5.44	10.97	14.73	32.78	40.74
RS 41	1.0	5.50	10.43	15.12	34.96	40.74
RS 42	1.25	4.82	8.27	11.72	26.91	29.62
RS 43	1.25	5.79	11.32	16.42	33.51	38.88
RS 44	3.0	1.05	2.41	3.32	10.58	11.11
RS 45	4.75	1.96	4.15	8.72	21.57	11.11
RS 46	1.75	2.70	5.26	7.46	19.54	11.11
RS 47	1.0	3.57	7.55	11.31	26.21	33.33
RS 48	1.50	2.96	5.13	6.79	17.90	11.11
RS 49	1.08	1.21	3.28	6.13	17.22	11.11
RS 50	1.08	7.53	13.87	21.67	44.21	66.67
RS 51	1.0	4.26	5.83	8.70	19.81	11.11
RS 52	1.0	3.38	6.93	10.33	24.45	20.36
RS 53	1.0	4.36	8.86	13.17	31.85	33.33
RS 54	2.08	4.11	7.60	11.18	26.25	27.77
RS 55	3.16	2.92	8.15	11.07	26.41	33.33
RS 56	1.16	3.04	6.16	9.15	22.21	12.96
RS 57	1.08	15.53	27.70	35.54	72.17	100.00
RS 58	1.08	6.28	11.81	17.06	39.29	55.56
Mean	1.53	4.81	8.70	12.84	29.10	32.66
CD					3.5057	6.9671
SEm					1.2560	2.4961

The pooled Kharif data for 2016 and 2017 are listed in table 4.4. The aggressiveness quality (Fig. 4.12) was divided into the following four categories: weakly aggressive (WA = PDI% 2-21), moderately aggressive (MA = PDI% 22-43), aggressive (A = PDI% 44-65) and highly aggressive (HA=PDI percent 66-87) with a susceptible Swarna variety. The result showed that among the fifty-eight isolates, twenty two weakly aggressive isolates (RS8, RS9, RS11, RS20, RS21, RS22, RS23, RS24, RS31, RS32, RS33, RS35, RS36, RS37, RS38, RS44, RS45, RS46, RS48, RS49, RS51 and RS56), followed by seventeen moderately aggressive isolates (RS7, RS13, RS18, RS26, RS27, RS28, RS29, RS30, RS39, RS40, RS41, RS42, RS47, RS52, RS53, RS54 and RS55), twelve aggressive isolates (RS6, RS10, RS12, RS14, RS15, RS16, RS17, RS19, RS25, RS43, RS50 and RS58) and seven highly aggressive isolates (RS1, RS2, RS3, RS4, RS5, RS34 and RS57). The PDI of the isolates was between (11.11 - 98.15%). All isolates were found to be aggressive to rice and could develop lesions on leaves, leaf sheaths and susceptible stems of rice. The results showed that significant differences were found in the aggressiveness of isolates. The isolates varied depending on the lesion height, incubation period, relative lesion height, severity of the disease and percent disease index.

Of all 58 isolates, a maximum PDI of 98.15 percent was shown with RS57 isolate, followed by RS 5 (92.59 percent) and RS 3 (88.89 percent), while RS8, RS9, RS20, RS22, RS23, RS32, RS33, RS 35, RS36, RS37, RS44, RS48 and RS 49 isolates showed the lowest PDI value (11.11). The incubation period was between 1.0 and 4.75 days. The minimum incubation time (1.0 days), indicated by RS10, RS20 and RS51 isolates, and the maximum incubation time (4.75 days), indicated by RS37 isolate. The RS5 isolate (69.99 cm) showed the highest relative lesion height, while the RS44 (9.66 cm) showed the lowest. The results of a pooled data analysis showed the isolates of *R. solani* were variable (Fig. 4.11). These results are in agreement with the results of Madhavi *et al.* (2012) and Jayaprakashvel and Mathivanan (2011). Adhipathi *et al.* (2013), Pavani *et al.* (2018), Singh *et al.* (2001) and Kumar *et al.* (2008) reported similar observations.

4.4: Evaluation of Aggressiveness of different isolates of *Rizoctonia solani* under pot condition (Pooled data of year 2016 and 2017):

Isolates	Incubation period	Lesion length (c.m.)			Relative Lesion Height (cm)	PDI (%)
		1 week	2 weeks	3 weeks		
RS 1	1.33	9.88	16.30	22.89	52.29	71.29
RS 2	1.16	7.48	15.28	24.52	52.63	75.00
RS 3	1.12	13.36	23.17	31.62	68.97	88.89
RS 4	1.08	10.08	18.60	26.84	59.19	75.00
RS 5	1.20	14.86	23.04	31.93	69.99	92.59
RS 6	1.12	6.19	11.72	18.25	43.24	55.56
RS 7	1.12	5.54	8.55	12.67	30.61	35.26
RS 8	4.54	1.70	3.97	6.15	17.23	11.11
RS 9	3.54	1.10	3.17	5.19	14.37	11.11
RS 10	1.00	7.00	11.52	16.73	37.08	52.78
RS 11	1.58	2.27	6.10	9.73	22.69	15.74
RS 12	1.58	5.97	11.64	19.42	42.28	56.48
RS 13	1.21	4.41	8.84	13.33	29.66	34.26
RS 14	1.04	6.51	11.95	17.80	38.16	52.78
RS 15	1.24	6.22	12.09	19.25	41.15	55.56
RS 16	1.29	5.27	10.53	16.40	36.51	46.29
RS 17	1.17	4.70	9.51	15.92	34.58	44.44
RS 18	2.42	3.98	7.20	13.05	28.73	35.18
RS 19	1.29	5.41	10.30	18.70	39.56	53.70
RS 20	1.00	3.81	6.03	7.73	17.33	11.11
RS 21	1.67	2.66	5.26	7.62	17.88	18.52
RS 22	1.29	2.40	4.33	6.38	13.88	11.11
RS 23	3.00	0.98	2.50	3.96	11.49	11.11
RS 24	2.50	1.74	5.24	8.03	18.12	12.04
RS 25	1.20	8.58	12.86	18.37	38.34	54.63
RS 26	1.21	4.50	8.18	12.33	26.91	32.35
RS 27	1.13	3.81	6.78	10.03	22.20	22.22
RS 28	2.37	3.31	7.65	11.62	25.79	30.55
RS 29	1.75	3.87	7.28	10.65	23.75	22.22
RS 30	1.88	4.86	8.62	12.90	28.97	34.26
RS 31	1.58	3.28	6.14	9.08	21.41	14.81
RS 32	2.83	1.34	3.19	4.41	12.90	11.11
RS 33	3.83	1.08	3.45	5.70	14.98	11.11
RS 34	1.54	8.39	14.81	23.12	48.74	66.20
RS 35	2.04	1.93	4.85	7.21	17.67	11.11
RS 36	3.36	1.17	2.65	3.57	11.04	11.11
RS 37	4.75	0.53	2.22	3.55	11.06	11.11
RS 38	2.67	2.11	4.31	6.38	16.46	12.04

Isolates	Incubation period	Lesion length (c.m.)			Relative Lesion Height (cm)	PDI (%)
		1 week	2 weeks	3 weeks		
RS 39	1.13	6.50	9.77	14.48	32.13	38.89
RS 40	1.12	4.85	9.69	13.80	30.56	37.04
RS 41	1.04	5.66	9.76	14.08	31.90	37.04
RS 42	1.25	4.80	8.34	11.83	26.38	31.48
RS 43	1.29	5.45	10.30	16.26	35.48	45.37
RS 44	3.25	1.01	2.16	3.10	9.66	11.11
RS 45	2.88	2.65	5.57	9.52	22.14	17.59
RS 46	2.54	2.14	4.94	7.13	17.98	13.89
RS 47	1.13	3.60	7.24	10.36	23.67	24.07
RS 48	2.38	2.33	4.84	6.89	17.27	11.11
RS 49	1.92	1.48	4.01	6.61	15.26	11.11
RS 50	1.04	8.64	15.28	22.85	44.88	63.89
RS 51	1.00	3.88	6.22	8.73	19.71	12.96
RS 52	1.17	3.67	7.10	10.65	24.60	24.99
RS 53	2.50	2.51	7.23	12.24	28.54	33.33
RS 54	1.67	3.57	6.78	10.62	24.44	24.99
RS 55	2.20	2.77	6.94	9.60	22.56	22.22
RS 56	2.20	2.63	6.69	9.26	22.44	16.66
RS 57	1.04	13.73	24.89	33.51	69.61	98.15
RS 58	1.08	5.60	11.45	17.14	39.61	56.48
Mean	1.82	4.65	8.78	13.13	29.60	34.55
CD					2.9093	5.3383
SEm					1.0423	1.9125

4.2.2 Cultural and morphological variation in *R. solani* isolates of different rice growing areas of Chhattisgarh

The variability of *R. solani* isolates based on some cultural and morphological features was examined in the present study. Fifty-eight *R. solani* isolates collected from various locations in Chhattisgarh were taken for the study presented in the Materials and Methods section. Variability studies among these *R. solani* isolates were performed based on morphology, mycelial growth pattern and other cultural characteristics. With all isolates of *R. solani*, which were collected in different places, variations of the cultural and morphological properties were observed. Morphological properties *i.e.* sclerotial size, shape and color, growth rate, growth pattern and color of the mycelium etc. were observed. All of the isolates collected were purified and

confirmed according to the current species concept by *R. solani* (Parmeter and Whitney, 1970). The isolates differ in growth pattern, color of the colony, growth rate and size, shape, color and pattern of sclerotic formation. The results is shown in tables 4.5 and 4.6 and fig. 4.7, 4.8 and 4.9.

4.2.2.1 Growth pattern:

The data in table 4.5 show that significant variations in mycelial growth were observed from *R. solani* isolates collected at different locations in Chhattisgarh. Among the fifty-eight isolates, the *R. solani* fungus was divided into three classes based on the complete radial mycelial growth pattern. The isolated completion of the radial growth was recorded in the intervals of 24 hours, 48 hours, 72 hours and 96 hours and then divided into 3 groups: abundant (fast) covering petriplates (90 mm diameter) in 72 hours, moderately covering petriplates (90 mm diameter) in 96 hours, slightly covering petriplates (90 mm diameter) longer than 96 hours. Of the 58 isolates from *R. solani*, ten rapidly growing isolates RS1, RS2, RS3, RS4, RS5, RS12, RS19, RS34, RS50 and RS57 completed their radial growth within 72 hours after inoculation, and were found to be abundant grow and be categorized accordingly Group 1. Fourteen medium-sized isolates, namely RS6, RS10, RS13, RS14, RS15, RS16, RS17, RS18, RS25, RS26, RS39, RS41, RS43 and RS58, ended their radial growth within 96 hours after inoculation, with a moderate growth pattern exposed and divided into group 2, while the remaining thirty-four isolates, namely RS7, RS8, RS9, RS11, RS20, RS21, RS22, RS23, RS24, RS27, RS28, RS29, RS30, RS31, RS32, RS33, RS35, RS36, RS37, RS38, RS40, RS42, RS44, RS45, RS46, RS47, RS48, RS49, RS51, RS52, RS53, RS54, RS55 and RS56 grew very slowly and completed the complete radial growth after 96 hours of inoculation, which was considered slow growing was considered to have a slightly low growth pattern and should therefore be divided into group 3. Similarly, Burpee *et al.* (1980) divided the growth pattern into the same three groups. The diameter growth rate was recorded after 24, 48 and 72 hours. The isolates were divided into three groups - fast, medium and slow. Ten isolates covered the entire plate (90 mm) in 48 hours. However, the RS-22 isolate did not cover the plate even after 72 hours. Fast and medium growing isolates were more

pathogenic than the slow growing isolates. Cultural and morphological variations in *R. solani* have been reported by various workers, namely Singh *et al.* (1999), Panja *et al.* (2011) etc. Singh *et al.* (1990) reported the AG-1 group from *R. solani*'s isolates, which showed different morphological properties in culture, were collected at five different endemic locations of sheath blight, namely Assam, Andhra Pradesh, Tamil Nadu and Andaman, India . Sclerotia was formed in 9 isolates in the aerial mycelium and in all isolates with the exception of RS-22 on the surface of the mycelium. The location of the sclerotia as aerial, surface and embedded was also described by Singh *et al.* (2002) reports. Growth of this pathogen was good and very fast as in some isolates. Sclerotia were found mostly thin and their colours were brown, dark brown as well as blackish brown (Yaduman *et al.*, 2019).

4.2.2.2 Colony colour:

Of fifty-eight isolates, thirteen are isolates of (RS1, RS-6, RS-15, RS-16, RS-21, RS-22, RS-27, RS-29, RS-33, RS-39, RS- 43, RS-51 and RS-57) *R. solani* consisted of brown colored thirty-eight isolates (RS-3, RS-5, RS-7, RS-8, RS-9, RS-10, RS-11, RS -12, RS -13, RS-14, RS-17, RS-18, RS-19, RS-20, RS-23, RS-24, RS-25, RS-26, RS-28, RS-30, RS-31 , RS-32, RS-35, RS-37, RS-38, RS-40, RS-42, RS-44, RS45, RS-47, RS-48, RS-49, RS-50, RS-52 , RS-54, RS-55, RS-56 and RS-58) were colored light brown, six isolates (RS-2, RS-4, RS-34, RS-36, RS-41 and RS-46) were dark brown colored (table 4.5). The discoloration of the growth media is mainly attributed to the production of pigments by the pathogen. The difference in the intensity of the color can also correspond to the amount of pigments released by the respective isolate in the media. Similarly, morphological characterizations of *R. solani* isolates based on the mycelium color in the Petri dish were carried out on the PDA medium (Banniza *et al.*, 1996; Sherwood *et al.*, 1969; Vijayan *et al.*, 1985; Vilgalys and Cubeta, 1994). Sunder *et al.* (2003) also reported that the colony color was between brown, light brown, dark brown, and yellowish brown. The discoloration of the growth media is mainly attributed to the production of pigments by the pathogen. Other variations in the type and color of the mycelium as well as the size, color, number and type of sclerotia among the isolates from *R. solani* (Sinha and Ghufuran,

1988). Mishra *et al.* (2014) found that 22 *R. solani* isolates derived from rice were analyzed for their cultural, morphological and pathogenicity variability. The colonial appearance of the isolates was light brown and of sparse color. Yaduman *et al.* (2019) studies variability of 24 isolates of *R. solani*, and observed in different colours like, light yellow, whitish yellow, pale yellow, light cream yellow, yellow and cream yellow.

Table 4.5: Cultural and morphological variation in *R. solani* isolates of different rice growing areas of Chhattisgarh:

Isolates	Growth Pattern			Colony colour	Colony growth diameter (mm) at different intervals				Mean
	Abundant*	Moderate	Slight		24h	48h	72h	96h	
RS1	Abundant	-	-	Brown	18.19	47.26	90.0	90.0	61.36
RS2	Abundant	-	-	Dark brown	23.19	50.06	90.0	90.0	63.31
RS 3	Abundant	-	-	Light brown	23.93	55.73	90.0	90.0	64.92
RS4	Abundant	-	-	Dark brown	20.39	53.33	90.0	90.0	63.43
RS5	Abundant	-	-	Light brown	24.19	66.33	90.0	90.0	67.63
RS 6	-	Moderate	-	brown	29.4	50.19	71.48	90.0	60.27
RS7	-	-	Slight	Light brown	15.26	36.26	54.46	74.32	45.08
RS 8	-	-	Slight	Light brown	6.33	15.19	26.53	39.79	21.96
RS 9	-	-	Slight	Light brown	8.35	16.0	22.33	30.73	19.35
RS10	-	Moderate	-	Light brown	23.67	49.23	69.79	90.0	58.17
RS11	-	-	Slight	Light brown	12.39	32.33	52.13	78.13	43.75
RS 12	Abundant	-	-	Light brown	22.59	49.46	90.0	90.0	63.01
RS 13	-	Moderate	-	Light brown	16.13	30.66	62.90	90.0	49.92
RS14	-	Moderate	-	Light brown	18.19	45.26	60.26	90.0	53.43
RS15	-	Moderate	-	Brown	18.99	47.46	72.06	90.0	57.13
RS16	-	Moderate	-	Brown	10.16	36.19	57.33	90.0	48.42
RS17	-	Moderate	-	Light brown	11.0	45.39	75.33	90.0	55.43
RS18	-	Moderate	-	Light brown	12.06	39.76	62.43	90.0	51.06
RS19	Abundant	-	-	Light brown	19.13	50.99	90.0	90.0	62.53
RS20	-	-	Slight	Light brown	12.20	24.07	40.13	54.20	32.65
RS21	-	-	Slight	brown	11.13	25.20	40.13	54.13	32.65
RS22	-	-	Slight	Brown	6.19	13.73	19.39	33.73	18.26
RS 23	-	-	Slight	Light brown	6.33	9.13	16.86	25.33	14.41
RS24	-	-	Slight	Light brown	5.19	15.26	26.19	41.26	21.98
RS25	-	Moderate	-	Light brown	23.19	46.19	65.26	90.0	56.16
RS26	-	Moderate	-	Light brown	22.33	41.25	62.33	90.0	53.98

Isolates	Growth Pattern			Colony colour	Colony growth diameter (mm) at different intervals				Mean
	Abundant*	Moderate	Slight		24h	48h	72h	96h	
RS27	-	-	Slight	Brown	16.19	41.86	60.19	75.60	48.46
RS28	-	-	Slight	Light brown	22.79	49.26	71.47	85.33	57.21
RS 29	-	-	Slight	Brown	20.33	40.33	61.26	80.13	50.51
RS30	-	-	Slight	Light brown	19.30	47.13	66.86	87.07	55.09
RS 31	-	-	Slight	Light brown	9.13	24.53	43.76	66.60	36.01
RS32	-	-	Slight	Light brown	6.80	10.47	18.87	26.46	15.65
RS33	-	-	Slight	Brown	2.13	17.07	23.73	32.26	18.80
RS 34	Abundant	-	-	Dark brown	20.50	50.26	90.00	90.00	62.69
RS 35	-	-	Slight	Light brown	10.23	17.19	28.39	39.26	23.77
RS 36	-	-	Slight	Dark brown	5.99	12.73	18.73	24.99	15.61
RS37	-	-	Slight	Light brown	0.0	9.26	17.79	24.06	12.78
RS38	-	-	Slight	Light brown	10.26	20.40	30.73	40.20	25.40
RS 39	-	Moderate	-	Brown	22.69	45.99	68.53	90.0	56.80
RS 40	-	-	Slight	Light brown	15.26	41.33	59.59	76.19	48.09
RS41	-	Moderate	-	Dark brown	16.73	44.06	60.19	90.0	52.75
RS42	-	-	Slight	Light brown	20.33	47.06	59.29	81.73	52.10
RS 43	-	Moderate	-	Brown	22.16	43.23	69.53	90.0	56.23
RS 44	-	-	Slight	Light brown	8.13	12.93	17.33	21.13	14.88
RS 45	-	-	Slight	Light brown	16.76	35.86	50.59	70.14	43.34
RS 46	-	-	Slight	Dark brown	9.80	21.20	32.93	45.00	27.23
RS 47	-	-	Slight	Light brown	16.93	33.6	54.53	73.33	44.60
RS 48	-	-	Slight	Light brown	9.32	20.13	32.33	43.60	26.35
RS 49	-	-	Slight	Light brown	10.19	25.26	35.33	44.36	28.79
RS 50	Abundant	-	-	Light brown	18.16	49.59	90.0	90.0	61.94
RS 51	-	-	Slight	Brown	10.66	23.99	36.13	49.39	30.04
RS 52	-	-	Slight	Light brown	16.53	30.67	51.13	77.73	44.02
RS53	-	-	Slight	Dark brown	16.33	45.19	64.26	84.33	52.53
RS 54	-	-	Slight	Light brown	15.20	36.00	53.26	74.13	44.65
RS55	-	-	Slight	Light brown	8.07	14.13	26.47	49.80	24.62
RS 56	-	-	Slight	Light brown	7.26	15.26	31.73	73.20	31.86
RS57	Abundant	-	-	brown	25.66	53.13	90.0	90.0	64.70
RS58	-	Moderate	-	Light brown	19.33	39.33	70.19	90.0	54.71

Abundant*(Rapid)- Covering petriplate (90mm dia.) in 72 hrs., **Moderate**-Covering petriplate (90mm dia.) in 96 hrs., **Slight**- Covering petriplate (90mm dia.) more than 96 hrs.

The isolates differ in colour of the colony, growth rate and size, shape, colour and pattern of sclerotia formation (fig. 4.7).

4.2.2.3 Time taken for sclerotia formation:

Based on the time required for the formation of sclerotia (table 4.6) in the Petri dishes, fifty eight *R. solani* isolates were divided into three groups, namely Group I (0-5 days) and Group II (5-10 Days) and Group III (10-15 days). All isolates showed large differences in the time required for the initiation of sclerotial formation (days) of isolates in the Petri dish (Table 4.4). Eighteen isolates RS-1, RS-2, RS-3, RS-4, RS-5, RS-6, RS-10, RS-12, RS-14, RS-15, RS-17, RS-19, RS-25, RS-26, RS-34, RS-50, RS-57 and RS-58 took 0-5 days to initiate sclerotial formation (with only three isolates RS-19, RS-34 and RS- 50 took 3 days to initiate sclerotia). Twenty nine isolates RS-9, RS-11, RS-13, RS-16, RS-18, RS-20, RS-21, RS-22, RS-24, RS-27, RS-28, RS-29, RS-30, RS-35, RS-36, RS-38, RS-39, RS-40, RS-41, RS-43, RS-45, RS-46, RS-47, RS-48, RS - 49, RS-52, RS-53, RS-55 and RS-56 took 5-10 days to initiate sclerotia formation (in which twenty isolates RS-1, RS-2, RS-3, RS-4, RS- 5, RS-6, RS-10, RS-12, RS-13, RS-14, RS-15, RS-16, RS-17, RS-25, RS-26, RS-27, RS- 28, RS-41, RS-57 and RS-58 took only 3-6 days), while eleven isolates RS-7, RS-8, RS-23, RS-31, RS-32, RS-33, RS-37, RS-42, RS-44, RS-51 and RS-54 took 10-15 days to initiate the formation of sclerotia (with two isolates RS-32 and RS-37 taking 12-15 days). Of these 58 isolates, fifteen are RS-7, RS-8, RS-9, RS-23, RS-31, RS-33, RS-42, RS-44, RS-47, RS-48, RS- 49, RS-51, RS-52, RS-54 and RS-56 took 9-12 days to initiate the formation of sclerotia. According to Meena *et al.* (2001) the time for the formation of sclerotia ranged from 3 to 11 days.

4.2.2.4 Diameter of sclerotia:

The isolates tested were divided into two groups based on the diameter of the sclerotia (Table 4.6). Group 1 had a diameter range of 1-2 mm and Group 2 had a diameter range of 2-3 mm. The diameter of the sclerotia was observed up to the maximum range in isolates RS-6 (2.95 mm) and minimally up to RS-31 (1.56 mm). Seventeen isolates (RS-1, RS-9, RS-10, RS-14, RS-15, RS-18, RS-21, RS-23, RS-31, RS-35, RS-36, RS-38 , RS-46, RS-49, RS-51, RS-54 and RS-56) were classified in group 1 with a diameter range between 1 and 2 mm. Forty-one isolates (RS-2, RS-3, RS-4, RS-5, RS-6, RS-7, RS-8, RS-11, RS12, RS-13, RS-16, RS-17, RS -19, RS-20,

RS-22, RS-24, RS-25, RS-26, RS-27, RS-28, RS-29, RS-30, RS-32, RS-33, RS-34, RS-37, RS-39, RS-40, RS-41, RS-42, RS-43, RS-44, RS-45, RS-47, RS-48, RS-50, RS-52, RS-53, RS-55, RS-57 and RS-58) were divided into group 2 with a diameter range between 2-3 mm. Dath (1985) and IRRI (1986) also reported that the diameter of the *R. solani* sclerotia was in the range of 1 to 3 mm. The size of the sclerotia ranged from 0.85 to 3.05 mm (Hoa, 1994). Basu *et al.* (2004) reported that the sclerotial diameter was between 0.23 and 1.91 mm and that the frequency and size of the sclerotia determine the virulence of an isolate. The size of the sclerotia varied between 1.31 and 2.08 mm (Guleria *et al.*, 2007).

4.2.2.5 Number of sclerotia:

Based on the number of sclerotia of *R. solani* per petriplate (Table 4.6 and Fig. 4.7, 4.8 and 4.9), various counted isolates were divided into six groups. Out of 58 isolates, none of the isolates were divided into group 1 (poor: no sclerotia) and group 2 (Fair: 1-10), while group 3 (moderate: 11-20) comprised eight isolates (RS-40), RS-41, RS-46, RS-47, RS-48, RS-49, RS-50 and RS-51). Group 4 (good: 21-40) comprised eighteen isolates (RS-28, RS-29, RS-32, RS-33, RS-34, RS-36, RS-37, RS-39, RS-42, RS-43, RS-44, RS-45, RS-52, RS-53, RS-54, RS-55, RS-56 and RS-57), group -5 (very good: 41-60) comprised six isolates (RS-5, RS-6, RS-30, RS-31, RS-35 and RS-38) and group 6 (Excellent: more than 60) comprised 26 isolates (RS-1, RS-2, RS-3, RS-4, RS-7, RS-8, RS-9, RS-10, RS-11, RS-12, RS-13, RS-14, RS-15, RS-16, RS-17, RS-18, RS-19, RS-20, RS-21, RS-22, RS-23, RS-24, RS-25, RS-26, RS-27 and RS-58). Basu *et al.* (2004) found that the frequency and size of sclerotia determine the aggressiveness of an isolate. He collected sheath blight infected rice samples from various locations in West Bengal, namely R1 (Mashuri: Burdwan, Dist), R2 (IR 36), R3 (IR 50), R5 (Jaya: all from Chinsurah Dist. Hooghly), R7 (Saket 4 : Pandua, Dist. Hooghly), R9 (Pankaj Arambagh Dist. Hooghly), R11 (IR 36: Howrah Dist.) And R12 (Jaya, Bhangar Dist.). Aerial growth was abundant (R12) to abundant (R1, R5, R7, R9 and R11) in most isolates. It was moderate in R2 and sparse in R3. The colony color ranged from creamy (R5 and R7) to light brown (R1, R2, R3, R9, R11 and R12). Sclerotia were not differentiated in isolates R3 and R5. Sclerotial production was poor

in isolates R1 and R7, adequate in R12 and good in R2, R9 and R11. The sclerotial size was largest in R9 and smallest in isolate R2. The severity of the disease was lowest in seedlings inoculated with isolates R3 and R5 and highest in seedlings inoculated with isolates R9 and R11. Basu *et al.* (2004) found that the virulence of an isolate is determined by the frequency of sclerotia. The majority of isolates developed a high number of sclerotia in the range of 40 to 60 within 3 to 10 days (Mishra *et al.*, 2014). Number of sclerotia was ranged between 53.67-164.00 .Different distribution patterns were observed in sclerotia production viz., central, peripheral and scattered (Yaduman *et al.*,2019).

Table 4.6: Sclerotial characteristics of different isolates of *R. solani*:

Isolates	Time taken for initiation of sclerotia formation (Days)	Average diameter (mm) of 15 sclerotia per plate	Avg. no. of sclerotia per Petridish	Category (Excellent*/Good*/Very good*)
RS1	4	1.71	68.33	Excellent
RS2	4	2.07	73.44	Excellent
RS3	4	2.46	69.84	Excellent
RS4	4	2.15	61.00	Excellent
RS5	4.2	2.27	58.11	Very good
RS6	5	2.95	59.22	Very good
RS7	11.8	2.02	63.11	Excellent
RS8	11	2.02	64.44	Excellent
RS9	10	1.97	61.17	Excellent
RS10	5	1.99	69.89	Excellent
RS11	8	2.23	66.78	Excellent
RS12	4	2.26	73.55	Excellent
RS13	5.6	2.62	73.55	Excellent
RS14	5	1.87	67.44	Excellent
RS15	5	1.92	70.24	Excellent
RS16	6	2.26	64.67	Excellent
RS17	5	2.06	62.77	Excellent
RS18	7	1.72	69.33	Excellent
RS19	3	2.09	62.55	Excellent
RS20	8.60	2.36	61.00	Excellent
RS21	8.80	1.83	64.06	Excellent
RS22	9	2.01	78.00	Excellent
RS23	11.4	1.61	77.22	Excellent
RS24	8.80	2.5	75.67	Excellent

Isolates	Time taken for initiation of sclerotia formation (Days)	Average diameter (mm) of 15 sclerotia per plate	Avg. no. of sclerotia per Petridish	Category (Excellent*/Good*/Very good*)
RS25	4	2.10	76.44	Excellent
RS26	5	2.13	77.67	Excellent
RS27	5.80	2.04	77.00	Excellent
RS28	6	2.09	39.00	Good
RS29	8	2.01	36.89	Good
RS30	7	2.38	42.22	Very good
RS31	11.00	1.56	42.67	Very good
RS32	12.40	2.66	36.55	Good
RS 33	11	2.04	39.47	Good
RS 34	3	2.26	39.89	Good
RS 35	8.20	1.83	43.78	Very good
RS 36	9.0	1.82	36.78	Good
RS 37	12.8	2.11	35.78	Good
RS 38	8	1.99	42.89	Very good
RS 39	6.20	2.02	39.82	Good
RS 40	8.0	2.12	20.89	Moderate
RS 41	6.0	2.11	17.11	Moderate
RS 42	11.60	2.39	25.44	Good
RS 43	7.0	2.29	24.22	Good
RS 44	12	2.45	23.78	Good
RS 45	7	2.02	22.28	Good
RS 46	7.8	1.63	14.66	Moderate
RS 47	9.80	2.56	16.89	Moderate
RS 48	9.8	2.60	13.22	Moderate
RS 49	10	1.90	20.44	Moderate
RS 50	3	2.15	20.33	Moderate
RS 51	11	1.65	17.11	Moderate
RS 52	9.60	2.58	27.33	Good
RS 53	8	2.05	23.66	Good
RS 54	10.60	1.59	29.89	Good
RS 55	7.8	2.38	28.00	Good
RS 56	9.80	1.86	29.00	Good
RS 57	4	2.07	27.57	Good
RS 58	5	2.05	70.11	Excellent

Sclerotia forming isolates were categorized as: No sclerotia-poor, 1-10 fair, 11-20 moderate, 21-40 good, 41- 60 very good and >60 as excellent.

4.2.2.6 Manner of sclerotia formation within the petridish:

Based on the manner of sclerotium formed in the petri dishes (Table 4.7 and Fig. 4.7), the isolates of *R. solani* were divided into three groups. Sclerotium formed in the central ring was divided into group 1, which consisted of eleven isolates (RS-5, RS-6, RS-8, RS-10, RS-14, RS-24, RS-36, RS-39, RS -45, RS-55 and RS-58). Seven isolates (RS-4, RS-11, RS-19, RS-32, RS-34, RS-40 and RS-46) were those in which sclerotium was formed peripherally and divided into group 2. Those isolates in which sclerotium was formed, which was scattered in the Petri dish, *i.e.* neither peripherally nor centrally, were divided into a separate group 3, which included forty isolates (RS-1, RS-2, RS-3, RS-7, RS-9, RS12, RS-13, RS-15, RS-16, RS-17, RS-18, RS-20, RS-21, RS-22, RS-23, RS-25, RS-26, RS-27, RS-28, RS-29, RS-30, RS-31, RS-33, RS-35, RS-37, RS-38, RS-41, RS-42, RS-43, RS-44, RS-47, RS-48, RS-49, RS-50, RS-51, RS-52, RS-53, RS-54, RS-56 and RS-57). Sclerotic formation was developed in the same way by Singh *et al.* (1990) and Singh *et al.* (2002) reports that Central, peripheral or scattered. Lal M. and Kandhari J. (2009) found that the morphological variation of 25 isolates from different rice growing areas was investigated. In these isolates, colony size, colony growth, color and sclerotia formation (central, peripheral or scattered), location (air or surface) and texture (smooth or rough) varied. Mishra *et al.* (2014) observed that the sclerotia of the isolates were light brown, brown, dark brown and black in color and formed as a central, sub-central ring, peripheral ring, scattered and irregular.

4.2.2.7 Location of sclerotia formation:

The location of the sclerotia was observed based on where the sclerotia actually formed in the fungal colony (Table 4.7 and Fig. 4.7). Based on the location of the formation of sclerotia in the Petriplate, these isolates were divided into three groups. The first group included the four isolates in which sclerotium formed in the aerial mycelium (RS-6, RS-8, RS-22 and RS-36). The second group included the eleven isolates in which sclerotia developed on the surface of the mycelium (RS-5, RS-10, RS-14, RS-20, RS-24, RS-31, RS-32, RS-41 , RS-46, RS-49 and RS-53). Forty-three isolates RS-1, RS-2, RS-3, RS-4, RS-7, RS-9, RS-11, RS-12, RS-13, RS-

15, RS-16, RS-17, RS-18, RS-19, RS-21, RS-23, RS-25, RS-26, RS-27, RS-28, RS-29, RS-30, RS-33, RS-34, RS - 35, RS-37, RS-38. RS-39, RS-40, RS-42, RS-43, RS-44, RS-45, RS-47, RS-48, RS-50, RS-51, RS-52, RS-54, RS- 55, RS-56, RS-57 and RS-58 had sclerotia embedded in the fungal mycelium itself. Singh *et al.* (2002) reported the location of the sclerotia as aerial, surface and embedded. Similarly, the morphological characterization of *R. solani* isolates was performed based on the size and position of the sclerotia in the Petri dish on the PDA medium (Banniza *et al.*, 1996; Sherwood *et al.*, 1969; Vijayan *et al.*, 1985; Vilgalys and Cubeta, 1994). Basu *et al.* (2004) collected sheath blight infected rice samples from various locations in West Bengal, namely R1 (Mashuri: Burdwan, Dist), R2 (IR 36), R3 (IR 50), R5 (Jaya: all from Chinsurah Dist.Hooghly), R7 (Saket 4: Pandua, Dist.Hooghly), R9 (Pankaj Arambagh Dist.Hooghly), R11 (IR 36: Howrah Dist.) And R12 (Jaya, Bhangar Dist.). Air growth was luxuriant (R12) to abundant (R1, R5, R7, R9 and R11) in most isolates.

