The Pharma Innovation Journal 2021; 10(5): 1661-1671

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(5): 1661-1671

www.thepharmajournal.com
Received: 12-02-2021
Accepted: 29-04-2021

K Nikhil Raman
Department of Plant Pathology, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
K Nikhil Raman
Department of Plant Pathology, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Eco-friendly technologies for the management of paddy sheath blight (*Rhizoctonia solani*)

K Nikhil Raman

Abstract
Sheath blight of rice caused by *Rhizoctonia solani* (Khun) is a potential threat to rice cultivation causing yield losses ranging from 32-70%. There are no host resistant varieties available so far. Fungicidal management for its control are damaging to environment. Eco-friendly approaches had attained major role in the suppression of the pathogen. Research studies are undertaken in order to reduce the incidence of the sheath blight all over the world. Seed and foliar spraying with Microbial agents such as Bacteria and Fungi provide the biological control of sheath blight.

It infects all the stage of the crop. As the primary infection initiates with soil borne sclerotia. So the reducing the soil borne inoculum by the addition of organic amendments *viz.* rice chaff, neem cake, mustard cake, saw dust and farmyard manure helps in reducing the seedling infection. The application of Bioagents such as *Trichoderma harzianum* + *Pseudomonas Floroscens* + farmyard manure prior to transplanting in soil gives maximum reduction in the severity of the Disease. The application of bioagents along with organic amendments will manage the disease effectively and shows positive correlation in the yield. This review gives the overall innovative eco-friendly approaches using today worldwide for environment friendly and economical management of the most destructive disease in rice ecosystem (Sheath Blight).

Keywords: Sheath blight, *Rhizoctonia solani*, eco-friendly management, cultural practices, biocontrol agents, organic amendments, host plant resistance, QTL

Introduction

Rice (Paddy): *Oryza sativa* (Poaceae/Gramineae)

Rice is a major staple food crop for almost 50% of the world population (Kuenzer and Kauner 2013) [19] and There are more than 12% of the paddy fields in the global crop land area (FAOSTAT, 2002). Asia has the largest paddy rice fields (Maclean and Hettel, 2002) [57] and produced more than 90% of rice in 2011 (Kuenzer and kauner, 2013) [19]. Approximately one third of the fresh water irrigation are used for paddy irrigation (Bouman, 2007) [8]. The high water demands of irrigated agriculture have raised concern about improving water resource management (Kuenzer and Kauner, 2013) [19]. The species *Oryza sativa* includes three subspecies. Indica, japonica and javanica (Gowda *et al.*, 2003) [32]. The indica is predominantly tropical subspecies while javanica is grown in equatorial region and japonica is temperate type. (Zhang *et al.*, 1992) [17]. Asian countries like (China, India, Indonesia, Bangladesh, Vietnam and Japan) contribute 80% of the world production and consumption (Abdullah *et al.*, 2015) [2].

Major constraints of rice production

Rice has the major production constraints in India. Some of them are drought and submergence, Bacterial blight, leaf bast, Sheath blight, weeds Brown plant hopper and poor soil fertility. Besides this biotic and abiotic constraints, Poor management practices such as low or high input use, low plant spacing and selection of unhealthy and susceptible cultivars are some of the technical constraints (Jha *et al.*, 2012) [38]. The average yield losses are 25-30% per annum due to diseases it is regular to India (Jha *et al.*, 2012) [38]. Major emerging disease of the rice is Sheath blight. Since it was identified primarily in oriental countries hence the name Oriental sheath blight (Ou *et al.*, 1973) [75].

In India first noticed the Sheath blight disease by Butler (1918) [12] with symptoms similar to those of banded sclerotial disease of sugarcane later Paracer and Chahal (1963) [78] they reported the incidence of disease from Gurdaspur district of Punjab. They also identified the caual organism as *Rhizoctonia solani*. It has become major constraint in Punjab, Haryana, Eastern Uttar Pradesh, Bihar, West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Karnataka and Kerala, Jammu and Kashmir, Madhya Pradesh and Assam, Manipur and Tripura (DRR, 2006-2010) [25].

Economic importance of paddy

Agriculture is the backbone of Indian economy. Rice is the important economical crop mostly consumed in India. and it is the one of the most widely grown and staple food crop in world (Punit KA, *et al*., 2018) [85]. Rice (*Oryza sativa)* is the most widely grown cereal crop in India and contributes 14% of the Indian GDP.

Rice has rich diversity and Sheath blight is the destructive disease in rice causing huge economic losses (Singh *et al*., 2004; Zheng *et al*., 2013; Bhunkal *et al*. 2015b) [10, 90, 118]. Sheath blight became a major production constraint to rice yield. Hybrids and high yielding varieties contribute the incidence of the disease. The average annual losses ranging from 4-50% based on the disease severity of the infection and environmental conditions (Singh *et al*., 2004; Zheng *et al*., 2013; Bhunkal *et al*., 2015b) [10, 90, 118]. In tropical and sub-tropical Asia the disease was reported with the average loss of 5-10% (Willocquet *et al*., 2011) [93]. Sheath blight annual losses was (24-38) thousand tons in japan (Premalatha Dath., 1990) [84]. Philippines reported 24% of yield losses. However in Arkanas USA 5-15% of yield losses attributed (Annou *et al*., 2005) [5].

Sheath blight germplasm was screened by several researchers. Sheath blight resistance was governed by several minor genes (Horizontal resistance) QTL Shown with some extent and moderate resistance to sheath blight has been reported like Jasmine 85 (Zou *et al*. 2000) [115]. Tetep (Channamallikarjuna *et al*. 2010) [16], Teqing (Zuo *et al*. 2014) [117], ARC 1053 (Yadav *et al*. 2015) [107] and about 50 QTL has been identified.

Table 1: Yield losses reported among various countries due to sheath blight are listed below

Country	Year	Yield losses	Scientist reported
Japan	1910	20-25%	Myake (1910)
China	1934	10-30%	Yu *et al*. 2019; Zhou *et al*. 2019 [114, 121]
Africa	2011	2025%	Pareja. L, V. Heizen (2011) [76]
USA	2001	50%	Meng. QZ, Liu. ZH, Wang HY, Zhang. SS, Wet SH (2001) [56]
Thailand	1982	Up to 70%	Gangopadyay and Chakrabarty 1982
Vietnam	1985	40-50%	Ou, 1985 [74]

Diseases of paddy

The rice ecosystem is affected by several soil borne and seed borne disease. Blast and sheath blight became the destructive and most widely occurring diseases in India (Ali Ma; Teli GN; Bhat GA, Parry, Wani SA) and *Maganaporthe grisea* pathogen anamorph (*Pyricularia grisea* syn *Pyricularia oryzae)* causes disease based on location and environmental conditions. (Hossian M Ali MA; Hossian MD).

Rice brown spot (BS) is a caused by *Cochilobolus miyabeanus* (Ito and Kuribha Yashi) Drechs. ex Dastur. (Anamorph) *Bipolaris oryzae* (Breda de haan) Shoemaker. The It drastically affects the millions of hectares of rice population (Chakrabarti 2001; Padmanabhan 1973; Savary *et al* 2000a [77, 92].

Sheath blight of paddy (*Rhizoctonia solani* (Khun))

Sheath blight is the major important disease in paddy which contributing huge economic losses and the yield reduction ranged from 20% to 42% in artificially inoculated plots (Cu *et al*., 1996) [21]. The use of high yielding and semi dwarf varieties (HYV) caused a sharp rise in the incidence of this disease (Savary *et al*., 1995) [91]

However, The strain causing sheath blight is different in India, Sheath blight of rice is caused by anastomosis group of the fungus (AG-1) having 3-16 nuclei per cell. Sheath blight and banded sclerotial stage is reported on many crops such as Maize, Sorghum and even in wheat.

