STUDIES ON THE INTERACTION AMONG *Rhizoctonia solani*, *Rhizoctonia oryzae* AND *Rhizoctonia oryzae-sativae* CAUSING SHEATH DISEASES OF RICE

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CERTIFICATE

This is to certify that the thesis entitled, *"STUDIES ON THE INTERACTION AMONG Rhizoctonia solani, Rhizoctonia oryzae AND Rhizoctonia oryzae-sativae CAUSING SHEATH DISEASES OF RICE"* submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of *MASTER OF SCIENCE in PLANT PATHOLOGY*, embodies the result of a piece of bona fide research work carried out by *Md. Akherur Rahman*, **Roll No. 00392, Registration No. 25287/00392,** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or sources of information, received during the course of this investigation have been duly acknowledged by him.

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Dedicated to

My

Beloved Parents

ABBREVIATIONS AND ACRONYMS

AEZ	: Agro-Ecological Zone
BAU	: Bangladesh Agricultural University
BBS	: Bangladesh Bureau of statistics
BRRI	: Bangladesh Rice Research Institute
cm	: Centimeter
et al.	: and others
etc	: Etcetera
FAO	: Food and Agriculture Organization
g	: Gram
hr	: Hour
IRRI	: International Rice Research Institute
kg	: Kilogram
LSD	: Least significant difference
m	: Meter
m	: Meter
m^2	: Square meter
ml	: Millimeter
Newsl	: Newsletter
Ns	: Not significant
%	: Percent
^0C	: Degree Celsius

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The Author

STUDIES ON THE INTERACTION AMONG *Rhizoctonia solani, Rhizoctonia oryzae* AND *Rhizoctonia oryzae-sativae* CAUSING SHEATH DISEASES OF RICE

ABSTRACT

Experiments were conducted both in laboratory and experimental field of Plant Pathology Division of Bangladesh Rice Research Institute (BRRI), Gazipur during Boro season, 2005-2006, to find out the interaction among the three *Rhizoctona* species namely, *Rhizoctonia solani, Rhizoctonia oryzae and Rhizoctonia oryzae-sativae.*

In laboratory condition, the interaction between *Rhizoctonia* species was observed in dual culture and found that the radial growth of *R. solani* was always higher than the growth of *R. oryzae* and *R. oryzae-sativae.* But the radial growth of *R. oryzae* or *R. oryzae-sativae* was more or less similar. In *R. solani* versus *R. oryzae* and *R. solani* versus *R. oryzae-sativae* interactions, *R. solani* fused with *R. oryzae* or *R. oryzae-sativae* within 24 hours and was slightly overlapping on *R. oryzae* and *R. oryzae-sativae*, respectively at 96 hours. Both *R. oryzae* and *R. oryzae-sativae* were comparatively slow growing fungi. *R. oryzae* fused with *R. oryzae-sativae* at 96 hours but no overlapping was recorded within this period. In interactions, *R. solani* versus *R. oryzae* and *R. solani* versus *R. oryzae sativae*, the colony growth ratios (CGR) of *R. solani* over *R. oryzae* and *R. oryzae sativae* were higher compared to control at 72 and 96 hrs after inoculation indicating positive antagonistic effect on *R. oryzae* and *R. oryzae sativae. R. oryzae sativae* did not show any antagonistic effect on *R. oryzae.*

In field experiment, % relative lesion height (RLH) and % infected tiller were significantly differed among the combination of *R. solani, R. oryzae and R. oryzae-sativae* or either of two or each alone. The % RLH and % infected tiller in sheath blight were higher in *R. solani* only. In case of aggregate sheath spot, % RLH and infected tiller were also higher in *R. oryzae-sativae* alone compared to mixed with both *R. solani* and *R. oryzae* or any of them. Similar trend was followed in sheath spot disease. The highest percentage of RLH and infected tiller were found at maturity followed by hard dough and flowering stage. Inoculation of three pathogens, *R. solani*, *R. oryzae* and *R. oryzae sativae* alone evidenced the highest disease severity and incidence compared to combination of three or any of two pathogens in three-growth stages (flowering, hard dough and maturity). The severity and incidence of each disease were inhibited very slightly by the inocula mixed with three or two pathogens. No significant yield losses was observed in combination of three pathogens or mixed with two or each alone. Among the three diseases, the higher % of yield losses (13.86-18.93 %) occurred when *R. solani* inoculated alone or mixed with both of *R. oryzae sativae* and *R. oryzae* or any of them.