4.2.2.8 Texture of sclerotia:

Based on the texture of the sclerotia formed in the petri dishes, the 58 isolates from *R. solani* were divided into two groups, *i.e.* Smooth and rough (Table 4.7 and Fig.4.7). Fifty-one isolate from all 58 isolates RS-1, RS-3, RS-4, RS-5, RS-6, RS-7, RS-9, RS-10, RS-11, RS-12, RS-13, RS-15, RS- 16, RS-17, RS-18, RS-19, RS-20, RS-21, RS-22, RS-23, RS-26, RS-27, RS-28, RS-29, RS-30, RS-31, RS-32, RS-33, RS-34, RS-35, RS-36, RS-37, RS-38, RS-39, RS-40, RS-41, RS-42, RS- 44, RS-45, RS-46, RS-47, RS-48, RS-49, RS-50, RS-51, RS-52, RS-53, RS-54, RS-55, RS-57 and RS-58 had a smooth category of sclerotium and 7 remaining isolates, namely RS-2, RS-8, RS-14, RS-24, RS-25, RS43 and RS-56 had a broad category of sclerotium. Basu *et al.* (2004) recorded the diameter of sclerotium in the range from 0.23 to 1.91 mm and observed how often and large sclerotia judged the aggressiveness of the isolate. Hoa (1994) also observed that brown, light / dark brown, black brown, chocolate brown varied in the sclerotial color. The sclerotial texture was divided into two smooth and rough classes. 12 isolates were divided into the smooth category and the remaining 12 isolates into the rough category.

4.2.2.9 Colour of sclerotia:

All fifty-eight *R. solani* isolates showed variations in the color of sclerotium (Table 4.7). Based on the pigmentation of the sclerotium, the isolates were divided into four groups, *i.e.* dark brown including isolates RS-7, RS-14, RS-34 and RS-49, light brown including isolates RS-3, RS-8, RS-21, RS-28, RS-33, RS-40 and RS-50, brown including isolates RS-1, RS-2, RS-4, RS-5, RS-6, RS-9, RS- 10, RS-11, RS-12, RS-13, RS-15, RS-16, RS-17, RS-18, RS-19, RS-20, RS-22, RS-23, RS-24, RS -25, RS-26, RS-27, RS-29, RS-30, RS-31, RS-32, RS-35, RS-36, RS-37, RS-38, RS-39, RS- 41, RS-42, RS-43, RS-44, RS-45, RS-46, RS-47, RS-48, RS-51, RS-52, RS-53, RS-54, RS-55, RS -56, RS-57 and RS-58. Hoa (1994) also observed that brown, light / dark brown, black-brown varied in the sclerotial color. The sclerotia of the isolates were colored light brown, brown, dark brown and black and formed as a central, sub-central ring, peripheral ring, scattered and irregular (Mishra *et al.*, 2014). Guleria *et al.* (2007) found that the overall sclerotic color, with the exception of two isolates, was dark brown and most of them were found scattered throughout the colony.

Manjunath, O. (2016) examined the morphological and cultural variation in *R. solani* with regard to the important basic factors for the identification of a fungus and its variability, colony color, colony texture, colony diameter and growth rate showed the presence of significant variations between the isolates. 15 days after the inoculation, observations were made on the variation of the sclerotial properties such as color of the sclerotia, place of formation, production pattern, number of sclerotia and weight. The color of the colony varied from ivory to light brown. Among the twenty isolates, five were ivory, two olive, nine sand yellow, and four light brown.

Table 4.7: Formation, location, texture and colour of sclerotia of different isolates of *R. solani*

Isolates	Manner of sclerotia Formation			Location of sclerotia			Texture of sclerotia		Colour of sclerotia
	Central	Peripheral	Scattered	Arial	Surface	Embedded	Smooth	Rough	Brown
RS1	-	-	Scattered	-	-	Embedded	Smooth	-	-
RS2	-	-	Scattered	-	-	Embedded	-	-	Brown
RS3	-	-	Scattered	-	-	Embedded	Smooth	-	Light brown
RS4	-	-	-	-	-	Embedded	Smooth	-	Brown

Isolates	Manner of sclerotia Formation			Location of sclerotia			Texture of sclerotia		Colour of sclerotia
	Central	Peripheral	Scattered	Arial	Surface	Embedded	Smooth	Rough	Brown
RS5	Central	-	-	-	-	-	-	-	Brown
RS6	Central	-	-	Arial	-	Embedded	Smooth	-	Brown
RS7	-	-	Scattered	-	-	Embedded	Smooth	-	Dark brown
RS8	Central	-	-	-	-	-	-	Rough	Light brown
RS9	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS10	Central	-	-	-	Surface	-	Smooth	-	Brown
RS11	-	Peripheral	-	-	-	Embedded	Smooth	-	Brown
RS12	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS13	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS14	Central	-	-	-	Surface	-	-	Rough	Dark brown
RS15	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS16	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS17	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS18	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS19	-	Peripheral	-	-	-	Embedded	Smooth	-	Brown
RS20	-	-	Scattered	-	Surface	-	-	-	brown
RS21	-	-	Scattered	-	-	-	Smooth	-	Light brown
RS22	-	-	Scattered	Arial	-	-	Smooth	-	Brown
RS23	-	-	Scattered	-	-	-	Smooth	-	Brown
RS24	Central	-	-	-	Surface	-	-	Rough	Brown
RS25	-	-	Scattered	-	-	-	-	-	Brown
RS26	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS27	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS28	-	-	Scattered	-	-	Embedded	Smooth	-	Light brown
RS29	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS30	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS31	-	-	Scattered	-	-	-	Smooth	-	Brown
RS32	-	Peripheral	-	-	Surface	-	Smooth	-	Brown
RS 33	-	-	-	-	-	Embedded	Smooth	-	Light brown
RS 34	-	Peripheral	-	-	-	Embedded	Smooth	-	Dark brown
RS35	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 36	Central	-	-	-	-	-	-	-	Brown
RS 37	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 38	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 39	Central	-	-	-	-	Embedded	Smooth	-	Brown
RS 40	-	Peripheral	-	-	-	Embedded	Smooth	-	Light brown
RS 41	-	-	Scattered	-	Surface	-	-	-	Brown
RS 42	-	-	Scattered	-	-	Embedded	Smooth	-	Brown

Isolates	Manner of sclerotia Formation			Location of sclerotia			Texture of sclerotia		Colour of sclerotia
	Central	Peripheral	Scattered	Arial	Surface	Embedded	Smooth	Rough	Brown
RS 43	-	-	Scattered	-	-	Embedded	-	Rough	Brown
RS 44	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 45	Central	-	-	-	-	Embedded	Smooth	-	Brown
RS 46	-	Peripheral	-	-	Surface	-	-	-	Brown
RS 47	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 48	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 49	-	-	Scattered	-	Surface	-	Smooth	-	Dark brown
RS 50	-	-	Scattered	-	-	Embedded	Smooth	-	Light brown
RS 51	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 52	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 53	-	-	Scattered	-	Surface	-	Smooth	-	Brown
RS 54	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 55	Central	-	-	-	-	Embedded	Smooth	-	Brown
RS 56	-	-	Scattered	-	-	Embedded	-	Rough	Brown
RS 57	-	-	Scattered	-	-	Embedded	Smooth	-	Brown
RS 58	Central	-	-	-	-	Embedded	Smooth	-	Brown

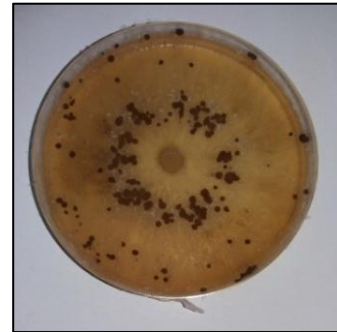
Fig.4.7: Cultural and morphological characters of *R. solani*:



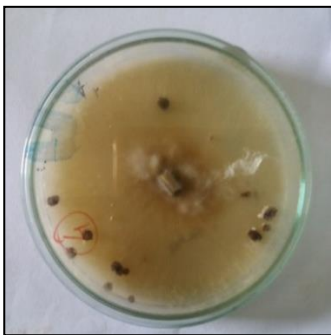
Isolate RS-1 (Scattered sclerotia)



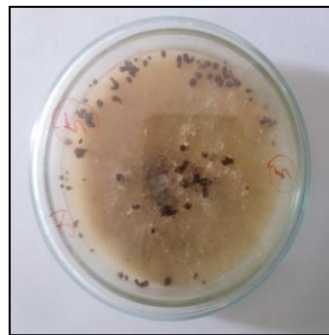
Isolate RS-2



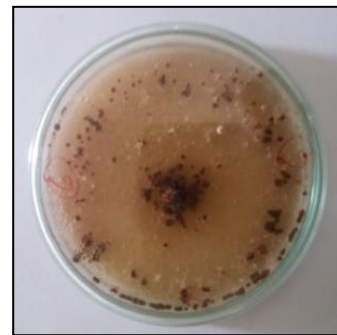
Isolate RS-3 (Central sclerotia)



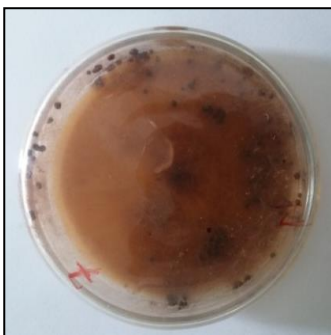
Isolate RS-4



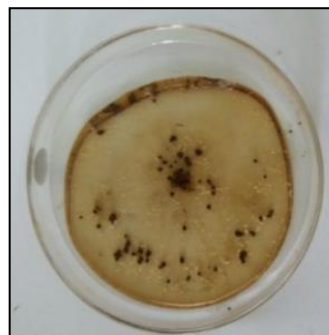
Isolate RS-5



Isolate RS-6



Isolate RS-7



Isolate RS-8



Isolate RS-9



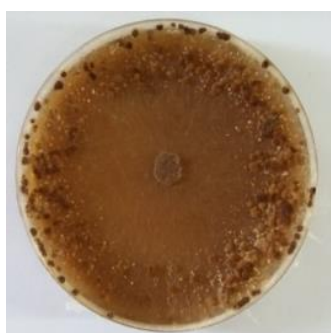
Isolate RS-10



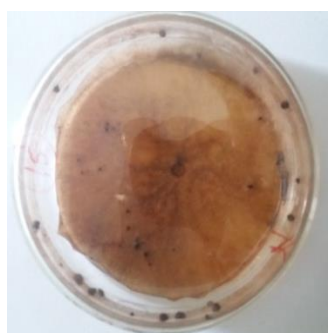
Isolate RS-11



Isolate RS-12

Isolate RS-13 (Peripheral,
Abundant, sclerotia)

Isolate RS-14



Isolate RS-15



Isolate RS-16



Isolate RS-17



Isolate RS-18 (Slight growth)

Fig.4.8: Cultural and morphological characters of *R. solani*:



Fig.4.9: Cultural and morphological characters of *R. solani*:



Isolate RS-36



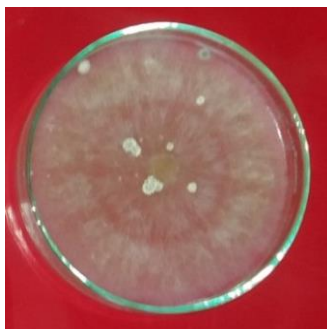
Isolate RS-37



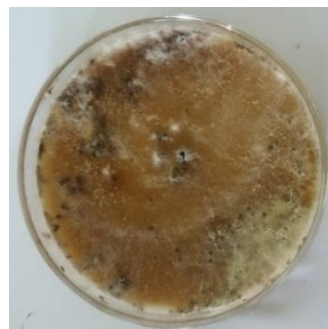
Isolate RS-39



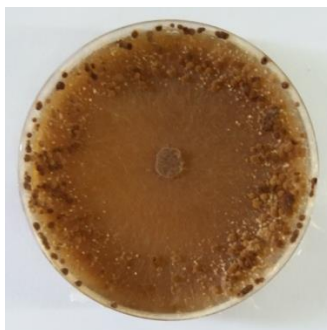
Isolate RS-40



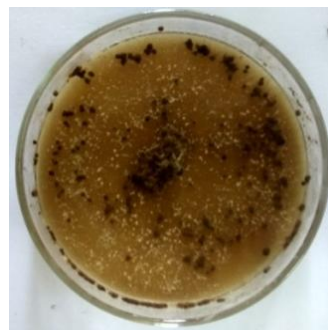
Isolate RS-43



Isolate RS-44

Isolate RS-45(Central
Embedded)

Isolate RS-46



Isolate RS-47



Isolate RS-48



Isolate RS-49



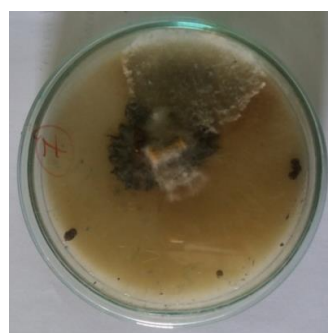
Isolate RS-50



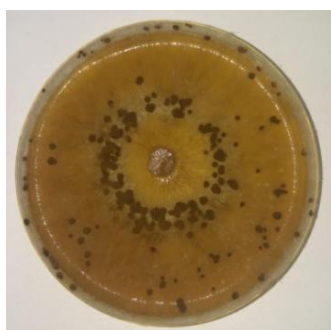
Isolate RS-51



Isolate RS-52



Isolate RS-54



Isolate RS-55



Isolate RS-57(Abundant growth)



Isolate RS-58 (Moderate growth)

Integration of technologies to manage sheath blight of rice:

4.3 Screening of native isolates of *Trichoderma* spp against *R. solani* in vitro:

4.3.1 Under dual culture study :

The present study was undertaken during the kharif 2016 to screen the native isolates of *Trichoderma* spp against *R. solani* in vitro. Treatments were allocated under completely randomized design (CRD). The data presented in the table no. 4.8 and fig. 4.10, 4.11 and 4.12 showed that in dual culture study, all the native *Trichoderma* isolates were significantly inhibited the mycelial growth of *R. solani* over the control. The mycelial growth of *R. solani* was highly inhibited by the Th-2 (34.66%) with 61.47% decrease over control which is statistically on par with the Th-1 with 35.40mm mycelial growth and 60.66% decrease over control treatment, Th-5 with 35.60mm mycelial growth and 60.22% decrease over control, Th-3 with 36.80mm mycelial growth and 59.11% decrease over control and Th-4 with 41.97mm mycelial growth and 53.70% decrease over control treatment. The maximum mycelial growth was recorded under control treatment (90.00 mm). The sclerotial production was not observed in all the *Trichoderma* isolate treated plates. Similar results are in the agreement with Kumar and Marimuthu (1994) revealed that *Trichoderma* sp. with *R. solani* in dual-cultures and found that *T. viride* was the most antagonistic followed by *T. harzianum* and *T. longibrachiatum*. Salam (2007) tested that all the isolates of *Trichoderma* in dual culture inhibited mycelial growth of *R. solani* and inhibition ranged from 60.37 to 71.48 per cent over control. A clear visible band was formed in the zone of contact between the two fungal growth. The sclerotial production was not recorded in all the *Trichoderma* isolate treated plates. Chakravarthy and Nagamani (2007) tested the antagonistic potential of twenty-six isolates against *R. solani* Kuhn and reported that *T. harzianum* (M10P) and *T. aureoviride* (TA1) were more aggressive and significantly reduced the formation of sclerotia of *R. solani*.

4.3.2 Effect of volatile compounds on *R. solani*:

Results showed that all *Trichoderma* isolates secreted volatile compounds significantly reduces the mycelial growth of *R. solani* (table no. 4.8 and fig. 4.12). Among all *Trichoderma* isolates, the volatile compound of *Trichoderma* isolate Th-4

was found significantly superior to check the mycelial growth of *R. solani* (19.60mm) with 78.51% decrease over control and found most effective for release of volatile compounds against *R. solani*. It is followed by Th-1 isolate (with 39.06mm and 56.66% decrease over control), Th-2 (with 40.13mm and 55.55% decrease over control), Th-5 (with 44.80mm and 50.37% decrease over control) and Th-3 (with 55.53mm and 38.51% decrease over control) treatment of volatile compound. The maximum mycelial growth was recorded under control untreated treatment (90.00 mm). Since, *Trichoderma* sp. known to exhibit the various types of mechanisms when come into contact with other microorganisms especially with soil borne fungal pathogens. Mycoparasitism, release of volatile and non-volatile diffusible compounds (antibiotics) and hydrolytic enzymes are mainly responsible for their effectiveness against other microorganism. In this study, native isolates of *Trichoderma harzianum* were also evaluated for some of the mechanisms like mycoparasitism (dual culture) and release of volatile compounds against *R. solani* and result showed that isolate Th-2 was found best for mycoparasitism and isolate Th-4 for release of volatile compounds. Similar results are in the agreement with Salam (2007) revealed that five isolates of *Trichoderma harzianum* inhibited the mycelial growth and sclerotial formation of the *R. solani* by the production of volatile compounds. Similarly, efficacy of various species of *Trichoderma* against *R. solani* was also observed by several workers when they evaluated *Trichoderma* sp. by various ways, supports the present findings (Ogura and Akai 1965; Hashioka and Fukita 1969; Dennis and Webster 1971; Well *et al.* 1972; Elad *et al.* 1982; Kumar and Marimuthu 1994; Cliquet and Scheffer 1996; Dubey, 1998; Das *et al.* 1998; Das and Hazarika, 2000; Kharakrang *et al.* 2002; Mishra and Sinha, 2002; Nagaraju *et al.* 2002; TangZia Bin *et al.* 2002; Kazempour *et al.* 2003; Meena *et al.* 2003; Rudresh *et al.* 2005 and Chakravarthy and Nagamani, 2007). A more sustainable approach for Sheath blight management in rice with less reliance on synthetic fungicides, greater use of natural fungicides such as strobilurins and biological agents like *Trichoderma spp.*, *Pseudomonas spp.*, *Gliocladium spp.*, *Bacillus spp.* to restrict disease (Singh *et al.*, 2019).

Table 4.8: Effect of native *Trichoderma* isolates on mycelial growth and sclerotia formation of *R. solani*

<i>Trichoderma</i> isolates	Mycelial growth (mm) of <i>R. solani</i>	% decrease over control	Volatile compounds (Mycelial growth)	% decrease over control
Th-1	35.40	60.66	39.06	56.66
Th-2	34.66	61.47	40.13	55.55
Th-3	36.80	59.11	55.53	38.51
Th-4	41.97	53.70	19.60	78.51
Th-5	35.60	60.22	44.80	50.37
Control	90.0	-	90.0	-
SE(m)+	2.50051		2.21560	
CD (5%)	7.70486		6.82694	

Production and inhibitory effect of volatile compounds of *Trichoderma* isolates tested against *R. solani*. Such antagonism tested by Dual culture technique.

4 plates per replication



After 48 hrs.



After 72 hrs.

Fig.4.10: Effect of native *Trichoderma* isolates on mycelial growth of *R. solani*

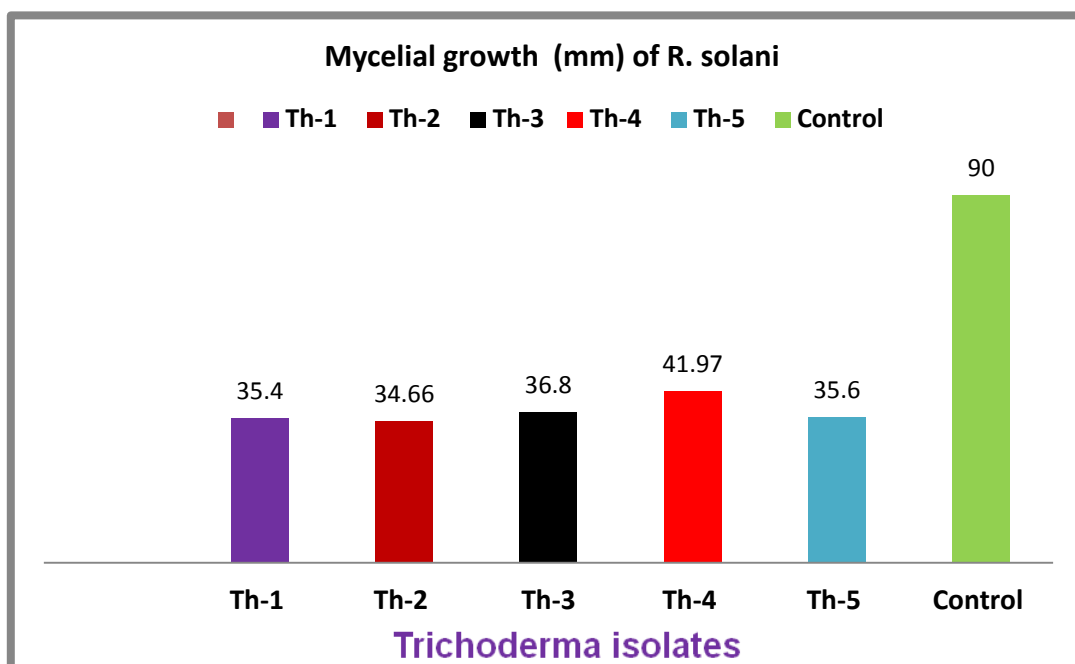


Fig4.11: Effect of native *Trichoderma* isolates (Dual culture) on mycelial growth of *R. solani*

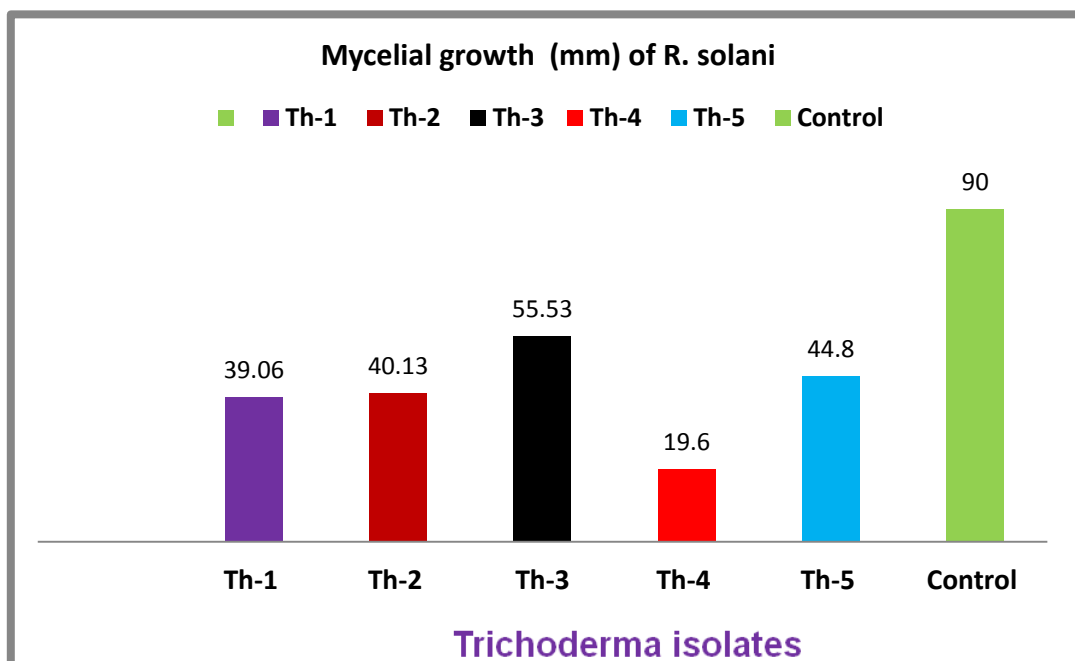


Fig. 4.12: Effect of native *Trichoderma* isolates (volatile compounds) on mycelial growth of *R. solani*

4.3.3 Effect of native *Pseudomonas fluorescence* strains on mycelial growth and sclerotia formation of *R. solani*

To screen the native isolates of *Pseudomonas fluorescence* against *R. solani* *in vitro*, the present study was undertaken during the kharif 2016. Treatments were allocated under completely randomized design (CRD). The data presented in the table no. 4.9 showed that in dual culture study, all the native *Pseudomonas* strains were significantly inhibited to the mycelial growth of *R. solani* over the control. The mycelial growth of *R. solani* was highly inhibited by the Pf-05 (with 7.94mm mycelial growth and 91.18% decrease over control) and was found on par with the Pf-01 (with 9.54mm mycelial growth and 89.40% decrease over control) which is followed by Pf-02 (with 16.67mm mycelial growth and 81.48% decrease over control), Pf-03 (with 55.60mm mycelial growth and 39.34% decrease over control) and Pf-04 (with 60.67mm mycelial growth and 32.59% decrease over control). The maximum mycelial growth was recorded under control treatment (90.00 mm). No sclerotial formation was recorded in all the isolates taken in the study.

Mishra and Sinha (2000) found two strains of *P. fluorescens*, viz. PF1 and FP7, inhibited the mycelial growth of sheath blight fungus *R. solani* and enhanced rice plants seedling vigour and yield under greenhouse and field conditions. Treatment *Pseudomonas* with rice cv. IR50 led to induction of systematic resistance against *R. solani* as a result of increase in chitinase and peroxidase activity (Nandakumar *et al.* 2001). Singh Rajbir and Sinha (2005) recorded *P. fluorescens* strains 1 and 5 having an effect on sheath blight, *R. solani* on rice under glasshouse conditions. They found that higher rate of *P. fluorescens* i.e., 8 g/l was highly effective in reducing 60 percent of disease severity and 35.6 percent of incidence (and raising grain yield (33.8%) and 1000-grain weight (12.9%).

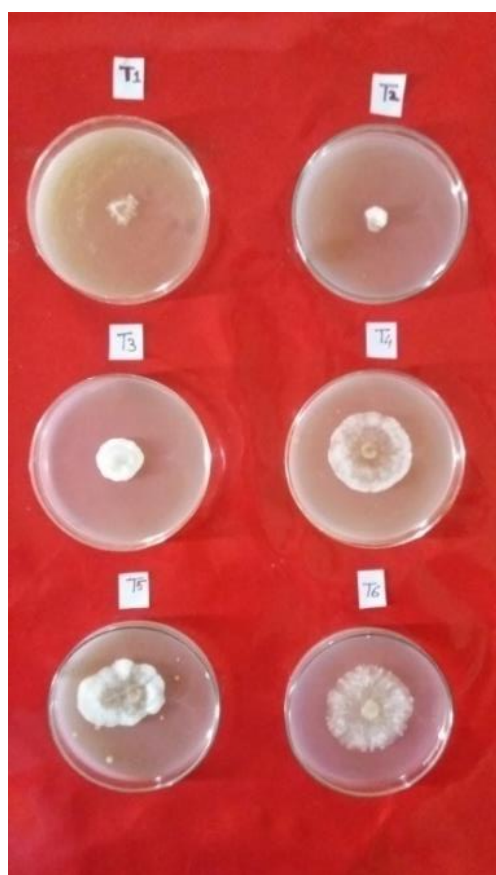
Table 4.9: Effect of native *Pseudomonas fluorescence* strains on mycelial growth and sclerotia formation of *R. solani*

<i>P. fluorescence</i> strain	Mycelial growth (mm) of <i>R. solani</i>	% decrease over control
P.f 01	9.54	89.40
P.f 02	16.67	81.48
P.f 03	55.6	39.34
P.f 04	60.67	32.59
P.f 05	7.94	91.18
Control	90.0	0.0
SE(m)+	1.466919	
CD (5%)	4.520028	

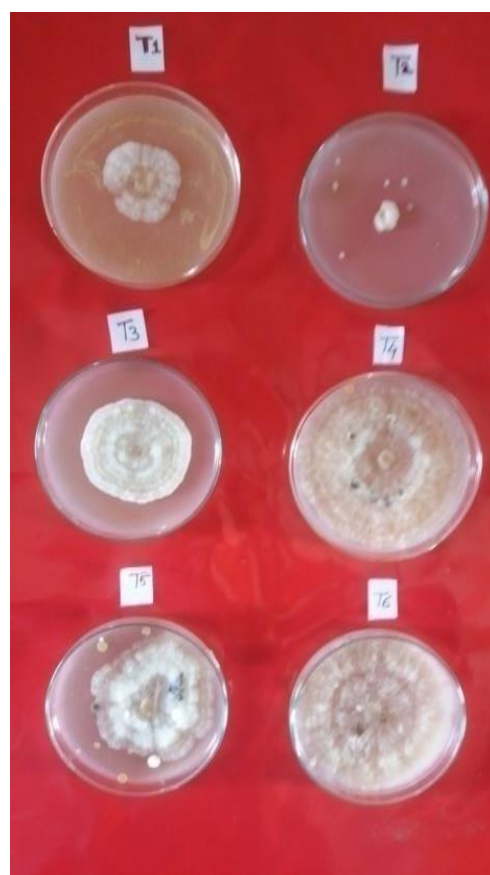
4.4 Evaluation of ITK (Indigenous Technical Knowledge's) techniques viz application of panchgavya and plant extracts against *R. solani* *in vitro*

4.4.1 *In vitro* condition:

The present study was undertaken during the kharif 2016 to evaluate the ITK (Indigenous Technical Knowledge's) techniques viz application of panchgavya and plant extracts against *R. solani* *in vitro*. Four plant leaf extracts namely, Neem (*Azadirachta indica*), Garlic (*Allium sativum*), Datura (*Datura stramonium*), Lemon grass (*Cymbopogon flexuosus*) and Panchgavya (at 10% concentration) were tested under *in vitro* condition in cold water, hot water and acetone against *R. solani*. Observations for mycelial growth was recorded and presented in table 4.8 and fig. 4.13.



After 3 days



After 7 days

Fig.:4.13: Effect of medicinal plant extracts and Panchgavya on growth of *R. solani*

4.4.2 Under cold water:

The results presented in the table 4.10 indicated that under cold water, medicinal plant leaf extracts and panchgavya significantly reduced the mycelial growth of *R. solani*. The mycelial growth of *R. solani* was highly inhibited by Garlic extract (17.53mm mycelial growth with 80.51% decrease over control) and was found highly effective followed by Neem extract (36.20mm mycelial growth with 59.77% decrease over control), Dhatura extract (53.80mm mycelial growth with 40.22% decrease over control) and Panchgavya (73.27mm mycelial growth with 18.59% decrease over control). The maximum mycelial growth was recorded under control treatment (90.00 mm). Garlic leaf extract, Dhatura extract, Neem extract, Panchgavya and Lemon grass extract showed significant difference with each other while Lemmon grass extract was not significantly different over the control treatment. Salam *et al.*, 2009 found the similar results that medicinal plant leaf extracts taken in the study showed significant reduction in disease over control when used at 10% concentration. Absence of sclerotia formation, less mycelia growth and reduced disease severity were observed as a result of plant extracts.

4.4.3 Under hot water:

The results showed that under hot water, all the treatments significantly reduced the mycelial growth of *R. solani* over control. The mycelial growth of *R. solani* was highest reduced by Garlic extract (with 22.33mm mycelial growth and 75.18% decrease over control) and was found highly effective followed by Datura extract (with 48.67mm mycelial growth and 45.92% decrease over control), Neem extract (52.47mm mycelial growth and 41.70% decrease over control), Panchgavya (62.66mm mycelial growth and 30.36% decrease over control) and Lemmon grass extract (72.07mm mycelial growth and 19.92% decrease over control). The maximum mycelial growth was recorded under control treatment (90.00 mm). These medicinal plant leaf extracts and panchgavya showed significant differences with each other.

4.4.4 Under Acetone:

The results indicated that among the medicinal plant leaf extracts and panchgavya, The Datura extract (with 32.40mm mycelial growth and 63.99% decrease

over control) was found significantly superior to check the mycelial growth of *R. solani* and was found statistically on par with Garlic extract (with 37.13mm mycelial growth and 58.74% decrease over control), followed by Neem extract (with 46.86mm mycelial growth and 47.92% decrease over control), Panchgavya (with 58.40mm mycelial growth and 35.11% decrease over control) and Lemon grass extract (with 84.87mm mycelial growth and 5.70% decrease over control).

Among cold water, hot water and acetone, the Panchgavya was found highly effective in acetone chemical followed by hot water against *R. solani* (fig. 4.14).

