REVIEW OF LITERATURE

2.1 Sheath blight of Rice

Sheath blight of rice, hitherto regarded a minor disease, has assumed the status of major one in the rice growing tracts of India. The disease was first recorded from Japan by Miyake in 1910 which had been widespread in the East and South-East Asian Countries and therefore, was popularly known as 'oriental sheath and leaf blight' (Roy, 1993). Although first report of sheath blight on rice from India is comparatively recent (Paracer and Chahal, 1963) 'banded sclerotial disease' of sugarcane caused by the same fungus was recorded by Butler in 1918. This disease is considered second most important fungal disease of rice after blast (Marshall and Rush, 1980).

Intensive methods of rice cultivation involving early season culture, double cropping, use of high doses of nitrogenous fertilizers, higher plant populations per unit area and growing early maturing, short-culmed, high tillering and compact susceptible cultivars have intensified the severity of the disease throughout the rice producing areas of the world, in both tropical and temperate climates (Kannaiyan and Prasad, 1978). A close correlation occurs between the severity of sheath blight development and yield losses (Hori, 1969 and Hashiba, 1984). On an average, 20 to 50% annual yield losses caused by sheath blight have been reported in both tropics as well as in temperate conditions (Miruta, 1956; Hori, 1969; Hashoika, 1970; Kozaka, 1975; Boyatee *et al.* 1979; Arunyanart *et al.* 1984; Hashiba, 1984 ; Rajan, 1987). Under severe conditions of sheath blight incidence more than 70% loss in yield was estimated in Southern India (Baby, 1992).

The disease has characteristic symptoms of water-soaked, circular to oblong, ellipsoid or ovoid or even irregularly elongated discoloured patches or lesions in early or late tillering stages on the leaf sheath at or above the water level in lowland and at ground level in upland fields (Singh *et al.* 1988, 1989).

The fungus causing sheath blight of rice is variously named but the most commonly used one is *Rhizoctonia solani* Kuhn. Teleomorph is identified in *Thanatephorus cucumeris* (Frank) Donk. Naiki (1978) classified *T. cucumeris* into five anastomosis groups (AG) according to their virulence. The isolate causing sheath blight in India belongs to AGI group having 3 to 16 nuclei (Ahuja and Payak, 1985)

2.2 Morphological, Cultural and Pathogenicity variability

Among 12 (AG) described in *R. solani* (Carling *et al.* 1996), isolates of AG-1 IA have been described to be associated with the rice sheath blight pathogen (Gangopadhay and Chakrabarti, 1982; Ou, 1985). Although earlier studies suggested that AG-1 IA represented a homogenous group of isolates (Kuninaga and Yokosawa, 1982), recent investigations support the hypothesis that the sheath blight pathogen is far more diverse than previously assumed (Liu and Sinclair, 1993).

In India, three to four morphological groups were identified in *R. solani* among the isolates from rice and various other hosts (Kohli, 1966; Vijayan and Nair, 1985). Diversity within rice sheath blight isolates has been studied by morphological characterization (Sherwood, 1969; Vijayan and Nair, 1985) and pathogenicity testing (Jones and Belmar, 1989; Banniza *et al.* 1996). Akai *et al.* (1960) found that the strains with

poor mycelial growth were less pathogenic, while Tu (1967) reported that the strains with less aerial mycelium were more virulent.

Yang *et al.* (1996) studied the virulence of isolates of *R. solani* AG-9 in Central and North Eastern Alberta, Canada agricultural soils. They isolated 130 isolates of *R. solani* AG-9. Cultures developed a brown to tan mycelium and irregularly shaped, brown to dark brown sclerotia (0.5-2.0 mm), singly or in clumps on PDA. Nuclei per vegetative hyphal cell ranged from 3 to 17. Less than 20% of the isolates were thiamine auxotrophic. Variability in growth rate and cultural characteristics of *R. solani* isolates from different crops has been reported (Raj *et al.* 1974; Bansal *et al.* 1990). Among the morphological characters variability was observed in hyphal cell size (Sharma *et al.* 2005).