The rice pathogen produces a toxin which is host specific (RS-toxin). It is a carbohydrate containing glucose, mannose, N-acetyl galactosamine and N-acetyl glucosamine. The toxin is detected in infected leaves. Sensitivity of the phytotoxins correlated with the susceptibility of the host cultivar. It is also reported that the toxin is inactivated by a putative alpha glucosidase form coconut leaves and also the isolates of Trichoderma.

Sheath blight of rice incited by *Rhizoctonia solani* (anamorph) (Khun) and its sexual stages are *Thanetophorus cucumeris*. (Frank Donk). It is the one of the most devasting rice diseases world-wide (Rao *et al*. 2020) [1]. The disease is also called "snake skin disease" ", Mosaic foot stalk" and "rotten foot stalk" because of its special disease symptoms (Molla *et al*. 2020; Zhang *et al*. 2019b) [62, 63, 121]. The past decades have witnessed the sharp increase in the incidence of RSB in the field largely due to the application of high dose of nitrogen fertilizers and large scale planting of semi-dwarf high yield cultivars (Yellareddigari *et al*. 2014). RSB was first reported in Japan 1910 and subsequently spread around the world particularly Asia, Africa and America. In china RSB was first reported in 1934 and causing yield loss up to 10-30% every year and 50% in rice growing region of Yangtze river valley (Yu *et al*. 2019; Zhu *et al*. 2019) [114, 116]. Due to the lack of resistant germplasm. Breeding for resistance became tough in rice. At present chemicals fungicides and cultivation approaches are major approaches to prevention of RSB. (Singh *et al*. 2019; Yellareddygari *et al*. 2014) [97, 111, 112].

Table 2: Sheath blight yield losses reported in India

State	Year	Yield losses	Scientist reported
Punjab	2005	20-50%	Chahal (2005) [78]
North east India	(2006-10)	20%	DRR (2006-2010) [25]
Tamil Nadu	2013	36-40%	Srinivas *et al*., 2013 [100]
Andhra Pradesh	1986 and 1989	20-50%	Rao, HSN Reddy, MTS kulkarni1989 [1]
Karnataka	2002	50%	Neeraja *et al*. 2002a [72]
Telangana	2018	40-50%	Deepakreddy (2018)

Chemicals used in the control of sheath blight

Fungicides which are tested for sheath blight control are 13 in number (Arunayanart *et al*. 1984) [4] where Pencycuron 25% WP and validamycin 3% liquid, Carbendazim 60% WP and Propiconazole 25% found most effective.

Propiconazole (tilt) applied twice or followed by Benomyl significantly reduces the severity and yield (Jones *et al*. 1987) [47].

Basically chemical control of any fungal plant disease consist of application of both systemic and contact fungicides. The application of systemic fungicides is prevalent since 1960 and found better management than non-systemic one (Gullino *et al*. 2000) [34]. The fungicides which belongs to strobulin group are most widely used for the control of this disease. Among them Azoxy strobulin is most widely used (Groth DE bond JA 2006) [30]. Meanwhile antifungal activity shown by *Streptomyces. spp* and PM5 can be used against sheath blight disease (Prabhavathy *et al*. 2006) [83].

Effect of fungicides on yield, morphological characters and disease parameters of the rice plant

Sheath blight is the one of the most important rice disease and ranks number two after Blast disease. (Prasannakumar *et al*. 2011c) [82] evaluated three new QoI fungicides (Kersoxim methyl, Metaminostrobin and Trifloxystrobin) and combinations with other group are evaluated for two seasons against blast and Sheath blight disease and improved the growth of plant in terms of height, test weight and yield. Keroxim methyl 40% and Hexaconazole 8% Sc @200 + 40g ai was effective against sheath blight (Prasannakumar *et al*.2011c) [82].

Trifluzamide is the new fungicide group of Carboxynilide was tested for its efficacy against sheath blight disease (Prasanna kumar *et al*. 2012) [81]. They found it among different concentrations trifluzamide 24%SC at 110g ai/ha was effective in reducing the disease severity [12% (2005), 21.33 (2009) when compared to uncontrolled check (47% 2005 and 59.67 (2009) fungicide was efficient and curative without phytotoxicity.

In vitro* study of chemicals against *Rhizoctonia solani

An *in vitro* study was conducted by talking six chemicals along with control *viz* (Tebuconazole 50% Trifloxystrobin 25%) 75WG, Propiconazole 25% EC, Azoxystrobin 25% SC and Validamycin 3L, Carbendazim 50% WP, Hexaconazole 5% SC in different concentrations of 50 ppm by poisoned food technique (Nene and Thapliyal, 1993) [70].

Chemical with Formulation Dose (Per litre water) Chemical group 1 (Tebuconazole 50% + Trifloxystrobin 25%) 75 WG 0.4g Strobilurin + Triazole 2 Propiconazole 25% EC 1ml Triazole 3 Hexaconazole 5% SC 2ml Strobilurin 4 Carbendazim 50% WP 1.5ml Aminoglycoside antibiotics 5 Validamycin 3% L 1ml Benzimidazole 6 Azoxystrobin 25% SC 1ml Triazole.

Bio efficacy study of chemicals against sheath blight under field conditions

After observing the efficacy of the chemicals against the pathogen *in vitro* a field experiment conducted in the Regional research and Technology Transfer Station (OUAT). Ranital Bhadrak for two consecutive years for (2018 kharif and 2019 kharif) to study the efficacy of the chemicals in the field conditions. The design of the experiment was Randomized Block Design (RBD). The rice variety MTU7029) was taken susceptible to sheath blight disease. (IARIRice sheath blight grade chart (IRRI, 2002) [44]. No infection observed 1 Lesion limited to lower (20) percent of the height of the plant 3 Lesion limited to (21-30) percent of the height of the plant 5 Lesion limited to (31-45) percent of the height of the plant 7 Lesion limited to (46-65) percent of the height of the plant 9 Lesion more than (65) percent of the height of the plant (2002) The chemicals were sprayed twice in respective plots at 15 days interval at active tillering stage (45 DAP) and (60 DAP).

Eco-friendly management strategies for the control of paddy sheath blight

1) Cultural methods used in the control

a) Application of organic manures and amendment

Considering the effect of all OM types on all pathogens OM was suppressive in 45% and non-significant 35% of the cases while in 20% in the significant increase in the disease incidence was found (Serra *et al.* 1996; Stone *et al*. 2001).

Four oils *viz.*, neem oil (Source: seeds of *Azadiracta indica)*, lemon grass oil (source: leaves of (*Cymbopogon flexuosus* (Nee ex Steudel) J.F. watson), mahua oil (source: *Madhuca longifolia* (J. Konig) and tree tea oil (source: leaves of *Melaleuca alternerifolia* (Maiden and Betche) at 5% concentration was found effective. The antifungal nature of the different oils and oil cakes was tested by poisoned food technique (Nene and Thalpiyal.1993) [70].

b) Field sanitation in management of soil borne inoculum

Field sanitation plays important role in control of sheath blight and many soil borne diseases. Field sanitation and the foliar application of Streptomyces padanus PMS-702 for the control of sheath blight is found effective. (Yang CJ, Huang, Tp Huang, Jw Field). The aim of this studies were to develop biocontrol strategies focusing on the field sanitation and foliar application with biocontrol agent for ShB management. Streptomyces padanus PMS-702, at 3.07mg/I inhibited 50% mycelial growth, caused leakage of cytoplasm and inhibited the formation of infection structures of *R. solani*.

Addition of 0.5% *S. padanus*, PMS-702 broth in to soil decreased the survival rate of pathogen. Soil amend with *S. padanus* broth and 0.5% tea seed pomace resulted in the death of *R. solani* mycelia in infested rice straws, and the germination of sclerotia was inhibited 21 days after treatment. (source: WWW.ncbi.nlm.nih.gov)

The soil bornre sclerotia and mycelia in plant debris are the main survival structures and primary innoculum (Lee and Rush 1983) [27]. Strategies used to measure the sheath blight disease consists of host resistance, rotation schemes (Lee and Rush 1983) [27]. However, the control efficacy for the sheath blight disease is very limited because sclerotia could survive for more than 2 years in the temperature rice production fields (Lee and Rush 1983) [27].