The results are in agreement with the results of Salam (2007) that it was found that all plant leaf extracts tested significantly reduce the disease compared to the control. Maximum reduction in the percent disease severity was observed in the Datura extract (42.80%), followed by the neem extract (39.35%) compared to the control. Devi *et al.* (1982) reported that lemongrass oil 0.4 ppm (very low concentration) inhibits sclerotial germination and mycelial growth. Reddy and Sudhakar (2002) observed that aspirin was effective in reducing mycelial growth and sclerotic production (100%), followed by extracts from *Allium sativum* (61.8%), *Azadirachta indica* (24.9%) and *Allium cepa* (19, 3%). Ansari (1995) examined many plant extracts against *R. solani* and confirmed *T. Ammi* and *Ocimum* sp. Extracts (leaves) were fungicidal, while the *Cymbopogon flexuosus* extract was fungicidal, *Mentha* sp., *Rauwolfia* sp., *Lawsonia inermis* and *Vitex trifolia* were fungistatic.

Raja and Kurucheve (1997) also observed the effectiveness of Panchgavya ingredients, *i.e.* cow urine and milk, *in vitro* against *R. solani*, the causative agent of sheath blight, and found that a concentration of 10% and 20% of cow urine inhibited mycelial growth and sclerotia production completely inhibited. Previous workers reported the antifungal activity of cow urine (Basak & Lee, 2005) and manure made by cow dung (Ashlesha *et al.*, 2009) against soil pathogens. The strong fungitoxicity of Panchgavya against various fungal pathogens, namely *F. oxysporum*, *F. solani*, *Rhizopus oligosporus* (Joseph & Sankarganesh, 2011), *R. solani*, *S. rolfsii* (Sugha, 2005; Dogra, 2006), *Sclerotinia sclerotiorum* (Shalika, 2009) was examined. The release of antimicrobial compounds can be attributed to the microorganisms (bacteria,

fungi and actinomycetes) present in Panchgavya (Swaminathan *et al.*, 2007). Panchgavya was found to be most effective at a 10 percent concentration under *in vitro* conditions (Ashlesh and Paul, 2014).

The variation in effectiveness may be due to the presence of different antifungals in different solvents. It is not necessary for all antifungals to be present in all solvents (extracts), or the amount may vary depending on the type of solvent used for the extraction. No sclerotial formation and less mycelial growth were observed in this study. This could be due to a decrease in active mycelial growth, and ultimately mycelial strands do not aggregate to form sclerotia. The effectiveness of medicinal plant extracts extracted in various solvents against *R. solani*, including neem-based formation, has been reported by various workers, which supports the present results (Naidu and John, 1981; Devi *et al.* 1982; Tewari and Premalatha Dath, 1984; Shukla *et al.* 1990; Kotasthane and Lakpale, 1994; Ansari, 1995; Shivpuri *et al.* 1997; Dubey, 1998; Kandhari and Singh, 2000 and Reddy and Sudhakar, 2002).

Table 4.10: Inhibitory effect of different plant leaf extracts and panchgavya on mycelial growth of *R. solani* in vitro condition (at 10% concentration):

Plant species	Cold water		Hot water		Acetone	
	Mycelial Growth (mm)	% decrease over control	Mycelial Growth (mm)	% decrease Over control	Mycelial Growth (mm)	% decrease over control
T1 – Neem (<i>Azadirachta indica</i>)	36.2	59.77	52.47	41.7	46.86	47.92
T2 - Garlic (<i>Allium sativum</i>)	17.53	80.51	22.33	75.18	37.13	58.74
T3 - Datura (<i>Datura stramonium</i>)	53.8	40.22	48.67	45.92	32.4	63.99
T4 - Lemon grass (<i>Cymbopogon flexuosus</i>)	90.0	0.0	72.07	19.92	84.87	5.70
T5- Panchgavya	73.27	18.59	62.66	30.36	58.40	35.11
Control	90.0	-	90.0	-	90.0	-
SE(m)+	2.6312		1.9808		2.6464	
CD (5%)	8.1078		6.1035		8.1545	

The extract of each plant species were prepared in cold water and hot water by leaf issues and solvent in 1:1 ratio (w/v).

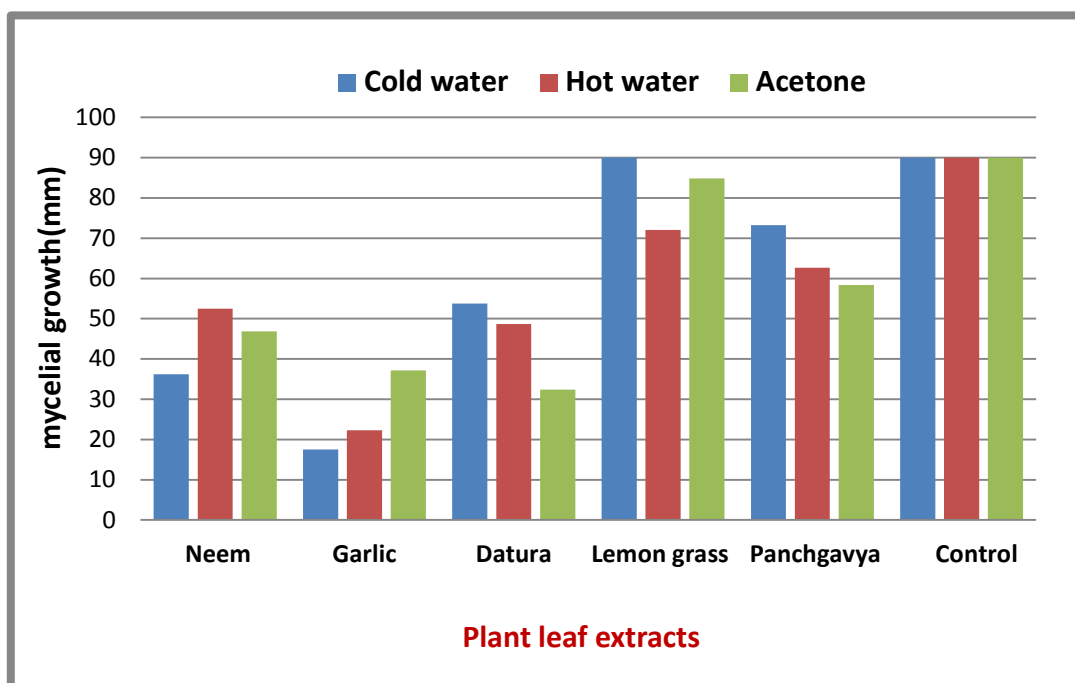


Fig 4.14: Effect of medicinal plant leaf extract on mycelial growth of *R. solani* (at 10 % concentration)

4.5 Impact of sheath blight on seedlings and plant vigour:

The present study was undertaken during kharif 2016 and kharif 2017 in pot and field conditions. Seed vigour was recognized by earlier researchers as an important quality parameter and distinct from germinability. Decline in germinability was also attributed to decline in vigour and might be due to several factors including the seed infection with micro-organisms (Seshu *et al.*, 1987).

4.5.1 Pot condition:

The present study was carried out during the Kharif 2016 and the Kharif 2017. The data from Kharif 2016 shown in table 4.11 showed that both Swarna and Mahamaya achieved the highest percentage of germination when the seeds were obtained from healthy plants panicle (T1) (77.0% and 80.5%) and this treatment is significantly superior over percent of germination when the seeds were obtained from diseased plants panicles. The germination per cent of the seeds harvested from

diseased panicles (T2) were 63.5% (Swarna) and 66.75% (Mahamaya). The seeds of diseased panicles showed a reduction in the percentage germination for Swarna (63.5%) or Mahamaya (66.75%). The shoot length was also longer for healthy plant seeds for both varieties Swarna and Mahamaya 19.46 c.m. and 24.81 c.m. for healthy and 16.70 c.m. and 20.23 c.m. for sick plant seeds. The shoot length was influenced in the case of diseased plant seeds. The seedling vigour index was statistically significant between healthy and diseased plant seeds in both varieties after 30 days of sowing. A similar trend was observed for the root length of the healthy plant seeds of Swarna (8.13 c.m.) and Mahamaya (10.88 c.m.) after 30 DAS (table 4.11). The diseased plant seeds had a root length of 6.77 c.m. and 8.62c.m.in the same period. The calculated seedling vigour index clearly showed that healthy plant seeds in both varieties, *i.e.* Swarna (2129.05) and Mahamaya (2870.83), were more than the corresponding diseased plant seeds (*i.e.* 1489.71 and 1921.89, respectively). The statistical analysis also clearly showed that the differences in root, shoot and seedling vigour index between the healthy plant seeds (T1) and those of the diseased plant seeds (T2) were significant.

During the year 2017 the data in table 4.12 shows that on 30 days after sown seedlings the seedling vigour index calculated clearly revealed that healthy plant seeds in both the varieties *i.e.*, Swarna (2087.26) and Mahamaya (2761.67) was significantly more than the corresponding diseased plant seeds (*i.e.*, 1403.64 and 1876.97, respectively). A similar trend was observed for the root length of the healthy plant seeds of Swarna (8.09 cm) and Mahamaya (10.77 cm) after 30 DAS. In the same period, the diseased plant seeds had a root length of 6.76 c.m. and 8.57 c.m. The shoot length of the healthy plant seeds for Swarna was 19.70 c.m. and 24.66 c.m. for Mahamaya. The shoot length was also affected in diseased plant seeds, which were 16.44 cm. and 20.17 c.m. during the same observation period. The calculated seedling vigour index clearly showed that healthy plant seeds in both varieties, *i.e.* Swarna (2087.26) and Mahamaya (2761.67), were more than the corresponding diseased plant seeds (*i.e.* 1403.64 and 1876.97, respectively). The statistical analysis also clearly showed that the differences in root, shoot and seedling vigour index between the healthy plant seeds (T1) and those of the diseased plant seeds (T2) were significant.

Table 4.12: Effect of sheath blight incidence on seedling vigor under pot conditions (Year-2017)

Treatment	Seed Source (Quality)	30 Days After Sown Seedlings									
		% Germination		Root length(cm)		Shoot Length (cm)		Seedling vigor index			
		V1	V2	Avg.	V1	V2	Avg.	V1	V2	Avg.	Avg.
T1	Seeds from healthy panicle	75.0	78.0	76.5	8.09	10.77	9.43	19.70	24.66	22.18	2087.26 2761.67 2424.46
T2	Seeds from diseased panicle	60.5	65.25	62.87	6.76	8.57	7.66	16.44	20.17	18.30	1403.64 1876.97 1640.30
	Average	67.75	71.62	69.68	7.425	9.67	8.54	18.07	22.41	20.24	1745.45 2319.32 2032.38
	Variety (V)			0.04			0.04			0.04	0.49
SE(m)+	Seed Source (Quality)(T)			0.04			0.04			0.04	0.49
	V x T			0.06			0.05			0.05	0.69
	Variety (V)			0.13			0.11			0.12	1.50
CD (5%)	Seed Source (Quality)(T)			0.13			0.11			0.12	1.50
	V x T			1.19			0.15			0.16	2.13
CV (%)				1.46			3.30			2.33	3.09

V1- Swarna V2- Mahamaya *Average of four replications* Square root transformation

The pooled data in the table 4.13 clearly showed that both Swarna and Mahamaya had the significant highest percent germination when the seeds came from panicles (T1) of healthy plants (76.0% and 79.25%, respectively) over the seeds harvested from diseased panicles (T2) recorded 62.0% (Swarna) and 66.0% (Mahamaya). On 30 days after sown seedlings, the shoot length for healthy plant seeds was also significantly greater for both varieties Swarna and Mahamaya than for sick (19.58 cm and 24.73 cm for healthy while 16.57cm and 20.20cm for diseased plant seeds). A root length of healthy plant seeds from Swarna (8.11 cm) and Mahamaya (10.82 cm) were observed after 30 DAS. During the same period, the diseased plant seeds had a root length of 6.76 cm and 8.59 cm. The shoot length for the healthy plant seeds for Swarna was 19.58 cm and for Mahamaya was 24.73 cm. The shoot length was also influenced in the case of diseased plant seeds, which were 16.57 cm and 20.20 cm in the same observation period. The calculated seedling vigour index clearly showed that healthy plant seeds in both varieties Swarna (2108.15) and Mahamaya (2816.25) were significantly higher than the corresponding diseased plant seeds (ie 1446.67 and 1899.43). The statistical analysis also clearly revealed that root, shoot and seedling vigor index differences were significant between the healthy plant seeds (T1) to that of diseased plant seeds (T2). The results are consistent with the findings of Persaud (2009) that plants grown from plants infected with sheath blight significantly reduced seed germination, root length and seedling vigour index compared to plants grown from seeds of healthy plants. Seeds from infected panicles showed a decrease in seed germination by 19.87% and 15.39% compared to seeds from healthy plants under greenhouse and field conditions. The root length (0.59 cm & 1.13 cm), the shoot length (4.40 cm & 3.08 cm) and the seedling vigour index (1041.07 & 605.93) were significantly lower in seeds from infected plant panicles compared to healthy plant panicles in one month old seedlings under pot or field conditions. Pant 4, was significantly superior in seed germination, root length, shoot length and seedling vigour index in comparison to cv. swarna in glass house conditions.

Table 4.13: Effect of sheath blight incidence on seedling vigor under Pot conditions (Pooled)

Treatment	Seed Source (Quality)	30 Days After Sown Seedlings											
		% Germination			Root Length (cm)		Shoot Length (cm)		Seedling Vigor index		Avg.	Avg.	
		V1	V2	Avg.	V1	V2	Avg.	V1	V2	V1			V2
		V1	V2	Avg.	V1	V2	Avg.	V1	V2	V1			V2
T1	Seeds from healthy plant panicle	76	79.25	77.625	8.11	10.825	9.465	19.58	24.735	22.155	2108.155	2816.25	2462.2
T2	Seeds from diseased plant panicle	62	66	63.995	6.765	8.595	7.675	16.57	20.2	18.38	1446.675	1899.43	1673.05
	Average	72.62	70.81	7.43	9.71	8.57	18.07	22.46	20.26	1777.41	2357.84	2067.62	72.62
	Variety (V)			0.06			0.04			0.04			0.85
SE(m)+	Seed Source (Quality)(T)			0.06			0.04			0.04			0.85
	V x T			0.08			0.05			0.05			1.20
	Variety (V)			0.18			0.11			0.11			2.63
CD (5%)	Seed Source (Quality)(T)			0.18			0.11			0.11			2.63
	V x T			0.26			0.16			0.16			3.71
CV (%)				1.98			3.38			2.31			5.38
V1- Swarna	V2- Mahamaya	*Average of four replications				Square root transformation							

4.5.2 Field condition:

A field experiment was carried out during the Kharif 2016 and 2017. During 2016, the data shown in table 4.14 showed that similar trends were also observed for both varieties under field conditions at 30 days after sowing. The root length for Swarna seeds of healthy plant panicles was significantly taller 8.73 cm compared to seeds of the same variety that were collected from diseased plant panicles, was 7.57 cm. The root length for healthy Mahamaya panicle seeds was 11.80 cm compared to the same variety seeds collected from diseased panicles, *i.e.* 9.95 cm. Similarly, at 30 days the shoot length for Swarna was 25.65 cm and for Mahamaya was 33.27 cm for the healthy seeds tested and significantly superior over diseased plants. The shoot length was 20.77 cm for Swarna and 31.56 cm for Mahamaya for the diseased seeds tested at 30 days. The seedling vigour index was also significantly higher in healthy plant seeds 2747.21 in Swarna and 3714.33 in Mahamaya in 30 days as compared with in the diseased plant seeds. Similar results have also been observed by Fakir *et al.* (2002) concluded that seed-borne diseases cause serious losses to our crop. Sometimes the infected seeds cannot germinate diseases that spread from seed to seedling and from seedling to 26 growing plants. Nanda and Chaudhary (1972) conducted studies in tropical Asia and reported that the germination percentage was higher (98 percent) and faster with normal than with diseased / spotted seeds (<90 percent). Ou, 1985 and Neergaard, 1979 observed that out of 55 fungi reported to be pathogenic in rice, 43 was seed borne or seed transmissible. Binesh and Torabi (1985) reported seed samples collected from infected rice fields and tested when infected seeds were sown in sterile soil up to 5 percent of the seedlings were killed by *R. solani* and 6.2-11.7 percent of the surviving plants developed sheath blight symptoms.

The year 2017 the data in table 4.15 shows that similar trends were also observed in field conditions at 30 days after sowing. The root length for Swarna's healthy panicle seeds was 9.06 cm and was significantly superior compared to the same variety seeds collected from the panicle of the disease plant, was 7.59 cm, and the root length for Mahamaya plant healthy seeds was found 12.05 cm compared to the same seeds that were collected from the diseased plant panicle was 9.80 cm. Similarly, the shoot lengths were 25.88 cm and 20.90 cm for healthy and sick panicles of Swarna and 33.47 cm and 31.16 cm for Mahamaya at 30 days for the healthy and sick seeds tested. The seedling vigor index was higher for healthy plant seeds (2442.93 in Swarna and 3647.95 in Mahamaya in 30 days for healthy seeds) than for diseased plant seeds. They were also statistically significant. The percent germination, root length, shoot length and seedling vigor index were significantly higher in both varieties (Swarna and Mahamaya) in the healthy plant seeds (T1) as compared to the diseased plant seeds (T2), in both trials conducted under the green house (pot) and field conditions at 30 DAS observation.

The pooled data clearly show in Table 4.16 that both Swarna and Mahamaya had the highest percent germination (79.0% and 81.12%) when the seeds harvested from healthy plants panicle (T1) while the seeds harvested from diseased panicles (T2) showed the germination percent were 64.62% (Swarna) and 67.0% (Mahamaya). On 30 days after sown seedlings, the root length of healthy plant seeds was greater for both the Swarna and Mahamaya varieties than for sick plant seeds (8.89c.m. and 11.92c.m. for healthy and 7.58c.m. and 9.87c.m. for diseased plant seedlings). On 30 days after sown seedlings, the shoot length was also higher in healthy plant seeds than diseased for both the varieties Swarna and Mahamaya (25.76c.m., 33.37c.m. for healthy and 20.83c.m. and 31.36c.m. for diseased plant seeds). The seedling vigor index were statistically significant between healthy and diseased plant seeds in both varieties after 30 days of sowings. The seedling vigour index calculated clearly revealed that the seedlings from healthy plants in both the varieties *i.e.*, Swarna (2595.07) and Mahamaya (3681.14) were more than the corresponding seeds from diseased seedlings (*i.e.*, 1837.14 and 2762.62, respectively). The shoot length in the healthy plant seed for Swarna was 25.76 and for Mahamaya was 33.37. The statistical analysis also clearly revealed that root, shoot and seedling vigor index differences were significant between the healthy plant seeds (T1) to that of diseased plant seeds (T2).

Table 4.16: Effect of sheath blight incidence on seedling vigor under field conditions (Pooled data)

Treatment	Seed Source (Quality)	30 Days After Sown Seedlings									
		% Germination		Root length(cm)		Shoot length (cm)		Seedling Vigor index			
		V1	V2	Avg.	V1	V2	Avg.	V1	V2	Avg.	Avg.
T1	Seeds from healthy panicle	79.0	81.12	80.06	8.89	11.92	10.40	25.76	33.37	29.56	2595.07
T2	Seeds from diseased panicle	64.62	67.0	65.81	7.58	9.87	8.72	20.83	31.36	26.09	1837.14
	Average	71.81	74.06	72.93	8.23	10.89	9.56	23.29	32.36	27.82	2216.10
	Variety (V)			0.73			0.12			0.31	72.40
SE(m)+	Seed Source (Quality)(T)			0.73			0.12			0.31	72.40
	V x T			1.03			0.17			0.44	102.39
	Variety (V)			2.33			0.38			0.99	231.62
CD (5%)	Seed Source (Quality)(T)			2.33			0.38			0.99	231.62
	V x T			3.29			0.54			1.40	327.56
CV (%)				2.82			3.54			3.15	7.53

V1- Swarna V2- Mahamaya *Average of four replications Square root transformation

The seed vigour was recognized by previous researchers as an important quality parameter and differs from the germination capacity. A decrease in germination capacity has also been attributed to a decrease in vigour and could be due to various factors, including seed infection with microorganisms (Seshu *et al.*, 1987). Seedlings raised from seeds of infected panicles had poor seedling vigour and a reduced root length was more pronounced than a reduced shoot length (Hegde and Anahosur, 2000). Most seedlings of infected, partially developed seeds died before they reached maturity. Velazhahan (1991) also found that the culture filtrate of the rice sheath blight causative agent had a pronounced inhibitory effect on germination in all 7 tested varieties and also reduced the shoot and root lengths of the seedlings.

Seed is the most elementary and specific resource of agriculture and also the basis of agricultural production. Improving the quality of seeds is one of the most important measures to ensure high efficiency, quality and productivity. Seed vigour is the important index for measuring seed quality. Seed vigour tests are used by researchers to predict the emergence of seedlings under field conditions. A seed vigour test can reflect the potential of seeds in the field or under storage (Zhang *et al.*, 2007). Seed-borne diseases cause huge losses to our crop. The infected seeds sometimes cannot germinate and transmit diseases from seeds to seedlings and from seedlings to growing plants (Fakir *et al.*, 2002). Anselme (1987) suggested that the assessment of germination percentage, vigour and dormancy in addition to the studies on infections by bacteria, fungi and viruses etc. was an important parameter. Abnormal and diseased seeds in a batch of seeds also indicate poor seed health. Seed health mainly refers to the presence or absence of various types of pathogens (International Seed Testing Association (ISTA, 1985). Udbatta, brown spot, Blast, bakanae, sheath blight and stack burn are internally seed borne fungal diseases and resulted the diseased seedlings (Kota *et al.*, 1987).

Evaluation of antagonists and the effectiveness of application methods in pot condition:

4.6.1 Effects of *Trichoderma* isolates on disease severity at 30 DAT and 60 DAT in pot condition during the year 2016:

In the kharif 2016 the data presented in table 4.17 and fig. 4.15 and 4.18 showed that foliar treatment of all the isolates of *Trichoderma* and check fungicide hexaconazole were significantly reduced the disease severity after inoculation of pathogen at 30 DAT. The chemical check fungicide Hexaconazole was found to be most effective with 19.25% disease severity and 48.14% reduction in disease severity after 15 days of first spray. Among the *Trichoderma* isolates foliar spray of Durg isolate (TD3) was most effective (27.24% disease severity) and showed 26.80 reduction in percent disease severity followed by Raipur isolate (TR2) with 30.14% disease severity and 19.01 reduction in percent disease severity and Rajnandgaon isolate (TR1) with 33.47% disease severity and 9.92 reduction in disease severity percent over control). The highest disease severity was recorded in control treatment (37.27%). The data showed (table 4.18 and fig. 4.24) that all the isolates of *Trichoderma* spp. significantly reduced severity of the disease after inoculation of the pathogen at 60 DAT. The chemical check fungicide Hexaconazole was found to be highly effective with 35.22% disease severity and 49.03% reduction in disease severity. Among the *Trichoderma* isolates foliar spray with Durg isolate (TD3) was most effective (51.28% disease severity) and showed 25.86% reduction in disease severity followed by Raipur isolate (TR2) with 55.16% disease severity and 20.27% reduction in disease severity and Rajnandgaon isolate (TR1) with 59.45% disease severity and 13.98% reduction in disease severity). The highest disease severity was recorded in control treatment (69.20%).

4.6.2 Effect of *Trichoderma* isolates on yield per plant when inoculated at 30 DAT and 60 DAT during the year 2016:

It was evident from the table 4.17 effect on yield per plant when inoculated at 30 DAT that all the isolates of *Trichoderma* and Hexaconazole treatment significantly increased the yield per plant as compared to control. The highest grain yield 12.21g

per plant (with 32.70% increase in grain yield) was obtained with foliar spray of Hexaconazole treatment. Among the *Trichoderma* isolates, the highest yield per plant (11.44g and 28.06% increase in grain yield) was obtained with foliar spray of Durg isolate (TD3) followed by foliar spray of Raipur isolate (TR2) and Rajnandgaon isolate (TR1) isolates which was the yield of 10.39g/plant with 21.02% increase in grain yield and 9.16g/plant with 10.27% increase in grain yield, respectively. The minimum grain yield (8.22g per plant) was obtained in control treatment. It was evident from the table 4.18 effect on yield per plant when inoculated at 60 DAT that all the isolates of *Trichoderma* and chemical significantly increased the yield per plant as compared to check. The highest yield per plant (12.94g and 32.60% increase in grain yield) was obtained with foliar spray of Hexaconazole followed by TD3 (12.16g and 29.0% increase in grain yield), TR2 (11.0g and 20.74% increase in grain yield) and TR1 (9.73g and 10.32% increase in grain yield). The minimum grain yield (8.72g per plant) was obtained in control treatment. The disease severity and grain yield was less when inoculated at 30 DAT than the plants inoculated at 60 DAT. These results showed that when the plants attacked by the pathogen at early stages may lead to produce less number of panicles per hill and more empty grains. Among both the treatments, the hexaconazole treatment was found most effective in reducing disease severity and increasing grain yield.

Table 4.17: Comparative efficacy of different isolates of *Trichoderma* spp. on disease severity and yield at 30DAT during 2016

Treatments (30 DAT)	Disease severity (%)	Reduction in disease severity (%)	Grain yield (g/plant)	Increase in grain yield (g/plant)
T1. Foliar application of Rajnandgaon isolates	33.47 (35.35)	9.92	9.16 (17.62)	10.27
T3 : Foliar application of Raipur isolates	30.14 (33.30)	19.01	10.39 (18.81)	21.02
T5. Foliar application of Durg isolates	27.24 (31.45)	26.80	11.44 (19.77)	28.06
T7. Foliar application of Hexaconazole @ 0.2%	19.25 (26.01)	48.14	12.21 (20.46)	32.70
T9. Control	37.27 (37.62)	-	8.22 (16.66)	-
SEd	0.8700		0.0907	
CD (5%)	1.9385		0.2022	
SE(m)+	0.6151		0.0641	
CV (5%)	3.2538		0.5954	

Means of three replications *Data in parenthesis shows Arcsine transformation

Abbreviations: **S.Ed**: Standard Error Deviation; **CD**: Critical Difference; **SEm**: Standard Error Mean;**CV**: Coefficient of Variation**Table 4.18: Comparative efficacy of different isolates of *Trichoderma* spp. on disease severity and yield at 60 DAT during 2016**

Treatments (60 DAT)	Disease severity (%)	Reduction in disease severity (%)	Grain yield (g/plant)	Increase in grain yield (g/plant)
T2. Foliar application of Rajnandgaon isolates	59.45 (50.45)	13.98	9.73 (18.17)	10.32
T4 : Foliar application of Raipur isolates	55.16 (47.96)	20.27	11.0 (19.37)	20.74
T6. Foliar application of Durg isolates	51.28 (45.73)	25.86	12.16 (20.41)	29.0
T8. Foliar application of Hexaconazole @ 0.2%	35.22 (36.39)	49.03	12.94 (21.08)	32.60
T10. Control	69.20 (56.29)	-	8.72 (17.17)	-
SEd	0.9365		0.2415	
CD (5%)	2.0867		0.5382	
SE(m)+	0.6622		0.1708	
CV (5%)	2.4215		1.5375	

*Data in parenthesis shows Arcsine transformation



Fig.4.15: Comparative efficacy of *Trichoderma* isolates with reduced disease severity of sheath blight and increased yield of paddy

4.6.3 Effects of *Trichoderma* isolates on disease severity at 30 DAT and 60 DAT in pot condition during the year 2017:

In the kharif 2017, data (Table 4.19) showed that all the isolates of *Trichoderma* spp. significantly reduced the severity of disease after inoculation of pathogen at 30 DAT. The chemical check fungicide Hexaconazole was found to be most effective with 18.94% disease severity and 46.72% reduction in disease severity after 15 days of first spray. Among the *Trichoderma* isolates foliar spray with Durg isolate (TD3) was most effective (26.45% disease severity) and showed 25.69% reduction in disease severity followed by Raipur isolate (TR2) with 29.47% disease severity and 17.17% reduction in disease severity and Rajnandgaon isolate (TR1) with 31.38% disease severity and 11.82% reduction in disease severity). The highest disease severity was recorded in control treatment (35.57%). The data showed (table 4.20) that all the isolates of *Trichoderma* spp. significantly reduced severity of the disease after inoculation of the pathogen at 60 DAT. The chemical check fungicide Hexaconazole was found to be most effective with 33.61% disease severity and 49.16% reduction in disease severity. Among the *Trichoderma* isolates foliar spray with Durg isolate (TD3) was most effective (50.38% disease severity) and showed 23.84% reduction in disease severity followed by Raipur isolate (TR2) with 54.25% disease severity and 18.0% reduction in disease severity and Rajnandgaon isolate

(TR1) with 57.21% disease severity and 12.85% reduction in disease severity). The highest disease severity was recorded in control treatment (66.15%).

4.6.4 Effect of *Trichoderma* isolates on yield per plant when inoculated at 30 DAT and 60 DAT during the year 2017:

It was evident from the table 4.19 effect on yield per plant when inoculated at 30 DAT that all the isolates of *Trichoderma* and Hexaconazole treatment significantly increased the yield per plant as compared to control. The highest grain yield 11.22g per plant (with 29.11% increase in grain yield) was obtained with foliar spray of Hexaconazole. Among the *Trichoderma* isolates, the highest yield per plant (11.18g and 28.96% increase in grain yield) was obtained with foliar spray of Durg isolate (TD3) followed by foliar spray of Raipur isolate (TR2) and Rajnandgaon isolate (TR1) isolates which was the yield of 10.24g/plant with 22.37% increase in grain yield and 9.55g/plant with 16.83% increase in grain yield, respectively. The minimum grain yield (7.94g per plant) was obtained in control treatment. It was evident from the table 4.20 effect on yield per plant when inoculated at 60 DAT that all the isolates of *Trichoderma* and chemical significantly increased the yield per plant as compared to check. The highest yield per plant (11.94g and 29.68% increase in grain yield) was obtained with foliar spray of Hexaconazole followed by TD3 (11.86g and 29.26% increase in grain yield), TR2 (11.14g and 24.76% increase in grain yield) and TR1 (10.16g and 17.28% increase in grain yield). The minimum grain yield (8.38g per plant) was obtained in control treatment.

The disease severity was less when inoculated at 30 DAT than the plants inoculated at 60 DAT. Though the severity and incidence was less when inoculated at 30 DAT, the grain yield was also low when compared to the plants inoculated at 60 DAT. These results showed that when the plants attacked by the pathogen at early stages may lead to produce less number of panicles per hill and more empty grains. Among both the treatments, the hexaconazole treatment was found most effective in reducing disease severity and increasing grain yield. Among the three potential *Trichoderma* sprayed TD3 isolate was found most effective in reducing disease

severity. The TD3 was found most effective in controlling the disease and increasing grain yield followed by TR2 and TR1 isolate.

All the isolates of *Trichoderma* and hexaconazole were significantly checked the sheath blight disease as well as increased the grain yield significantly. Highest reduction of disease severity and increase in grain yield was done by hexaconazole while Durg isolates of *Trichoderma* followed by Raipur and Rajnandgaon were significantly reduced the disease severity as well as increased the grain yield over control. After 60 days of transplanting the foliar spray of hexaconazole 0.2% was significantly reduced the disease severity and significantly increased the grain yield over the control. Durg isolate followed by Raipur and Rajnandgaon were significantly reduced the disease severity and increased the grain yield over the control but all the isolates were not at par with hexaconazole in accordance to disease severity and grain yield.

Table 4.19 : Comparative efficacy of different isolates of *Trichoderma* spp. on disease severity and yield at 30DAT during 2017

Treatments (30 DAT)	Disease severity (%)	Reduction in disease severity (%)	Grain yield (g/plant)	Increase in grain yield (g/plant)
T1. Foliar application of Rajnandgaon isolates	31.38 (34.06)	11.82	9.55 (18.0)	16.83
T3 : Foliar application of Raipur isolates	29.47 (32.87)	17.17	10.24 (18.66)	22.37
T5. Foliar application Durg isolates	26.45 (30.94)	25.69	11.18 (19.54)	28.96
T7. Foliar application of Hexaconazole @ 0.2%	18.94 (25.79)	46.72	11.22 (19.56)	29.11
T9. Control	35.57 (36.61)	-	7.94 (16.37)	-
SEd	0.8462		0.1897	
CD (5%)	1.8855		0.4228	
SE(m)+	0.5983		0.1341	
CV (5%)	3.2331		1.2612	

*Data in parenthesis shows Arcsine transformation

Table 4.20: Comparative efficacy of different isolates of *Trichoderma* spp. on disease severity and yield at 60 DAT during 2017

Treatments (60 DAT)	Disease severity (%)	Reduction in disease severity (%)	Grain yield (g/plant)	Increase in grain yield (g/plant)
T2. Foliar application of Rajnandgaon isolates	57.21 (49.40)	12.85	10.16 (18.58)	17.28
T4 : Foliar application of Raipur isolates	54.25 (47.44)	18.00	11.14 (19.50)	24.76
T6. Foliar application Durg isolates	50.38 (45.22)	23.84	11.86 (20.14)	29.26
T8. Foliar application of Hexaconazole @ 0.2%	33.61 (35.43)	49.16	11.94 (20.21)	29.68
T10. Control	66.15 (54.42)	-	8.38 (16.83)	-
SEd	0.8449		0.2625	
CD (5%)	1.8825		0.5849	
SE(m)+	0.5964		0.1856	
CV (5%)	2.2308		1.6873	

*Data in parenthesis shows Arcsine transformation

4.6.5 Effects of *Trichoderma* isolates on disease severity at 30 DAT and 60 DAT in pot condition during both the year 2016 and 2017 as pooled:

The pooled data presented in the table 4.21 and fig. 4.16 showed that all the isolates of *Trichoderma* spp. significantly reduced the severity of disease after inoculation of pathogen at 30 DAT. The chemical check fungicide Hexaconazole was found to be most effective with 19.09% disease severity and 47.44% reduction in disease severity after 15 days of first spray. Among the *Trichoderma* isolates foliar spray with Durg isolate (TD3) was most effective (26.84% disease severity) and showed 26.24% reduction in disease severity followed by Raipur isolate (TR2) with 29.81% disease severity and 18.09% reduction in disease severity and Rajnandgaon isolate (TR1) with 32.43% disease severity and 10.87% reduction in disease severity). The highest disease severity was recorded in control treatment (36.42%). The data showed (table 4.22 and fig. 4.17) that all the isolates of *Trichoderma* spp. significantly reduced severity of the disease after inoculation of the pathogen at 60 DAT. The

chemical check fungicide Hexaconazole was found to be most effective with 34.41% disease severity and 49.09% reduction in disease severity. Among the *Trichoderma* isolates foliar spray with Durg isolate (TD3) was most effective (50.83% disease severity) and showed 24.85% reduction in disease severity followed by Raipur isolate (TR2) with 54.70% disease severity and 19.13% reduction in disease severity and Rajnandgaon isolate (TR1) with 58.54% disease severity and 13.38% reduction in disease severity). The highest disease severity was recorded in control treatment (67.67%).