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Chapter I

INTRODUCTION

Rice (*Oryza sativa*) comprised the staple food of 60% of the world population and also the most important cereal crop for about 135 million people of Bangladesh. It occupies about 75% of the total cropped area covering 26.6 million acres and is the only source of income for many farmers in our country (FAO, 2002). In Bangladesh more than 25.2 million metric ton of rice produced from total 26.6 million hectares of cultivable land in the year 2002-2003 (BBS, 2004). The average world production of the rice is 3.75 metric ton per hectare. But the average yield of our country is unfortunately poor, only 1.98 metric ton per hectare (FAO, 2002). Per hectare yield of rice in Bangladesh is very low considering the other rice producing countries of the world (Chandle, 1979).

There are so many reasons accountable for the low yield of rice in our country. Among them vulnerability of the crop to pests and diseases is important one (Fakir, 1982). Rice diseases grounds by different groups of microorganisms are grouped into virus, bacteria, fungi, nematodes etc. In Bangladesh around 31 rice diseases have been identified of which ten are considered as major (Miah and Shahjahan, 1987; Anonymous, 1995).

The *Rhizoctonia* sheath diseases, caused by *Rhizoctonia solani*, *Rhizoctonia oryzae*, and *Rhizoctonia oryzae-sativae* are the important fungal diseases in rice plant. *R. solani* causes rice sheath blight disease *R. oryzae* causes sheath spot and *R. oryzae-sativae* incites aggregate sheath spot of rice. *R. oryzae* the causal fungus of sheath spot and *R. oryzae-sativae* causal fungus of aggregated sheath spot is known to occur in East Asia. Both produce lesions on leaf sheath very similar to those of leaf blight. As a consequence the diagnosis of these diseases by visual observation is extremely difficult and often inaccurate, particularly at the early stages of lesion development.

When all the three fungi together attack rice plant, *Rhizoctonia* sheath disease complex is developed (Ou, 1985). Shahjahan *et al.* (1988) observed that the symptom of aggregate rice spot is very similar to that sheath blight caused by *R. solani*. Sheath blight is one of the most important diseases of rice in most tropical and subtropical countries of the world, while sheath spot and aggregate sheath spot are of minor importance (Ou, 1985) In Bangladesh, out of 31 diseases of rice sheath blight caused by *R. solani* Kuhn [(*Thanatephorus cucumeris*) (Frank Donk)] is considered as a major disease of the crops (Miah *et al.*, 1985). Yield losses due to the diseases ranged from 14 to 31% under experimental and farmer field conditions (Shahajahan *et al.*, 1986).

In Bangladesh until 1988 there was no report of *R. oryzae* and *R. oryzae-sativae* except *R. solani* which is the most common pathogen of rice sheath blight disease. A survey of rice crops conducted by Shahjahan *et al.* (1988) revealed that aggregate sheath spot caused by *R. oryzae-sativae* was widespread in the Bangladesh Rice Research Institute (BRRI) farm during all the three rice growing seasons. It was observed on both local and modern cultivars and advanced breeding lines. Shahjahan *et al.* (1988) observed that the symptoms of the disease were very similar to that of sheath blight caused by *R. solani*. The spots were small, oval with light brown border and green-grey to ash colour centre. Many spots were found to produce on the same sheath at boot stage. The spots coalesced to cover most of the leaf sheath area but did not appeared to spread like sheath blight. Both the *Rhizoctonia* were isolated from such symptoms. They observed that the cultures of *R. oryzae-sativae* produce light grey-brown, small round and loose sclerotia, which were distinguishable from *R. solani* that produced large and brown sclerotia.

The major factors conducive to sheath blight development include the presence of viable sclerotia in the field soil and prevalence of high relative humidity and temperature especially below the crop canopy (Shahjahan *et al.*, 1987). Other factors in which the disease has been found to be severe are the cultivars with semi-dwarf, early maturing and high tillering characters, closer plantings and application of high amount of nitrogenous fertilizers (Shahjahan and Mew, 1989). The wide spread adoption of new changes in cultural practices associated with these cultivars favour development of sheath blight and have contributed greatly to its rapid increase in incidence and severity in rice producing areas throughout the world (Rush and Lee, 1992).