Guleria *et al.* (2007) studied the morphological and pathological characteristics of twenty eight isolates of *R. solani* collected from different rice varieties grown in various regions of Punjab. Majority of the isolates were fast growing with raised and fluffy colonies while four exhibited moderate growth rate. Colony colour in all except two isolates was light yellowish brown. Sclerotial number per 5.0 mm culture disc of the test isolates ranged between 2 to 11 and their size varied from1.31 to 2.08 mm. Sclerotial colour in all except two isolates was dark brown and most of these were found scattered in the colony. But there was no relationship between morphologically similar isolates and their pathogenicity.This result was found to be in agreement with the reports of Singh *et al.* (1990) who reported that among the isolates collected from five different endemic

locations of sheath blight, there was no relationship between the growth of aerial mycelial and the virulence pattern.

Understanding of disease epidemiology and host-pathogen interaction is greatly dependent on knowledge of the diversity of the pathogen at the field level and such information also helps in planning for the management of the sheath blight of rice and also in selecting the effective and suitable *R.solani* isolates to detect the quantitative resistance in rice cultivar (Yeshi *et al.* 2007).

Manoj Kumar *et al.* (2008) collected a total of 25 isolates of *R.solani* collected from different regions of Eastern Uttar Pradesh (India) and analysed for variability using morphological and virulence characteristics. Among the morphological characters, variation was observed in hyphal growth and distribution pattern, colour, size and weight of sclerotia on PDA medium. Most of the isolates were fast growers having dark brown mycelium with large sclerotia distributed throughout the medium on the Petri plate with the average weight ranging from 0.04 to0.82 mg. Few isolates had off white mycelium with sclerotia distributed near the inoculation point. Virulence diversity was analysed by artificial inoculation on 10 rice cultivars under greenhouse conditions at 28 ± 3°C. In most of the isolates, the symptoms appeared after 48 h of inoculation but in some of them the disease appeared after 96 h of inoculation. The disease severity of *R. solani* isolates was analysed by AUDPC (area under disease progress curve) value on the basis of lesion length recorded at days 4, 8, 12 and 16 after inoculation. Most of the isolates were moderately virulent, some were highly virulent and a few of them were less

virulent. A comparative analyses of *R. solani* isolates indicated that fast growing isolates having large sclerotia were highly virulent compared to slow growers with large sclerotia. Rice cultivars NDR-359 and Ajaya depicted highly resistant disease reaction with most of the isolates, whereas Swarna depicted highly susceptible disease reaction.

Thind and Aggrawal (2008) evaluated the morphological and pathogenic relationships of *R.solani* isolates from potato-rice system to ascertain the cross infectivity of the isolates. Representative rice isolates (66.6%) showed faster growth rate and larger sclerotia than potato isolates. A variation of 7.2 to 12.1 µm was observed in hyphal width of isolates of both the crops. Some of the rice isolates were pathogenic to potato but the potato isolates did not infect the rice plants. Significant variation in response of both the representative isolates to fungicides was reported.

Chien and Chung (1963) studied 300 isolates from Taiwan, inoculated on 16 rice cultivars. Based upon the degree of pathogenicity (number of leaves infected), they classified the 300 isolates into 7 cultural types and 6 physiological races. They found correlations between cultural characteristics and races, for instance race 1 was of cultural type 3, race 2 of cultural type 6 etc. Among 7 isolates of *R.solani*, 4 pathotypes were identified based on the differential rice cultivars, procedures for inoculation of host differentials and scoring of infection required in the identification of pathogenic variation in different countries. Now it is accepted that there are three species of *Rhizoctonia*, which cause sheath blight, sheath spot and aggregate sheath spot symptoms in rice (Table 1).