Streptomyces species is the largest genus of the Actinobacteria and the type genus of the family Streptomycetaceae (Kampfer, 2006) [49], they produce 61% of the agriculturally essential antibiotics (Waksman *et al*. 2010) [106]. Streptomyces species is the biocontrol agent for controlling the plant disease or biofertilizer to enhance the plant growth and yield (Buzo'n-Duran *et al* 2020; Sharma *et al*. 2020) [99]. Streptomyces species involving the production if chitinases, glucanases and excretion of fungal metabolites and plant growth regulators, induction of plant immune responses and modulation of enzymatic and defence path

ways (Mun *et al*. 2020; Sharma *et al*. 2020) [67, 99]. However there are limited biopesticide products of this species are available (Gwynn, 2021; Sharma *et al*., 2020) [36, 37, 99].
The Utilization of organic amendments for management of soil borne pathogens and diseases has often been considered as the non-chemical and Eco-friendly strategy used in agriculture (Bonanomi *et al*. 2004) [33] Zhou and Everts (2004) [123].

2) Host resistance
Future rice demand is speculated to be higher due to the increasing trend in the consumption of rice and rising the world populations. Resistance breeding remain unsuccessful till the date of owing to the inability to identify any resistance resources from the available rice germplasms. More ever high genitic variability, Extensive host compatibility and the ability of the pathogen to survive from one crop season to next by forming dormant sclerotia made additional difficulties in controlling the pathogen. (Mohanty, 2013) [60].
Plants have several strategies to defend themselves from pathogen attack. (Mohanty, 2013) [60]. Infection cushions are convoluted hyphal aggregates developed from the runner hyphae of *R. solani.* (Molla *et al*. 2013) [61, 66]. Complex molecular strategies are involved in executing those stratagies. However recent advances in molecular, biotechnological and sequencing technologies have led the researcher to focus on Investigating the genetics of sheath blight tolerance, Decoding molecular features and studying pathogenesis mechanisms. In this current review, we report a comprehensive up-to date synthesis on the recent advancement of the understanding of rice and *R. solani* interaction in the post-genomic era. The progress made regarding the identifications of the genetic regions quantitative trait loci (QTLs) and molecular markers associated with sheath blight resistance has also been analytically reviewed. We also provide critical discussion on the deployment of the disease resistance genes from rice and non-rice sources for developing sheath blight resistant transgenic rice.

Table 3: Resistant varieties of sheath blight disease in India

Variety	Reference	Released institution
IR24, IR26, IR, 29. Jaya, Rajeshwari, Supriya Sabari.	Rajan and Nair (1979)	IRRI
MTU-3, MTU-7, MTU-13, BPT-6	Ansari *et al.*	PJTSAU
HKR 99-103, HKR1059, IR64683-87-2-2-3-3	Singh *et al*. 2010	PAU
TRC 05-2-6-4-39-3-6, UPR-2327, 23	Agarwal and Sundar (2013b) [3]	Pantanagar (GB Pant)
N2 2 (Acc6264), N22 (ACC19379), HKR-05476	Bhunktal *et al.* (2015b)	PAU
SM801, 10-3, Ngnololasha, Gundhan	Dey *et al*. 2016 [98]	NRRI
Tetep and ARC10531	Yadav *et al*. 2015 [107]	NRRI

Molecular interactions between rice and *R.* solani
On pathogen attack, Plant protects themselves by activating highly complex interacting signalling pathways. Salicylic acid (SA) Jasmonic acid (JA) and Ethylene (ET) are the important vital role players in most of the pathogen responsive signalling pathways in a significant advance in 2018, Kouzai *et al*. suggested a hemibiotrophic nature of *R. solani*.
In general SA mediated signalling induces resistance against biotrophic pathogens. While JA mediated signalling induces resistance against necrotrophs (Oka *et al*. 2013) [73]. The pathogen *R. solani* uses a diverse strategies to successfully colonize the host and infect rice plant, while in turn rice plant produce different signalling pathways and antimicrobial molecules to fight against them We discuss the molecular interplay section three different segments. A perspective from the pathogen, angle from the host plant and chemical battle between host and pathogen.

Perspective from the pathogen
Effectors; secreted fungal effectors molecules favour fungal colonization on host plants through subduing plant defence (Lo presti *et al*., 2015). The potential secreted effectors *viz.* cytochrome c oxidase) assembly protein ctaG/coX11 domain, gluco acetyl transferase GT family 2 domain and peptidase inhibitor 19 domain of *R. solani* AG1-1A were validated that could trigger crop defence responses in the form of cell death phenotype. Similarly inhibitor 19 containing proteins have been abundantly detected from the pathogen.

Secondary messenger
Heteromeric G protein, made up of G (alpha, beta and gamma units) is an important signalling component which plays an significant role in virulence and pathogenesis of filamentous fungi. Interestingly study has demonstrated that disruption of *R. solani* gene Rga1, encoding a protein alpha subunits negatively affect the pathogenicity and the sclerotia forming ability source https://www.ncbi.nlm.nih.gov

Varietal selection
Rice variety selection is the first important step towards reducing the crop yield losses due to the disease. At present there are no complete resistant varieties against sheath blight. However rice varieties with different levels of resistance are available. In general most of the hybrid varieties are resistant than the inbred lines. Medium grain varieties are more resistant than long grain varieties. Therefore selecting a rice variety that is less susceptible or moderately resistant to sheath blight is most effective way to reduce the damage caused by the disease.

Management practices to avoid dense canopy
High seeding rate and over use of the nitrogen fertilizer usually increase the stand and induce excess vegetative growth and canopy density, creating a moist microclimate favourable for disease development. Therefore avoid high seeding rates and excessive application of fertilizers, especially nitrogen, can reduce the damage caused by the sheath blight.

Crop rotation in sheath blight control
Continuous rice or rotation with the alternate host of the fungus such as soybeans increases the inoculum in the field soils. Fallow periods along with efforts at reducing the inoculum by destroying the collateral and weed hosts that could harbour sclerotic are available management practices. source; www.aspnet.org

Effect of ultraviolet radiation on the survival of *R. solani* AG-11a

Mycelia and sclerotia are irradiated under the UV radiation wavelength of 254nm. Soil solarisation is a method of heating soil by covering it with transparent polythene sheeting during the periods of hot to control soil borne diseases. Biological control methods have the advantage of having being nontoxic to the environment. Biological control is an innovative, cost effective and eco-friendly approach.

Soil solarisation technology alone in combination with soil amendments (farm yard manure, chicken farm yard manure, neem leaves and biokhad) was used to control the mycotoxins.

Innovative approaches in sheath blight contr

Field sanitation in sheath blight control

Prevention

Considering the factors responsible for survival of the pathogen and disease development it must be ensured that weed hosts are kept at minimum within and around the rice crop and proper sanitation is required by removal of stubbles and badly infected crops, Burning of stubbles may not totally destroy the sclerotia in plant debris left in field, Semi dwarf cultivars suffer more than the tall cultivars. Rotation with non-host cereal crop also reduces the sclerotial density in the soil.

Counter measures from host

To counteract the effects from pathogenicity factors in plant pathogens, plants develop multiple layers of defences against pathogen attacks. During pathogen infection PAMPs are recognized by the plant PRRs and thus triggering PTI.As the first layer of the defence, PTI responses include the activation of defence gene expression and mitogen activated protein kinase (MPAK) cascades, reactive oxygen species burst (ROS), Accumulation of secondary metabolites and defence related phytoharmones signalling pathways (Bigeard *et al* 2015; Yu *et al*. 2017; Zipfel 2014) [11, 17, 125] on the other hand intracellular immune receptors R proteins in host plant recognize certain pathogen effectors and therefore causes hypersensitive responses, Which are rapid and robust responses called effector-triggered immunity. Jones and Dang 2006; Peng *et al*., 2018 [40, 46].