To manage sheath disease of rice, several techniques, such as agronomic modification and application of fungicides and to some extents biological control are recommended. Resistant sources against these diseases are not yet found in Bangladesh or elsewhere, and the present intensive rice cultivation practices offer a favorable condition for disease development. Cultural manipulations (Butrano, 1988; Shahajahan *et al.*, 1990) appeared to be controlling the limited effect of these diseases. The use of fungal antagonists as biocontrol agent of soil-borne pathogen has recently been increasing.

Considering the present situation the investigations have been under taken with the following objectives:

1. To find out the antagonistic effect among three species of *Rhizoctonia.*
2. To study the interaction effect among three species of *Rhizoctonia* on disease incidence and severity of rice sheath diseases.

Chapter 2
Review of literature

Chapter II

REVIEW OF LITERATURE

Studies on the interaction among *R. solani*, *R. oryzae*, *R. oryzae-sativae* causing sheath disease of rice is so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings so far been done at home and abroad on this aspect have been reviewed in this chapter.

2.1 History and distribution

Sheath blight disease was first identified in Japan (Miyake, 1910). Subsequently, in Sri Lanka, China and the Philippines, the causal pathogen was identified as *R. solani* (Park and Bertus, 1932; Wei, 1934, Reinking, 1918). Since the disease was first identified and reported from oriental countries it was commonly called oriental sheath blight of rice. The disease was also reported from Brazil, Surinam, Venezuela, Madagascar and the USA (Ryker and Gooch, 1938).

Sheath blight is measured the second most important rice disease in Japan next to blast. The average area pretentious during the five -year period from 1978 to 1982 was estimated at 1.08 million hectares which was equal to about 44% of the total cultivated rice area of 2.36 million hectares (Hori, 1984). Sheath blight of rice is now considered one of the major diseases of rice in the tropical, subtropical and temperate regions of Asia, Africa and the America. (Ou, 1985).

Bordered sheath spot and aggregate sheath spot caused, respectively by *R. oryzae* Ryker and Gooch (1938) and *R. oryzae-sativae*. Mordue (1974) were only minor diseases in Japan, USA, Taiwan, Vietnam and Thailand (Hashioka and Makino, 1969; Ou 1985). The shift in the cultivation practices and varieties appeared to have increased the occurrence of these two diseases. This is evident from reports of their occurrence in the Philippines, USA, Japan India and Bangladesh (Mukherjee *et al.*, 1980, Gunnel and Webster, 1984; Shahjahan and Mew, 1986; Shahjahan *et al.*, 1988).

Incidence of sheath blight caused by *R. solani* in cultivar, PSB RC2 in two farmer's fields in Pila, Laguna (Philippines) was recorded for a period of eight weeks starting at maximum tillering stage in an attempt to monitor the progression of naturally occurring epidemics (Raymundo *et al.*, 1994). Therefore, sheath blight disease was common in both the field. Eight weeks later, disease spread was observed in 80% of the hills.

Rice sheath blight disease caused by the fungus *Thanatephorus cucumeris* (Frank) Donk (*R. solani* Kuhn) was first reported in Bangladesh by Talukdar in 1968. Later on, Miah (1973) confirmed its occurrence and reported that the incidence of the disease was increasing in Bangladesh. With the intensification of rice cultivation, it has now become a major disease of rice in the country. Sugiyama (1988) stated that the areas affected by sheath blight in Japan increased from 35% of the cultivated areas in the 1960's to 46% in 1970's and to 48% in 1980's.

2.2 Symptomology

The symptomology for sheath blight, sheath spot and aggregate sheath spot are presented below -

2.2.1 Symptoms of sheath blight

Symptoms of sheath blight generally does not appear until plants are in the late tillering or early internode elongation growth stages. Occasionally symptoms are found on young plants. Initial symptoms consist of circular, oblong, or ellipsoid, green-gray, water-soaked spots about 1 cm long that occur on the leaf sheaths near the waterline. The lesions enlarge to approximately 2-3 cm in length and 1 cm in width, and the centers of the lesions become pale green or white and are surrounded by an irregular purple-brown border. Under favorable conditions, i.e. low sunlight, humidity near 95%, and high temperature (28-32^{0}C), infection spreads rapidly by means of runner hyphae to upper plant parts, including leaf blades, and to adjacent plants. Lesions on the upper portion of plants may coalesce to encompass entire leaf sheaths and stems. Sclerotia are produced superficially on or near infected tissue after symptoms first appear and are loosely attached and easily dislodged from the plant when they are mature. Heavily infected plants produce poorly grains, particularly in the lower portion of the panicle. Additional losses in yield result from increased lodging or reduced ratoon production as a result of death of the culm (Gunnel and Webster, 1984).