Table : 1

Sheath blight and related diseases

S.No.	Feature	Sheath blight by *Rhizoctonia solani*	Sheath spot by *Rhizoctonia oryzae*	Aggregate sheath spot by *Rhizoctonia oryzae-sativae*
1	Lesion on rice sheath	Grey-green lesions, at waterline, become oval with white or straw-colored centres and reddish brown margins; 3 to 4 cm long and 1-2 cm wide, discrete or continuous band on sheath and extending to the leaf blades	Lesions oval in shape, 0.5 to 2.0 cm long and 0.5 to 1.0 cm wide with pale green, cream or white centres and reddish brown margins. Lesions are distinct and do not coalesce.	Oval lesions, 0.5 to 4.0 cm long, with grey-green centres and distinct brown margins. Lesions expandto become concentric bands.
2	Mycelia and sclerotia of the pathogen on PDA	Mycelial colonies are light brown and produce compact, spherical, large sclerotia	Colonies are light greyish and produce many small, round and loose sclerotia	Colonies are pinkish and produce salmon-coloured, small flat sclerotia.
3	Perfect state	*Thanatephorus cucumeris*	*Waite circinata*	*Ceratobasidium oryzae-sativae*
4	Nuclear status	Multinucleate	Multinucleate	Binucleate

Banniza *et al.* (1999) collected the isolates of *Rhizoctonia* from diseased plant materials and the soils in which they grew. They found that the soil as well as plant isolates of the fungus collected from paddy rice fields was indistinguishable but diversity in morphological characters was much higher in plant than in soil isolates and the plant isolates were distinctively more virulent.

2.3 Molecular diversity among strains of *Rhizoctonia solani* causing sheath blight of rice

Sheath blight disease of rice is regarded as an internationally important disease causing huge yield loss in most of the high yielding varieties. Study of genetic variability in this pathogen might be helpful in breeding resistant rice varieties.

Duncan *et al.* (1993) analysed genetic variation in Australian isolates of *R. solani* by Random Amplified Polymorphic DNA (RAPD) assay. Isolates originated from different geographic locations in Australia belonged to a number of different anastomosis and pectic zymogram groups. Using 4 different oligonucleotide primers, fingerprint patterns were generated for each isolate. All of the anastomosis and pectic zymogram groups (including subgroups) tested could be distinguished. For some groups there was considerable variation in the fingerprint patterns among the isolates. This variation was more marked among isolates from different geographic locations. Other groups showed very little variation among isolates. It is concluded that RAPD-PCR analysis is a very useful alternative to anastomosis grouping for identification of isolates of *R. solani.*

Cenis *et al.* (1995) used PCR and RAPD to study genetic variation of 38 *R. solani* isolates from different hosts and different areas in Spain. The use of a single primer of an arbitrary sequence differentiated 37 of 38 strains and a combination of 3 primers differentiated all the strains. A great genetic variation within this group of isolates was confirmed.

Yang *et ai.* (1995) used RAPD-PCR to characterize isolates of *R. solani* from bare patches in cereal and pasture crops at 2 locations in Western Australia. Yang *et ai.* (1996) collected agricultural soils in Central and Northeastern Alberta, Canada, and isolated 130 isolates of *R. solani* AG-9 to study genetic variations. There was considerable variation within the *R. solani* AG-9 group and it is suggested that AG-9, considered indigenous to Alaska, is present in a variety of environments and different geographic areas. It is concluded that AG-9 is a heterogeneous group and the genetic variation within the AG-9 group can be identified by the RAPD-PCR technique.

Toda *et al.* (1999) assessed the genetic relatedness among 41 isolates of *R. solani* belonging to 11 AGs based on the fragment pattern analysis obtained by the amplification of genomic DNA by 3 RAPD primers. Based on the banding patterns of PCR-amplified products, 7 putative groups among the 41 isolates were recognized. RAPD-PCR generated multiple distinct products showing considerable variability among the isolates of different AG types. Isolates originated from the same geographical origin or host plants were not always genetically related.