Secondary metabolites

R. solani secretes variety of secondary metabolites, including host selective toxins and biologically active molecules. These factors contribute the pathogen virulence through breaking host physical barriers and interfering with host physiological functions and host defences (Brooks 2007; Constanzo *et al*. 2011; Howlett 2006.) [20]. The host specific toxin in *R. solani* has been partially purified and identified as carbohydrate consisting of mannose, N-acetylglucosamine, glucose and N-acetyl galactosamine. Highly virulent produces more host specific toxins than weekly virulent isolates.

Biological control using PGPR: Antagonism between organisms is common in the ecosystem and is more prevalent among soil microorganisms. Natural interference between beneficial soil microorganisms and plant pathogens results in the zone of buffer, thereby inhabiting or reducing disease development. Various microbial defence mechanism may work independently or together. Depending on the Rhizosphere or phyllosphere characters. Advancements in biological control have led to identification and development of antagonistic bacteria with plant root growth stimulating activity.

Rhizosphere-isolated free living soil bacteria with proven plant beneficial properties are known as plant and root growth stimulating ability. Besides PGPR role in increasing the plant growth and N uptake, Phosphate solubilization, Phytoharmone synthesis and production of iron chelating siderophores. Some PGPR are used commercially to enhance plant growth and health. Seed treatment of rice with PGPR resulted in increased shoot and root length of seedlings.

PGPR are also known for biological control of various soil inhabiting bacteria. They are naturally available in environment and provide resistant to broad spectrum of pathogens. The microbial populations in Rhizosphere can be influenced by soil characteristics, agronomic practices and plant type. Inconsistent results of PGPR application between the laboratory and green house and field studies due to change in climate and soil. An improvement understanding of microbial population dynamics is needed before amending the farming practices to enhance the yield and growth

Silencing essential pathogenicity genes via RNA interference in the fight against *R. solani*

Cross kingdom trafficking of small RNA sRNAs and double stranded RNAs, which causes which can silence fungal pathogenicity genus Huang *et al*. 2019 [42]; Wang *et al*. 2016) [103] the host delivered RNA interference HD-RNAI technology has been developed to silence the pathogenicity MAP KINASE-1 (PMK-1) homologues, RPMK1-1 and RPMK1-2 in *R. solani*. the transgenic show an increased resistance to RSB (Tiwari *et al*. 2017) [102]. Besides, silencing of the key pathogenicity gene AG11A_04727 encoding polygalacturonase via HD-RNAi significantly enhance the rice resistance to *R. solani* by HD-RNAi is a novel promising strategy for durable control of RSB.

Targeting essential pathogenicity factors in *R. solani* via transgenic technology

The attempts in inhibiting the PG activity via PGIP over expression are also successful in suppressing infection. Over expression of OsPGIP1 significantly improves the rice resistance to RSB (Chen *et al*. 2016; Rathinam *et al*. 2020; Wang *et al*. 2015b) [17, 86]. Although OsPGIP2 a homolog of OsPGIP1 has no inhibitory activity to PGs, the mutant protein OsPGIP2 confers resistance to *R. solani*. Furthermore, the transgenic rice plants constitutively expressing ZmPGIP3 exhibit significantly elevated expression of some rice PGIP genes and enhanced resistance to sheath blight compared to wild type of plants (Zhu *et al*. 2019) [116]. Importantly these transgenic plants do not show any detrimental phenotypic and agronomic effect. The findings that indicate that genome editing and natural allele mining of plant PGIP genes provide important strategies to improve RSB resistance in rice.

Since OA is essential pathogenicity factor for necrotrophic pathogens. Expression of OA detoxifying enzymes in host plant leads to enhanced resistance against necrotrophic pathogens. Including *R. solani* (Nagarajkumara *et al*. 2005; Liang and Rollins 2018) [54]. Over expression of the rice oxalate oxidase4 gene (OsOXO4) and simultaneous overexpression of OsOxo4 and the chitinase gene OSCHI!11 driven by green tissue- specific promoters both significantly confer enhanced and durable resistance to sheath blight (Karmakar *et al*. 2015; Molla *et al*. 2013) [61, 66]. Expression of the oxalate decarboxylase Bacisubin, an oxalate-degrading enzyme from *Bacillus subtilis,* also enhances resistance to RSB and fungal blast disease (Qi *et al*. 2017) [86]. In the transgenic plants expressing oxalate oxidases and ODCs, OA released by *R. solani* degraded by these OA- detoxifying enzymes to generate H2O2.Hydrogen peroxide plays key role in activating defence responses, such as phytoalexin biosynthetic pathways, hypersensitive response, systemic acquired resistance, and subsequently induces the expression of PR genes. As another virulence factor in *R. solani* the phytotoxin PAA induces the production of the cytotoxic metabolite methylglyoxal MG in rice a common consequence of many abiotic and biotic stresses. The Transgenic rice plants overexpressing glyoxalase for MG detoxification have been demonstrated have too much less accumulation of MG and enhanced resistance towards damage caused by PAA. The finding provide another transgenic technology to develop RSB resistant rice plants. (Gupta *et al*. 2017) [35]. The mechanism of observed tolerance of the glyoxalase overexpressing plants towards diverse abiotic and biotic stresses involves enhanced detoxification and reduced oxidative damage, leading to better protection of chloroplast and mitochondrial infrastructure and maintained photosynthetic efficiency under stress conditions.

Enhancing sheath blight resistance by manipulating expression of plant defence-associated genes

Although no complete resistance gene for sheath blight has been identified in rice, many successful attempts have been performed to develop resistant rice lines by expressing defense-associated genes. Non expressor of pathogenesis related genes1 (NPR1) was first identified in Arabidopsis to be a master regulator of systemic acquired resistance which confers broad spectrum resistance to various pathogens (Fu and Dong 2013) [28]. Tissue specific expression of Arabidopsis NPR1 gene in rice enhances sheath blight resistance without phenotypic and agronomic costs (Molla *et al*. 2016) [64]. The transgenic *indica* rice lines expressing *Brassica juncea* Npr1 also exhibit enhanced resistance to *R. solani* (Sadumpati *et al*. 2013) [94]. Over expression of Pathogenesis related genes such as PR3 and PR5 results in enhanced resistance to sheath blight, manifested by reduced disease lesion sizes in transgenic rice plants (Datta *et al*. 2001); (Datta *et al*.2002) [22, 23]. In addition over expression of OsGSTU5 a tau class glutathione-S-Transferase in rice effectively increases the activities of superoxide dismutase and Peroxidase, There by accumulation of Hydrogen peroxide and oxygen anion enhances sheath blight resistance. Various MAPKs plays important role in plant adoptive responses to biotic stresses. Silencing of OsMAPK20-5 remarkably reduces resistance to *M. oryzae* but increase resistance against *R. solani.*

QTL for disease resistance to RSB

It is well recognized that rice resistance to sheath blight is a quantitative trait controlled by multiple genes (Zuo *et al*. 2014) [117] therefore identification, mapping and subsequent charcterization of RSB resistance.QTL will be of great significance for sheath blight resistance breeding in rice (Jia *et al*. 2012; Molla *et al*. 2020; Taguchi Shiobara *et al*. 2013; Yadav *et al*. 2015) [62, 63, 107].

Since the first RSB resistance QTL was identified in 1995 more than 110 RSB resistance QTL have been mapped to different chromosomes in rice (Molla *et al*. 2020; Wen *et al*. 2015; Zhang *et al*. 2019a) [62, 63]. However, only qSRB 9-b qSBR11-1, qSB-9TQ and qSB 11 have been finally mapped and no RSB resistance QTL has yet been isolated in rice (Channamallikarjuna *et al* 2010; Zuo *et al*. 2013; Zuo *et al*.2014a) [16, 117, 129]. A total of 14, 12, 12 and 26 putative genes have been predicted in the qSHB 9-2, qSHB-9TQ, qSB-11LE and qSBR11 regions respectively.