2.2.2 Symptoms of sheath spot

The lesions are usually found on leaf sheaths midway up the tiller and sometimes on the leaf blades. Lesions are oval, 0.5-2.0 cm long and 0.5-1.0 cm wide. Lesions may be pale green, cream or white, with a broad, dark, reddish brown margin. The lesions are usually separate and do not coalesce to form the large areas of continuous infection typical of sheath blight. The pathogen may also attack and weaken the culm under the sheath lesion on very susceptible cultivars, and weakened culms may lodge or break. Lodging caused by sheath spot is atypical, because infection usually occurs midway up rather than near the base of the culm (Gunnel and Webster, 1984).

2.2.3 Symptoms of aggregate sheath spot

The disease is characterized by oval lesions with a gray-green to straw-colored center surrounded by a distinct brown margin. A stripe of necrotic cells runs down the middle and is conspicuous in young lesions. Often the lesions expand, forming a series of concentric bands. Initially, lesions occur on the lower leaf sheaths at the waterline and range from about 0.5 to 4 cm in length. As the disease progresses, lesions spread vertically up the rice plant to the upper leaf sheaths. Leaves of diseased sheaths generally turn yellow and die. The fungus may at times also infect the base of the leaf blade. Occasionally, the fungus causes a culm rot or infects the panicle rachis, resulting in sterile grains or partially filled heads. Aggregate sheath spot symptoms are similar to those of sheath blight, caused by *R. solani* kuhn, and sheath spot, caused by *R. oryzae* (Gunnel and Webster, 1984).

2.3 Causal organism

The mycelium of *R. solani* is colorless in young culture and yellow brown in older cultures. The hyphae have a prominent dolipore septum, multinucleate and are generally 8-12 μm (Ou, 1985). Three types of specialized mycelium produced by the pathogen and these are straight runner hyphae, lobate hyphae and monilioid cells. The straight running mycelium grows on the surface of the plant tissue. The lobate type infects the plant tissue and produce lesions. Monilioid cells are short, broad cells produced in short chain continue to produce sclerotia.

Sclerotia are superficial, more or less globose but flattened below, white when first formed and then turning brown or dark brown. The sclerotia reach their maximum size after 30 hours and starts to pigment. Individual sclerotia measure up to 5 mm but may unite to form a large mass in culture (Ou, 1985). Initially, sclerotia are dense and sink in water, but at maturity the cells in the outer layer become vacuolated, and the sclerotia become buoyant in water (Hashiba *et al.*, 1974). They considered the fungus as a new species and named it as *R. oryzae*. The most obvious differences between this fungus and *R. solani* are found in culture. The sclerotial masses of *R. oryzae* are of indefinite shape and size and are frequently formed above the main hyphal branches. The color of the sclerotial masses varies somewhat with the substrate but is generally a shade of salmon (Ou, 1985).

The sclerotia of *R. solani* are large and round and more regular in shape, and generally brown. The mycelium is superficial or submerged in culture, 6-10 μm in width, branching at a right angle with a slight constriction and with a septum a short distance from the point of constriction. Mordue (1974) transferred it to *R. oryzae* and *R. oryzae-sativae*. It has also been reported from Japan, Vietnam, and East, Northeast and Southeast China. The fungus causes lesions similar to those of sheath blight but they are smaller (0.5 -1.0 cm) with distinct margins (Ou, 1985).

2.4 Epidemiology of sheath diseases

2.4.1 Damage by sheath diseases

Ahn and Mew (1986) premeditated relation between rice sheath blight and yield. No significant yield reduction was found when RLH was less than 20%. If lesion reached the 3rd sheath from the sheath bearing the flag leaf and if RLH was about 30% a significant yield loss was seen. Forty six percent yield losses are possible in milled rice if sheath blight lesion reaches 90% of RLH.