Runhua *et al.* (2002) analysed forty-eight rice sheath blight strains of *Rhizoctonia solani* AG-1 IA from 7 counties of Guangdong Province, China for genetic diversity using the RAPD technique. Ninety-eight RAPD bands were amplified with 10 arbitrary decamer primers, of which 89.9% were polymorphic. Analysis of amplified polymorphic DNA fragments showed that the Nei's similarity coefficients of the isolates ranged from 0.560 to 0.949. The tested isolates could be classified into 5 RAPD groups (A, B, C, D and E), and most of the isolates from the same area were clustered in the same group by UPGMA (unweighted paired group method with arithmetic averages) analysis. The results revealed the existence of abundant genetic diversity among rice sheath blight populations and the genetic variation was very significant in *R. solani* AG-1 IA population from different counties in the Guangdong Province.

Vineeta-Singh *et al.* (2002) studied morphological characteristics, pathogenicity, anastomosis behaviour and RAPD fingerprinting of *R. solani* isolates from the rice fields of Dehradun and Nagina. Neeraja *et al.* (2002) assessed the genetic variability of the 18 isolates of *R. solani* collected from different rice growing regions of India by using RAPD markers. The similarity values of RAPD profiles ranged from 0.41 to 0.85 with an average of 0.66 among the isolates. The percentage polymorphism detected per primer varied from 79.2 to 100%. All the primers could be used to fingerprint the individual isolates. The cluster analysis using UPGMA could distinguish between *R. solani* isolates as well as the virulent and avirulent isolates on rice.

Singh *et al.* (2003) evaluated intrafield variation among 46 Indian rice isolates of *R. solani*, collected from two fields in Uttar Pradesh, India, i.e. one at Seola-Kala, Dehradun district (hilly region, 24 isolates), and one at Nagina, Bijnore district (plain region, 22 isolates) by RAPD markers. Of the 22 primers that were screened, 8 were selected for DNA amplification. A dendrogram was constructed using Jaccard's similarity coefficient and UPGMA clustering. All the isolates were multinucleate and shared typical characteristics with *R. solani*. These isolates exhibited varying degrees of virulence on Pusa Basmati 1 and, based on disease severity could be classified as highly virulent, moderately virulent, less virulent and avirulent .The isolates gave 2 (incomplete fusion) or 3 types of anastomosis reaction (compatible fusion) with the test isolate of *R. solani* (N15) belonging to AG-1 IA. The dendrogram, constructed using 88 polymorphic markers obtained with 8 primers and 41 isolates, was divided into 7 clusters. The lack of perfect state, wide intrafield variability, and compatible fusion among morphologically and virulent-wise dissimilar isolates (D19 and N14) indicated heterokaryosis as the major mechanism for creating intrafield variability.

Sharma *et al.* (2005) studied the genetic variability of twenty-four isolates of *R. solani* (teleomorph: *Thanatephorus cucumeris*) collected from soil, root and collar rot or foliage blight-infected rice plants from several locations of North India by using 11 RAPD primers, four universal rice primers (URPs) and two inter simple sequence repeat (ISSR) markers and fingerprint patterns generated for each isolate.

Feng *et al.* (2005) characterized pathogenicity and molecular genetic variation of 15 fungal isolates from rice and 7 isolates from maize in Sichuan Province, China. All the isolates were identified as *Rhizoctonia solani* AG-1 IA and showed significant pathogenicity variation. The genetic variation of these isolates was assessed with RAPD method. In the dendrogram derived from RAPD data by UPGMA, the isolates could be classified into 5 subgroups at 0.92 similarity level. The isolates from the same host plant showed similar RAPD marker patterns and were clustered into the same genetic group or subgroup. These results suggest that a certain degree of genetic similarity exists among isolates recovered from the same host, whereas the pathogenicity variation was not related to host origin of isolates and RAPD groups.

Guleria *et al.* (2007) studied the genotypic variability of nineteen isolates of *R. solani* by using 10 ISSR and eight RAPD markers. The size of amplified DNA bands ranged from 0.25 to 3.0 and 0.5 to 4.0 kb with ISSR and RAPD markers, respectively. Combined data set of 155 DNA markers were analysed with UPGMA resulting five clusters with 49-89% genetic similarity. Most of the isolates showed grouping specific to the host variety. Out of these two types of DNA markers, RAPD markers were able to detect more genetic variability when compared to ISSR markers.