Multiple QTL for RSB resistance have been detected in several resistant varieties, including Teqing Jasmine 85, Zhaiyeqing8, Xiangzaoxian19, Tetep and Pecos (Datta *et al*. 2001) [22] some major QTLs for RSB resistance such as qSB-9TQ, qSB-11LE and qSB-11HJX have been utilised in resistance breeding program, Pyramiding disease resistance QTL has been considered as an important strategy to develop RSB resistant cultivars.

Moving forward with integrated disease management

In many countries rice is grown in the same field year after year making it more susceptible to soil borne pathogens. Over time pathogen inoculum accumulates in crop or soil surrounding fields and can cause epiphytotic disease. Over the use or over dependence on chemical control or any single control method is not sufficient to manage rice SHB.A systemic control approach using all SHB management options may produce better pathogen management. Integrated Disease Management (IDM) of rice SHB is broad based, ecological plant pathogen control method compensating the deficiencies of other. IDM is recommended year round to monitor major crop programs. Regardless of any complete SHB resistance, growers may manage the disease using IDM. Forthcoming, educating farmers and disseminating information about effective and environmentally sound IDM mitigate rice SHB pathogen damage accomplishing sustainable farming although challenging, future research should also focus on identifying and developing cost effective complete resistance lines through conventional and molecular breeding.

Citation: Kumar KVK Reddy, Kloepper, JW, Lawrence, KS., Groth, DE *et al.* (2009) [48]. Sheath blight of rice (*Oryza sativa.* L.) An overview of Biosciences. Biotechnology Research Asia 6:465:480.

Biological control of sheath blight

Biological control can be defined as population levelling process. In which population of one species lowers the number of another species by mechanism such as predation and parasitism, pathogenesis and competition. Biological control is an efficient disease management strategy gaining momentum in recent times. Several microorganisms belonging to Genera *Bacillus*, *Pseudomonas*, *Streptomyces*, *Trichoderma* were used as BCA to control Sheath blight in rice. Several marine bacteria isolated from coastal sea water were also found to be antagonistic activity against *R. solani*. In this context, the present study has been aimed to isolate the Rhizobacteria from coastal and sand dune plants. Is yet to be given the coastal sand dunes are one of the neglected marine ecosystems. The microbiology of the Rhizosphere of the plants in costal areas is given much importance. In the present study several Rhizobacteria such as Fluroscent pseudomonads (FP) were screened and isolated for their antifungal activity against *R. solani.* The study has primarily concluded that marine associated fluroscent pseudomoands should be potential candidate as biocontrol agent against SHB disease.

Citation: Jeffries, P, Gian Nozz, S, Perotto, S, Tarnauk, Barea (2003) [39]. The contribution of Arbuscular Mycorrhizal, Fungi in Sustainable maintenance of Plant health and Soil fertility. Biofertisoils 37:1-16.

Future aspects

Plant breeders and plant pathologists will work together to combine similar rice genes with some different race specific genes. It will provide quantitative resistance. We should identify the proper antagonistic Biocontrol agent. QTL mapping and its resistance genotypes having sheath blight resistance genes. All the races are backcrossed that may give rise to resistance against this fatal disease. (Shailesh *et al*. 2015) [96]. Sheath blight became a runious disease. Management should be more effective and it should consume less time. Environmental friendly management is helpful to protect the soil from pollution and protect the beneficial microbes in soils. The farmers should be educated well and the correct relevant information about environment friendly and effective integrated disease management of sheath blight disease. Both molecular breeding and conventional breeding will have to focus on identifying and developing resistant genes. (Yellareddygari *et al*. 2014) [111, 112].

Conclusions

Sheath blight became the emerging and most destructive disease in rice. Eco-friendly management for this disease has been well considered as the cost friendly and effectively efficient and environmentally friendly strategy to control the disease. However there is no genetic resistance gene has been discovered. Development of molecular interactions between *R. solani* and the host plant reveals many pathogenicity factors in *R. solani.* It is also efficient to develop sheath blight resistant germplasms By inducing the essential pathogenicity factors in pathogen and via host derived RNAi and transgenic technology, manipulating the expression of plant defence associated genes, pyramiding the RSB resistance QTLs.

In order to maintain the soil health for future generation farmers should focus mainly on eco-friendly management of the diseases and need based use of the fertilizers such that this review is mainly focusing on the non-chemical management and different innovative approaches using today in the management of sheath blight

With the advancement of Genetic engineering and genomic sequencing technology and increasing affordability, It will be easier to generate enormous genomic resources which are exploring natural variation in defence related genes among all the genotypes. That can be further validated for major association with disease resistance. In this regard all land races, farmer's variety, weedy rice and wild relatives could also be exploited to find hidden treasure in the form of sheath blight resistance.

Despite all advantages field-level deployment of Biocontrol agents also improves the plant growth promoting activities. They give enough resistance to plants to maintain healthy defence against *Rhizoctonia solani*. The present review focused on the use of *Trichoderma asperellum*, its mass multiplication with the help of commonly available organic wastes, and assessment of its efficiency in plant growth promotion and disease suppression against *R. solani.* The activity of biocontrol agents and organic amendments and host resistant varieties make the pathogen ineffective and less effective than synthetic chemical fungicides. It also decreases the environmental risks and protect the environment and the lack of effective chemical methods safer eco-friendly methods are being sought.

References

1. Ammani K, Venkateshwarlu, Rao AS. Development of Vesicular 1985.
2. Alias Abdullah, Hajime A, Kobayashi H, Ichizen Mastumura I, Shoichi ITOS. World Rice demands towards 2050. Impact of decreasing demand for per capita rice consumption for China and India. Research gate 2015, 1-8.
3. Agarwal M, Sunder S. Screening of rice genotypes of resistance to sheath blight. Pl. Dis Res 2013b;28:97-99.
4. Arunayanart P, Surin A. Rice Yield losses to sheath blight IRRN 1984;9 (6):10.
5. Annou MM, Wallies EJ, Thomsen MR. A Dynamic technology adoption under uncertainty case of herbicide resistant rice. J Agril. Appl. Econ 2005;37:161-172.
6. Arbuscular Mycorrhizial fungi of the upland rice, Curr. sci 59, 1120-1122.
7. Aruna Yanart P, Surin A. Rice yield loss to Sheath blight IRRN 1984;9 (6):10.
8. Bouman B, Lampaya AM, RM, Tuong TP. Water management in Irrigated rice cropping with water scarcity IRRI. Laos Banos Philippines 2007. http://WWW.Knowledgebank.irri.org.
9. Bhunkal N, Ram Singh, Mehta N. Assessment of losses and identification of slow blighting genes against Sheath blight of rice in relation to J Mycel, Pathol 2015;43:447-451.
10. Bhunkal N, Ram Singh, Mehta N. Assessment of losses and identifying slow blighting genotypes against sheath blight of rice. J mycol. Pl. Pathol 2015b;43:447-451.
11. Bigeard J, Colcombet J, Atirt. Signalling mechanism in pattern triggered immunity (PTI) Mol plant 2015, 8521-539.
12. Butler EJ. Fungi and Diseases in Plants. Thacker spink and Co, Calcutta 1918, 410.
13. Deepak B, Reddy B, Vidyasagar V, Prakasham Sridevi Gajula. Survey on Sheath blight Disease of rice in Telangana states. International journal of current Microbiology and Applied sciences 2018;7 (09):3525-3531.
14. Chakrabarthi NK. Epidemology and Disease management of Brown spot of rice in India: Major functional diseases of rice. Recent advances, Kluwer academic Publishers 2001, 293-306.
15. Channa Mallikarjuna, Sonah V, Prasad H, Rao M, JN G, Chand S, Upreti HC *et al*. Identification of major Quantitative trait loci qSRB-1 for sheath blight resistance in field. Mol Breed 2010;25:155-166.
16. Channamallikarjuna V, Scan H, Prasad M, Rao GJN, Chand S, Upreti HC *et al*. Identification of major quantitative trait loci qSRB11-1 for sheath blight resistance in rice. Mol Breeding 2010;25:155-166.
17. Chen YJ, Chen Y, Zhang LN, Xu b, Zhang JH, Chen ZX *et al*. Over expression of OSPGIP1, enhances rice resistant to Sheath blight, plants Dis 2016;100:388-395.
18. Clarkson DT. Factors affecting mineral nutrition acquisition by plants, Annu, Rev, Pl. Physical 1985;1 (36):77-115.
19. Claudia Kuenzer, Kim Kauner. Remote sensing of Rice Crop areas-A review. International journal of remote sensing 2013;34 (6):2101-2139.
20. Constanzo S, Jackson AK, Brooks SA. High resolution mapping of RSn1 aqgene controlling sensitivity of rice to necrosis inducing phytotoxin from *Rhizoctonia solani*