4.6.6 Effect of *Trichoderma* isolates on yield per plant when inoculated at 30 DAT and 60 DAT during both the year as pooled:

The pooled data presented in the table 4.21 and fig. 4.27 showed that foliar application of all the isolates of *Trichoderma* and Hexaconazole treatment significantly increased the yield per plant as compared to control. The highest grain yield 11.71g per plant (with 30.90% increase in grain yield) was obtained with foliar spray of Hexaconazole. Among the *Trichoderma* isolates, the highest yield per plant (11.31g and 28.51% increase in grain yield) was obtained with foliar spray of Durg isolate (TD3) followed by foliar spray of Raipur isolate (TR2) and Rajnandgaon isolate (TR1) isolates which was the yield of 10.31g/plant with 21.67% increase in grain yield and 9.35g/plant with 13.55% increase in grain yield, respectively. The minimum grain yield (8.08g per plant) was obtained in control treatment. It was evident from the table 4.22 and fig. 4.28 effect on yield per plant when inoculated at 60 DAT that all the isolates of *Trichoderma* and chemical significantly increased the yield per plant as compared to check. The highest yield per plant (12.43g and 31.14% increase in grain yield) was obtained with foliar spray of Hexaconazole followed by TD3 (12.01g and 29.13% increase in grain yield), TR2 (11.07g and 22.75% increase in grain yield) and TR1 (9.94g and 13.80% increase in grain yield). The minimum grain yield (8.52g per plant) was obtained in control treatment.

In the pooled data, the disease severity was less when inoculated at 30 DAT than the plants inoculated at 60 DAT. The grain yield was also low when compared to the plants inoculated at 60 DAT. These results showed that when the plants attacked

by the pathogen at early stages may lead to produce less number of panicles per hill and more empty grains. Among both the treatments, the hexaconazole treatment was found most effective in reducing disease severity and increasing grain yield. Among the three potential *Trichoderma* sprayed TD3 isolate was found most effective in reducing disease severity. The TD3 was found most effective in controlling the disease and increasing grain yield. TR2 has found effective followed by TR1 isolate. All the isolates of *Trichoderma* and hexaconazole were significantly check the sheath blight disease as well as increase the grain yield significantly. Highest reduction of disease severity and increase the grain yield was done by hexaconazole while Durg isolates of *Trichoderma* followed by Raipur and Rajnandgaon were significantly reduced the disease severity as well as increase the grain yield over control. After 60 days of transplanting the foliar spray of hexaconazole 0.2% was significantly reduced the disease severity and significantly increase the grain yield over the control. Durg isolate followed by Raipur and Rajnandgaon were significantly reduced the disease severity and increase the grain yield over the control but all the isolates were not at par with hexaconazole in according to disease severity and grain yield.

Present investigation and reports showed that both the foliar application of chemical and biocontrol treatments were significantly reduced disease severity. Though the disease severity was more on plants treated with TD3 than plants treated with hexaconazole, the increase in grain yield was almost same in both the treatments. The bioagents can effectively control the disease and at the same time improve growth characters and thus is a better alternative to chemical application. Though hexaconazole controls the disease severity, it did not enhance plant growth to that extent. But when biocontrol agents were introduced, the growth of the plants was promoted and at the same time they could effectively increased grain yield. The results were in agreement with Windham *et al*, 1986 who reported that the activity of biocontrol agents could also reduce the concentration of substances in soil are inhibitory to plant growth. Baby and Manibhushan Rao (1993) observed 25 per cent increase in growth of rice plnats, where antagonists were applied to the soil. Mishra *et al*. (1989) observed that seed treatment or soil application of fungal biocontrol agents

(*Trichoderma harzianum*, *Gliocladium virens* and *Aspergillus niger*) significantly increased root and shoot growth of rice plants.

The results are in agreement with the findings of Prasad and Reddi (2011) regarding management strategies to control sheath blight using biocontrol agent *T. harzianum*. Khan and Sinha (2007) reported that all the isolates of *Trichoderma* spp. significantly reduced incidence and severity of sheath blight of rice. *Trichoderma harzianum* was most effective showing 38.8 per cent and 24.6 per cent reduction in disease severity and incidence. The highest increase in grain yield /plant (21%) and 1000 grain weight (6.3%) was obtained with *T. harzianum*. Of the five isolates of *Trichoderma* spp. screened under *in vitro* and glasshouse conditions, *T. harzianum* was found most effective against *R. solani*.

Table 4.21 : Comparative efficacy of different isolates of *Trichoderma* spp. on disease severity and yield at 30DAT (Pooled data of kharif 2016 and 2017):

Treatments (30 DAT)	Disease severity (%)	Reduction in disease severity (%)	Grain yield (g/plant)	Increase in grain yield (g/plant)
T1. Foliar application of Rajnandgaon isolates	32.43 (34.71)	10.87	9.35 (17.81)	13.55
T3 : Foliar application of Raipur isolates	29.81 (33.09)	18.09	10.31 (18.73)	21.69
T5. Foliar application Durg isolates	26.84 (31.20)	26.24	11.31 (19.64)	28.51
T7. Foliar application of Hexaconazole @ 0.2%	19.09 (25.90)	47.44	11.71 (20.01)	30.90
T9. Control	36.42 (37.12)	-	8.08 (16.51)	-
SEd	0.6188		0.1144	
CD (5%)	1.3788		0.2550	
SE(m)+	0.4375		0.0809	
CV (5%)	2.3383		0.7561	

*Data in parenthesis shows Arcsine transformation

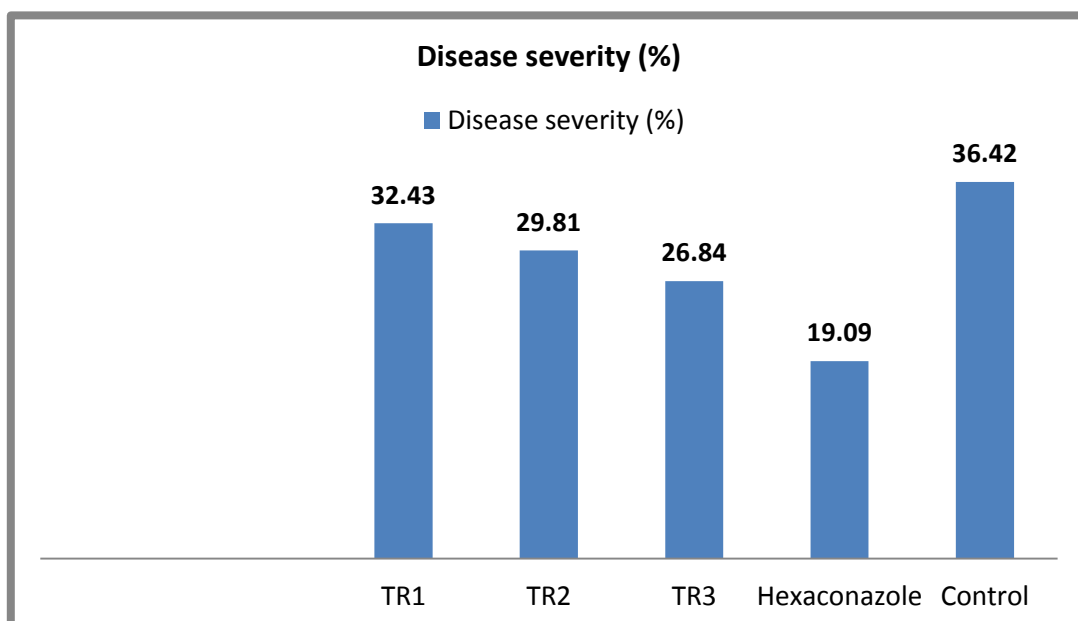


Fig.4.16: Comparative efficacy of different isolates of *Trichoderma* spp. on disease severity and yield at 30DAT (Pooled data of kharif 2016 and 2017)

Table 4.22 : Comparative efficacy of different isolates of *Trichoderma* spp. on disease severity and yield at 60 DAT (Pooled data of kharif 2016 and 2017):

Treatments (60 DAT)	Disease severity (%)	Reduction in disease severity (%)	Grain yield (g/plant)	Increase in Grain yield (g/plant)
T2. Foliar application of Rajnandgaon isolates	58.54 (49.92)	13.38	9.94 (18.37)	13.80
T4 : Foliar application of Raipur isolates	54.70 (47.70)	19.13	11.07 (19.44)	22.75
T6. Foliar application Durg isolates	50.83 (45.47)	24.85	12.01 (20.27)	29.13
T8. Foliar application of Hexaconazole @ 0.2%	34.41 (35.91)	49.09	12.43 (20.65)	31.14
T10. Control	67.67 (55.35)	-	8.52 (16.97)	-
SEd	0.5645		0.1716	
CD (5%)	1.2579		0.3824	
SE(m)+	0.3992		0.1213	
CV (5%)	1.4743		1.0983	

*Data in parenthesis shows Arcsine transformation

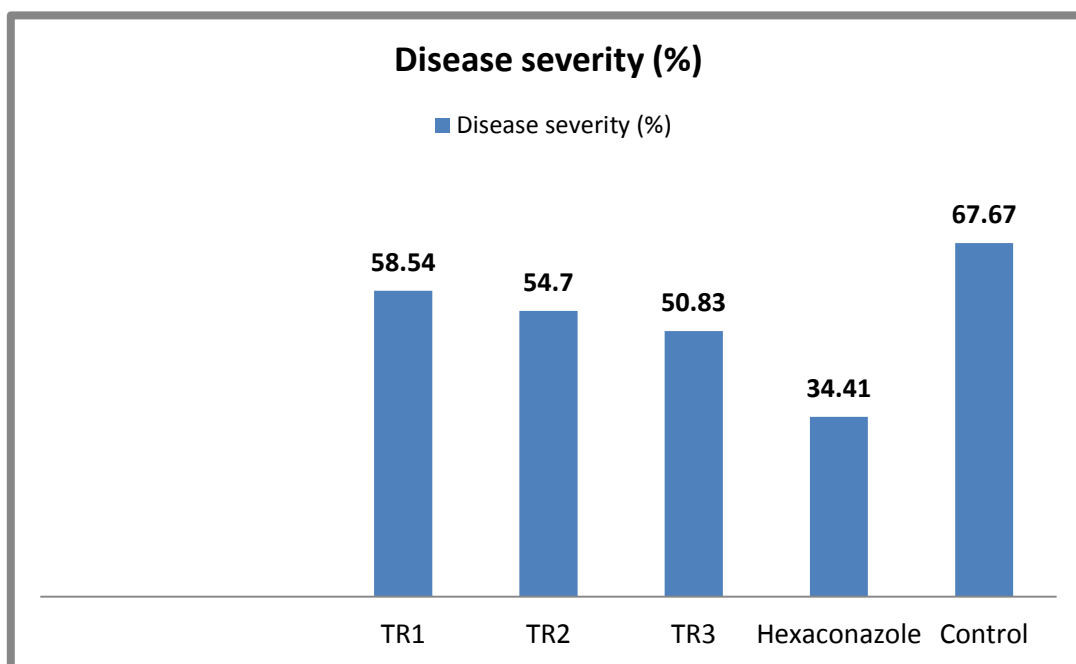


Fig.4.17: Comparative efficacy of different isolates of *Trichoderma* spp. on disease severity and yield at 60 DAT (Pooled data of kharif 2016 and 2017):



Fig.4.18: Symptoms developed on plants at 10 days after second inoculation

4.7 Effect of *Trichoderma* rich organic amendments on plant vigour index, No. of propagules and sheath blight of rice:

The present study was undertaken during kharif 2016 and kharif 2017 to test the effect of four organic soil amendments for the management of disease sheath blight of rice under the pot condition. Treatments were allocated under completely randomized design (CRD) and recorded the disease severity on 21 days of inoculation and percent disease index was calculated.

During the kharif 2016, the data presented in the table 4.23 and fig. 4.19 indicated that application of organic amendments significantly reduced the sheath blight disease severity over all treatments as compared to control (without organic amendment and antagonist) either alone or enriched with *Trichoderma harzianum* isolate. The result indicated that among the treatments, T6 (*R. solani* +Neem cake+ *T. harzianum*) was found most effective to reduce the sheath blight disease with the least PDI of 11.11% with 78.53% decrease over control and it is statistically on par with T5 (*R. solani*+ Karanj cake + *T. harzianum*) 14.50% PDI with 72.01% decrease over control followed by T8 (*R. solani*+ FYM + *T. harzianum*) 20.67% PDI with 60.09% decrease over control, T7 (*R. solani*+ Mustard cake + *T. harzianum*) 22.22% PDI with 57.10% decrease over control, T9 (*R. solani* + *T. harzianum*) 23.14% PDI with 55.32% decrease over control, T2 (*R. solani* + Mustard cake) 32.09% PDI with 38.01% decrease over control, T1 (*R. solani* +Neem cake) 32.71% PDI with 36.84% decrease over control, T3 (*R. solani* + Karanj cake) 33.33% PDI with 35.67% decrease over control and T4 (*R. solani* + FYM) 37.64% PDI with 27.36% decrease over control. The highest percent disease index (51.84%) was recorded in control treatment.

The treatment T6 (*R. solani* +Neem cake+ *T. harzianum*) was found significantly superior with highest seedling vigour index (4221.11) and was statistically on par with treatments T5 (*R. solani*+ Karanj cake + *T. harzianum*) with 4074.96 seedling vigour index, T8 (*R. solani*+ FYM + *T. harzianum*) with 3906.49 seedling vigour index, T7 (*R. solani*+ Mustard cake + *T. harzianum*) with 3831.87 seedling vigour index, T9 (*R. solani* + *T. harzianum*) with 3826.37 seedling vigour index and T2 (*R. solani* + Mustard cake) with 3818.02 vigour index followed by T1

(*R. solani* +Neem cake) with 3764.70 seedling vigour index, T3 (*R. solani* + Karanj cake) with 3685.95 seedling vigour index and T4 (*R. solani* + FYM) with 3666.58 seedling vigour index.

Similar trend was observed for residual number of propagules of antagonist in rhizosphere soil also, where maximum number of propagules observed in treatment T6 (*R. solani* +Neem cake+ *T. harzianum*) which is statistically at par with treatments T5 (*R. solani*+ Karanj cake + *T. harzianum*) followed by T8 (*R. solani*+ FYM + *T. harzianum*), T7 (*R. solani*+ Mustard cake + *T. harzianum*) and T9 (*R. solani* + *T. harzianum*).

Table 4.23: Influence of *Trichoderma* rich organic amendments on sheath blight disease development (Year-2016)

Treatments	Seedling vigour index	No. of Propagules (CFU/g of soil)(X10 ⁵)	PDI (%)	% decrease over control
T1 - <i>R. solani</i> +Neem cake	3764.70	-	32.71 (34.88)	36.84
T2 - <i>R. solani</i> +Mustard cake	3818.02	-	32.09 (34.50)	38.01
T3 - <i>R. solani</i> +Karanj cake	3685.95	-	33.33 (35.26)	35.67
T4 - <i>R. solani</i> +FYM	3666.58	-	37.64 (37.84)	27.36
T5 - <i>R. solani</i> +Karanj cake+ <i>T. harzianum</i>	4074.96	4.9	14.50 (22.30)	72.01
T6 - <i>R. solani</i> +Neem cake+ <i>T. harzianum</i>	4221.11	5.1	11.11 (19.47)	78.53
T7 - <i>R. solani</i> +Mustard cake+ <i>T. harzianum</i>	3831.87	4.2	22.22 (28.12)	57.10
T8 - <i>R. solani</i> +FYM+ <i>T. harzianum</i>	3906.49	4.7	20.67 (26.86)	60.09
T9 - <i>R. solani</i> + <i>T. harzianum</i>	3826.37	2.5	23.14 (28.64)	55.32
T10 – <i>hizoctonia solani</i> (Control)	3306.97	-	51.84 (46.03)	-
SE(m)	136.07	0.0605	2.6811	
CD(5%)	401.41	0.1786	7.9094	

* Data in parenthesis shows Arcsine transformation

In the kharif 2017, the data presented in the table 4.24 and 4.20 indicated that among the treatments, T6 (*R. solani* +Neem cake+ *Trichoderma harzianum*) was found most effective to reduce the sheath blight disease as it recorded the least PDI of 12.34% with 77.76% decrease over control followed by T5 (*R. solani*+ Karanj cake + *T. harzianum*) 23.46% PDI with 57.75% decrease over control, T8 (*R. solani*+ FYM + *T. harzianum*) 29.01% PDI with 47.76% decrease over control, T9 (*R. solani* + *T. harzianum*) 29.32% PDI with 47.20% decrease over control, T7 (*R. solani*+ Mustard cake + *T. harzianum*) 32.10% PDI with 42.20% decrease over control, T2 (*R. solani* + Mustard cake) 33.34% PDI with 39.97% decrease over control, T1 (*R. solani* +Neem cake) 36.11% PDI with 35.0% decrease over control, T3 (*R. solani* + Karanj cake) 42.90% PDI with 22.76% decrease over control. The highest percent disease index (55.56%) was recorded in control treatment.

Among all treatments, the treatment T6 (*R. solani* +Neem cake+ *T. harzianum*) was found significantly superior with highest seedling vigour index (4184.67) which is statistically on par with treatments T5 (*R. solani*+ Karanj cake + *T. harzianum*) with 3969.88 vigour index, T8 (*R. solani*+ FYM + *T. harzianum*) with 3912.88 vigour index, T7 (*R. solani*+ Mustard cake + *T. harzianum*) with 3889.52 vigour index and T9 (*R. solani* + *T. harzianum*) with 3846.82 vigour index and followed by T2 (*R. solani* + Mustard cake) with 3666.54 vigour index, T1 (*R. solani* +Neem cake) with 3603.78 vigour index, T3 (*R. solani* + Karanj cake) with 3539.42 vigour index and T4 (*R. solani* + FYM) with 3512.92 vigour index. The lowest seedling vigour index (3466.64) was recorded in control treatment (fig. 4.21).

Similar trend was observed for residual number of propagules of antagonist in rhizosphere soil, where maximum number of propagules observed in treatment T6 (*R. solani* +Neem cake+ *T. harzianum*) which is statistically on par with treatments T5 (*R. solani*+ Karanj cake + *T. harzianum*) followed by T8 (*R. solani*+ FYM + *T. harzianum*), T7 (*R. solani*+ Mustard cake + *T. harzianum*) and T9 (*R. solani* + *T. harzianum*).

Table 4.24: Influence of *Trichoderma* rich organic amendments on sheath blight disease development (Year-2017)

Treatments	Seedling vigour index	No. of Propagules (CFU/g of soil)(X10 ⁵)	PDI (%)	% decrease over control
T1 - <i>R. solani</i> + Neem cake	3603.78	-	36.11 (36.92)	35.00
T2 - <i>R. solani</i> + Mustard cake	3666.54	-	33.34 (35.26)	39.97
T3 - <i>R. solani</i> + Karanj cake	3539.42	-	42.90 (40.91)	22.76
T4 - <i>R. solani</i> + FYM	3512.92	-	53.08 (46.76)	4.44
T5 - <i>R. solani</i> + Karanj cake + <i>Trichoderma harzianum</i>	3969.88	4.8	23.46 (28.95)	57.75
T6 - <i>R. solani</i> + Neem cake + <i>T. harzianum</i>	4184.67	5.0	12.34 (20.56)	77.76
T7 - <i>R. solani</i> + Mustard cake + <i>T. harzianum</i>	3889.52	4.1	32.10 (34.51)	42.20
T8 - <i>R. solani</i> + FYM + <i>T. harzianum</i>	3912.88	4.5	29.01 (32.58)	47.76
T9 - <i>R. solani</i> + <i>T. harzianum</i>	3846.82	2.4	29.32 (32.67)	47.20
T10 – <i>Rhizoctonia solani</i> (Control)	3466.64	-	55.56 (48.19)	-
SE(m)+	132.86	0.0516	1.0257	
CD(5%)	391.94	0.1523	3.0260	

* Data in parenthesis shows Arcsine transformation

Pooled data of kharif 2016 and 2017 presented in the table 4.25 and fig. 4.22 and 4.35 indicated that among the treatments, T6 (*R. solani* +Neem cake+ *Trichoderma harzianum*) was found significantly superior to reduce the sheath blight disease severity over all the treatments as it recorded the least PDI of 11.72% with 78.12% decrease over control followed by T5 (*R. solani*+ Karanj cake + *T. harzianum*) 18.98% PDI with 64.60% decrease over control, T8 (*R. solani*+ FYM + *T. harzianum*) 24.84% PDI with 53.73% decrease over control, T9 (*R. solani* + *T. harzianum*) 26.23% PDI with 51.14% decrease over control, T7 (*R. solani*+ Mustard cake + *T. harzianum*) 27.16% PDI with 49.45% decrease over control, T2 (*R. solani* + Mustard

cake) 32.72% PDI with 39.02% decrease over control, T1 (*R. solani* +Neem cake) 34.41% PDI with 35.90% decrease over control, T3 (*R. solani* + Karanj cake) 38.12% PDI with 29.06% decrease over control and T4 (*R. solani* + FYM) 45.37% PDI with 15.48% decrease over control. The highest percent disease index (53.71%) was recorded in control treatment.

Among all treatments, the treatment T6 (*R. solani* +Neem cake+ *T. harzianum*) was found significantly superior with highest seedling vigour index (4202.89) which is statistically on par with treatments T5 (*R. solani*+ Karanj cake + *T. harzianum*) with 4022.42 vigour index and T8 (*R. solani*+ FYM + *T. harzianum*) with 3909.68 vigour index over the control and followed by T7 (*R. solani*+ Mustard cake + *T. harzianum*) with 3860.69 vigour index, T9 (*R. solani* + *T. harzianum*) with 3836.59 vigour index, T2 (*R. solani* + Mustard cake) with 3742.28 vigour index, T1 (*R. solani* +Neem cake) with 3684.24 vigour index, T3 (*R. solani* + Karanj cake) with 3612.68 vigour index and T4 (*R. solani* + FYM) with 3589.75 vigour index. The lowest vigour index (3386.80) was recorded in control treatment.

Residual number of propagules of antagonist in rhizosphere soil was observed, where maximum number of propagules observed in treatment T6 (*R. solani* +Neem cake+ *T. harzianum*) followed by treatments T5 (*R. solani*+ Karanj cake + *T. harzianum*), T8 (*R. solani*+ FYM + *T. harzianum*), T7 (*R. solani*+ Mustard cake + *T. harzianum*) and T9 (*R. solani* + *T. harzianum*).

Decreased disease severity owing to organic amendments may be attributable to altered soil and rhizosphere climate. That changes adversely affects the growth of the fungus and increase the capacity of plants to resist infection through improved plant vigour and/or altered root physiology. Decomposition of organic modifications strengthens the soil structure after amendment, which encourages root growth of the host plant and soil holding capacity of water. Specific biochemical released during decomposition, which can include antibiotics and phenols released through the decomposition of materials containing lignin, cause resistance to disease in the tissues when absorbed. After germination, intense antagonistic activity occurred during the decomposition of organic modifications by organic amendments hence, killed the

germ tubes. The organic amendments induce the activity of antagonistic organisms in soil such as *Trichoderma*. Increasing numbers and activities of antagonistic microorganisms placed heavy demand on limited supply of oxygen, nutrients, space, etc. during the decomposition of organic amendments. The pathogen with poor competitive capacity can not contend for these criteria with other soil saprophytes and will perish.

All the above mentioned effects of decomposing organic amendments result in the absorption of organic compounds by plant roots, altered physiology of the host, potential production of pathogen resistance and perishing. The organic amendments can therefore reduce inoculum density, inoculum potential, host proneness and can also increase host resistance; the net result is reduction of disease severity. The present findings are in agreement with the facts mentioned earlier as the improved vigour index, abundance propagules of antagonist in rhizosphere and reduced disease severity were observed. Neem and its products already being known for their effectiveness against *R. solani* (found effective in the present investigation also) and when it coupled with *Trichoderma* isolate, produced synergistic effect on reduction of pathogen propagules, increased number of *Trichoderma* propagules and increased plant vigour index as well and thereby reduced the disease severity. Addition of various types of organic amendments in soil either alone or in combination with antagonists shows effectiveness in reduction of pathogen propagules, improved plant vigour etc. were also reported by earlier worker against *R. solani* (Rajan and Menon, 1975; Kannaiyan and Prasad, 1981, 1983c; Padma Kumari and Balakrishanan, 1991; Das *et al.* 1995; Prasad *et al.* 1997; Dubey, 1998; Meena and Muthusami, 1999 and Bhagawati and Roy, 2004; Salam, 2007) agreeing with the present findings.

Fig.: 4.19: *R. solani* + Neem cake



Fig.4.20: *R. solani* + Mustard cake



Fig.4.21: Sheath blight disease control with improved growth characters by application of *Trichoderma* rich organic amendments under pot condition (Year-2016)

Table 4.25: Influence of *Trichoderma* rich organic amendments on sheath blight disease development ((Pooled data of kharif 2016 and kharif 2017):

Treatments	Seedling vigour index	No. of Propagules (CFU/g of soil)(X10 ⁵)	PDI (%)	% decrease over control
T1 - <i>R. solani</i> + Neem cake	3684.24	-	34.41 (35.91)	35.90
T2 - <i>R. solani</i> + Mustard cake	3742.28	-	32.72 (34.88)	39.02
T3 - <i>R. solani</i> + Karanj cake	3612.685	-	38.12 (38.12)	29.06
T4 - <i>R. solani</i> + FYM	3589.75	-	45.37 (42.34)	15.48
T5 - <i>R. solani</i> + Karanj cake + <i>Trichoderma harzianum</i>	4022.42	4.85	18.98 (25.82)	64.60
T6 - <i>R. solani</i> + Neem cake + <i>T. harzianum</i>	4202.89	5.05	11.72 (20.01)	78.12
T7 - <i>R. solani</i> + Mustard cake + <i>T. harzianum</i>	3860.69	4.15	27.16 (31.41)	49.45
T8 - <i>R. solani</i> + FYM + <i>T. harzianum</i>	3909.68	4.60	24.84 (29.84)	53.73
T9 - <i>R. solani</i> + <i>T. harzianum</i>	3836.59	2.45	26.23 (30.74)	51.14
T10 – <i>Rhizoctonia solani</i> (Control)	3386.80	-	53.71 (47.12)	-
SE(m)	105.57	0.0357	0.8128	
CD(5%)	311.43	0.1054	2.3980	

*Data in parenthesis shows Arcsine transformation

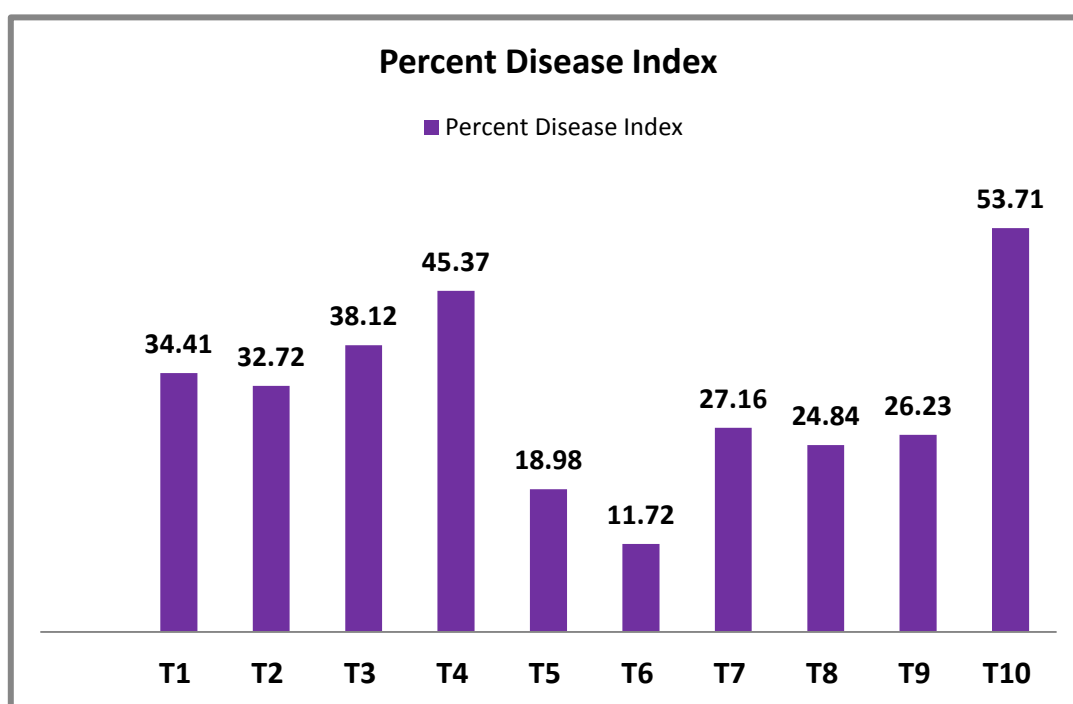


Fig.4.22: Influence of *Trichoderma* rich organic amendments on sheath blight disease development (Pooled data of kharif 2016 and kharif 2017)

Details:

- T1 – *R. solani* + Neem cake
- T2 – *R. solani* + Mustard cake
- T3 – *R. solani* + Karanj cake
- T4 – *R. solani* + FYM
- T5 – *R. solani* + Karanj cake + *Trichoderma harzianum*
- T6 – *R. solani* + Neem cake + *T. harzianum*
- T7 – *R. solani* + Mustard cake + *T. harzianum*
- T8 – *R. solani* + FYM + *T. harzianum*
- T9 – *R. solani* + *T. harzianum*
- T10 – *R. solani* (Control)

4.8 Evaluation of disease management practices combined with different doses of 'N' fertilizer under field condition:

The present study was undertaken during kharif 2016 and kharif 2017 to evaluate the disease management practices combined with different doses of 'N' fertilizer under the field condition. Treatments were allocated under randomized block design (RBD). Disease severity and percent disease index were recorded.

In the kharif 2016, the data presented in the table no. 4.26 indicated that all treatments of disease management practices combined with different doses of Nitrogen fertilizer significantly superior to reduce the sheath blight severity over control treatment on 15th day of inoculation. The data revealed that minimum percent disease index (11.12%) was recorded in T4 (SV + 100% RDN + three spray of Hexaconazole 5 Sc) treatment which is exactly similar to the T5 (SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc) treatment (11.12% PDI), T6 (SV + 1/2 RDN + single spray of Hexaconazole 5 Sc) treatment (11.12% PDI) and T7 (SV + 1/2 RDN + three spray of Hexaconazole 5 Sc) treatments (11.12% PDI) which statistically at par with T3 (SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc) treatment with 11.57% PDI over the control, above treatments are followed by T2 (SV + 100% RDN + single spray of Hexaconazole 5 Sc) treatment with 16.21% PDI, and T1 (SV + 2/3rd RDN) with 30.56% PDI. Maximum PDI (35.19%) was found in the control treatment (SV + 100% RDN).

Results (table no. 4.26) showed that on 30th day of inoculation revealed that minimum percent disease index of 11.12% was recorded in SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) and was found significantly superior among all the treatments to reduce the disease severity followed by SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) treatment with 31.71% PDI, SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) treatment with 33.34% PDI, SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) treatment with 33.34% PDI, SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) treatment with 39.82% PDI, SV + 100% RDN + single spray of Hexaconazole 5 Sc (T2) treatment with 46.76% PDI and SV + 2/3rd

RDN (T1) treatment with 55.56% PDI. Maximum percent disease index (56.25%) was recorded in control treatment SV + 100% RDN (T8).