2.4 Biological control of sheath blight of rice

Biological control has attained utmost importance in modern agriculture as an alternative disease management strategy that could curtail the hazards of extensive use of toxic chemicals for pest and disease control. This approach is ecology-conscious, environment-friendly

and efficient but may not be adequate by itself to achieve substantial sheath blight reductions on a consistent basis in different field situations.

Biological control with Bacteria:

It is known that antagonistic bacteria reduce the severity of sheath blight (Mew and Rosales, 1986; Vasanthadevi *et al.* 1989; Thara and Gnanamanickam, 1994). The bacteria that produce fluorescent and non-fluorescent pigments on Kings medium B also showed antagonism against *R. solani* (Mew and Rosales, 1986; Thara, 1994). However there was a lack of correlation between chitinase production by bacterial antagonists and suppression of sheath blight disease (Thara and Gnanamanickam, 1994).

Rabindran and Vidhyasekaran (1996) reported that *Pseudomonas fluorescens* isolated from the rhizosphere of different crops inhibited the growth of *Rhizoctonia solani* causing rice sheath blight. A peat-based formulation was developed for an efficient strain PfALR2. The effective dose of a peat formulation was assessed for seed treatment, root treatment, soil application and foliar spraying. All individual treatments controlled the disease effectively. However, a combination of all four treatments resulted in the best sheath blight control in the greenhouse. In field trials, application of the peat-based formulation of PfALR2 effectively controlled the disease and increased yield. Its efficacy was comparable to that of the commercially available fungicide, Carbendazim.

Researchers are now aware of several mechanisms that are involved in biological suppression of sheath blight by bacteria. Sheath blight was reduced up to 80% with *Pf* 7-14 and up to 58-60% with

Pseudomonas putida (Thara, 1994; Valasubramanian, 1994; Chatterjee *et al.* 1996; Krishnamurthy, 1997; Krishnamurthy and Gnanamanickam, 1998). Production of antifungal antibiotics encoded by clusters of genes (Chatterjee *et al.* 1996) causing degradation of *R. solani* toxin and induction of salicylic acid-mediated systemic resistance (Krishnamurthy and Gnanamanickam, 1997) are some of the mechanisms known in the biological control of sheath blight.

Bacteria are applied to rice plants either as seed treatments or as foliar sprays. Two or three foliar spray applications with efficient strains afforded sheath blight control upto 70-80% (Krishnamurthy and Gnanamanickam, 1998). Results showed that the strains survived in rice roots for 120 days while they migrated to rice shoots only for 9-10 days after seedling emergence. This clearly provided a compelling reason for 2-3 foliar spray applications of the bacterium. Such studies on survival or migration of biocontrol agents are rare but are essential to plan modes of application of the bacterium used as a biocontrol agent. Insertion of *lac*ZY marker genes into *P. fluorescens* and *P. putida* V14i made it possible to study the survival and migration of bacterial strains in the rice plants in greenhouse experiments (Krishnamurthy, 1997; Krishnamurthy and Gnanamanickam, 1998).

Other bacterial formulations have also been tested to afford substantial sheath blight control and marginal increases in rice yield (Vidhyasekaran and Muthamilan, 1999).

Chen *et al.* (2000) tested antagonism against *R. solani in vitro* with 41 isolates of *Bacillus amyloliquefaciens.* Lai van *et al.* (2001) selected six strains of beneficial bacteria from 300 strains isolated from seeds and other components of the rice ecosystem in Mecong Delta. These strains were tested for suppression of sheath blight disease caused by *R. solani* and their ability to promote seed germination and seedling development. They significantly reduced the spread of sheath blight both under greenhouse and field conditions.