AG1-1A, Theor Apl, Genet 2011;123:33-41.
21. Cu RM, TW, Cassman KG, Teng PS. Effect of Sheath blight on yield in tropical intensive rice production system, Plant Disease 1996;80:1103-1108.
22. Datta K, Tu J, Oliva N, On2, Vetazhahan R, Mew TW, Muthukrishnan S *et al*. Enhanced resistance to sheath blight by constitutive expression of infection related genes in rice chitinase in transgenic rice elite indica rice cultivars Plant Sci 2001;160:405-414.
23. Datta K, Baisakh N, Maung T, Thet Km, Tu J, Datta S. Pyramiding transgenes for multiple resistance in rice against bacterial blight, yellow stem borer and sheath blight. Theor Appl Genet 2002;106:1-8.
24. Datta K, Tu J, OLiva N, Ona2, Velazhanan R, Mew TW, Muthukrishnan S *et al*. Enhanced resistance to sheath blight by consecutive expression of infected related rice. Chitinase in transgenic elite indica rice cultivars plant sci 2001;160:405-414.
25. DRR (2006-2010), Progress report (2005-2009), Crop protection Entomology and Pathology, All India Coordinated Rice Improvement Project. ICAR, DRR., Rajendranagar, Hyderabad, Andhra Pradesh, India Vol:2.
26. FAO Food and Agricultural organisation of the United Nations reducing poverty and hunger. The critical role for financing food, Agriculture and rural development 2002.
27. Freet Lee N, Rush MC. Rice sheath blight a major disease 1983.
28. Fu ZQ, Dong YN. Systemic infection turning local infection to global Defense. Annu, Rev, Plant Biol 2013;64:839-863.
29. Gangopadhyay S, Chakrabarthi NK. Sheath blight of rice rev, plant pathol 1982;61:451-460.
30. Groth DE, Bond JA. Initiation of rice Sheath blight epidemics and effect of application of azoxystrobin on Disease incidence severity and Yield and milling quality Plant disease 2006;90:1073-1076.
31. Groth DE. Effects of cultivar resistance and single Fungicide application on rice sheath blight, Yield and quality. Crop protection 2008;27:1125-1130.
32. Gowda Venu M, Roopa RC, Laxmi K, Sree Rekha MV, Kulakarni RS. Advances in rice breeding Genetics and Genomics. Mol breeding 2003;11:337-353.
33. Gulliano Bonanomi. Vincenzo, Antigani, C. pane, Felicae scala. Suppression of soil borne fungal diseases with organic amendments. Journal of plant Pathology 2007;89 (30).
34. Gullino ML, Leroux P, Smith CM. Uses and Challenges of Novel Compounds for plant disease control, Crop Protection 2000;19:1-11.
35. Gupta BK, Shaookk Ghosh A, Tripati AK, Anwar K, Das P, Singh AK *et al*. So Pary SK, Singla Pareek SK. Manipulation of Glyoxalase pathway confers tolerance to multiple stresses in rice plants. Cell Environ 2017;41:186-1200.
36. Gwynn R. Manual of Biocontrol agent 2021. Online URL http://WWW.bopc.org/My account 16, December 2020.
37. Gwynn R. Manual of biocontrol agent 2021. Online URL. http://WWW.bopc.Org/My account 16, December 2020.
38. Jha A, Singh K, Meena KM, MS, Singh RKP. Constraints of rain fed rice production in eastern India: An overview. SSRN electronic journal 2012, 1-9.
39. Jeffries P, Gianinazzi S, Perotto Turnau K, Barea JM. The contribution of arbuscular Mycorrhizal fungi in sustainable maintenance of plant health and soil fertility Biol. Ferti, soils 2003;37:1-16.
40. Jones RK, Belmar SB, Jeger MJ. Evaluation of Benomyl and Propiconazole for the control of Sheath blight. Plant Diseases 1987;71(3):222-225.
41. Howlet. Secondary metabolite toxins and nutrition of plant pathogenic fungi. Curropin plant Biol 2006;9:371-375.
42. Huang CY, Wang H, Hu P, Hamby R, Jin HL. Small RNA s and Big players in Plant microbe interactions Cell host microbe 2019;26:173-182.
43. Indica lines expressing *Brassica juncea*, non-expresser of pathogenesis related genes 1 (BJNPR1) exhibit enhanced resistance to major pathogenes. J Biotechnol 166, 114-21.
44. IRRI. Standard evaluation system for rice, 5th edn, Nov (2002). NGER, Genetic Resources centre, IRRI, P.O, BOX 993, 1099, Manila. Philippines 2002, 56.
45. Jial LYan W, Zhu C, Agrama HA, Jackson A, Yeater K, Li XB *et al*. Allelic analysis of sheath blight resistance with association of mapping of rice PLos one 2012;7:e32703.
46. Jones JD, Dang JL. The plant immune system Nature 2006;444:323-329. 10.1038/natune 05286.
47. Jones RK, Belmar M, SB, Jeger MJ. Evolution of benomyl and Propiconazole for controlling Sheath blight of rice caused by *Rhizoctonia soalni*; Plant Disease control 1987;71(3):222-225.
48. Vijayakrishna Kumar K, Krishnam Raju S, Munagala Reddy S, Joseph Kloepper. Evaluation of commercially available PGPR For the control of Rice Sheath blight caused by *Rhizoctonia solani*. Journal of pure and applied microbiology 2009;3(2).
49. Kampfer P eds by Dworkin M, Fallow S, Rosenberg E, KH, Cheleifer SE. Stackebr and taxonomy and In the Prokaryotes a hand back on the biology of bacteria, Formicutes, actinomycetes, 3rd edition. Vol 3:Springer, Newyork. N, USA 538-604.
50. Karmakar S, Molla KA, Chanda PK, Sarkar SN, Datta SK, Datta K. Green tissue specific expression of Chitinase and oxalate oxidase 4 genes in rice for enhanced resistance against sheath blight Planta 2015;243:115-130.
51. Kouzai Y, Kimura M, Watanable M, Kusunoki K, Osaka D, Suziki T *et al.* Salicylic acid and dependent immunity contributes the resistance against *Rhizoctonia solani* a necrotrophic fungal agent of Sheath blight in rice and *Brachypodium distachyon* a New Phytol 2018;217:771, 783.
52. Laura Buzon, Duran, Eduard Perez, Jesus martin-Gill, Mercedes Sanchez. Application of Streptomyces spp, Enhanced compost in Sustainable Agriculture 2020.
53. Li N, Wei ST, Chen J, Yang FF, Kong LG, Chen CX *et al*. OSASR2 regulates the expression of defence related genes OS2H16 by targeting the GT-1 cis element, Plant Biotechnol J 2018;16:771-783.
54. Liang XF, Rollins JA. Mechanism ODF Broad host range of Necrotrophic pathogens in *Sclerotonia sclerotiorum*, Phytopathology 2018;108:1128-1140.
55. Libera Prestei LO, Daniel Lanver, Gabriel Schweizer, Shigeyaki Tanaka. Fungal effectors and Plant suceptibility, Annual review of plant biology 2015;66(1):513-45.
56. Meng QZ, Liu ZH, Wang HY, Zhang SS, Wei SH. Research progress in Rice sheath blight (In Chinese and