During the final observation *i.e.* at 40 DAI (table no. 4.26) of sheath blight disease showed all the treatments were significantly superior to reduce the disease over the control. Data revealed that minimum PDI of 33.34% was recorded in SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) treatment and was significantly reduced the sheath blight disease severity followed by SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) treatment with 34.72% PDI, SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) treatment with 35.64% PDI, SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) treatment with 36.57% PDI, T3 (SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc) treatment with 54.17% PDI, T2 (SV + 100% RDN + single spray of Hexaconazole 5 Sc) treatment with 54.63% PDI and T1 (SV + 2/3rd RDN) with 57.41% PDI. The maximum PDI (77.31%) was recorded in control treatment SV + 100% RDN (T8).

The treatment of SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) also increased the yield (4480.24 kg/ha.) which was significantly superior over all treatments and on par with SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) treatment (4416.47 kg/ha.) followed by SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) treatment (4320.0 kg/ha.), SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) treatment (4224.0 kg/ha.), SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) treatment (4160.0 kg/ha.), SV + 100% RDN + single spray of Hexaconazole 5 Sc (T2) treatment (4000.37 kg/ha.) and SV + 2/3rd RDN (T1) treatment (3680.0 kg/ha.) over the control (T8) treatment (3552.44 kg/ha.).

Table 4.26: The efficacy of disease management practices combined with different doses of 'N' fertilizer (Year-2016):

Treatment No.	Treatments	Percent Disease Index	Percent Disease Index	Percent Disease Index	Yield (Kg/ha)
		15 DAI	30 DAI	40 DAI	
T1	SV + 2/3 rd RDN	30.56 (33.51)	55.56 (48.19)	57.41 (49.26)	3680.0
T2	SV + 100% RDN + single spray of Hexaconazole 5 Sc	16.21 (23.54)	46.76 (43.12)	54.63 (47.65)	4000.37
T3	SV + 2/3 rd RDN + single spray of Hexaconazole 5 Sc	11.57 (19.88)	39.82 (39.04)	54.17 (47.39)	4160.0
T4	SV + 100% RDN + three spray of Hexaconazole 5 Sc	11.12 (19.48)	31.71 (34.27)	35.64 (36.66)	4320.0
T5	SV + 2/3 rd RDN + three spray of Hexaconazole 5 Sc	11.12 (19.48)	33.34 (35.27)	34.72 (36.10)	4416.47
T6	SV + 1/2 RDN + single spray of Hexaconazole 5 Sc	11.12 (19.48)	33.34 (35.27)	36.57 (36.93)	4224.0
T7	SV + 1/2 RDN + three spray of Hexaconazole 5 Sc	11.12 (19.48)	11.12 (19.48)	33.34 (35.27)	4480.24
T8	SV + 100% RDN (Control)	35.19 (36.38)	56.25 (48.59)	77.31 (61.54)	3552.44
SV	Swarna				
Spray	3				
	SE(m)+-	1.1685	1.5242	0.395	26.115
	CD (5%)	3.5444	4.6231	1.1991	79.1988
	CV	8.4667	6.9644	1.5614	1.1019
	SEd	1.6525	2.1555	0.5590	36.926

*Figures in Parenthesis are are sine transformed value

During the kharif 2017, the data presented in the table no. 4.27 revealed that on 15th day of inoculation, minimum percent disease index of 11.12% was recorded in SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) treatment which showed significantly superior in reducing the sheath blight disease severity and was statistically on par with SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) treatment with 11.58% PDI, SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) with 16.21% PDI and SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) with 16.67% PDI and followed by SV + 100% RDN + single spray of Hexaconazole 5 Sc

(T2) treatment with 25.93% PDI, SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) treatment with 29.63% PDI and SV + 2/3rd RDN (T1) treatment with 34.72% PDI. The maximum PDI (37.50%) was recorded in control in SV + 100% RDN (T8) treatment.

Results (table no. 4.27) showed that on thirty day of inoculation of sheath blight disease, minimum disease severity was recorded with a PDI of 31.95% in SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) treatment and was significantly reduced the sheath blight disease and was statistically on par with SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) treatment with 32.41% PDI and SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) treatment with 35.65% PDI followed by SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) treatment with 41.20% PDI, SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) treatment with 42.59% PDI, SV + 100% RDN + single spray of Hexaconazole 5 Sc (T2) treatment with 53.70% PDI and SV + 2/3rd RDN (T1) treatment with 71.75% PDI over the control treatment. The maximum PDI (72.22%) was recorded in control in SV + 100% RDN (T8) treatment.

During the final observation on 40 DAI (table no. 4.27) of sheath blight disease, all treatments of disease management practices combined with different doses of Nitrogen fertilizer significantly superior to reduce the sheath blight severity over control treatment. Minimum percent disease index 32.41% was recorded in SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) and was significantly reduced the sheath blight disease severity over all treatments which was statistically on par with SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) with 33.34% PDI followed by SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) with 37.04% PDI, SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) with 38.89% PDI, SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) with 48.61% PDI, SV + 100% RDN + single spray of Hexaconazole 5 Sc (T2) with 54.63% PDI and SV + 2/3rd RDN (T1) treatments with 69.91% PDI. Control treatment SV + 100% RDN (T8) showed the maximum percent disease index (74.54%).

All treatments of disease management practices combined with different doses of Nitrogen fertilizer significantly increased the yield over control treatment.

Maximum grain yield (4672.47 kg/ha.) was also recorded in SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) treatment and was significantly superior among all treatments which is on par with SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) treatment (4608.37 kg/ha.) followed by SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) treatment (4416.24 kg/ha.), SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) treatment (4320.14 kg/ha.), SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) treatment (4288.17 kg/ha.), SV + 100% RDN + single spray of Hexaconazole 5 Sc (T2) treatment (4096.0 kg/ha.) and SV + 2/3rd RDN (T1) treatment (3744.60 kg/ha.) over the control. The minimum yield (3616.24 kg/ha.) was recorded with control treatment.

Table 4.27: The efficacy of disease management practices combined with different doses of 'N' fertilizer (Year-2017)

Treatment No.	Treatments	Percent Disease Index (PDI)	Percent Disease Index (PDI)	Percent Disease Index (PDI)	Yield (Kg/ha)
		15 DAI	30 DAI	40 DAI	
T1	SV + 2/3 rd RDN	34.72 (36.09)	71.75 (58.07)	69.91 (56.95)	3744.60
T2	SV + 100% RDN + single spray of Hexaconazole 5 Sc	25.93 (30.33)	53.70 (47.12)	54.63 (47.66)	4096.0
T3	SV + 2/3 rd RDN + single spray of Hexaconazole 5 Sc	29.63 (32.89)	42.59 (40.68)	48.61 (44.20)	4288.17
T4	SV + 100% RDN + three spray of Hexaconazole 5 Sc	16.21 (23.54)	35.65 (36.64)	37.04 (37.48)	4416.24
T5	SV + 2/3 rd RDN + three spray of Hexaconazole 5 Sc	11.58 (19.89)	32.41 (34.70)	33.34 (35.27)	4608.37
T6	SV + 1/2 RDN + single spray of Hexaconazole 5 Sc	16.67 (23.59)	41.20 (39.85)	38.89 (38.58)	4320.14
T7	SV + 1/2 RDN + three spray of Hexaconazole 5 Sc	11.12 (19.48)	31.95 (34.41)	32.41 (34.70)	4672.47
T8	SV + 100% RDN (Control)	37.50 (41.50)	72.22 (58.35)	74.54 (59.70)	3616.24
SV	Swarna				
Spray	3				
	SE(m)+-	2.1063	2.607	1.4588	31.127
	CD (5%)	6.3887	7.9076	4.4248	94.414
	CV	12.8391	10.32	5.7017	1.2774
	SEd	2.9787	3.6869	2.0630	44.020

*Figures in Parenthesis are are sine transformed value

Pooled data of kharif 2016 and kharif 2017 presented in the table no. 4.28 and fig. 4.23 on 15th day of inoculation revealed that minimum percent disease index (11.12%) was recorded in SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) treatment which showed significantly superior in reducing the sheath blight disease severity and was statistically on par with SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) treatment with 11.35% PDI, SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) with 13.67% PDI and SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) with 13.90% PDI followed by treatment SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) with 20.60% PDI, treatment SV + 100% RDN + single spray of Hexaconazole 5 Sc (T2) with 21.07% PDI and treatment SV + 2/3rd RDN (T1) with 32.64% PDI over the control. The maximum percent disease index (36.35%) was recorded in control treatment SV + 100% RDN (T8).

Results (table no. 4.28 and fig. 4.24) showed that on thirty day of inoculation, minimum percent disease index (21.54%) was recorded in SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) treatment and was significantly reduced the disease severity which is followed by SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) treatment with 32.88% PDI, SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) treatment with 33.68% PDI, SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) treatment with 37.27% PDI, SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) treatment with 41.21% PDI, SV + 100% RDN + single spray of Hexaconazole 5 Sc (T2) treatment with 50.23% PDI, SV + 2/3rd RDN (T1) treatment with 63.65% PDI. The maximum percent disease index (64.24%) was recorded in control (T8) treatment SV + 100% RDN.

During the final observation *i.e.* at 40 DAI of sheath blight disease (table no. 4.28 and fig.4.25) showed all treatments of disease management practices combined with different doses of Nitrogen fertilizer significantly superior to reduce the sheath blight severity over control treatment. Among the treatments, minimum percent disease index (32.88 %) was recorded in treatment SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) which was found significantly superior and on par with SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) with 34.03% PDI and SV + 100%

RDN + three spray of Hexaconazole 5 Sc (T4) with 34.72% PDI followed by SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) treatment with 37.49% PDI, SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) treatment with 51.62% PDI, SV + 100% RDN + single spray of Hexaconazole 5 Sc (T2) treatment with 54.41% PDI, SV + 2/3rd RDN (T1) treatment with 63.67% PDI. The maximum percent disease index (75.93%) was recorded in control (T8) treatment SV + 100% RDN.

All treatments of disease management practices combined with different doses of Nitrogen fertilizer significantly increased the yield over control treatment. Maximum grain yield (4576.35 kg/ha.) was recorded in SV + 1/2 RDN + three spray of Hexaconazole 5 Sc (T7) treatment and was significantly superior over all treatments and which is statistically on par with SV + 2/3rd RDN + three spray of Hexaconazole 5 Sc (T5) treatment (4512.42 kg/ha.) followed by SV + 100% RDN + three spray of Hexaconazole 5 Sc (T4) treatment (4368.12 kg/ha.), SV + 1/2 RDN + single spray of Hexaconazole 5 Sc (T6) treatment (4272.07 kg/ha.), SV + 2/3rd RDN + single spray of Hexaconazole 5 Sc (T3) treatment (4224.09 kg/ha.), SV + 100% RDN + single spray of Hexaconazole 5 Sc (T2) treatment (4048.20 kg/ha.) and SV + 2/3rd RDN (T1) treatment (3712.30 kg/ha.) as compared to the control treatment. The minimum yield (3584.33 kg/ha.) was recorded with control treatment.

Similar findings also reported by Anonymous (2009) that the integration of disease management practices like growing disease specific resistant/moderately resistant or susceptible variety with 100% or 2/3rd RDN along with need based fungicidal protection in case of fungal diseases like blast and sheath blight and nitrogen management in case of Bacterial leaf blight are promising in checking the disease severity/incidence and improving the grain yield. Use of excessive Nitrogen fertilizer has been observed to increase sheath blight damage to rice was also reported by Slaton *et al*, 2003. Jagat Janni (2011) evaluated the disease management practices combined with different doses of nitrogen fertilizer and observed the significant decrease in sheath blight severity and increase in yield in Resistant variety and 100% recommended dose of nitrogen fertilizer with different doses of hexaconazole were the effective practice. Dev and Mary (1982) reported that heavy application of nitrogen

fertilizer increases the number of tillers/plant and this leads to an increase in relative humidity of the plant microclimate thereby favouring the development of sheath blight. Under high nitrogen levels, even the traditional tall indica cultivars are rated as susceptible to highly susceptible.

Table 4.28: The efficacy of disease management practices combined with different doses of 'N' fertilizer (Pooled data of kharif 2016 and kharif 2017):

Treatment No.	Treatments	Percent Disease Index (PDI) 15 DAI	Percent Disease Index (PDI) 30 DAI	Percent Disease Index (PDI) 40 DAI	Yield (Kg/ha)
T1	SV + 2/3 rd RDN	32.64 (34.82)	63.65 (53.03)	63.67 (52.95)	3712.30
T2	SV + 100% RDN + single spray of Hexaconazole 5 Sc	21.07 (27.10)	50.23 (45.14)	54.41 (47.52)	4048.20
T3	SV + 2/3 rd RDN + single spray of Hexaconazole 5 Sc	20.60 (26.95)	41.21 (39.90)	51.62 (45.93)	4224.09
T4	SV + 100% RDN + three spray of Hexaconazole 5 Sc	13.67 (21.63)	33.68 (35.47)	34.72 (37.07)	4368.12
T5	SV + 2/3 rd RDN + three spray of Hexaconazole 5 Sc	11.35 (19.69)	32.88 (34.98)	34.03 (35.68)	4512.42
T6	SV + 1/2 RDN + single spray of Hexaconazole 5 Sc	13.90 (21.71)	37.27 (37.59)	37.49 (37.76)	4272.07
T7	SV + 1/2 RDN + three spray of Hexaconazole 5 Sc	11.12 (19.48)	21.54 (27.64)	32.88 (34.98)	4576.35
T8	SV + 100% RDN (Control)	36.35 (37.07)	64.24 (53.28)	75.93 (60.62)	3584.33
SV Spray	Swarna 3				
	SE(m)+-	1.3844	1.2871	0.6516	22.855
	CD (5%)	4.1992	3.9041	1.9765	69.323
	CV	9.2027	5.4525	2.5611	0.9510
	SEd	1.9578	1.8202	0.9215	32.3218

*Figures in Parenthesis are are sine transformed value

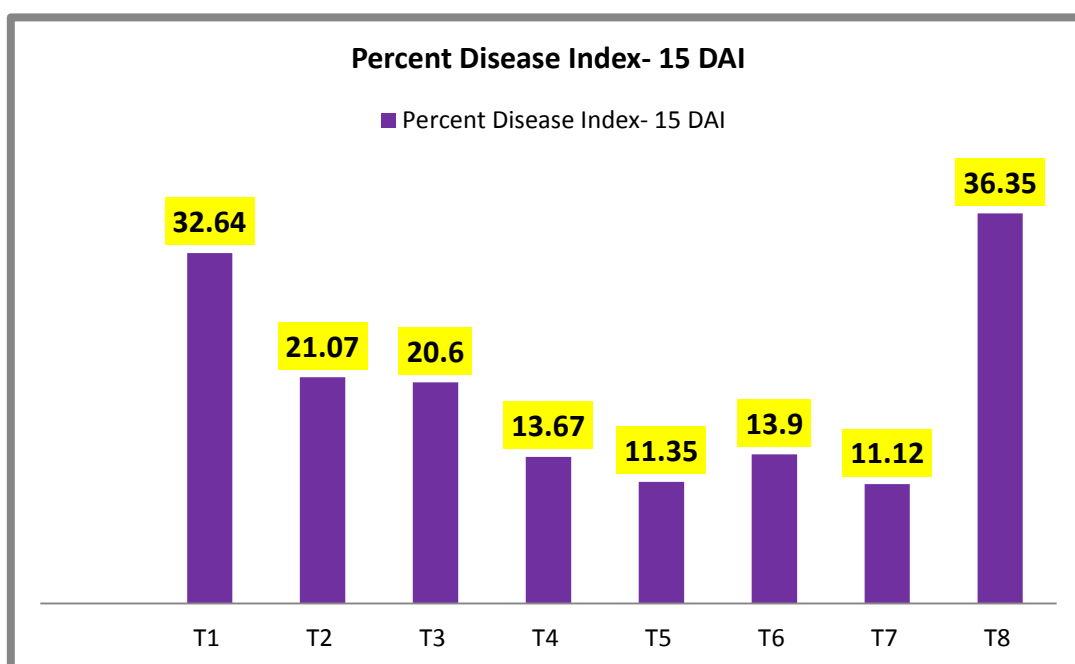


Fig.4.23: The efficacy of disease management practices combined with different doses of 'N' fertilizer (Pooled data of kharif 2016 and kharif 2017)

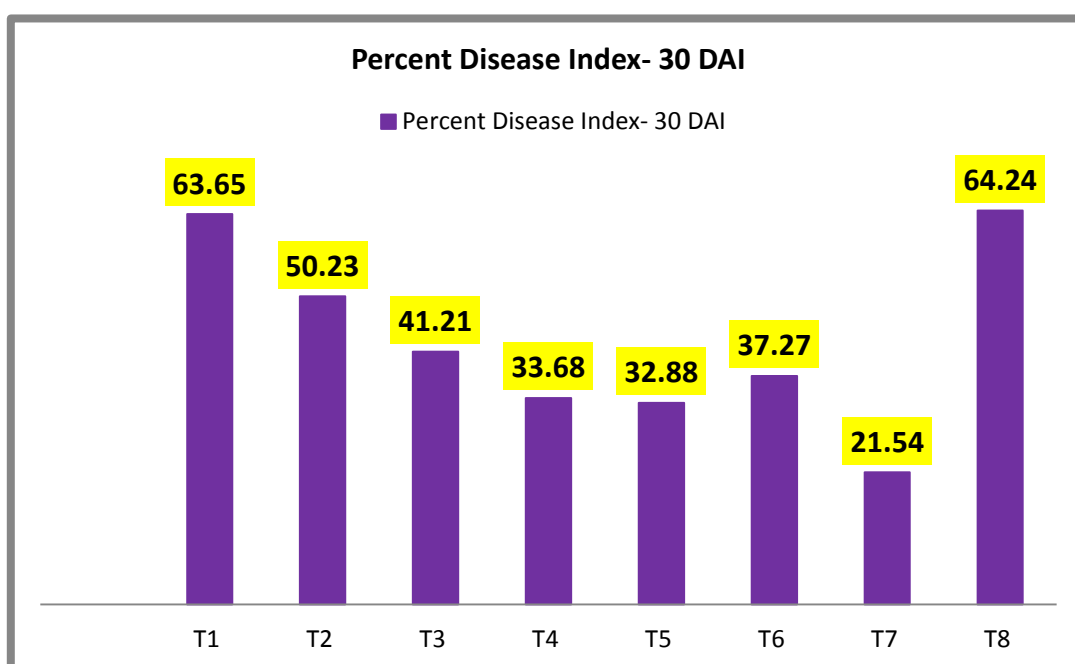


Fig.4.24: The efficacy of disease management practices combined with different doses of 'N' fertilizer (Pooled data of kharif 2016 and kharif 2017)

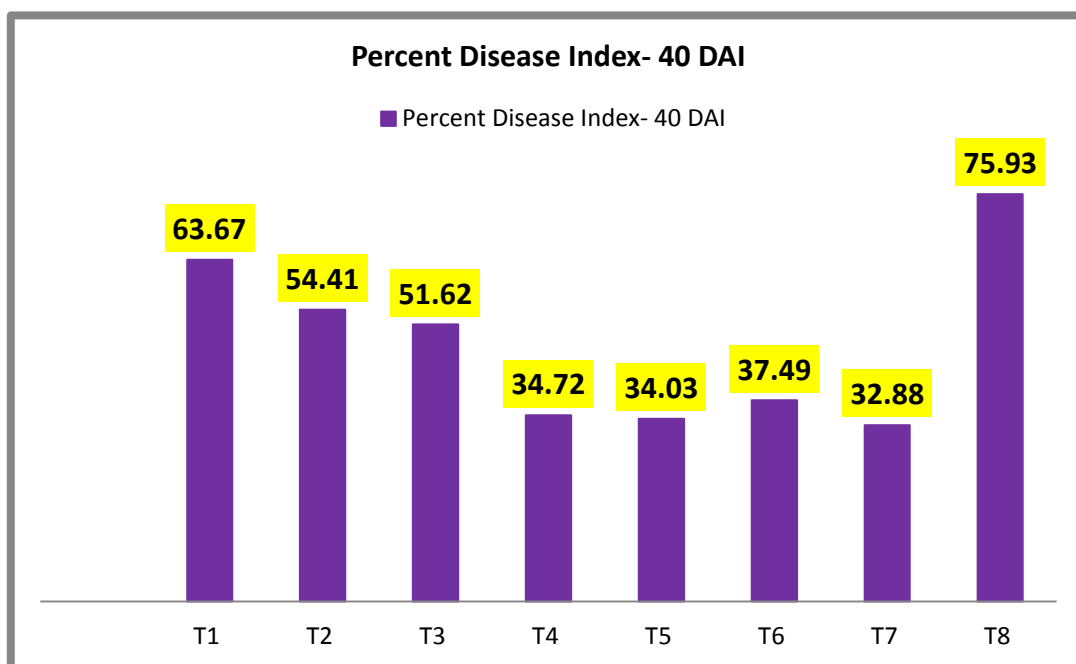


Fig.4.25: The efficacy of disease management practices combined with different doses of 'N' fertilizer (Pooled data of kharif 2016 and kharif 2017)

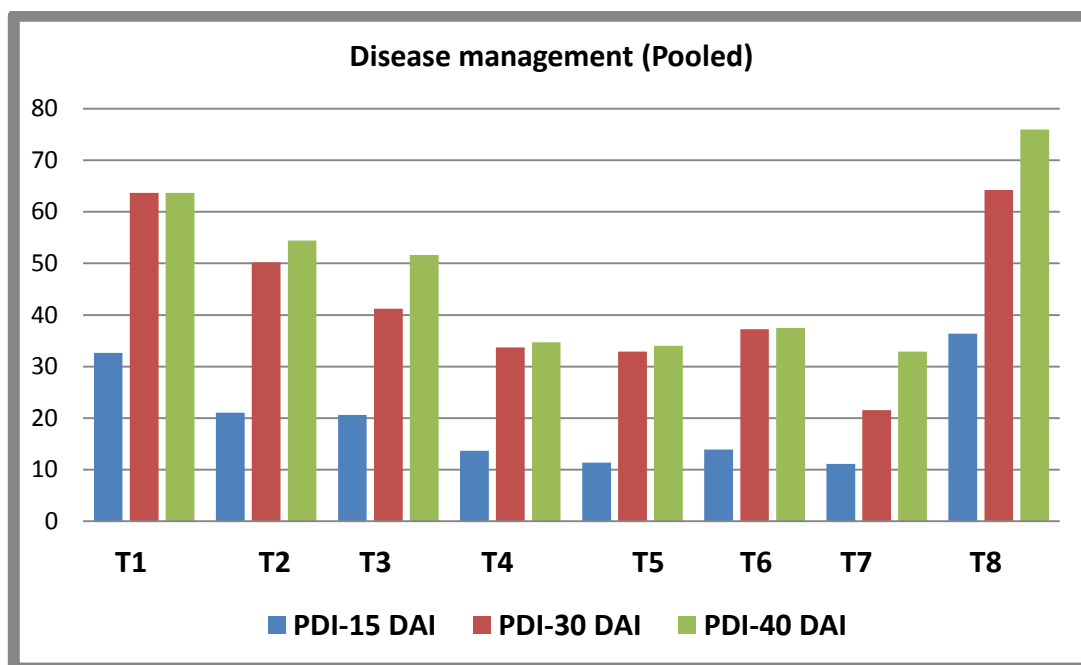


Fig.4.26: The efficacy of disease management practices combined with different doses of 'N' fertilizer (Pooled data of kharif 2016 and kharif 2017)

To assess effectiveness of stimulants, conventional and non conventional chemicals imparts resistance against sheath blight

4.9 Role of chemical stimulants such as salicylic acid, Jasmonic acid, Rose Bengal and oxallic acid in imparting resistance against sheath blight of rice:

The use of chemicals that induce systemic resistance would therefore be the appropriate alternative strategy to improve the management of sheath blight diseases in rice. It is studied that pretreatment with salicylic acid, which is used in agriculture, can unexpectedly lead to resistance to sheath blight in plants. Salicylic acid treatment inhibits the advancement of *R. solani* to the point in the infection process where fungal biomass shows remarkable expansion and developed the specific infection machinery. Therefore the study was undertaken for the use of salicylic acid, rose bengal, jasmonic acid and oxallic acid under *in vitro* and pot condition for the management of *R. solani*.

4.9.1 In vitro study:

In vitro studies shows in the table 4.29 and fig. 4.27 that mycelial growth of *R. solani* was overall influenced by the resistance inducing chemicals are described below:

4.9.1.1 The role of salicylic acid:

The minimum and significant reduction in mycelial growth of *R. solani* (16.50mm with 81.66% decrease over control) was observed in 250µg/ml concentration and was followed by 100µg/ml concentration (85.95mm mycelial growth with 4.5% decrease over control). The mycelial growth of *R. solani* was not influenced by the salicylic acid in concentrations of 25µg/ml and 50µg/ml. The maximum mycelial growth was recorded under control treatment (90.00 mm).

4.9.1.2 The role of rose bengal :

All concentrations of Rose bengal showed significant differences in reduction of mycelial growth of *R. solani* as compare to the control. Among all rose bengal treatment the minimum mycelium growth of *R. solani* (49.75 mm with 44.72% decrease over control) was observed in 250µg/ml concentration and was significantly superior treatment from all treatment concentration of rose bengal to reduce the mycelial growth of *R. solani*, this treatment was followed by 100µg/ml concentration

(70.80 mm mycelial growth with 21.33% decrease over control), 50µg/ml concentration (72.55 mm mycelial growth with 19.38% decrease over control) and 25µg/ml concentration (77.90 mm mycelial growth with 13.44% decrease over control) of rose bengal. The maximum mycelial growth was recorded under control treatment (90.00 mm).

4.9.1.3 The role of jasmonic acid:

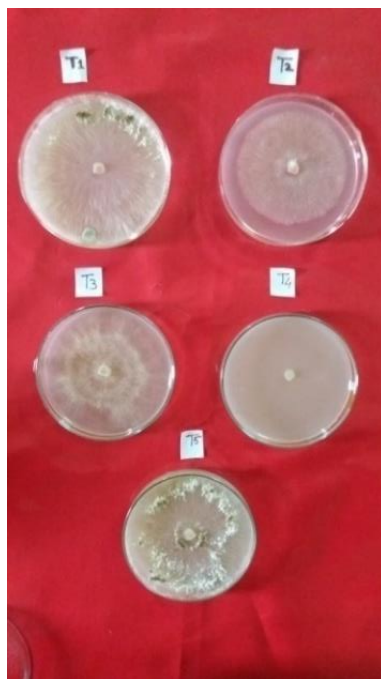
The mycelial growth of *R. solani* (45.12 mm mycelial growth with 48.83% decrease over control) was significantly reduced with 250µg/ml concentration of jasmonic acid and was followed by 100µg/ml concentration (72.75 mm mycelial growth with 19.16% decrease over control), 50µg/ml concentration (81.55 mm mycelial growth with 9.39% decrease over control) of jasmonic acid was observed. The mycelial growth of *R. solani* was not influenced by the jasmonic acid in a concentration of 25µg/ml concentration (90.0mm mycelial growth with 0.0% decrease over control). The maximum mycelial growth was recorded under control treatment (90.00 mm).

4.9.1.4 The role of oxallic acid:

The mycelial growth of *R. solani* was strongly influenced by oxallic acid in all concentrations. The mycelial growth was significantly reduced by both the concentrations of 250µg/ml and 100µg/ml (0.0mm mycelial growth with 100% decrease over control) respectively was followed by 50µg/ml and 25µg/ml (0.5mm mycelial growth with 99.44% decrease over control) concentrations. The maximum mycelial growth was recorded under control treatment (90.00 mm).

Table 4.29 : Effect of resistance inducing chemicals on growth of *R. solani* under *in vitro*:

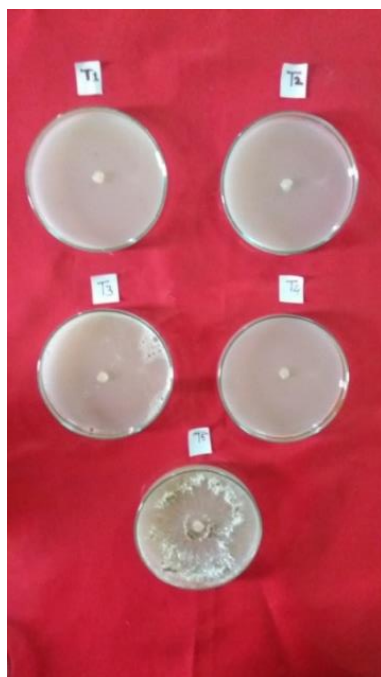
Concentration (µg/ml)	Salicylic acid *		Rose Bengal *		Jasmonic acid *		Oxallic acid*	
	Mycelial growth (mm)	% decrease over control	Mycelial growth (mm)	% decrease over control	Mycelial growth (mm)	% decrease over control	Mycelial growth (mm)	% decrease over control
25	90.0	0.0	77.9	13.44	90.0	0.0	0.5	99.44
50	90.0	0.0	72.55	19.38	81.55	9.39	0.5	99.44
100	85.95	4.5	70.8	21.33	72.75	19.16	0	100.0
250	16.5	81.66	49.75	44.72	45.12	48.83	0	100.0
Control	90.0		90.0		90.0		90.0	
SE(m)±	3.50939		1.29935		1.61333		0.31622	
CD (5%)	10.57845		3.91669		4.8631		0.95321	



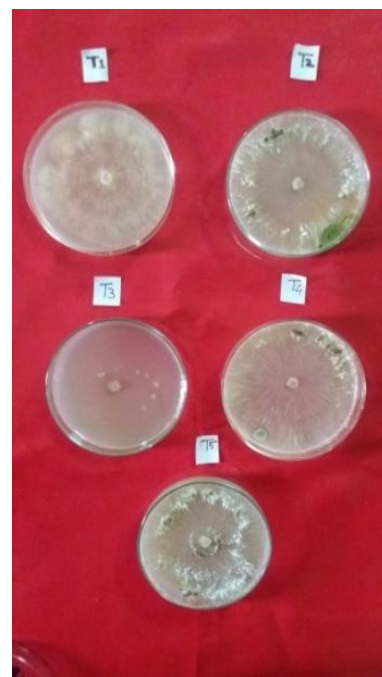
T1-Salicylic acid, T2-Rose Bengal, T3-Jasmonic acid, T4-oxalloacetic acid, T5-Control



Rose Bengal



oxalloacetic acid



Salicylic acid

Fig.4.27: Effect of resistance inducing chemicals on growth of *R. solani* under *in vitro*

4.9.2 The role of chemical stimulants in imparting resistance against sheath blight of rice under pot conditions:

An experiment to find out the possibility of inducing resistance against sheath blight of rice in a susceptible variety (Swarna) with non-conventional chemicals viz. salicylic acid, rose bengal, jasmonic acid and oxallic acid at the concentration level of 25, 50, 100 and 250 µg/ml was carried out in the seasons kharif 2016 and kharif 2017 in a CRD with 4 replications and 5 treatments including control. The treatments were applied 72 hours before inoculation with the sheath blight pathogen (*R. solani*) at the maximum tillering stage. The observations on the disease severity of sheath blight were recorded after 21 days of inoculation. The percentage disease index (PDI) was calculated and presented.

4.9.2.1 Role of chemical stimulants in imparting resistance against sheath blight of rice during the kharif 2016 under pot study:

During the year 2016 the data presented in the table 4.30 indicated that percent disease index was significantly reduced over control in all the concentrations of chemical stimulants used under the study in concentration level of 25, 50, 100 and 250 µg/ml in general over control treatment.

4.9.2.1a. The role of salicylic acid:

All concentrations significantly reduced the disease severity as well as PDI compared to the control treatment. Among at the concentrations, 250µg/ml concentration of salicylic acid was found most effective to check the sheath blight disease (with 33.34% PDI and 57.13% disease reduction over control) and the treatment was statistically on par with 100µg/ml concentration (35.19% PDI with 54.75% disease reduction over control) followed by 50µg/ml (PDI 50.0% with 35.70% disease reduction over control) and 25µg/ml (PDI 53.70% with 30.94% disease reduction over control). The maximum percent disease index (77.78%) was recorded under untreated (control) treatment.

4.9.2.1b. The role of rose Bengal:

All concentrations significantly reduced the Percent Disease Index of sheath blight disease in rice as compared to the untreated control. Among all the

concentrations of rose bengal, the 250µg/ml concentration was found significantly superior to check the sheath blight disease (with 33.34% PDI and 57.13% disease reduction over control) and was statistically on par with 100µg/ml concentration (34.44% PDI with 55.72% disease reduction over control) was followed by 50µg/ml (PDI 35.55% with 54.29% disease reduction over control) and 25µg/ml (PDI 38.89% with 49.99% disease reduction over control). The maximum percent disease index (77.78%) was recorded under untreated (control) treatment.

4.9.2.1c. The role of jasmonic acid:

All concentrations of the jasmonic acid treatments significantly reduced the disease severity and percent disease index compared to the control. The minimum percent disease index (33.34% with 57.13% disease reduction over control) was recorded at concentrations of 250µg/ml which is significantly superior to check the incidence of the disease and found statistically on par with concentrations of 100µg/ml (35.19% with 54.75% disease reduction over control) over the control followed by 50µg/ml (38.89% with 49.99% disease reduction over control) and 25µg/ml (53.70% with 30.94% disease reduction over control) concentrations. The maximum percent disease index (77.78%) was recorded under untreated (control) treatment.