Nandakumar *et al.* (2001) tested three plant growth promoting rhizobacterial (PGPR) strains of *Pseudomonas fluorescens*, PF1, FP7 and PB2 for suppression of rice sheath blight pathogen and promotion of plant (rice cv. IR50) growth under glasshouse and field conditions. The mixture of PGPR strains significantly reduced the sheath blight incidence when applied as either bacterial suspension through seed, root, foliar and soil application in glasshouse conditions, or as talc-based formulation under field conditions, compared to the respective individual strains. Though seed treatment of either single strain or strain mixtures alone could reduce the disease, subsequent application to root, leaves or soil further reduced the disease and enhanced the plant growth. The mixture consisting of PF1 plus FP7 was the most effective in reducing the disease and in promoting plant growth and grain yield.

Radja Commare (2002) tested the talc-based formulation of two *Pseudomonas fluorescens* strains (PF1 and FP7) independently as well as in combination against sheath blight and leaffolder in rice. The application of talc-formulation of the individual strains through seed, root, soil and

foliar spray significantly reduced the sheath blight and leaffolder incidence both under greenhouse and field conditions. However the mixture of two strains performed better than the individual strains.

Kazempour (2004) reported that *Pseudomonas fluorescens* isolates collected from the rhizoplane and rhizosphere soils of healthy and diseased rice plants inhibited the growth of *R. solani.* Out of 288 isolates tested only 8 isolates with antagonistic ability were demonstrated by using the dual culture method. According to the results of biochemical and morphological trials, all isolates were identified as *P. fluorescens* biovar 3. The volatile metabolites and production of extracellular enzymes and antibiotics by these isolates inhibited mycelial growth of *R. solani in vitro.* All *P. fluorescens* isolates which produced siderophore on King's B medium inhibited the mycelial growth of *R. solani.* Antagonistic isolates reduced the sclerotial germination of *R. solani.*

Nagaraj kumar *et al.* (2004) isolated fourteen strains of *P.fluorescens* from rhizosphere soil of rice and tested their antagonistic effect against *R.solani*, the rice sheath blight fungus. Among them, PfMDU2 was the most effective in inhibiting mycelial growth of *R.solani in vitro.* Production of chitinase, β-1, 3-glucanase, siderophores, salicylic acid (SA) and hydrogen cyanide (HCN) The extracellular metabolites secreted by the bacterial antagonists had lethal effect on the rice sheath blight pathogen. The metabolites seemed to have strong lethal effect on the mycelial growth of pathogen which was reflected by the percentage reduction of mycelial growth compared to direct mycelial interaction in dual culture and volatile compounds. Pfr 1 was observed to

be superior over other isolates with 68.6% of mycelial growth reduction over control. This was followed by the isolates Pfr 12, Pfr 9, Pfr 7 and Pfr 2 by *P. fluorescens* strains was evaluated. The highest β-1, 3-glucanase activity, siderophore production, SA production and HCN production were recorded with PfMDU2. A significant relationship between the antagonistic potential of *P. fluorescens* against *R. solani* and its level of β-1, 3-glucanase, SA and HCN was observed.

Rajbir Singh and Sinha (2005) examined the efficacy of potential strains of *P. fluorescens* against sheath blight of rice, caused by *R. solani*, under field conditions. Foliar sprays with Pfr 1 applied 7 days before pathogen inoculation resulted in maximum reduction in sheath blight severity (60 -64%) and incidence (37-40%) and maximum increase in grain yield (31-32%) and 1000-grain weight (27-30%).

Niza *et al.* (2005) studied the antagonistic potential of rhizobacteria against the soil borne pathogen *R. solani.* Soil bacteria were isolated from the rice fields of Agricultural Research Station, Mannuthy and screened against *R. solani.* Out of the 22 rhizosphere bacteria tested, 10 were found to be antagonistic to *R. solani.* The potentiality of these rhizobacterial antagonists can be exploited for the management of soil borne pathogens like *R. solani.*

Mathivanan *et al.* (2005) investigated the effect of talc formulations of *Pseudomonas fluorescens* and *Trichoderma viride* applications either alone or in combination on crop growth, sheath blight disease and grain yield in rice. Increased root and shoot length, dry weight and plant height were recorded following treatment of plants with *P. fluorescens* and

T. viride either alone or in combination when compared with control. Application of *P. fluorescens* and *T. viride* resulted in a significant reduction of sheath blight incidence and was comparable to the treatment with Carbendazim. The number of productive tillers, grains per panicle and grain weight was also significantly increased in the treated plots with commensurate increase in grain and straw yields when compared with control. Hence, the talc formulations of biocontrol agents either alone or in combination can be recommended as one of the crop protection strategies for the management of sheath blight of rice.