English Abstract). J Shenyang Agric University 2001;32:376-381.
57. Maclean JL, Dawe DC, Harley B, Hettel GP. The Rice Yield, nitrogen utilization and Ammonia vitalization as influenced by Modified rice cultivation at varying Nitrogen rates. Rice almanac 3rd edition, International Rice Research Institute LaBafes 2002, 25-3.
58. Marx DH, Schenck NC. Potential of mycorrhizial symbiosis in agricultural and fungal productivity in kommendahl and PH William (eds) Challenging the problem in Plant health 75th annual publication of American Psychopathological Society, St. Paul, Minnescta, USA 1983.
59. Miyake I. Studien uber die Pilze der reispfalnzae in Japan, journal of college of agriculture, Imperial University of Tokyo 1910;2:237-276.
60. Mohanty. Trends in Global rice consumption, Rice today 2013;12:44-45.
61. Molla KA, Karmakar S, Chanda Pk, Ghosh S, Sarkar SN, Datta SK *et al*. Rice oxalate oxidase gene driven by green tissue specific promoter. Increases tolerance to sheath blight pathogen (*Rhizoctonia solani)* in transgenic rice. Mol. Plant path. 2013;14:910-922.
62. Molla KA, Karmakar S, Molla J, Bajaj p, Varshney Rk, Datta Sk *et al*. Understanding the sheath blight resistance in rice: The road behind and the road ahead. Plant Biotechnol J 2020;18:895-915.
63. Molla KA, Karmakar S, Molla J, Bajaj P, Varshney RK, Datta K Understanding sheath blight resistance in rice: The road behind and the road ahead. Plant biotechnol J 2020;18:895-915.
64. Molla KA, Karmakar S, Chandra Pk, Sarkar SN, Datta K Tissue specific expression of Aradiopsis NPR gene 1 in rice for sheath blight resistance without compromising phenotypic cost. Sci 2016;250:105-114.
65. Molla KA, Karmakar S, Molla J, Bajaj P, Varshney RK, Patta Sk *et al*. Understanding sheath blight resistance in rice: The road behind and the road the road ahead. Plant Biotechnol. J 2020;18:895-915.
66. Molla KA, Karmakar S, Chanda Pk, Ghosh S, Sarkar SN, Datta SK *et al*. Rice oxalate oxidase gene driven by green tissue specific promoter increase toleranceto sheath blight in transgenic rice. Plant pathol 2013;14:910-922.
67. Mun B-G, Lee W-H, Kang SM, Lee S-U, Lee S-M, Lee D-Y *et al*. *Streptomyces* sp.Lh4 promotes plant growth and resistance against *Sclerotinia sclerotiorum* in cucumber via enzymatic modulation and defense pathways Plant soil. 2020;448:87-103.
68. Nagrajkumar M, Jayraj J, Muthikrishnan S, Baskaran R, velazhahan R. Detoxification of Oxalic acid by *Pseudomonas fluroscens* strain of PfMDU2, Implication for the biological control of rice sheath blight caused by *Rhizoctonia solani*. Microbiol Ros, 2005;160:291-298.
69. Neene and Thapliyal Fungicides in plant disease control, Oxford and IBH, Publishing Hous, New Delhi, 1993, 163.
70. Nene, Thalpiyal, Nene YL, Thalpiyal PN. Fungicides in Plant disease control 3rd edition, Oxford and IBH. Publishing company. pvt ltd Calcutta, 1993.
71. Nene, Thapliyal. Fungicides in Plant Disease control, Oxford and IBH Publishing House New Delhi, 1993, 163.
72. Neeraja CN, Shenoy VV, Reddy CS, Sarma NP. Isozyme polymorphism and Virulence of Indian isolates of Rice Sheath blight Disease. Rice science 2002a;23(4):42-50.
73. Oka Ka, Amano YY, katou S, Seo S, Kawaza k, Moch zuki A *et al.* Tobacco MAP kinase phosphotase (CNtMKP1) negitively regulates. wound responses and induced resistance against necrotrophic pathogens. and lepidopteran hrbivores. Mol. Plant microbe interact, 2013;26:668-675.
74. Ou SH. Rice diseases, Common Wealth Mycological Institute, Great Britan, 1985.
75. Ou Sh, Bandong Jm, Nuque El. Some studies on Sheath blight of rice at IRRI, International RIce Research Conference. Los Banos, Philippines CAP 1973, 23-27, 1-6.
76. Pareja Fernandez L, Alba AR, Cesio V, Heinzen H. Analytical methods for pesticides residues in rice.Trac trends in analytical chemistry 2011;30:270-291.
77. Padmanabhan SY. The Great Bengal famine Annual review of Phyto pathology, 1973;11:11-26.
78. Paracer CS, Chahal DS. Sheath blight of rice caused by *R.solani* Indian Phyto Path 1963;46:197-205.
79. Peng YJ, Wersch RV, Zhang XL. Convergent and Divergent signalling in pamp triggered immunity and effector triggered immunity. Mol plant microbe interaction 2018;31:403-409.
80. Prabhavarthy VR, Mathivannan N, Murugesan K Control of blast and Sheath blight diseases of using antifungal metabolites produced by Streptomyces sp (PM5). Biological control, 2006;39:257-560.
81. Prasannakumar Mk, Siddegowda DK, Panduranga gowda KT, Vishwanath K. A new carboxide group fungicide against paddy Sheath blight RES. J, Agri sci 2012;3(2):500-505.
82. Prasanna kumar MK, Sidde gowda DK, Kiran kumar N, Atheekur Rehman HM, Chandrashekar SC, Pandurange Gowda KT *et al.* New strobulin group fungicide in rice disease management. pestology 2011c;XXXV(9):34-39.
83. Prabhavathy VR, Mathivannan N, Murugesan K. Control of blast and sheath blight diseases of rice by using antifungal metabolites produced by Streptomyces sp.PM5. Biological control 2006;39:257-260.
84. Premalatha Dath. Sheath blight of Rice and Management associated Publishing. Co., Shidipura, karol, Bagh, Newdelhi, 1990, 129.
85. Punit Kumar Agarwal. Research article, Economic Analysis of costs and return structure of Paddy cultivated under Traditional and SRI method, 2018.
86. QI ZQ, Yu JJ, Shen LR, Yu Zc, Yu MN, Du Y et al. Enhanced resistance to rice blast and Rice sheath blight by expressing oxalate carboxylase. protein. Bacisubin from *Bacillus subtilis* Plant Sci. 2017;265:51-60.
87. Rao TB, Chopperla R, Prathi NB, Balakrishnan M, Prakasham V, Balachandran SM *et al*. A comprehensive gene expression on profile of pectin degradation and Pathogenesis enzyme reveals the molecular events during the cellwall degradation and pathogenesis of rice Sheath blight pathogen *Rhizoctonia soalni* AG1-1 (fungi, 671), 2020
88. Rathinam M, Rao U, Sreevasthava R. Novel biotechnological stratagies to combat biotic stresses Polygalacturonase inibitor (PGIP) proteins as a comprehensive option. Appl Microbiol Biotech, 2020;100:2333-2342
89. Rao HSN, Reddy MTS, Kulkarni N. Rice reaction to sheath blight on newly grown rice cultivars. Agricultural