4.9.2.1d. The role of oxallic acid :

All concentrations of oxallic acid treatments were significantly superior to reduce the sheath blight disease severity over the control. The concentration level of 250µg/ml and 100µg/ml was significantly reduced the sheath blight disease (with 33.34% PDI and 57.13% disease reduction over control) followed by 50µg/ml (35.55% PDI and 54.29% disease reduction over control) and 25µg/ml (37.04% PDI and 52.37% disease reduction over control) concentrations. The maximum percent disease index (77.78%) was recorded under untreated (control) treatment.

Table 4.30: Effect of resistance inducing chemicals on sheath blight disease development under pot condition (Year 2016):

Concentration (µg/ml)	Salicylic acid *		Rose Bengal *		Jasmonic acid *		Oxalloacetic acid*	
	Percent Disease Index	% Disease reduction over control	Percent Disease Index	% Disease reduction over control	Percent Disease Index	% Disease reduction over control	Percent Disease Index	% Disease reduction over control
T1 - 25	53.70 (47.12)	30.94	38.89 (38.56)	49.99	53.70 (47.12)	30.94	37.04 (37.47)	52.37
T2 - 50	50.0 (44.96)	35.70	35.55 (36.59)	54.29	38.89 (38.53)	49.99	35.55 (36.59)	54.29
T3 - 100	35.19 (36.36)	54.75	34.44 (35.93)	55.72	35.19 (36.36)	54.75	33.34 (35.27)	57.13
T4 - 250	33.34 (35.27)	57.13	33.34 (35.27)	57.13	33.34 (35.27)	57.13	33.34 (35.27)	57.13
T5 - Control	77.78 (61.88)	-	77.78 (61.88)	-	77.78 (61.88)	-	77.78 (61.88)	-
S Em±	1.5982		0.6678		1.1529		0.6622	
CD (5%)	4.8175		2.0132		3.4753		1.9962	

*Figures in parenthesis are arc sine transformed value

4.9.2.2 Role of chemical stimulants in imparting resistance against sheath blight of rice during the kharif 2017 under pot study:

During the year 2017 the data presented in the table 4.31 revealed that percent disease index were significantly reduced over control in all the concentrations of chemicals used *i.e.* 25, 50,100 and 250 µg/ml in general.

4.9.2.2a.The role of salicylic acid:

All concentrations of salicylic acid significantly reduced the sheath blight disease severity compared to the control treatment. Among all concentrations of salicylic acid, 250µg/ml concentration was found most effective to check the sheath blight disease (with 33.34% PDI and 57.13% disease reduction over control) and statistically on par with 100µg/ml concentration (38.89% PDI with 49.98% disease reduction over control) followed by 50µg/ml (PDI 50.0% with 38.08% disease reduction over control) and 25µg/ml (PDI 53.70% with 30.94% disease reduction over control). The maximum percent disease index (77.78%) was recorded under control treatment.

4.9.2.2b.The role of rose Bengal:

All concentrations of rose bengal treatment significantly reduced the Percent Disease Index of sheath blight as compared to the control. Among the concentrations of rose bengal, 250µg/ml concentration effectively reduced the sheath blight disease (with 33.34% PDI and 57.13% disease reduction over control) and was statistically on par with 100µg/ml concentration (34.44% PDI with 55.72% disease reduction over control) followed by 50µg/ml (PDI 38.89% with 49.98% disease reduction over control) and 25µg/ml (PDI 51.85% with 33.32% disease reduction over control). The maximum percent disease index (77.78%) was recorded under control treatment.

4.9.2.2c.The role of jasmonic acid:

The treatment of 250µg/ml concentration level was found significantly superior to control the sheath blight disease with 35.19% PDI and 54.75% disease reduction over control was followed by 100 µg/ml (with 50.0% PDI and 35.71% disease reduction over control), 50µg/ml (with 51.85% PDI and 33.32% disease reduction over control) and 25µg/ml (with 55.56% PDI and 28.56% disease reduction over control) concentrations compared to the control. The maximum percent disease index (77.78%) was recorded under control treatment.

4.9.2.2d.The role of oxallic acid:

All concentrations of oxallic acid treatments significantly reduced the disease severity in rice as compared to the control. The 250µg/ml concentration significantly reduced the sheath blight disease with 33.34% PDI and 57.13% disease reduction and was statistically on par with the 100µg/ml concentration (with 34.44% PDI and 55.72% disease reduction over control) over control followed by 50µg/ml (with 38.89% PDI and 49.98% disease reduction over control) concentration and 25µg/ml (with 53.70% PDI and 30.94% disease reduction over control) compared to the control. The maximum percent disease index (77.78%) was recorded under control treatment.

Table 4.31: Effect of resistance inducing chemicals on sheath blight disease development under pot condition (Year 2017):

Concentration (µg/ml)	Salicylic acid *		Rose Bengal *		Jasmonic acid *		Oxallic acid *	
	Percent Disease Index	% Disease reduction over control	Percent Disease Index	%Disease reduction over control	Percent Disease Index	% Disease reduction over control	Percent Disease Index	% Disease Reduction over control
T1 - 25	53.70 (47.12)	30.94	51.85 (46.05)	33.32	55.56 (48.19)	28.56	53.70 (47.12)	30.94
T2 - 50	50.0 (43.89)	38.08	38.89 (38.50)	49.98	51.85 (46.05)	33.32	38.89 (38.50)	49.98
T3 - 100	38.89 (38.50)	49.98	34.44 (35.93)	55.72	50.0 (44.99)	35.71	34.44 (35.93)	55.72
T4 - 250	33.34 (35.27)	57.13	33.34 (35.27)	57.13	35.19 (36.66)	54.75	33.34 (35.27)	57.13
T5 - Control	77.78 (61.88)	-	77.78 (61.88)	-	77.78 (61.88)	-	77.78 (61.88)	-
S Em±	2.0416		1.7562		1.4085		1.5496	
CD (5%)	6.1540		5.2937		4.2457		4.6712	

*Figures in parenthesis are arc sine transformed value

4.9.2.3 Role of chemical stimulants in imparting resistance against sheath blight of rice during both the year 2016 and 2017 as pooled under pot study:

The pooled data of year 2016 and 2017 presented in the table 4.32 and fig. 4.28 indicated that sheath blight disease severity was significantly reduced over control by all the concentrations of chemicals i.e. 25, 50, 100 and 250 µg/ml tested under study.

4.9.2.3a. The role of Salicylic acid :

Salicylic acid is a natural phenolic compound that plays an important role for disease resistance and for the development of systemic acquired resistance. It appeared to transduce this signal by inhibiting catalase activity and generating an elevated level of active oxygen species. All the concentrations of salicylic acid significantly decreased the disease severity of sheath blight in rice. Among all concentrations, 250µg/ml concentration was significantly reduced the sheath blight disease with 33.34% PDI and 57.13% disease reduction over control and was statistically on par with the 100µg/ml concentration (with 37.04% PDI and 52.37% disease reduction

over control) followed by 50µg/ml (with 50.0% PDI and 36.89% disease reduction over control) concentration and 25µg/ml (with 53.70% PDI and 30.94% disease reduction over control) as compared with control. The maximum percent disease index (77.78%) was recorded under control treatment.

4.9.2.3b. The role of Rose bengal :

All the concentrations of rose bengal decreased the disease severity significantly over control treatment. The 250µg/ml concentration most significantly reduced the sheath blight disease with 33.34% PDI and 57.13% disease reduction over control and was statistically on par with the 100µg/ml concentration (with 33.89% PDI and 56.42% disease reduction over control) followed by 50µg/ml (with 36.72% PDI and 52.78% disease reduction over control) concentration and 25µg/ml (with 45.37% PDI and 41.66% disease reduction over control) compared to the control treatment. The maximum percent disease index (77.78%) was recorded under control treatment.

4.9.2.3c. The role of Jasmonic acid :

Jasmonic acid proved as strong activator of resistance to sheath blight disease in rice. All concentrations of 250 µg/ml, 100 µg/ml, 50 µg/ml and 25 µg/ml were significantly reduced the disease severity over control treatment. The percent disease index ranged from 33.34 to 54.63 percent. Among all the concentrations of jasmonic acid, the minimum PDI was recorded in 250 µg/ml (with 34.27% PDI and 55.94% disease reduction over control) and was found significantly superior followed by concentrations of 100 µg/ml (with 42.60% PDI and 45.23% disease reduction over control), 50 µg/ml (with 45.37% PDI and 41.66% disease reduction over control) and 25 µg/ml (with 54.63% PDI and 29.75% disease reduction over control) compared to the control. The maximum percent disease index (77.78%) was recorded under control treatment. Sarkar and Sinha (1988) and Manibhushanrao *et al.* (1990) reported that in the case of rice plant, the induction of resistance to *R. solani* was found through the use of non-conventional chemicals.

4.9.2.3d. The role of oxalloacetic acid :

All concentrations of oxalloacetic acid significantly reduced the disease severity compared to the control. The 250µg/ml concentration was finally observed to reduced the sheath blight disease with 33.34% PDI and 57.13% disease reduction over control which was statistically on par with the 100µg/ml concentration (with 33.89% PDI and 56.42% disease reduction over control) and are followed by the concentration of 50µg/ml (with 37.22% PDI and 52.14% disease reduction over control) and 25µg/ml (with 45.37% PDI and 41.66% disease reduction over control). The maximum percent disease index (77.78%) was recorded under control treatment.

The result shows that the direct toxicity of the resistance-inducing chemicals to *R. solani* does not explain the decrease in the severity of the disease. It could also be assumed that the chemicals used appear to be metabolized in the host tissue and that the concentrations may have been further diluted due to the continued growth of the treated plants. Chemicals that inhibit the growth of *R. solani* on artificial medium support the above concentrations to some extent. Such chemicals have been found to play an important role in the induction of disease resistance and the development of systemically acquired resistance, which is consistent with the available knowledge in which they have also been recorded in reducing the severity of the disease.

Similar results in the agreement with Usharani *et al.* (2013) found that studies of the effect of leaf application on certain resistant inducing chemicals, namely acibenzolar, NAA, salicylic acid and jasmonic acid, on controlling sheath blight disease in IR-50 rice showed improved efficacy in salicylic acid induced by root or soil level SA treatment have been reported in tobacco, radish and arubidiopsis (Enedi *et al.*, 1992, Leeman *et al.*, 1995 and Van Loon and Antoni 1982). The present study also found that salicylic acid reduces sheath blight in rice and could be an indication of the increased systemic resistance of rice plants to *R. solani* as induced by salicylic acid (Meyer and Hofte, 1997).

Table 4.32: Influence of resistance inducing chemicals to reduce sheath blight disease development under pot condition (Pooled data of kharif 2016 and kharif 2017):

Concentration (µg/ml)	Salicylic acid *		Rose Bengal *		Jasmonic acid *		Oxallic acid*	
	Percent Disease Index	% Disease reduction over control	Percent Disease Index	% Disease reduction over control	Percent Disease Index	% Disease reduction over control	Percent Disease Index	% Disease reduction over control
T1 - 25	53.70 (47.12)	30.94	45.37 (42.33)	41.66	54.63 (47.65)	29.75	45.37 (42.33)	41.66
T2 - 50	50.00 (44.42)	36.89	36.72 (37.27)	52.78	45.37 (42.33)	41.66	37.22 (37.57)	52.14
T3 - 100	37.04 (37.46)	52.37	33.89 (35.60)	56.42	42.60 (40.72)	45.23	33.89 (35.60)	56.42
T4 - 250	33.34 (35.27)	57.13	33.34 (35.27)	57.13	34.27 (35.82)	55.94	33.34 (35.27)	57.13
T5 - Control	77.78 (61.88)	-	77.78 (61.88)	-	77.78 (61.88)	-	77.78 (61.88)	-
SEm	2.4861		0.8571		0.9291		0.8069	
CD (5%)	7.4939		2.5836		2.8006		2.4324	

*Figures in parenthesis are arc sine transformed value

Dempsey and Klessing (1995); Salam (2007); Silverman *et al.* (1995); Xiao *et al.* (1996) also examined the role of salicylic acid and reported that it plays an important role in inducing disease resistance and developing systemically acquired resistance, which is consistent with existing evidence that it also found in reducing the severity of salicylic acid illness. Several other workers such as Bhattacharya and Roy (1998) demonstrated the use of various chemicals such as phytoalexin inducers in rice plants that are effective against rice sheath blight, while Dantre *et al.* (2003) reported that SA (salicylic acid), BABA (DL-amino-n-butyric acid) and GABA (γ-amino-n-butyric acid) strongly suppressed disease lesion size when attached to cut rice leaf underneath in vitro. Conditions have been tested. Bhattacharya and Roy (2001) also ruled out a direct effect of the chemicals used in their effective concentration. Therefore, induction of resistance by the host appears to be mediated. A number of other researchers have found that induction of resistance by treating different plants with different non-conventional chemicals induces resistance to a variety of pathogens, and the effect appears to be mediated primarily by the host (Wain and Carter, 1972; Sinha 1984; Lazarovtis, 1988).

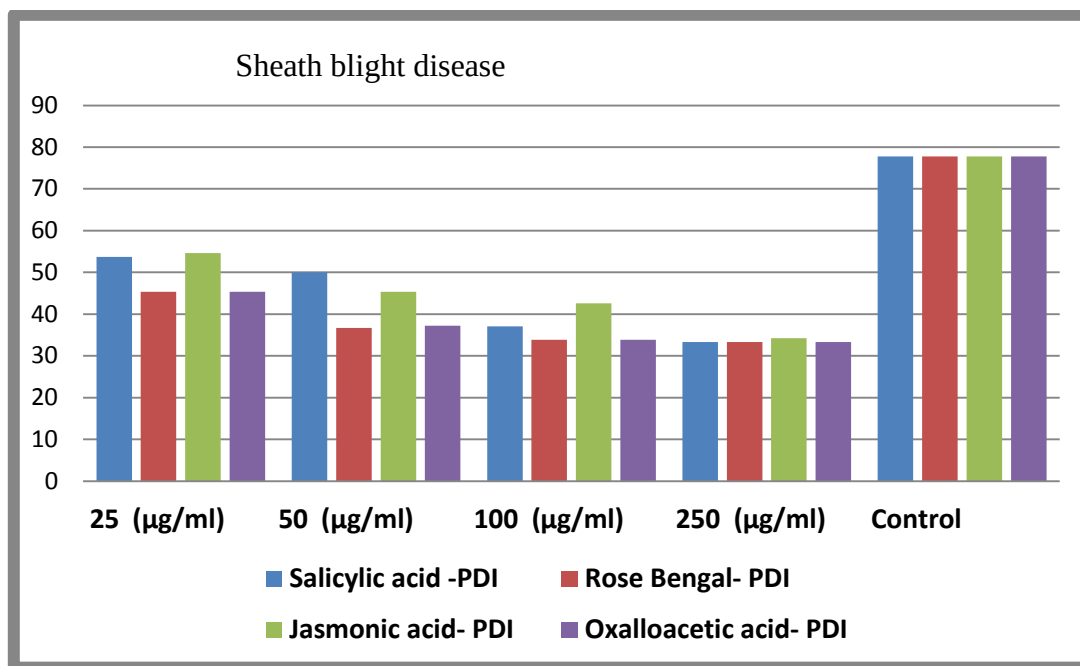


Fig.4.28: Effect of resistance inducing chemicals on sheath blight disease development under pot condition (Pooled data of kharif 2016 and kharif 2017)

4.10 Effects of micronutrients *i.e.* silicon, copper and zinc applications on sheath blight disease severity on rice

Rice sheath blight disease is the main disease that is difficult to control. An extreme shortage of soil micronutrients and a high dose of nitrogen fertilizers that lead to sheath blight have become an obstacle to rice production. A study was undertaken to understand the impact of micronutrient use on sheath blight and to determine the effects of the disease severity and yield of rice. The experiment was carried out under in vitro and pot conditions in a completely randomized design with four replications during kharif 2016 and kharif 2017. The nutrients included in the study were Cu as copper sulphate, Zn as zinc sulphate and silicon as silicon dioxide (SiO_2). Silicon (Si) is the second most common mineral element in the soil and plays an important role in reducing various environmental impacts and maximizing plant resistance to pathogens through the accumulation of Si in epidermal leaf cells that serve as a mechanical obstacle to fungal attack (Cai *et al.*, 2008). Zinc (Zn) is important for the biochemical

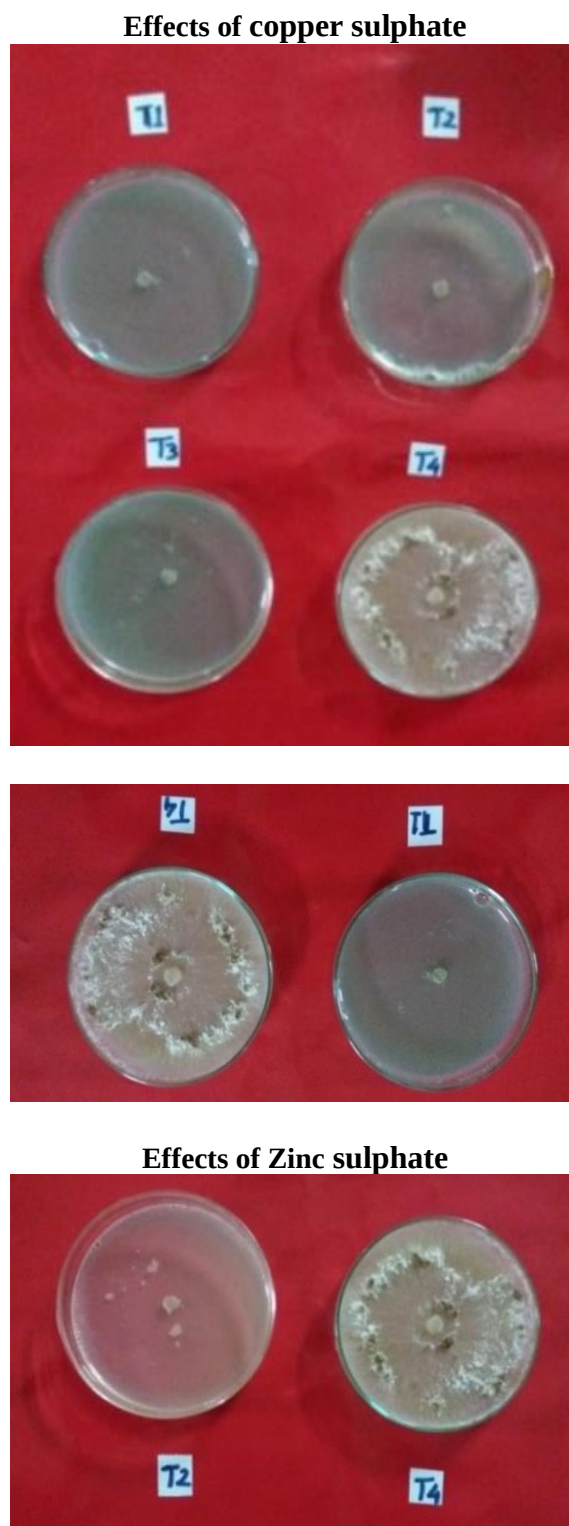
reactions of many rice plants, such as the formation of cytochrome and nucleotides, auxin synthesis, the formation of chlorophyll, enzyme stimulation and membrane integrity (IRRI, 2000). Numerous experiments (Korayemm A.M., 1993; Nand R., 1996; Sagwal *et al.* 1994, Selvi S., 1995) showed that the incorporation of Zn in rice plants improves the grain yield. Copper plays a crucial role in the development of chlorophyll and the increase is directly linked to an improvement in yield and fruit production (Heitholt *et al.*, 2002).

Under glasshouse conditions, sheath blight disease in pots were initiated by inoculation at maximum tillering stage of rice. Silica gel, copper sulphate and zinc sulphate were applied to the soil prior to planting at the rates of 360g, 0.30 g, 0.45g per 15 kg soil respectively. Micronutrients application reduced sheath blight severity and HRLH%. Fertilization with Cu was significantly more effective than Zn and Si treatments in minimizing yield loss due to sheath blight.

4.10.1 *In vitro* study:

Table 4.33 and Fig. 4.44 and Fig. 4.29 and 4.30 indicated that all micronutrients were significantly inhibit the mycelial growth of *R. solani* as compared to the control. Copper sulphate and zinc sulphate (with 0.0 mm mycelial growth and 100% decrease over control) significantly reduced the mycelial growth followed by silicon dioxide (with 73.24 mm mycelial growth and 18.61% decrease over control) compared to the control treatment. Mycelium growth was recorded to the maximum in control treatment (73.24 mm). No sclerotial formation was observed in copper sulphate and zinc sulphate while 53.74 sclerotia per plate was observed in silica compared to the control (61.08 per plate) treatment. Small sized sclerotia were generally formed in silica, but normal sclerotia were formed in the control.

Fig. 4.29: Effects of Silicon, Copper and Zinc Applications on Sheath Blight Disease Severity on Rice



Effects of Silicon dioxide

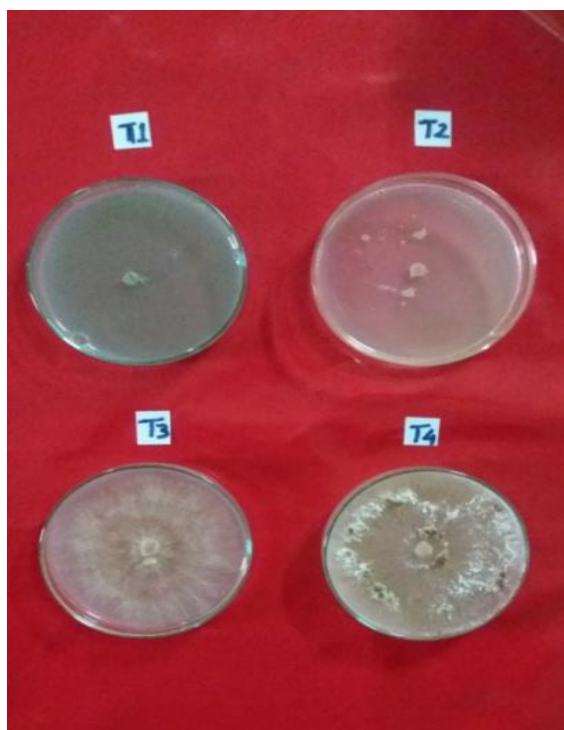
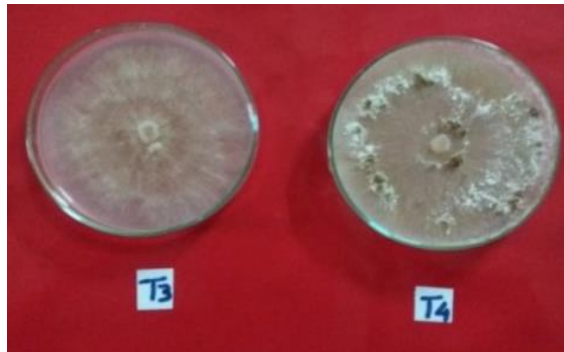


Table 4.33: Effects of Silicon, Copper and Zinc on mycelial growth and sclerotia formation of *R. solani*

Micronutrient (500ppm)	Mycelial growth (in mm)	No. of sclerotia per plate	% decrease over control
T1 - Copper sulphate	0.0 (0.71)	0.0 (0.71)	100.0 (10.03)
T2 – Zinc sulphate	0.0 (0.71)	0.0 (0.71)	100.0 (10.03)
T3 – SiO ₂	73.24 (8.58)	53.74 (7.30)	18.61 (4.34)
T4 – Control	90.0 (9.51)	61.08 (7.84)	-
S Em±	0.06508	0.120651	
CD (5%)	0.20053	0.371764	

*Figures in parenthesis are square root transformed value

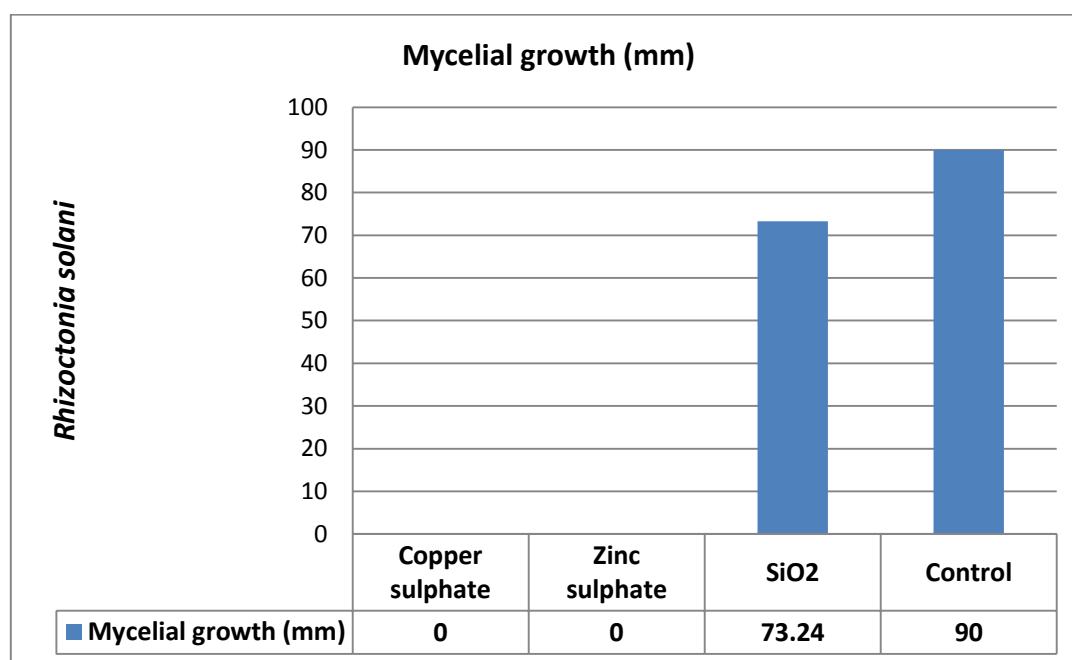


Fig.4.30: Effects of Silicon, Copper and Zinc on mycelial growth of *R. solani*

4.10.2 Pot study:

During kharif 2016, the data presented in table 4.34 showed that copper sulphate significantly reduced the sheath blight incidence (37.06%) over all treatments is followed by zinc sulphate (40.41%) and SiO₂ (46.99%) over the inoculated control treatment (52.30%). The HRLH % (Highest Relative Lesion Height percent) of sheath blight disease ranged from 27.43 to 36.17 per cent and found significant difference over the control among the micronutrients. Minimum HRLH% was also observed in copper sulphate (27.43%) is followed by zinc sulphate (31.24%) and SiO₂ (36.17%) treatment. The copper sulphate treatment significantly reduced the sheath blight disease (34.45% PDI) which is followed by zinc sulphate (45.56% PDI) and silica (54.44% PDI) treatment over control. Whereas 11.11% PDI was noted in the uninoculated control and 55.56% PDI for the inoculated control. The treatment of copper sulphate also significantly increased the yield (4469.60kg/ha) over all treatments are followed by zinc sulphate (4160kg/ha) and SiO₂ (3856kg/ha) over the inoculated control treatment (3480.0 kg/ha).

Table 4.34: Effect of micronutrients on sheath blight disease development under pot condition (Year-2016):

Treatments	Disease incidence (%)	HRLH (%) (Highest Relative lesion height %)	PDI (%)	Grain yield (Kg/ha.)
T1 - Copper sulphate	37.06 (37.49)	27.43 (31.56)	34.45 (35.93)	4469.60
T2 - Zinc sulphate	40.41 (39.47)	31.24 (33.98)	45.56 (42.40)	4160.0
T3 – SiO ₂	46.99 (43.27)	36.17 (36.97)	54.44 (47.55)	3856.0
T4 – Control (Un-inoculated)	5.59 (13.63)	2.52 (9.11)	11.11 (19.47)	4560.0
T5 - Control (Inoculated)	52.30 (46.31)	40.96 (39.79)	55.56 (48.19)	3480.0
S Em±	0.5655	0.4882	1.3452	38.331
CD (5%)	1.7048	1.4717	4.0550	117.052

*Figures in parenthesis are arc sine transformed value

During kharif 2017, the data presented in table 4.35 showed that the copper sulphate treatment is significantly reduced the sheath blight disease incidence (39.59%) is followed by zinc sulphate (41.50%) and SiO₂ (42.55%) over the inoculated control treatment (51.60%). Minimum HRLH% (Highest Relative Lesion Height percent) of sheath blight disease was observed in copper sulphate (30.42%) and was on par with zinc sulphate (31.13% HRLH) followed by SiO₂ (32.70% HRLH) over the inoculated control (40.16% HRLH). The copper sulphate significantly reduced the sheath blight disease (42.23% PDI) followed by zinc sulphate (50.0% PDI) and silica (53.34% PDI) over the inoculated control with 55.56% PDI. The significantly increased grain yield was recorded in copper sulphate (4326.25 kg/ha) and was on par with zinc sulphate (4264.0 kg/ha) and SiO₂ (4161.20 kg/ha) over the inoculated control. The minimum grain yield (3568.0 kg/ha) was observed in inoculated control treatment.

Table 4.35: Effect of micronutrients on sheath blight disease development under pot condition (Year-2017):

Treatments	Disease incidence (%)	HRLH (%) (Highest Relative lesion height %)	PDI (%)	Grain yield (Kg/ha.)
T1 - Copper sulphate	39.59 (38.98)	30.42 (33.47)	42.23 (40.49)	4326.25
T2 - Zinc sulphate	41.50 (40.10)	31.13 (33.91)	50.00 (44.98)	4264.0
T3 – SiO ₂	42.55 (40.71)	32.70 (34.83)	53.34 (46.91)	4161.2
T4 – Control(Un-inoculated)	7.04 (15.33)	3.64 (11.0)	11.11 (19.47)	4441.25
T-5 - Control (Inoculated)	51.60 (45.91)	40.16 (39.32)	55.56 (48.19)	3568.0
S Em±	0.5137	0.4028	1.4779	61.535
CD (5%)	1.5486	1.2142	4.4550	185.487

*Figures in parenthesis are arc sine transformed value

The pooled data of year 2016 and 2017 presented in the table 4.36 and fig. 4.31 revealed that the treatment copper sulphate significantly reduced the sheath blight disease incidence (38.34%) followed by zinc sulphate (40.96%) and SiO₂ (44.77%) over the inoculated control treatment (51.95%). The HRLH % (Highest Relative

Lesion Height percent) of sheath blight disease ranged from 28.93 to 34.44 per cent and found significant difference among the micronutrients. Minimum HRLH% (Highest Relative Lesion Height percent) of sheath blight disease was again interpreted in copper sulphate (28.93%) treatment is followed by zinc sulphate (31.19%) and SiO₂ (34.44%) treatments over the inoculated control (40.56%). The copper sulphate significantly reduced the sheath blight disease (with 38.34% PDI) followed by zinc sulphate (47.78% PDI) and silica (53.89% PDI) over the inoculated control (with 55.56% PDI). The pooled study also showed that the treatment with copper sulphate significantly enhanced the yield of paddy (4397.93 kg/ha) and recorded superior over all treatments was followed by zinc sulphate (4212.00kg/ha) and SiO₂ (4008.60 kg/ha) over the yield of inoculated control treatment (3524.00 kg/ha).

This study showed the potential contribution of copper, zinc and silicon to reducing the sheath blight severity and increasing rice yield as compared with the control treatment. Silicon fertilization could be incorporated as a sustainable and environmentally friendly practice for management of rice sheath blight disease.

Similar results in the agreement with Khaing *et al.*, 2014, which examined that the use of micronutrients reduced the incidence and severity of sheath blight disease regardless of the variety. Fertilization with Si was significantly more effective than treatment with Cu and Zn in both varieties in order to minimize the loss of yield. These results are consistent with other results (Rodrigues and Datnoff 2005 and Wang Meiqin, 2005) on disease reduction. Increased resistance to diseases due to the use of Si can be associated with an accumulation of Si in epidermal cells of leaves, which acts as a mechanical barrier against fungal attack (Cai *et al.*, 2008). The results of several workers were in agreement with the present result because they also reported the effectiveness of various micronutrients against *R. solani* (Kannaiyan and Prasad, 1979; Phillip and Joshi, 1980; Bhattacharya and Roy, 2001; Lakpale, 1992; Walia *et al.* 1992 and Ganguli and Sinha, 2003). In pots trial inoculated with *R. solani*, initial symptoms developed on 15 to 20% of the stems within 7 to 14 days of inoculation, and these infection levels were within sheath blight treatment thresholds for the varieties in the study. In the inoculated / untreated (control), severe sheath blight disease occurred, ranging from 49 to 53% infected stems with 38 to 43% of the lesion

length to the height of the rice plant. During the vegetation period, mild sheath blight was observed in the non-inoculated test pots, but did not reach the treatment threshold.