Xiangmin *et al.* (2007) reported that *Pseudomonas* strain P13 and *P. fluorescens* strain Pf7-14 and were antagonistic to *R. solani*. Ravikant and Rathi (2008) tested fifteen non conventional chemicals alone or in combination with fluorescent Pseudomonads (FLPs) strains RP-13 and RP-3 against sheath blight of rice caused by *R. solani* as inducers of resistance. Application of mixed inocula (RP-13+RP-3) in combination with salicylic acid was superior when applied as seed treatment and foliar spray and reduced the lesion length upto 74% and 69% respectively.

De Curtis *et al.* (2010) studied the effectiveness of two antagonistic bacteria (*Burkholderia cepacia*, TIA-2B and *Pseudomonas* spp.T4B-2A) against *R.solani* and *Sclerotium rolfsii* causing crown and stem rot disease in tomato. In all the experiments both the bacterial strains significantly reduced both incidence and severity of the diseases caused by *S. rolfsii* or *R. solani*.

Biological control with Fungi :

Trichoderma viride and other species of *Trichoderma* have also served as effective biocontrol agents to control sheath blight infection in rice (Baby, 1992). It is believed that chitinases produced by *Trichoderma* have a role in suppression of *R. solani* (Krishnamurthy *et al.* 1999). Some mutant strains of *Trichoderma* controlled *R. solani* in rice more efficiently than their parental strains (Baby, 1998). Degradation of *R. solani* toxin by chitinase(s) produced by *Trichoderma* reduces the pathogen's aggressiveness and contributes to disease suppression (Vidhyasekaran *et al.* 1997; Sriram *et al.* 2000).

Paul Diby *et al.* (2005) tested five strains of *Pseudomonas fluorescence* and *Trichoderma* spp. were efficient in suppressing root rot of black pepper caused by *Phytophthora capsici in vitro* for their efficiency in lysing the cell wall of *P. capsici.* The antagonists produced mycolytic enzymes viz β-1, 3-glucanases, β-1, 4-glucanases and lipases.

Khan and Sinha (2006) conducted a glasshouse experiment to evaluate the effects of different treatment combinations of N, P and K on the effectivity of *Trichoderma harzianum* against *R.solani* causing sheath blight of rice. Plants were inoculated with the pathogen at maximum tillering stage. Sprays of *T. harzianum* were given 2 days after inoculation and 15 days thereafter. Results showed that *T.harzianum* sprays reduced sheath blight severity and incidence and increased rice grain yield.

Khan and Sinha (2007) screened the isolates of *Trichoderma* spp. against *R. solani.* Of the five isolates of *Trichoderma* spp. screened under *in vitro* and glasshouse conditions, *T. harzianum* (rice leaf sheath isolate)

was found the most effective against *R. solani*.

Anjana *et al.* (2007) conducted an experiment *in vitro* to determine the efficacy of biological control agents, namely *Trichoderma harzianum*, *T. viride* and *Pseudomonas fluorescens*, against *Rhizoctonia solani* infecting soyabeans. *T. harzianum* was the most effective as it inhibited the mycelial growth of *R. solani* after 96 h of incubation followed by *T.viride* and *P. fluorescens.*

Khan and Sinha (2007) evaluated the potentiality of Talc+CMC based formulation of *T. harzianum*, and reported maximum reduction in disease severity (52%) and incidence (24%) in Pantnagar, Uttar Pradesh, India. Shalini and Kotasthane (2007) studied parasitism of *Rhizoctonia solani* by strains of *Trichoderma* spp. They reported that *Trichoderma* isolates coiled around the hyphae of *R. solani* and formed appresoria and hook-like structures.