research Institute Rajendra nagar Hyderabad. Andhrapradesh, India, 1989
90. Singh SK, Shukla V, Singh H, Sinha AP. Current status and impact of sheath blight on rice (*Oryza sativa*.L) a review. Agric REV 2004;25(4):289-297.
91. Savary S, Castilla N, Elazegui F, Mclaren C, Ynalveez M, Teng P. Direct and Indirect supply of nitrogen supply and Disease source structure on Rice Sheath blight spread.Phyto pathology 1995;85, 959, 965.
92. Savary S, Willocquet L, Elia Zegui FA, Castilla N, Teng PS. Rice pest constraints in tropical Asia, 2000b
93. Savary, Nelson A, Sparks AH, Willocquet L, Duveiller E, Mahu kuG *et al.* International agricultural research tackling the effects of global and climate changes of the plant diseases In developing the World plant disease, plant Disease 2011;48:1-40.
94. Sadumpati V, kalambur M, Vudem DR, Kriti PB, Khareedu VR. Transgenic indica rice lines expressing Brassica juncea non expressor of pathogenesis related gene (BjNPR1) exhibit enhanced resistance to major pathogens. J Biotechnol 2013;166:114-121.
95. Selman Wakaman A, Albert Scatz, Donald M. Reynolds Production of Antibiotic substances by actinomycetes. Analyses of the Newyork academy of Sciences 2010;1213(1):112-24.
96. Shailesh Y, Anuradha G, Kumar RR, Vemireddy LR, Suchakar R, Krishnaveni D *et al*. Identification of QTLs and possible candidate genes confering possible Sheath blight resistance in rice. springer plus 2015;4:175.
97. Singh P, Mazumbar P, Harikrishna JA, Babu S. Sheath Blight of rice a review and Identification of priorities for future research Planta, 2019;2501:1387-1407.
98. Susmita Dey, Badri J, Prakasham V, Bhadana VP, Eswari KB, Laha GS *et al.* Identification and Agro morphological charcherization of rice genotypes resistant to sheath blight.Australian plant pathology 2016;45:145-153.
99. Sharma V, Sharma A, Malannavar AB and Salwan R. eds by V. Sharma and R. salwan and LK, T AL-Ani. Molecular aspects of Biocontrol species of Streptomycin in Agricultural crops.In molecular aspects of Plants benificial microbes in Agriculture.Academic press, london, UK.PP.89-109.*Rhizoctonia solani* Khun.Inter J. APP. Bio Pharmaceae Technol 2002;61:80-97.
100. Srinivas P, Ratan VAP, Madhavi GB. Review on banded leaf and Sheath blight caused by
101. Taguchi-shiobara-F, Ozaki H, Sato H, Maeda H, Kojimax, Ebitani T, Yano M. Mapping and Validation of TL rice Sheath blight resistance Breed Sci 2013;63:301-30.
102. Tiwari IM, Jesurai A, Kamboj R, Devanna BN, Botella JR, Sharma TR. Host delivered RNAi.An efficient approach to increase rice resistant to sheath blight Pathogen (*Rhizoctonia solani)* Sci Ref 2017;7:7521.
103. Wang M, Weiberg A, Lin FM, Thomma, BP, Huang, HD, Jin H. Biodirectional cross kingdom RNAi and Fungal uptake of external RNAS confer plant protection, Not Plants 2016;2:1-10.
104. Wang M, Weiberg A, Lin FM, Thomma Bp, Huang HD, Jin H. Bio directional cross kingdom RNAi and Fungal uptake of external RNA confer plant protection, NAT plants 2016;2:1-10.
105. Wen JH, Zeng, XX, Ji, Zj and Yang, CD. Mapping quantitative trait loci foer sheath blight disease resistance in Yangdao 4 rice Genet Mol Res 12015;4:1636-1649.
106. Waksman SA, Schatz A and Reynolds DM. production of antibiotic substances by Actinomycetes Ann.N.Y Acad. Sci 1213:112-124.
107. Yadav S, Anuradha G, Kumar RR, Vemireddy LR, Sudhakar R, Donempudi K *et al.* identification of QTL and possible candidate genes confering Sheath blight resistance in rice Springer plus 2015;4:174.
108. Yadav S, Anuradha G, Kumar RR, Vemireddy LR, Sudhakar R, Donempudi K *et al.* Identification of QH's and candidate genes confering Sheath blight resitance in rice (*Oryza sativa. L)* Spinger plus. 2015;4:175.
109. Yang CJ, Huang Tp, Huang Jennwen, Huang. Field sanitation and Foliar application of *Streptomyces padanus* PMS-702, For the control of Rice sheath blight to Plant pathology journal 37(1):57-71.
110. Yellareddy gari, SKR, Reddy Ms, Kloepper J, w Lawrence, KS and Fadamira H. Rice sheath blight a Review of disease and pthogen management approaches. J. Plant Pathol, Microb 2014;5:241.
111. Yellareddygari, MS. Rice Sheath Blight:A review of Disease Pathogen and Management approaches.Journal of pathology and Microbiology 2014;05:04.
112. Yellareddygari SKR, Reddy Ms, Kloepper JW, Lawrence KS and Fadamiro H. Rice sheath blight are a review of of distance and pathogen management approaches and pathogen management approaches. J, Plant Pathol Microbiol 2014;24(10):4172/2157-7471.1000241
113. Yu X, Feng BM, He P Shan LB. From chaos to harmony responses and signalling upon Microbial pattern recognition Annu Phyto pathol 2012;59:109:13.
114. Yu YD, Sun HJ, Xia ZH. Progress on biological control of Sheath blight.Mol Plant Breeding 2019;17:600-605.
115. Zou JH, Pan XB, Chen ZX, XU, JY, LU, JF, Zhai WX and ZHU LH. Mapping Quantitative trait loci containg sheath blight resistance in two rice cultivars Theor. Appl. Genet 2000;101:569-575.
116. Zhu G, liang Ex, Lan X, Li Q, Qian JJ, Tao HX *et al*. ZmPGIP3 gene encodes a polygalacturonase inhibiting protein that enhances resistance to sheath blight in rice. Phytopathology 2019;109:1732-1740.
117. Zuo SM, Zhamg YF, Yin YJ, Chen Zx, Jiang W, Feng MH and Pan XB. Improving rice resistance to sheath blight by pyramiding QTL conditoning disease resistance and tiller angle Rice Sci 2014;21(6):318-326.
118. Zheng A, Lin R, Zhang D, Qin, P Xu, L Ai *et al*. The evolution and pathogenic mechanisms of the rice sheath blight pathogen, Nat. Commun 2013;4;1424.
119. Zhang Q diversity and differntiation of Indica and Japonica rice detected by RFLP analysis. Theor. Appl. Maroof, MA, Lu, T and Shen, BZ, Genetic Genet, 83:495-499.
120. Zhang Al in, R Zhang D, Qun P, Xu Al, P Ding, L Wang e*t al*. The evolution of Pathogenic mechanism of the Rice sheath blight pathogen. Nat common 2013;4:124.
121. Zhang F, Zong D, Zhang Cs, Lu, JL, Chen *et al.* Genome wide analysis of the genetic basis for sheath blight resistance in rice Rice 2019;12:93.
122. Zhang SW, Yang Y, Lik T. Occurence and control against Rice Sheath Blight. Biol Dissci 2019;42:87-91.
123. Zhou, XG and Everts KL. Supression of Fusarium wilt of watermelon by soil ammendments with hairy vetc. h Plant Dis 2004;88:1357-1365.
124. Zhu G, Liang Ex, Lanx, Liqian jj, Tao HX, Zhang *et al.*

ZMPGIP3 gene encodes a Polygalacturonase inhibiing protein that enhances resistance to sheath blight in rice. Phytopathology 2019;109:1732-1740.
125. Zipfel. Plant pattern recognition receptors, Trends Immunol 2014;35:345:351.
126. Zuo Sm, Zhang YF, Yin, YJ, Li, GZ *et al*. SB-9TQ a gene confering major quantitative resistance to rice sheath blight Molbreeding 34:2191:2203.
127. Zuo Sm, Zhang YF, Yin Yj, Li GZ, Zhang GW, Wang H, *et al*. Fine mapping of qSB-9TQ, a gene confering major quantitative resistance to rice shreath blight, Mol Breeding 2014;34:2191-2203.
128. Zuo S, Zhang Y, Wang H, Zhang Y, Chen Z, Gu S *et al.* Fine Mapping qSB-TQ.A gene confering major quantitative resistance to rice sheath blight Mol Breed 2014;34:2193-2203.
129. Zuo SM, Yin YJ, Pan CH, Chen ZX, Zhang YF, Gu SL *et al*. Fine mapping of qSB11-LE The QTL that confers partial resistance to rice sheath blight Theor Appl Genet 2013;126:1257-1272.