Table 4.36: Effect of nutrients on sheath blight disease development under pot condition (Pooled data of year 2016 and 2017):

Treatments	Disease incidence (%)	HRLH (%) (Highest Relative lesion height %)	PDI (%)	Grain yield (Kg/ha.)
T1 - Copper sulphate	38.34 (38.24)	28.93 (32.53)	38.34 (38.24)	4397.93
T2 - Zinc sulphate	40.96 (39.79)	31.19 (33.95)	47.78 (43.72)	4212.00
T3 – SiO ₂	44.77 (42.0)	34.44 (35.91)	53.89 (47.23)	4008.60
T4 – Control(Un-inoculated)	6.32 (14.56)	3.08 (10.10)	11.11 (19.47)	4500.63
T-5 - Control (Inoculated)	51.95 (46.12)	40.56 (39.56)	55.56 (48.19)	3524.00
S Em±	0.4191	0.3119	1.0046	30.542
CD (5%)	1.2634	0.9403	3.0282	92.066

*Figures in parenthesis are arc sine transformed value

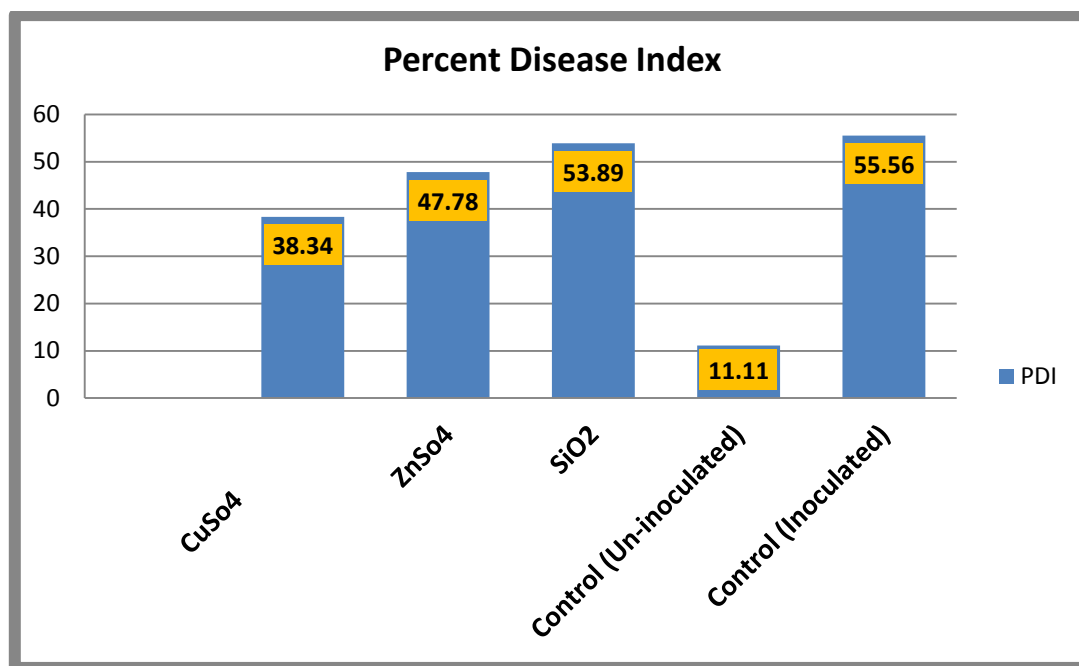


Fig.4.31: Effect of nutrients on sheath blight disease development under Pot condition (Pooled data of kharif 2016 and kharif 2017)

4.11 Efficacy of new molecules in the management of sheath blight:



Fig.4.32: Efficacy of new molecules in the management of sheath blight under field condition

4.11.1 *In-vitro* efficacy of new fungicide molecules against *R. solani*

Six fungicides were evaluated *in vitro* using the Food Poisoned Technique to find the most effective inhibitor for the growth of *R. solani* at different doses / liter. The observation for mycelial growth of *R. solani* were recorded at every 3 days intervals up to 30 days. The percent reduction of mycelial growth was calculated. The result is shown in table 4.37 and fig.4.33.

In the year 2016, new molecules were tested *in vitro* for their effectiveness against sheath blight disease. Table 4.37 and fig. 4.48 showed that all the tested fungicides significantly reduced the mycelial growth of *R. solani* over the control treatment. A complete inhibition of mycelial growth of *R. solani* by new molecules observed in different doses (@0.75ml, 1.0 ml, 1.25 ml, 2.5 ml per liter) of combination fungicide Azoxystrobin 18.2% + Difenoconazole 11.4% SC (Amistar top 32.5% SC) and it significantly reduced the mycelial growth with 0.0mm and 100.0% decrease over control and it is followed by Azoxystrobin 23% SC (Amistar 25% SC) @1.0 ml (with 2.10mm mycelial growth and 97.64% decrease over control), Difenoconazole 25% EC (Score 25% EC) @0.5 ml (with 12.99mm mycelial growth and 85.54% decrease over control), Hexaconazole 5% EC (Contaf 5% EC) @2.0ml (with 15.21mm mycelial growth and 83.10% decrease over control), Kitazin 48% (Kitazin 48% EC) @2.0ml (with 16.10mm mycelial growth and 82.10% decrease over control) and Iprodione 25%+Carbendazim 25% WP (Quintal) (with 18.0mm mycelial growth and 79.98% decrease over control) @1.0g over the control. The maximum mycelial growth was observed in control (untreated) treatment (90mm). (Fig. 4.56 in plates). The combination fungicides Azoxystrobin 18.2% + Difenoconazole 11.4% SC were found better as compare to the other solo fungicides.

The effectiveness of various chemicals against this disease has been reported by various workers. Ali and Archer (2003) reported that Carbendazim, Tilt and Contaf were highly effective against this pathogen *in vitro*. Haque (1997) reported that Hinosan is very effective under *in vitro* conditions. The results of the present *in vitro* study also confirm the effectiveness of new molecules on the growth of *R. solani*.

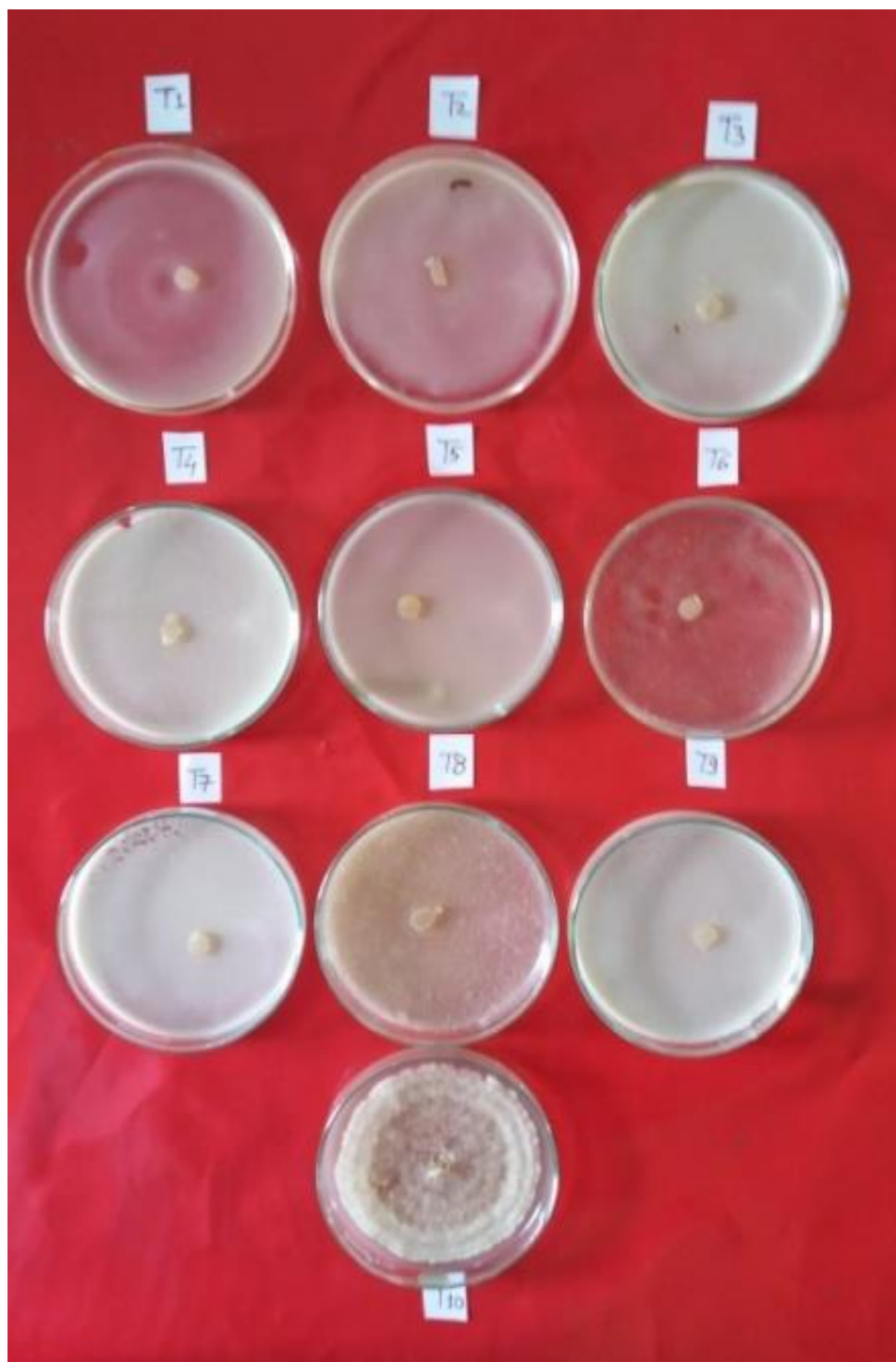


Fig. 4.33: Efficacy of new molecules in the management of sheath blight (*in vitro*)

4.11.2 Field conditions:

In kharif 2016, nine molecules were also examined for their effectiveness against the sheath blight disease under field condition. The first fungicidal spray was applied at the time of symptom expression of the disease. The second spray was applied after the 10th day from the 1st spray. The observation on disease severity and Per cent disease index were recorded at 10th day and 21st day have been given in table 4.38 and fig. 4.32. After 10 days of observation (Fig. 4.49), all new fungicidal molecules were significantly reduced the sheath blight disease severity over untreated (control) treatment. The combination fungicide treatment Azoxystrobin 18.2% + difenoconazole 11.4% SC (@ 2.5 ml/l) treatment (T4) significantly reduced the PDI of sheath blight disease (17.11% PDI) over all treatments followed by Difenoconazole 25% EC (Score 25% EC) @0.5 ml/lit (T6) with 19.78% PDI, Azoxystrobin 18.2% + Difenoconazole 11.4% SC @1.25ml/lit (T3) with 20.22% PDI, Azoxystrobin 23% SC (Amistar 25% SC) @1.0ml/lit (T5) with 20.81% PDI, Hexaconazole 5% EC (Contaf 5% EC) @2.0ml/lit (T9) with 21.11% PDI, Azoxystrobin 18.2% + Difenoconazole 11.4% SC @1.0ml/lit (T2) with 22.44% PDI, Azoxystrobin 18.2% + Difenoconazole 11.4% SC (Amistar top 32.5% SC) @0.75ml/lit (T1) with 24.88% PDI, Kitazin 48% EC (Kitazin 48% EC) @2.0ml/lit (T7) with 31.81% PDI, Iprodione 25% + carbendazim 25% WP (Quintal) @ 1.0g/lit (T8) with 36.88% PDI over the control. The maximum percent disease index (39.77%) was recorded in control (T10) treatment. After the two fungicide sprays, the observation on 21 day (table 4.40 and fig. 4.50) the results revealed the combination fungicide Azoxystrobin 18.2% + difenoconazole 11.4% SC (@ 2.5 ml/lit.) treatment (T4) significantly reduced the sheath blight disease (22.67% PDI) and was on par with Azoxystrobin 18.2% + Difenoconazole 11.4% SC @1.25ml/lit (T3) with 24.44% PDI followed by Azoxystrobin 18.2% + Difenoconazole 11.4% SC @1.0ml/lit (T2) with 28.22% PDI, Azoxystrobin 18.2% + Difenoconazole 11.4% SC (Amistar top 32.5% SC) @0.75ml/lit (T1) with 32.66% PDI, Azoxystrobin 23% SC (Amistar 25% SC) @1.0ml/lit (T5) with 36.44% PDI, Difenoconazole 25% EC (Score 25% EC) @0.5 ml/lit (T6) with 39.55% PDI, Hexaconazole 5% EC (Contaf 5% EC) @2.0ml/lit. (T9)

with 40.88% PDI, Kitazin 48% EC (Kitazin 48% EC) @2.0ml/lit (T7) with 42.44% PDI and Iprodione 25% + carbendazim 25% WP (Quintal) @ 1.0g/lit (T8) with 50.44% PDI over the control. The maximum percent disease index (70.67%) was recorded in control (T10) treatment. Between two observations there were fluctuations in the PDI in either the increase or decrease within the chemicals. A wide range of new fungicide molecules have been found to effectively reduce this disease severity. During the entire study, no phytotoxic symptoms were observed in any of the treatment plots.

All the fungicidal treatments were significantly enhanced the grain yield of paddy over the control (Fig. 4.51). The highest significant increased in grain yield was obtained in azoxystrobin 18.2% + difenoconazole 11.4% SC @ 2.5 ml (4560.25kg/ha) which is statistically on par with azoxystrobin 18.2% + difenoconazole 11.4% SC @ 1.25 ml (4536.25 kg/ha) and 1.0 ml/lit (4400.05 kg/ha) are followed by azoxystrobin 18.2% + difenoconazole 11.4% SC 0.75ml/lit (4305.75 kg/ha), Azoxystrobin 23%SC (4032.0kg/ha), Difenoconazole 25% EC (Score 25% EC) @0.5 ml/lit (3719.30kg/ha), Hexaconazole 5% EC (Contaf 5% EC) @2.0ml/lit (3661.0kg/ha), Kitazin 48% EC (Kitazin 48% EC) @2.0ml/lit (3640.0kg/ha) and Iprodione 25% + carbendazim 25% WP (Quintal) @ 1.0g/lit (3600.80kg/ha) over the control. The minimum grain yield (3031.70kg/ha) was recorded in control treatment.

Table 4.38: Efficacy of new molecules in the management of sheath blight and grain yield of rice under field condition (Year-2016)

	Treatments	Dose/ Liter	10th day (PDI)	21st day (PDI)	Yield (Kg/ha)
T1	Azoxystrobin 18.2% + Difenoconazole 11.4% SC (Amistar top 32.5% SC)	0.75 ml	24.88 (29.89)	32.66 (34.84)	4305.75
T2	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	1.0 ml	22.44 (28.26)	28.22 (32.07)	4400.05
T3	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	1.25 ml	20.22 (26.81)	24.44 (29.63)	4536.25
T4	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	2.5 ml	17.11 (24.41)	22.67 (28.42)	4560.25
T5	Azoxystrobin 23% SC (Amistar 25% SC)	1.0 ml	20.81 (27.13)	36.44 (36.83)	4032.0
T6	Difenoconazole 25% EC (Score 25% EC)	0.5 ml	19.78 (26.37)	39.55 (38.96)	3719.3
T7	Kitazin 48% EC (Kitazin 48% EC)	2.0 ml	31.81 (34.31)	42.44 (40.65)	3640.0
T8	Iprodione 25% + carbendazim 25% WP (Quintal)	1.0g	36.88 (37.37)	50.44 (36.63)	3600.8
T9	Hexaconazole 5% EC (Contaf 5% EC)	2.0 ml	21.11 (27.29)	40.88 (39.74)	3661.0
T10	Control (Untreated)		39.77 (39.09)	70.67 (57.21)	3031.70
	S Em±		0.886	1.812	79.060
	CD (5%)		2.5701	5.2581	229.376

Figures in parenthesis are Arc sine transformed values
Average of 4 replication

In kharif 2017, nine molecules were again repeated examined for their effectiveness against the sheath blight disease. The observation on disease severity and Per cent disease index were recorded at 10th day and 21st day have been given in table 4.39. After 10 days of observation (Fig. 4.32), the combination of Azoxystrobin 18.2% + difenoconazole 11.4% SC (@ 2.5 ml/l) treatment (T4) significantly superior to reduced the sheath blight disease (17.55% PDI) and was statistically is on par with Azoxystrobin 23% SC (Amistar 25% SC) @1.0ml/lit (T5) with 18.89% PDI was

followed by Azoxystrobin 18.2% + Difenconazole 11.4% SC @1.25ml/lit (T3) with 19.99% PDI, Difenconazole 25% EC (Score 25% EC) @0.5 ml/lit (T6) with 20.44% PDI, Azoxystrobin 18.2% + Difenconazole 11.4% SC @1.0ml/lit. (T2) with 22.88% PDI, Hexaconazole 5% EC (Contaf 5% EC) @2.0ml/lit (T9) with 23.11% PDI, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @0.75ml/lit (T1) with 23.77% PDI, Kitazin 48% EC (Kitazin 48% EC) @2.0ml/lit (T7) with 25.11% PDI and Iprodione 25% + carbendazim 25% WP (Quintal) @ 1.0g/lit (T8) with 26.89% PDI over the control. The maximum percent disease index (38.89%) was recorded in untreated control (T10) treatment. After the two fungicide sprays, the observation on 21 day in table 4.39 and fig. 4.53 showed that Azoxystrobin 18.2% + difenconazole 11.4% SC (@ 2.5 ml/lit.) treatment (T4) significantly reduced the sheath blight disease (22.89% PDI) followed by Azoxystrobin 18.2% + Difenconazole 11.4% SC @1.25ml/lit. (T3) with 25.55% PDI, Azoxystrobin 18.2% + Difenconazole 11.4% SC @1.0ml/lit. (T2) with 29.56% PDI, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @0.75ml/lit. (T1) with 31.99% PDI, Azoxystrobin 23% SC (Amistar 25% SC) @1.0ml/lit. (T5) with 36.89% PDI, Difenconazole 25% EC (Score 25% EC) @0.5 ml/lit. (T6) with 39.11% PDI, Hexaconazole 5% EC (Contaf 5% EC) @2.0ml/lit. (T9) with 42.67% PDI, Kitazin 48% EC (Kitazin 48% EC) @2.0ml/lit. (T7) with 43.33% PDI and Iprodione 25% + carbendazim 25% WP (Quintal) @ 1.0g/lit. (T8) with 50.91% PDI over the control. The maximum percent disease index (71.77%) was recorded in untreated control (T10) treatment. During the entire study, no phytotoxic symptoms were observed in any of the treatment plots.

Among all treatments, Azoxystrobin 18.2% + difenconazole 11.4% SC @ 2.5 ml showed significantly higher grain yield (4707.75kg/ha) (Fig. 4.54) which is statistically on par with azoxystrobin 18.2% + difenconazole 11.4% SC @ 1.25 ml (4704.30kg/ha), azoxystrobin 18.2% + difenconazole 11.4% SC @1.0 ml/l (4536.75kg/ha) and azoxystrobin 18.2% + difenconazole 11.4% SC @0.75ml/l (4402.50kg/ha) are followed by Azoxystrobin 23%SC (4230.60kg/ha), Difenconazole 25% EC (Score 25% EC) @0.5 ml/lit. (4219.75kg/ha), Hexaconazole 5% EC (Contaf

5% EC) @2.0ml/lit. (3815.60kg/ha), Kitazin 48% EC (Kitazin 48% EC) @2.0ml/lit. (3644.05kg/ha) and Iprodione 25% + carbendazim 25% WP (Quintal) @ 1.0g/lit. (3616.95kg/ha) over the control. The minimum grain yield (3048.45kg/ha) was recorded in control treatment.

4.39: Efficacy of new molecules in the management of sheath blight and grain yield of rice under field condition (Year-2017):

	Treatments	Dose /Liter	10 th day (PDI)	21 st day (PDI)	Yield (Kg/ha)
T1	Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC)	0.75 ml	23.77 (29.13)	31.99 (34.41)	4402.50
T2	Azoxystrobin 18.2% + Difenconazole 11.4% SC	1.0 ml	22.88 (28.57)	29.56 (32.92)	4536.75
T3	Azoxystrobin 18.2% + Difenconazole 11.4% SC	1.25 ml	19.99 (26.55)	25.55 (30.06)	4704.30
T4	Azoxystrobin 18.2% + Difenconazole 11.4% SC	2.5 ml	17.55 (24.75)	22.89 (28.57)	4707.75
T5	Azoxystrobin 23% SC (Amistar 25% SC)	1.0 ml	18.89 (25.74)	36.89 (37.09)	4230.60
T6	Difenconazole 25% EC (Score 25% EC)	0.5 ml	20.44 (26.87)	39.11 (38.70)	4219.75
T7	Kitazin 48% EC (Kitazin 48% EC)	2.0 ml	25.11 (30.64)	43.33 (41.16)	3644.05
T8	Iprodione 25% + Carbendazim 25% WP (Quintal)	1.0g	26.89 (31.21)	50.91 (45.51)	3616.95
T9	Hexaconazole 5% EC (Contaf 5% EC)	2.0 ml	23.11 (28.71)	42.67 (40.77)	3815.60
T10	Control (Untreated)		38.89 (38.56)	71.77 (57.92)	3048.45
	S Em±		0.800	0.780	110.704
	CD (5%)		2.3204	2.2626	321.1830

Figures in parenthesis are Arc sine transformed values
Average of 4 replication

The pooled data for both the years 2016 and 2017 presented in table 4.40 indicated that the test combination fungicide (azoxystrobin 18.2% + difenoconazole 11.4% SC) was found highly effective against rice sheath blight disease for the four concentrations tested as compared with the untreated control. The first fungicidal spray was applied at the first time the symptom appeared. The second spray was

applied after the 10th day from the 1st spray. The observation on disease severity and Per cent disease index were recorded at 10th day and 21st day have been given in table 4.40. After 10 days of observation (Fig. 4.34), the combination fungicide Azoxystrobin 18.2% + difenoconazole 11.4% SC (@ 2.5 ml/l) treatment (T4) was found significantly superior to reduce the sheath blight disease (17.33% PDI) over all treatments is followed by Azoxystrobin 23% SC (Amistar 25% SC) @1.0ml/lit (T5) with 19.85% PDI, Azoxystrobin 18.2% + Difenconazole 11.4% SC @1.25ml/lit (T3) and Difenconazole 25% EC (Score 25% EC) @0.5 ml/lit (T6) with 20.11% PDI, Hexaconazole 5% EC (Contaf 5% EC) @2.0ml/lit (T9) with 22.11% PDI, Azoxystrobin 18.2% + Difenconazole 11.4% SC @1.0ml/lit (T2) with 22.66% PDI, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @0.75ml/lit (T1) with 24.33% PDI, Kitazin 48% EC (Kitazin 48% EC) @2.0ml/lit (T7) with 28.46% PDI and Iprodione 25% + carbendazim 25% WP (Quintal) @ 1.0g/lit (T8) with 31.88% PDI over the control. The maximum percent disease index (39.33%) was recorded in untreated control (T10) treatment. After the two fungicide sprays, the observation on 21 day in table 4.40 and fig. 4.35 showed that Azoxystrobin 18.2% + difenoconazole 11.4% SC (@ 2.5 ml/lit.) treatment (T4) was found significantly superior to reduce the sheath blight disease (22.78% PDI) followed by Azoxystrobin 18.2% + Difenconazole 11.4% SC @1.25ml/lit (T3) with 25.0% PDI, Azoxystrobin 18.2% + Difenconazole 11.4% SC @1.0ml/lit (T2) with 28.89% PDI, Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) @0.75ml/lit (T1) with 32.33% PDI, Azoxystrobin 23% SC (Amistar 25% SC) @1.0ml/lit (T5) with 36.67% PDI, Difenconazole 25% EC (Score 25% EC) @0.5 ml/lit (T6) with 39.33% PDI, Hexaconazole 5% EC (Contaf 5% EC) @2.0ml/lit. (T9) with 41.78% PDI, Kitazin 48% EC (Kitazin 48% EC) @2.0ml/lit (T7) with 42.89% PDI and Iprodione 25% + carbendazim 25% WP (Quintal) @ 1.0g/lit (T8) with 50.68% PDI over the control. The maximum percent disease index (71.22%) was recorded in untreated control (T10) treatment. Between two observations there were fluctuations in the PDI in either the increase or decrease within the chemicals. A wide range of new fungicide molecules have been found to effectively reduce this disease

severity. During the entire study, no phytotoxic symptoms were observed in any of the treatment plots.

All the fungicidal treatments significantly increased the yield over control treatment. (Fig. 4.36). Increased yield was obtained in azoxystrobin 18.2% + difenoconazole 11.4% SC @ 2.5 ml (4634.0kg/ha) which is statistically on par with azoxystrobin 18.2% + difenoconazole 11.4% SC @ 1.25 ml (4620.28 kg/ha) and 1.0 ml/l (4468.40kg/ha) followed by azoxystrobin 18.2% + difenoconazole 11.4% SC 0.75ml/l (4354.13kg/ha), Azoxystrobin 23%SC (4131.30kg/ha), Difenoconazole 25% EC (Score 25% EC) @0.5 ml/lit. (3969.53kg/ha), Hexaconazole 5% EC (Contaf 5% EC) @2.0ml/lit. (3738.30kg/ha), Kitazin 48% EC (Kitazin 48% EC) @2.0ml/lit. (3642.03kg/ha) and Iprodione 25% + carbendazim 25% WP (Quintal) @ 1.0g/lit. (3608.88kg/ha) over the control. The minimum yield (3048.45kg/ha) was recorded in control treatment. The minimum yield (3040.08kg/ha) was recorded in control treatment.

A recent combination fungicide azoxystrobin 18.2% + difenoconazole 11.4% SC (Amistar Top 32.5% SC) at 2.5 ml / l was most efficient in the studies with the lowest disease severity. The results are consistent with the results of Bhuvaneswari V. and Raju Krishnam (2012) on management strategies to reduce sheath blight disease in rice using a new combination fungicide azoxystrobin 18.2% + difenoconazole 11.4% SC in various concentrations and are intended to: the reduction in disease severity and incidence may be helpful. Many researchers also considered the effectiveness of propiconazole + difenconazole 30 EC in conjunction with Contaf (hexaconazole) to be effective in minimizing the disease (Surulirajan and Khandari, 2003; Suryadai and Kadir, 1989). Singh and Sinha (2004) found that Contaf successfully reduced the severity of the disease and increased the grain yield and weight from 1000 grains to 23.5%, 60.9%, 34.2 g / plant and 29.3 g im Compared to 74.7%, 95.6% increased. 24.4 g / plant and 25.5 g administered. The efficacy of hexaconazole 5 EC at 2.0 ml / l, propiconazole 25 EC at 1.0 ml / l and tebuconazole 25 EC at 1.5 g / l against the sheath blight of rice was described by Krishnam Raju *et al.* (2008). There was a significant difference between treatments for sheath blight PDI,

and all treatments had a significantly lower PDI compared to the untreated control in both Kharif seasons. This finding is in full agreement with the earlier reports, which were also described by Ali and Archers (2003), Nath *et al.* (2005), Lenka and Bhaktavatsalam (2011) and Goswami *et al.* (2012), in which the effectiveness of azoxystrobin in reducing the incidence and increasing the blight occurred, the grain yield found.

Azoxystrobin falls under the category of strobilurins or QoI fungicides, which may have a typical mode of action to disrupt the production of energy and respiration in the fungal cell, ultimately through electron transfer in the cytochrome bc₁ compound at the oxidative quinole site (the Qo) Position), limitation of ATP formation. Azoxystrobins pass through the vascular system of plants in a translaminar and systemic manner. Many strobilurin fungicides on sprayed plants have growth-promoting properties, possibly by slowing down the senescence of the leaf and offering water-retaining properties. Strobilurin is successful against most fungal diseases. The study concluded that the Amistar Top 32.5 SC when sprayed at an appropriate concentration of 2.5 ml / l was considered effective against rice sheath blight.

Combination fungicides are better than the other solo fungicides only because of their broad range of action, the lower dose and the lower risk of developing fungicidal resistance in the target fungus population. So far, there are no resistant varieties against rice sheath blight. In epidemic conditions, the low bioeffectiveness of bioagents makes chemical control an essential tool for farmers to control this disease. Cultural practices combined with foliar fungicide spray are therefore the most common method of combating the disease in the current situation, and the need for fungicide-based use has also been suggested in an integrated disease management program (Bag *et al.*, 2016). A more sustainable approach for ShB management is greater use of natural fungicides such as strobilurins to restrict disease (Singh *et al.*, 2019).

4.40: Efficacy of new fungicide molecules in the management of sheath blight of rice under field condition (Pooled data of kharif 2016 and 2017)

Treatments		Dose/ Liter	10 th day (PDI)	21 st day (PDI)	Yield (Kg/ha)
T1	Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC)	0.75 ml	24.33 (29.52)	32.33 (34.63)	4354.13
T2	Azoxystrobin 18.2% + Difenconazole 11.4% SC	1.0 ml	22.66 (28.42)	28.89 (32.82)	4468.40
T3	Azoxystrobin 18.2% + Difenconazole 11.4% SC	1.25 ml	20.11 (26.69)	25.00 (29.85)	4620.28
T4	Azoxystrobin 18.2% + Difenconazole 11.4% SC	2.5 ml	17.33 (24.60)	22.78 (28.50)	4634.00
T5	Azoxystrobin 23% SC (Amistar 25% SC)	1.0 ml	19.85 (26.45)	36.67 (37.30)	4131.30
T6	Difenconazole 25% EC (Score 25% EC)	0.5 ml	20.11 (26.63)	39.33 (38.84)	3969.53
T7	Kitazin 48% EC (Kitazin 48% EC)	2.0 ml	28.46 (32.36)	42.89 (40.95)	3642.03
T8	Iprodione 25% + Carbendazim 25% WP (Quintal)	1.0g	31.88 (34.42)	50.68 (45.38)	3608.88
T9	Hexaconazole 5% EC (Contaf 5% EC)	2.0 ml	22.11 (28.02)	41.78 (40.26)	3738.30
T10	Control (Untreated)		39.33 (38.84)	71.22 (57.57)	3040.08
S Em±			0.682	0.482	62.53
CD (5%)			1.9779	1.3972	181.4312

*Figures in parenthesis are Arc sine transformed values

* Average of 4 replications

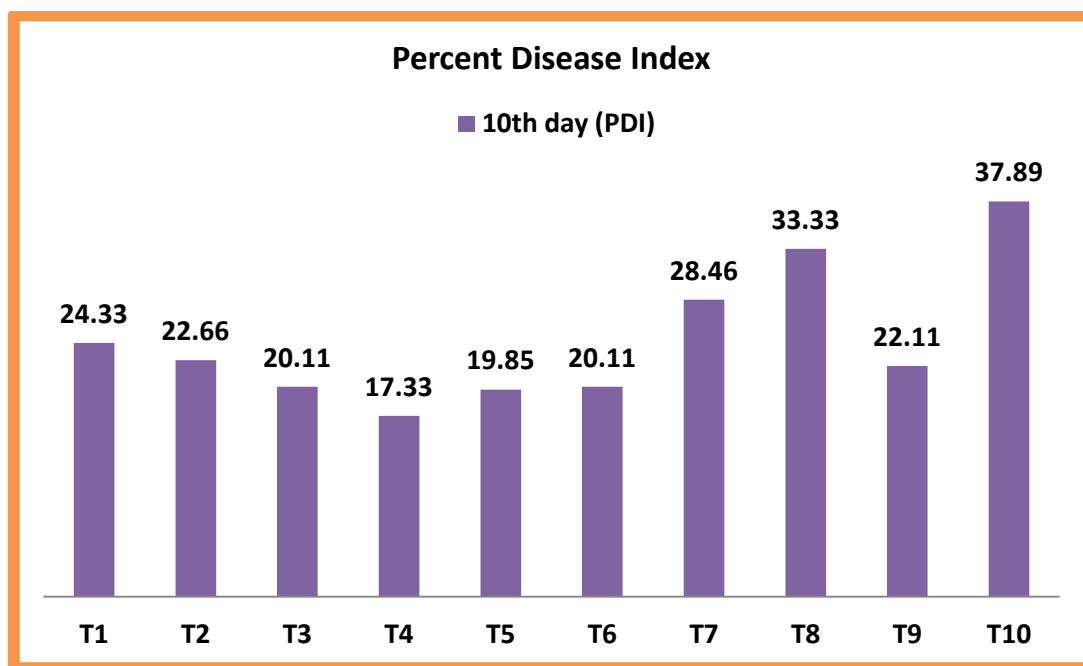


Fig.4.34: Efficacy of new molecules in the management of sheath blight under field condition on 10th day (Pooled data of kharif 2016 and 2017)

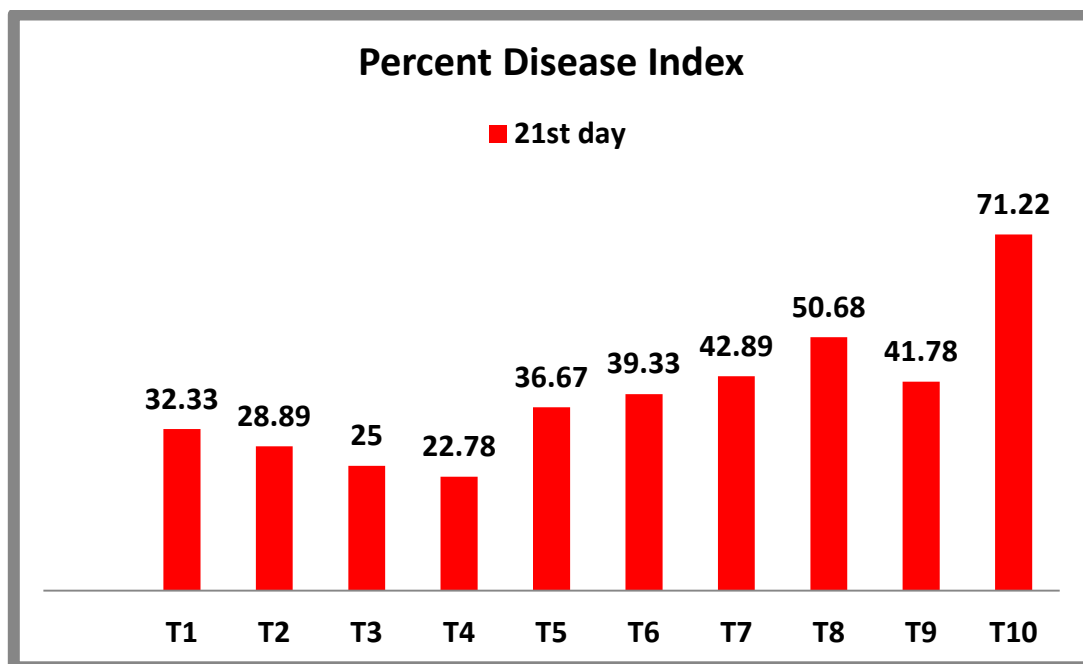


Fig.4.35: Efficacy of new molecules in the management of sheath blight under field condition on 21st day (Pooled data of kharif 2016 and 2017)

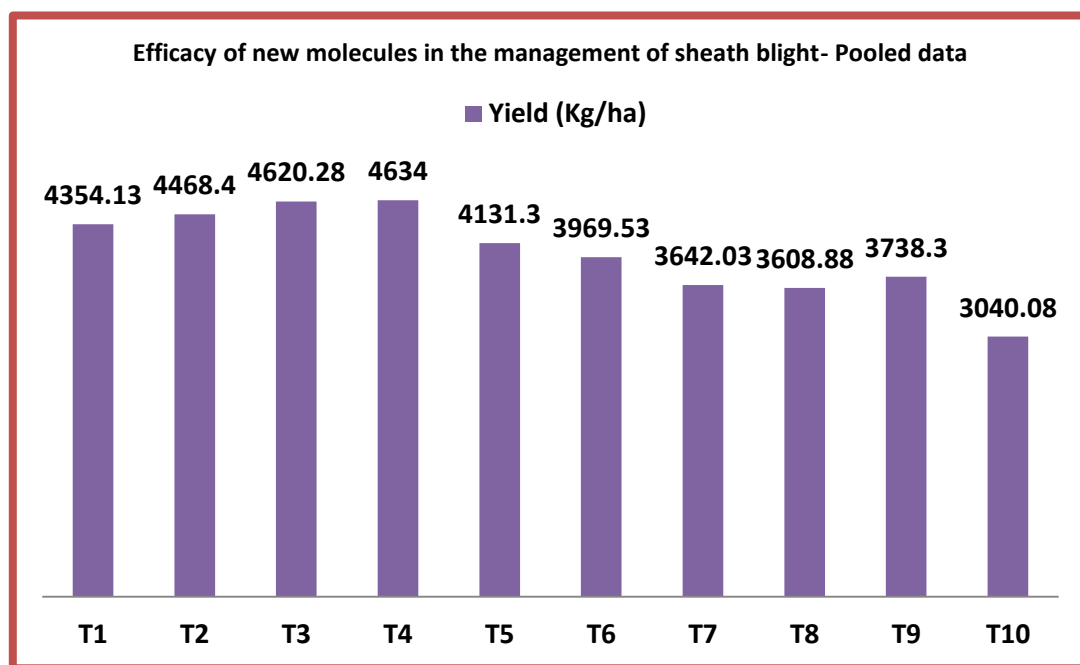


Fig.4.36: Foliar spray of fungicides on yield of rice against sheath blight disease under field condition (Pooled data of kharif 2016 and 2017)

Screening of germplasm entries/varieties against sheath blight disease of rice

4.12 Identification of the slow disease developing varieties for sheath blight:

To find out the slow disease developing varieties, nineteen rice entries were evaluated for their reaction against *R. solani* under natural field condition.