Shahjahan *et al.* (1986) reported that in a farmer's field trial yield losses due to sheath blight were 31.0% and 28.7% at mean disease incidence (DI) of 4.8 and 5.0 in susceptible varieties BR2 and BR3, respectively in Bangladesh. Under inoculated condition BRI and IR5 two susceptible varieties had a mean loss of 17.3% and 13.1% with mean DI differences of 4.1 (5.4-1.3) and 2.0 (4.8-2.8), respectively. Again in separate experiments SRI had a loss of 14.0% during Aus and 15.4% in IR5 during Aman seasons at DI 5.0 and 5.4, respectively.

Rajan (1987) reported that percent yield losses due to Sheath blight, caused by *R. solani* at 3, 5, 7 and 9 disease scores on a scale of 0-9 were 16.8, 22.9, 36.2 and 48.4, respectively. Nuque *et al.* (1989) reported that calculated mean yield ranged from 3.3 to 4.2 t ha^{-1}. The mean yield of the control plots differed significantly with those of the other inoculation treatments.

Naidu (1989) inoculated eight varieties with sheath blight pathogen *R. solani* using a stem tape method and scored for yield. Grain yield losses varied from 49% in phalguna to 69.1 % in Mansui. Dilla *et al.* (1993) observed that yield per hectare ranged from 3.10 to 7.67 t ha^{-1} during dry season and relatively lower during the wet season, ranging from 3.46 to 5.96 t ha^{-1}. The effect of sheath blight inoculation was very strong in all cases. The variation in yield losses ranged form 0.27 to 1.29 t ha^{-1} in the dry season and 0.23 to 1.37 t ha^{-1} in the wet season. Yield loss was strongly affected by amount of inoculum but not by population density and nitrogen levels. The value ranged from 3.59 to 27.01 % in the wet season and 3.16 to 28.62% in the dry season. Rajan (1989) reported that the vertical disease index was positively correlated with percent leaf area disease, sheath area disease and yield loss.

2.4.2 Survival of the pathogen

Sclerotia of the rice sheath blight pathogen on un-sterilized cowdung, rice straw and soil under dry and wet conditions remained viable upto nine months. Very few were viable upto 10 months on cowdung and rice straw although the survival capacity dropped considerably after 7 months. No difference in the capacity of sclerotia to survive was observed between sterilized and un-sterilized soil (Roy, 1987).

Sclerotia are most thickly disseminated on the surface soil (1-0 cm). As soil depth increases, the number of sclerotia decreases (Leu and Yang, 1985). Lakshamanan and Nair (1987) reported that the organism loses its viability when infected plant debris was buried in garden land soil and wet land soil under flooded conditions and also in cattle manure.

2.4.3 Humidity and temperature

Hashiba *et al.* (1974) reported that the pure cultures of *R. solani* isolates from high temperature regions grew well on PDA at 35°C but tended to grow poorly at 12°C, whereas those from low temperature regions grow poorly at 35°C and well at 12°C. There was no difference in growth between the isolates at 15°C with a daily average temperature of 26-28°C (daily maximum 30-32°) the rate of upward development of the disease caused by higher temperature isolates was greater than that of those caused by the low temperature isolates.

Yuno *et al.* (1978) reported that there was no significant difference in the growth of *R. solani* on rice leaf sheath held in the dark or light but lesions developed more rapidly in the light. Mycelial growth increased with temperature, 20-28°C from 25-26h after disease development, lesions of leaf sheaths were clearly defined and the lesions diameter then remained constant.

Hashiba *et al.* (1982) investigated rice sheath lesion disease development in Japan on the cultivar Koshijwase. Vertical disease development at 100% RH was 0.48 cm at 20°C, 1.13 cm at 23°C, 1.35 cm at 25°C and 1.58 cm at 28°C. Lesion development on 2, 5, 10 and 15-day old sheaths after heading stage 2 was 1.12, 1.32, 1.72 and 1.5 cm/day, respectively under the most favorable conditions (28°C, 100% RH).

Several workers have reported that the disease was especially destructive under condition of high humidity and high temperatures (Kim *et al.*, 1985; Shahjahan *et al.*, 1990). While the temperature and humidity in the rice field was greatly affected by the thickness of the stand. The close planting and heavy application of fertilizers, lead to thick growth, which increased humidity within the canopy. This also changes physiological characteristics of the rice plants favoring disease development.