Yao-Yanbo *et al.* (2007) studied the control of *Fusarium oxysporum* and *Rhizoctonia solani* in turfgrasses by *Trichoderma harzianum* preparation in laboratory, in greenhouse and in field. In laboratory, the *T. harzianum* preparation showed a relatively high antagonistic action against the two pathogens. The antagonistic mechanisms were competition, hyperparasitism and antibiosis. The biological control effects of *T. harzianum* on *F. oxysporum* in greenhouse and in field were 85 and 74%, respectively, and those on *R. solani* were 86 and 76%. It is inferred that *T. harzianum* could be used as a substitute for some agricultural chemicals.

Mahesh kumar *et al.* (2008) studied damping-off of chickpea caused by *R. solani. In vitro* evaluation of *T. viride* and *T. harzianum* showed strong antagonist activity against *R.solani.* Feng *et.al.* (2008) isolated a total of 136 fungi and 86 bacteria from the sclerotia of *Rhizoctonia solani*, collected from three different sources. The fungal isolates were identified as *Alternaria, Aspergillus, Cladosporium, Coniothyrium,Curvularia, Gliocladium, Fusarium, Metarhizium, Penicillium, Phoma, Phytophthora* and *Trichoderma.* Some isolates of *Trichoderma* and *Gliocladium* were found to inhibit the growth of *R. solani* strongly *in vitro.* Among the 86 bacterial isolates, 20 of them which belong to *Bacillus* and *Pseudomonas* could inhibit the growth of *R. solani.*

Nagdi and Khair (2008) studied biocontrol of root knot (*Meloidogyne incognita)* and root rot (*Rhizoctonia solani)* pathogens of eggplant. *T. harzianum* greatly reduced mycelial growth of *R. solani* followed by *T. viride, B. subtilis* and *P. fluorescens.* Culture filtrates of *T. harzianum* reduced damping-off and root-rot incidence in aubergines followed by those of *T. viride, P. fluorescens* and *B. subtilis.*

Sitansu and Someshwar (2008) isolated ten strains of *Trichoderma* from rhizosphere of different crops and evaluated their antagonistic potential against five soil borne plant pathogens, viz., *Rhizoctonia solani, Fusarium oxysporum , Macrophomina phaseolina* and *Sclerotium rolfsii* using dual culture technique and production of volatile and non-volatile antibiotics. These strains were highly effective against *R.solani* and *S. rolfsii.*

Biswas *et al.* (2008) tested bioagents such as *Trichoderma harzianum* and *T. viride*, bioformulation of *Pseudomonas fluorescens* and *T. harzianum* and botanicals such as garlic extract and Achook against brown spot pathogen (*Drechslera oryzae*) and sheath blight pathogen (*Rhizoctonia solani*) *in vitro.* In dual culture test, *T. harzianum* and its bioformulation reduced mycelial growth upto 56% and 43% in *D. oryzae* and *R. solani*, respectively.

Francesco vinale *et al.* (2009) studied antifungal and plant growth promoting activity of *Trichoderma harzianum* strain isolated from composted hardwood bark in Western Australia. *T. harzianum* produced a metabolite harzianic acid which showed antibiotic activity against *Phythium irregulare*, *Sclerotiana sclerotium* and *Rhizoctonia solani.*

Khair *et al.* (2010) studied the antagonistic effect of four *Trichoderma* spp. viz., *T. album*, *T. hamatum*, *T. harzianum* and *T.viride* against *Fusarium solani* and *R. solani* causing damping off disease of beans. All species significantly reduced the growth of two pathogenic fungi *in vitro* as well as the incidence of damping off in greenhouse experiments.

Shabir *et al.* (2010) evaluated two fungal antagonists viz., *T. viride* and *T. harzianum* along with a fungicide (Carbendazim 50wp) as seed treatment and soil drench against *R.solani* causing damping off disease in cabbage. *In vitro* these two strains significantly inhibited the growth of *R.solani* and under field conditions they caused significant reduction in damping off incidence, increased seed germination and improved plant growth vigour as compared to untreated control.