Fig.4.37: Identification of the slow disease developing varieties for sheath blight



During the year 2016 the data presented in table 4.41 and fig. 4.37 that the nineteen entries were screened against sheath blight of rice under artificial inoculation. No entry was recorded for highly resistance reaction. The two entries designated as RP-Patho-23 and IET No.-25916 were showed resistant reaction (Score-3). While the sixteen entries designated IET No.- 22240, IET No.- 545191, IET No.- 463893, IET No.- 22017, IET No.- R-2138-1037-1-415-1, IET No.- 24451, IET No.- 25033, IET No.- 25520, IET No.- 26351, IET No.- 25991, IET No.- 26103, IET No.- 25979, IET No.- 25924, IET No.- 26267, IET No.- 26394 and IET no,-24367 showed moderately resistant reaction (Score-5). Rest of the one entry Rasi was recorded as susceptible (Score-7) in their reactions against the disease.

Table 4.41: Identification of the slow disease developing varieties for sheath blight (Year2016):

S. No.	Grade	Varietal Reaction	Frequency Distribution	Varieties/entries (IET No.)
1	0	Immune	0	NIL
2	1	Highly Resistant	0	NIL
3	3	Resistant	02	IET No.-RP-Patho-23 and IET No.- 25916
4	5	Moderately Resistance	16	IET No.- 22240, IET No.- 545191, IET No.- 463893, IET No.- 22017, IET No.- R-2138-1037-1-415-1, IET No.- 24451, IET No.- 25033, IET No.- 25520, IET No.- 26351, IET No.- 25991, IET No.- 26103, IET No.- 25979, IET No.- 25924, IET No.- 26267, IET No.- 26394 and IET No.-24367.
5	7	Susceptible	01	Rasi
6	9	Highly Susceptible	0	NIL
Total entries = 19				LSI= 4.89

During the year 2017 the data presented in table 4.42 the nineteen were screened against sheath blight of rice under artificial inoculation. no entry was recorded for highly resistance reaction. The three entries designated as IET No.-RP-Patho-23, IET No.- 25916 and IET No.- 24367 were showed resistant reaction (Score-

3). While the fifteen entries designated IET No.- 22240, IET No.- 545191, IET No.- 463893, IET No.- 22017, IET No.- R-2138-1037-1-415-1, IET No.- 24451, IET No.- 25033, IET No.- 25520, IET No.- 26351, IET No.- 25991, IET No.- 26103, IET No.- 25979, IET No.- 25924, IET No.- 26267 and IET No.- 26394 showed moderately resistant reaction (Score-5). Rest of the one entry Rasi was recorded as susceptible (Score-7) in their reactions against the disease.

Table 4.42: Identification of the slow disease developing varieties for sheath blight (Year2017)

S. No.	Grade	Varietal Reaction	Frequency Distribution	Varieties/entries (IET No.)
1	0	Immune	0	NIL
2	1	Highly Resistant	0	NIL
3	3	Resistant	03	IET No.-RP-Patho-23, IET No.- 25916 and IET No.-24367
4	5	Moderately Resistance	15	IET No.- 22240, IET No.- 545191, IET No.- 463893, IET No.- 22017, IET No.- R-2138-1037-1-415-1, IET No.- 24451, IET No.- 25033, IET No.- 25520, IET No.- 26351, IET No.- 25991, IET No.- 26103, IET No.- 25979, IET No.- 25924, IET No.- 26267 and IET No.- 26394.
5	7	Susceptible	01	Rasi
6	9	Highly Susceptible	0	NIL
Total entries = 19				LSI= 4.78

Pooled data of kharif 2016 and kharif 2017 presented in the table 4.43 indicated that among nineteen entries, no entry was recorded for highly resistance reaction. The two entries designated as RP-Patho-23 and IET No.-25916 were showed resistant reaction (Score-3). While the sixteen entries designated IET No.- 22240, IET No.- 545191, IET No.- 463893, IET No.- 22017, IET No.- R-2138-1037-1-415-1, IET No.- 24451, IET No.- 25033, IET No.- 25520, IET No.- 26351, IET No.- 25991, IET No.- 26103, IET No.- 25979, IET No.- 25924, IET No.- 26267, IET No.- 26394 and IET no.-24367 showed moderately resistant reaction (Score-5). Rest of the one entry Rasi was recorded as susceptible (Score-7) in their reactions against the disease.

Few cultivars lines and wild rice species were reported to be resistant by different workers. Varieties like Kataktara DA-2 (IRRI, 1972), BR-430-51-2, BR-57-49-6 (Manian and Manibhushan Rao, 1979), KRC346, KRC355, RP1057-3 (Reddy *et al.*, 1981), PTB-33, Sinna Sivappa and CR57-11-2 (Gangopadhyay and Mishra, 1984), IET8748 (Dev and Mary, 1985), IR-8, IR-42, IR-32 (Iboto, 1985), CR-1014 and T141 (Premalatha Dath, 1985) and Tetep, IET-4699, Jawa-14 (Guo *et al.*, 1985) were reported to be resistant. Siani and Raina (1985) also reported 15 varieties as resistant from their evaluation trials.

Table 4.43: Identification of the slow disease developing varieties for sheath blight (Pooled data of kharif 2016 and 2017):

S. No.	Grade	Varietal Reaction	Frequency Distribution	Varieties/entries (IET No.)
1	0	Immune	0	NIL
2	1	Highly Resistant	0	NIL
3	3	Resistant	02	IET No.-RP-Patho-23 and IET No.- 25916
4	5	Moderately Resistance	16	IET No.- 22240, IET No.- 545191, IET No.- 463893, IET No.- 22017, IET No.- R-2138-1037-1-415-1, IET No.- 24451, IET No.- 25033, IET No.- 25520, IET No.- 26351, IET No.- 25991, IET No.- 26103, IET No.- 25979, IET No.- 25924, IET No.- 26267, IET No.- 26394 and IET No.-24367.
5	7	Susceptible	01	Rasi
6	9	Highly Susceptible	0	NIL
Total entries = 19				LSI= 4.83

4.13 Screening of different set of entries of rice against *R. solani*

The twenty four rice entries were screened for their reaction against *R. solani* under artificial inoculation.



Fig.4.38: Screening of different varieties of rice against *R. solani*

During the year 2016 the data presented in table no. 4.44 showed that no entry was recorded for highly resistance reaction. Among the twenty four rice varieties/entries designated *i.e.*, IET No.- R-2302-396-3-301-1, IET No.-VL-31289, Nidhi, IET No.- RP-Patho-4, IET No.-RP-Patho-6, IET No.-UPL R1-7, IET No.-R-1675-1844-2-1257-1, IET No.- R-2302-386-1-275-1, IET No.-R-2302-387-1-277-1, IET No.- R-2302-390-2-288-1, IET No.- R-1909-112-1-86-1, IET No.- R-2034-147-1-186-1, IET No.-Jaldoobi, IET No.- R-RGY-SI-13, IET No.- R-1670-3975-1-485-1, IET No.- SUVT-122, IET No.- SUVT-230, IET No.- SUVT-324, IET No.- SUVT-353, IET No.- SUVT-362, IET No.- SUVT-412, IET No.-Badshah bhog-2 and IET No.-Sarai phool and Swarna in check. Three entries IET No.- R-2302-396-3-301-1, IET No.-R-2302-387-1-277-1 and IET No.- SUVT-324 showed resistant reaction (Score-3). While, the twenty entries designated IET No.-VL-31289, IET No.-Nidhi, IET No.- RP-Patho-4, IET No.-RP-Patho-6, IET No.-UPL R1-7, IET No.-R-1675-1844-2-1257-1, IET No.- R-2302-386-1-275-1, IET No.- R-2302-390-2-288-1, IET No.- R-1909-112-1-86-1, IET No.- R-2034-147-1-186-1, IET No.-Jaldoobi, IET No.- R-RGY-SI-13, IET No.- R-1670-3975-1-485-1, IET No.- SUVT-122, IET No.- SUVT-230, IET No.- SUVT-353, IET No.- SUVT-362, IET No.- SUVT-412, IET No.-Badshah bhog-2 and IET No.-Sarai phool showed moderately resistant reaction (Score-5). Rest of the one entry swarna was recorded as susceptible (Score-7) in their reactions against the disease. The twenty four entries were screened against sheath blight of rice under artificial inoculation with one isolate collected from Raipur.

Table 4.44: Screening of different entries / varieties against sheath blight resistance (Year2016):

S. No.	Grade	Varietal Reaction	Frequency Distribution	Varieties/entries (IET No.)
1	0	Immune	0	NIL
2	1	Highly Resistant	0	NIL
3	3	Resistant	03	IET No.- R-2302-396-3-301-1 and IET No.- R-2302-387-1-277-1, IET No.- SUVT-324 IET No.-VL-31289, IET No.-Nidhi, IET No.- RP-Patho-4, IET No.-RP-Patho-6, IET No.- UPL R1-7, IET No.-R-1675-1844-2-1257-1, IET No.- R-2302-386-1-275-1, IET No.- R-2302-390-2-288-1, IET No.- R-1909-112-1-86-1, IET No.- R-2034-147-1-186-1, IET No.- Jaldoobi, IET No.- R-RGY-SI-13, IET No.- R-1670-3975-1-485-1, IET No.- SUVT-122, IET No.- SUVT-230, IET No.- SUVT-353, IET No.- SUVT-362, IET No.- SUVT-412, IET No.-Badshah bhog-2 and IET No.-Sarai phool.
4	5	Moderately Resistance	20	
5	7	Susceptible	01	Swarna
6	9	Highly Susceptible	0	NIL
Total entries = 24				LSI= 4.83

During the year 2017 the data presented in table no. 4.45 shows that no entry was recorded for highly resistance reaction. Among the twenty four rice varieties/entries, four entries IET No.-R-2302-387-1-277-1, IET No.- R-2302-390-2-288-1, IET No.- R-2302-396-3-301-1 and IET No.- SUVT-324 showed resistant reaction (Score-3). While, the nineteen entries designated IET No.-VL-31289, IET No.-Nidhi, IET No.-RP-Patho-4, IET No.-RP-Patho-6, IET No.-UPL R1-7, IET No.-R-1675-1844-2-1257-1, IET No.- R-2302-386-1-275-1, IET No.- R-1909-112-1-86-1, IET No.- R-2034-147-1-186-1, IET No.-Jaldoobi, IET No.- R-RGY-SI-13, IET No.- R-1670-3975-1-485-1, IET No.- SUVT-122, IET No.- SUVT-230, IET No.- SUVT-324, IET No.- SUVT-353, IET No.- SUVT-362, IET No.- SUVT-412, IET No.- Badshah bhog-2 and IET No.-Sarai phool showed moderately resistant reaction (Score-5). Rest of the one entry, swarna was showed as susceptible (Score-7) in their reactions against the disease.

Table 4.45: Screening of different entries / varieties against sheath blight resistance (Year2017):

S. No.	Grade	Varietal Reaction	Frequency Distribution	Varities/entries (IET No.)
1	0	Immune	0	NIL
2	1	Highly Resistant	0	NIL
3	3	Resistant	04	IET No.- R-2302-387-1-277-1, IET No.- R-2302-390-2-288-1, IET No.- R-2302-396-3-301-1 and IET No.- SUVT-324.
4	5	Moderately Resistance	19	IET No.-VL-31289, IET No.-Nidhi, IET No.-RP-Patho-4, IET No.-RP-Patho-6, IET No.-UPL R1-7, IET No.-R-1675-1844-2-1257-1, IET No.- R-2302-386-1-275-1, IET No.- R-1909-112-1-86-1, IET No.- R-2034-147-1-186-1, IET No.-Jaldoobi, IET No.- R-RGY-SI-13, IET No.- R-1670-3975-1-485-1, IET No.- SUVT-122, IET No.- SUVT-230, IET No.- SUVT-353, IET No.- SUVT-362, IET No.- SUVT-412, IET No.-Badshah bhog-2 and IET No.-Sarai phool.
5	7	Susceptible	01	Swarna
6	9	Highly Susceptible	0	NIL
Total entries= 24				LSI= 4.75

Pooled data of kharif 2016 and kharif 2017 presented in the table 4.46 and fig. 4.38 indicated that among twenty four rice varieties/entries, no entry was recorded for highly resistance reaction. Four entries IET No.-R-2302-387-1-277-1, IET No.- R-2302-390-2-288-1, IET No.- R-2302-396-3-301-1 and IET No.- SUVT-324 showed resistant reaction (Score-3). While, the nineteen entries designated IET No.-VL-31289, IET No.-Nidhi, IET No.-RP-Patho-4, IET No.-RP-Patho-6, IET No.-UPL R1-7, IET No.-R-1675-1844-2-1257-1, IET No.- R-2302-386-1-275-1, IET No.- R-1909-112-1-86-1, IET No.- R-2034-147-1-186-1, IET No.-Jaldoobi, IET No.- R-RGY-SI-13, IET No.- R-1670-3975-1-485-1, IET No.- SUVT-122, IET No.- SUVT-230, IET No.- SUVT-324, IET No.- SUVT-353, IET No.- SUVT-362, IET No.- SUVT-412, IET No.-Badshah bhog-2 and IET No.-Sarai phool showed moderately resistant reaction (Score-5). Rest of the one entry Swarna was showed as susceptible (Score-7) in their reactions against the disease.

The above results are accordance with the findings of Mosaddeque *et al.*, (2008) screened that forty four test entries of parental lines of rice with one susceptible (BR11) and one resistance check (BRR1 dhan29) were screened against sheath blight of rice. Ten lines were resistant, 31 were moderately resistant and 3 showed susceptible reaction at maximum tillering stage. Chandra *et al.* (2016) tested one hundred eight germplasms, screened under both natural and artificial inoculated conditions, were not found to be susceptible or immune to any of the entries. Out of eighty two entries, forty-five entries were found to be resistant to under artificial inoculated disease. Baigani black and Prasada reported moderately resistant reactions, with 70 moderately susceptible reactions, and 27 reactions noted.

Table 4.46: Screening of different entries / varieties against sheath blight resistance (Pooled data of kharif 2016 and 2017):

S. No.	Grade	Varietal Reaction	Frequency Distribution	Varieties/entries (IET No.)
1	0	Immune	0	NIL
2	1	Highly Resistant	0	NIL
3	3	Resistant	04	IET No.- R-2302-387-1-277-1, IET No.- R-2302-390-2-288-1, IET No.- R-2302-396-3-301-1 and IET No.- SUVT-324.
4	5	Moderately Resistance	19	IET No.-VL-31289, IET No.-Nidhi, IET No.-RP-Patho-4, IET No.-RP-Patho-6, IET No.-UPL R1-7, IET No.-R-1675-1844-2-1257-1, IET No.- R-2302-386-1-275-1, IET No.- R-1909-112-1-86-1, IET No.- R-2034-147-1-186-1, IET No.-Jaldoobi, IET No.- R-RGY-SI-13, IET No.- R-1670-3975-1-485-1, IET No.-SUVT-122, IET No.- SUVT-230, IET No.-SUVT-353, IET No.- SUVT-362, IET No.-SUVT-412, IET No.-Badshah bhog-2 and IET No.-Sarai phool.
5	7	Susceptible	01	Swarna
6	9	Highly Susceptible	0	NIL
Total entries= 24				LSI= 4.79

CHAPTER-V

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH WORK

The finding of the present investigation on “**Studies on variability of *Rhizoctonia solani* Kuhn and management of Sheath Blight of Rice**” were carried out at the Department of Plant Pathology, SKS College of Agriculture and Research Station, Rajnandgaon and College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The investigation mainly consist of following objectives:

- 1) Isolation, purification, identification and pathogenicity test of causal agent and symptomatology of disease.
- 2) Variability and cultural studies of *Rhizoctonia solani* Kuhn.
- 3) Integration of technologies to manage sheath blight of rice.
- 4) To assess effectiveness of stimulants, conventional and non conventional chemicals imparts resistance against sheath blight.
- 5) Screening of germplasm lines/varieties against sheath blight of rice.

The results obtained in present investigation were summarized as below:

The intensive survey of sheath blight infected farmers fields during the kharif 2015-16 at fourty one locations of fifteen district of Chhattisgarh plane were carried out and the disease samples are collected at maximum tillering stage of rice.

Sheath blight and banded blight symptoms were examined for detail study. Naturally infected plant samples of sheath blight have been obtained from the field in the laboratory for isolation and purification of sheath blight fungus. The pathogen was isolated on PDA and the subcultures were purified using a single hyphal tip cutting method and kept on PDA at $28 \pm 2^{\circ} \text{C}$.

The isolated fungus *R. solani* was identified on the basis of morphological properties. After artificial inoculation in susceptible variety swarna, all fifty eight isolates were confirmed by proving the procedure of Koch's postulates. The isolates

were isolated and purified by single hyphal tip method or single sclerotial germination method. The result showed that among fifty eight isolates, most of the isolates *i.e.* twenty two isolates were categorized as weakly aggressive, seventeen isolates were moderately aggressive, twelve isolates were aggressive and seven isolates were found highly aggressive. The PDI of the isolates was ranged between 11.11 - 98.15%, a maximum PDI of 98.15 percent was shown with RS57 isolate.

Variability studies among *R. solani* isolates were noted on the basis of morphology, mycelial growth pattern and other cultural characteristics *i.e.* sclerotial size, shape, color, growth rate, growth pattern and color of the mycelium were observed. The study revealed that, ten isolates were recorded as rapidly growing isolates (RS1, RS2, RS3, RS4, RS5, RS12, RS19, RS34, RS50 and RS57). The colony colour varied from light brown, brown to dark brown. All isolates took large time differences in time period required for formation of sclerotia ranged between 5 days to 15 days of inoculation. The size of sclerotia ranged from 1.56 to 2.95 mm. The number of sclerotia formation were also ranged from 13.22-78.0. The location of the sclerotia as embedded in the fungal mycelium were found in most of the isolates. Regarding texture of the sclerotia formed in the petriplates, most of the isolates were smooth textured and the colour varied to light brown to dark brown.

The study about screening of native isolates of *Trichoderma harzianum* against *R. solani* *in vitro* revealed that all native isolates of *Trichoderma harzianum* were significantly inhibited the mycelial growth of *R. solani*.

The maximum reduction in mycelial growth from *R. solani* in volatile compounds was recorded in Th-4 followed by Th-1, Th-2, Th-5 and Th-3.

The study of native *Pseudomonas fluorescens* on mycelial growth and sclerotial formation of *R. solani* revealed that all *Pseudomonas fluorescens* isolates significantly inhibited the mycelial growth of *R. solani*. The mycelial growth of *R. solani* was highly inhibited by Pf-05 isolate (with 7.94mm mycelial growth and 91.18% decrease over control).

The evaluation of ITK techniques *i.e.* application of plant extracts and panchgavya *in vitro* against *R. solani* were tested in cold water, hot water and acetone

solution. Minimum mycelial growth of *R. solani* was recorded in garlic extract under cold water and hot water extracts. The panchgavya was found to be highly effective in acetone solution followed by hot water extract.

In impact of sheath blight on seedling vigour study under pot and field conditions revealed that both variety Swarna and Mahamaya had the highest seed germination as compared to the seeds obtained from infected panicle. On 30 day of sowing in seedlings, the root and shoot length of healthy plant seeds of both Swarna and Mahamaya variety was greater than diseased seedlings. The seedling vigour index calculated clearly noted that it was more in healthy seedlings in both variety and was lower in diseased seedlings.

The results of comparative foliar application of Raipur, Durg and Rajnandgaon trichoderma isolates showed that all isolates of *Trichoderma spp.* significantly reduced the sheath blight disease severity in rice under pot conditions at 30 DAT and 60 DAT planting. Among the *Trichoderma* isolates, foliar spray of Durg isolate (TD3) was effectively showed 26.24% reduction in disease severity at 30 DAT and 24.85% reduction in disease severity at 60 DAT over control treatment. The highest disease severity was reduced by check fungicide hexaconazole. The Durg isolate (TD3) at 30 DAT and 60 DAT also increased the yield per plant as compared to Raipur (TR2) and Rajnandgaon isolates (TR1).

The study on the influence of trichoderma rich organic amendments on sheath blight disease severity in rice showed that among all the organic amendments riched by *Trichoderma harzianum* the treatment T6 (*R. solani* + neem cake + *T. harzianum*) was observed significantly superior to reduce the sheath blight severity by 78.12% decrease over control increase the seedling vigour index 4202.89 with the no. of propagules 5.05×10^5 cfu/g.

Disease management practices in combination with different doses of nitrogen fertilizer revealed that treatment of SV + 1/2 RDN + three spray of Hexaconazole 5 Sc significantly reduce the sheath blight disease severity (with 32.88% PDI) and increased the yield (4576.35 kg/ha) over control treatment. The maximum percent

disease index (75.93%) and minimum yield (3584.33 kg/ha) were recorded with control treatment.

Resistance-inducing chemicals such as salicylic acid, rose bengal, jasmonic acid, and oxallic acid showed good response when tested in both *in vitro* and pot conditions to minimize the severity of the disease caused by *R. solani*. The minimum mycelial growth (0.0mm) with 100% reduction over control of *R. solani* was observed in oxallic acid, followed by salicylic acid, jasmonic acid and rose bengal at a concentration of 250µg/ml as compared to the control (90.0 mm) when tested *in vitro*, while a concentration of 25 µg/ml was found to be less effective. The mycelium growth of *R. solani* was strongly influenced by oxallic acid in all concentrations. Under pot conditions, oxallic acid, salicylic acid, rose bengal and jasmonic acid showed the highest reduction in the percent disease index in 250 µg/ml, while the concentration of 25µg/ml was found to be the least effective. All concentrations in oxallic acid significantly reduced the severity of the disease with 33.34% PDI and 57.13% disease reduction over control (77.78%) treatment. This result clearly indicates that the induction of resistance by the chemicals was mediated by the host, whereby the formation of antifungals can be triggered by resistance-inducing chemicals in the plant system in response to fungal attack. Therefore, chemical modification of rice plant resistance to *R. solani* appears to be an effective tool for treating sheath blight.

The study on *in vitro* effects of micronutrients on mycelial growth of *R. solani* showed that the copper sulphate and zinc sulphate at 500 ppm (100%) and SiO₂ (18.61%) decrease the mycelial growth of *R. solani* over control treatment. These micronutrients were also applied to the rice under pot conditions by mixing in soil prior to the transplanting against sheath blight and results revealed that among all micronutrients, the treatment of copper sulphate significantly reduced the sheath blight incidence was recorded to lowest lesion length along with lowest PDI (38.34%) as compared to the control treatment (55.56% PDI). This treatment also enhanced the yield of paddy significantly (4397.93 kg/ha) over all treatment as compared to untreated (3524.00 kg/ha) treatment.

The new molecules of fungicides were evaluated under *in vitro* against *R. solani* and observation takes place up to 30 days at three days interval. The results showed that a complete inhibition of mycelial growth of *R. solani* at different doses (@0.75ml, 1.0 ml, 1.25 ml, 2.5 ml per liter) of the combination fungicide Azoxystrobin 18.2% + Difenconazole 11.4% SC (Amistar top 32.5% SC) as compared to other solo fungicide and untreated control (90.0 mm growth).

The above combination fungicides were also evaluated for their fungitoxicity to manage the sheath blight severity in rice under field condition and study revealed that after second spray the combination fungicide Azoxystrobin 18.2% + difenoconazole 11.4% SC (@ 2.5 ml/lit.) treatment was significantly reduced the Percent Disease Index of sheath blight (22.78%) over all treatments and increased the yield (4634.00 kg/ha) whereas the maximum PDI (71.22%) and minimum yield (3040.08 kg/ha) were under control treatment.

A set of nineteen rice entries were tested to identify the slow disease developing varieties against sheath blight disease. Among them, IET No. RP-Patho-23 and IET No. 25916 showed a resistant reaction against sheath blight disease, while IET No. 22240, IET No. 545191, IET No. 463893, IET No. 22017, IET No. R-2138-1037 -1-415-1, IET No. 24451, IET No. 25033, IET No. 25520, IET No. 26351, IET No. 25991, IET No. 26103, IET No. 25979, IET No. 25924, IET No. 26267 and IET No. 26394 and IET No. 24367 were recorded as moderately resistant as compared to the susceptible check Rasi.

The twenty-four rice entries were screened against sheath blight resistant in rice in the kharif 2016 and 2017. Among the tested rice entries, the entry IET No. R-2302-387-1-277-1, IET No. R-2302-390-2-288-1, IET No. R-2302-396-3 -301- 1 and IET No. - SUVT-324, recorded as a resistant reaction to sheath blight of rice, while IET No. VL-31289, IET No. Nidhi, IET No. RP-Patho-4, IET No. -RP-Patho-6 , IET No. UPL R1-7, IET No. R-1675-1844-2-1257-1, IET No. R-2302-386-1-275-1, IET No. .- R-1909-112-1 -86-1, IET No. R-2034-147-1-186-1, IET No. Jaldoobi, IET No. R-RGY-SI-13, IET No.- R-1670-3975-1-485- 1, IET No. - SUVT-122, IET No. - SUVT-230, IET No. - SUVT-353, IET No. - SUVT-362, IET No. - SUVT-412, IET No.

Badshah Bhog-2 and IET No. Sarai Phool showed the moderately resistant response as compared to the susceptible check variety swarna.

CONCLUSION

Based on findings of present investigation, some conclusion could be drawn like:

- ❖ Total fifty eight isolates were collected from different geographical area of Chhattisgarh plane noticed that among fifty eight isolates, most no. of the isolates *i.e.* twenty two isolates were categorized as weakly aggressive, seventeen isolates were moderately aggressive, twelve isolates were aggressive and seven isolates were found highly aggressive. The PDI of the isolates was ranged between 11.11 - 98.15%, a maximum PDI of 98.15 percent was shown with RS57 isolate.
- ❖ *R. solani* isolates showed significant variability in their cultural and morphological properties. The isolates differ in colony color, growth pattern and size, shape, color and pattern of sclerotia formation. The color varied from light brown, brown to dark brown, while the average sclerotial diameter ranged from 1.0 to 3.0 mm. The variability helps in determining the level of resistance in the germ plasm and in the selection of the parents in the crossing program.
- ❖ The seeds of healthy plant panicles showed a higher percentage of germination, root length, shoot length and seedling vigour index compared to seeds that were affected by sheath blight under pot conditions.
- ❖ The native *Trichoderma* and *Pseudomonas fleuroscence* isolates were screened under *in vitro* against *R. solani*. Under *in vitro* *Trichoderma* isolate Th-2 and *Pseudomonas fleuroscence* isolate Pf-05 reduces mycelial growth of *R. solani* 61.47% and 91.18% over control. The volatile compound producer trichoderma isolate reduced the mycelial growth 78.51% over the control.
- ❖ The results about foliar application of native trichoderma isolate showed that among Raipur, Durg, Rajnandgaon isolates, the Durg isolate (TD3) reduce the disease severity up to 24.85% over control and increased the yield.

- ❖ The study on evaluation of ITK techniques *i.e.* plant extracts and panchgavya against *R. solani* showed that the garlic extract effectively reduced the *R. solani* growth in cold and hot water extracts.
- ❖ The study on the influence of trichoderma rich organic amendments against *R. solani* showed that *R. solani* + neem cake + *T. harzianum* decreased the sheath blight severity by 78.12% over control and increase seedling vigour and no. of trichoderma population in amended soil.
- ❖ Evaluation of disease management practice combined with doses of N fertilizer noted that SV + 1/2 RDN + three spray of Hexaconazole 5 Sc reduce the sheath blight severity and increased the yield.
- ❖ Study on resistance-inducing chemicals on sheath blight showed that oxallic acid significantly reduced the PDI of sheath blight at all concentrations over control treatment.
- ❖ Among the micronutrients treatment, application of copper sulphate in soil significantly reduced the sheath blight severity (38.34%) and increased the yield (4397.93 kg/ha).
- ❖ The result of fungicidal new molecules were evaluated under *in vitro* and field condition showed that the combination fungicide Azoxystrobin 18.2% + Difenoconazole 11.4% SC (Amistar top 32.5% SC) @2.5 ml per liter significantly reduced the PDI (22.78%) of sheath blight and increased the yield (4634.00 kg/ha).
- ❖ The study on identification of the slow disease developing varieties under field conditions showed that the rice varieties, *i.e.* IET No. RP-Patho-23 and IET No. 25916, IET No.R-2302-387-1-277-1, IET No.R-2302-390-2-288-1, IET No.R-2302-396-3 -301-1 and IET No. SUVT-324 showed a resistant reaction to the disease of the sheath blight of rice were showed resistant ability for sheath blight on rice.

Suggestions for Future research work:

- ❖ The study on variability and aggressiveness of *R. solani* isolates may be helpful for assessing the virulence power of the pathogen for effective management practices.

- ❖ With the reconfirmation and the refinement in present experiment findings about management of sheath blight of rice by using native bioagents, mixing of bioagents in amended soil, use of micronutrients, application of new fungicidal molecules and slow developing disease varieties under the study may be helpful for development of IDM module for management of sheath blight of rice in Chhattisgarh region.
- ❖ The non-chemical practices resulted under present study *i.e.* use of native isolates of trichoderma, *Pseudomonas fleuroscence*, soil amendments + trichoderma, application of medicinal plant extracts and panchgavya ITK technique, slow resistant developing entries can be efficiently reduced the sheath blight disease severity to manage sheath blight of rice under organic rice farming in Chhattisgarh.
- ❖ Analysis of the variation at the molecular level using molecular markers such as SSR, ITS, RFLP and rDNA sequence analysis is best suited to understand the genetic diversity and pathogenic variability within *R. solani* isolates.
- ❖ Identification of R. genes in the slow resistant developing varieties may be helpful for incorporation or transfer of R genes in susceptible variety by using genetic engineering technique will be able to develop resistant varieties of sheath blight of rice.

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