The sheath blight fungus incites disease on nee over a temperature range of 23-35°C with an optimum 25-32°C and relative humidity (RH) 96-97%. At 32°C infection takes place in 18 and 28°C in 24 h with continuous wetting (Ou, 1985; Rao, 1995). Roy (1993) reported that high infection occurs at 100% humidity.

Hashiba and Kobayashi (1996) reported that sclerotia germinate over a temperature range of 16-32°C, with an optimum at 28-30°C. High relative humidity >90% is required for their germination.

Matsumoto *et al.* (1998) reported that high infection occurs at 100% humidity and minimum at 85 to 88% primary infection is closely correlated with the number of sclerotia adhering to the plants.

2.4.4 Rice varieties and spacing

Miah *et al.* (1979) and Ou, (1985) reported that the disease developed more rapidly in the high tillering and high yielding modern varieties than in the low tillering and yielding local varieties. Marchetti (1983) reported that on infection by *R. solani* semi dwarf rice lines showed more than twice the reduction in yield and milling quality sustained by closely related standard high lines. The disease developed more extensively in the semi dwarf because of the shorter distance between the water line (the usual infection court) and the panicles.

Shahjahan *et al.* (1987) reported that the extent of damage of rice sheath blight depended on the rice cultivars and the pathogen strains present in the field. Kannaiyan and Prasad (1983) conducted a field experiment to assess the influence of plant spacing on the spread of the sheath blight disease of rice. They observed that the disease spread was more rapid in the plots planted with closer spacing compared to the wider spacing. Increase in spacing proportionately decreased the disease intensity. There was no correlation between disease intensity and grain yield at different spacing. Yields were lower in wide spacing despite the slower spread of sheath blight.

Chang *et al.* (1985) reported that sheath blight was severe under closer spacing and it increased with the increasing amount of nitrogen applied. Mithrasena and Adikari (1986) studied the relation between sowing density (seed rate) and incidence of sheath blight of rice caused by *R. solani* Kuhn. Seven day old *R.*

solani culture on rice grains were inoculated by evenly spreading the grains on the water surface at panicle initiation. Recommended fertilization was applied and standard plant protection measures were taken. Disease incidence was assessed at harvest. The expected yield increase with higher plant densities was not found. Higher disease incidence affected yield. Borthakur and Addly (1988) reported that relationship between yield status and disease score indicated that resistance to *R. solani* may be achieved together with the high yield.

It was reported that sheath blight was severe under closer spacing and it increased with the increasing amount of N applied (Shahjahan *et al.,* 1990). Leano (1993) reported that incidence and severity of sheath blight were increased with increased crop density.

2.4.5 Plant growth stages

Kim and Min (1983) reported that the percentage of infected hills/stems increased more rapidly from 11 July to 1st August than 1st September (i.e. booting stage than flowering stage of crop growth). Miah *et al.* (1984) reported that plants inoculated with inocula of *R. solani* at maximum tillering, panicle initiation, booting and flowering stages and control without inoculation indicated that for sheath blight, the disease severity and yield losses were significantly higher when inoculated at booting stage than when inoculated at other stages.

Ou (1985) reported that before the heading stage the upper leaf sheaths and blades were more resistant than the lower ones, but after the heading stage, the susceptibility of the upper parts increased with increasing plant age. Nuque *et al.* (1989) conducted two experiments to determine the effects of inoculating rice plants with *R. solani* at different growth stages on the disease incidence and yield in 1987 wet and dry season. Results of the 1987 wet season experiment showed that disease incidence varied from 4.1 to 86.30%, intensity from 2 to 83.8% and relative lesion length from 5.2 to 75.5%. Percentage of relative lesion length differed significantly among treatments but not among replications. Computed yield from different treatments ranged from 2.2 to 3.1 t/ha. The mean yield of the plot sprayed weekly with iprodine differed significantly with those of the plots inoculated at different growth stages. They also reported that during the dry season of 1988 intensity of the disease varied from 50 to 100%, severity from 3.0 to 100% and percentage relative lesion length from 0 to 70%. Calculated mean yield ranged from 3.3 to 4.2 tons/ha. The mean yield of the control plots differed significantly with those of the other inoculation treatments.

Peng and Tang (1990) reported that the most suitable time for chemical control was at the jointing stage, when infection (by *R. solani)* started to develop rapidly. Suparyono and Nuryanto (1991) observed the severity of sheath blight and its effect on rice yield depended on the rice variety and the host growth stage at which plants were inoculated. Disease development was greatest when plants at maximum tillering and primordial stages were inoculated with the fungus of *R. solani.* Disease severity of the early maturing varieties was less when plants were inoculated at the later stage, although disease severity was affected less by the later plant growth stage on the long duration rice varieties. Yields of both early and long duration varieties were significantly reduced by the disease when the plants were inoculated at the maximum tillering and primordial plant growth stages. Yield reduction decreased when plants of the early maturing varieties were inoculated at the later stage, although the reduction of the yield loss was smaller on the long duration varieties.

Sharma and Teng (1996) reported that two rice cultivars IR42 and IR 72 were inoculated with *R. solani.* Disease development was found to be higher at later growth stages. Disease progress was faster at flowering and booting stages than at tillering and panicle initiation stages in both cultivars. The percent productive tillers, grain weight per plants, filled grain number per panicle, 100-grain weight, filled grain percent and total biomass per plant were usually higher at early stages of inoculation and lower at booting and flowering stages of inoculation. The disease development was also higher at later growth stages and consequently the yield parameters also declined. The yield losses at different stages of inoculation ranged from 23.01% - 32.15% and 13.53% - 34.83% in IR42 and IR72, respectively. The yield losses were high in flowering stage in both the cultivars than the other three stages.

2.4.6 Sclerotial population and sheath disease development

Mgonja *et al.* (1986) studied the relationship between inoculum density and sheath blight development in rice. Sites with many diseased plants had many sclerotia in the soil.

Butranu (I988) studied the production and survival of *R. solani* sclerotia as influenced by cultural practices. Rice, corn and mungbean were planted in sequential cropping systems under maximum and minimum cultural practices. *R. solani* was inoculated once during the first cropping season. The number of survival of *R. solani* was investigated before sowing and after harvest. The results demonstrated that minimum cultural practices increased sclerotia density and caused more serious disease infection to maximum cultural practices.

Maniytan and Paulsamy (1989) worked on biological control of sheath blight disease of rice. *Trichoderma aureoviride* restricted the mycelial growth. Sclerotial growth of a virulent isolate of *R. solani* was inhibited. Microscopic examination revealed that 25% of the *R. solani* mycelium inhibition zone was lysed and most of the hyphal tips showed bulb like terminal enlargements. The pot culture, soil amendment with *T. aureoviride* reduced the incidence and severity of sheath blight in TKM-9 rice.

Shahjahan *et al.* (1990) studied the sclerotia dynamics of *R. solani* Kuhn causing sheath blight of rice in relation to crop management practices in upland rice. The sclerotia production as assayed from the top soil at or after harvest was related to severity of the disease and as such it was higher in susceptible cultivars, IR58 (22.1/0.5 L soil) and in the inoculated (DL-1) plots (29.9/0.5 L soil). Fungicide (Brestan) spray reduced the disease severity as well as the sclerotia production. The sclerotia population on the top soil decreased as the land was ploughed. The viabilities of sclerotia of the inoculated (DL-1), inoculated and sprayed (DL-2) and control (DL-3) plots at harvest of the 1st crop were 52, 47 and 28%, respectively. But by the end of the following crop both the number and the viability were reduced. There was increase in the bacteria and *Trichoderma* populations of the soil in all treatment plots at harvest which appeared to be related to state of decomposition of crop residues.

Shahjahan *et al.* (1986) studied the effect of crop management practices on the sclerotia dynamics of *R. solani* in upland rice, where they showed that sclerotial production as assayed from top at or after harvest was related to the severity of sheath blight and was higher in inoculated plots. Spraying with Brestan (fentin acetate) reduced both disease severity and sclerotial production. The sclerotial population in the top soil decreased as the land was ploughed.

2.5 Diversity

The pathogens *R. solani*, *R. oryzae*, and *R. oryzae-sativae* causes respectively sheath blight, sheath spot and aggregate sheath spot diseases on rice produce very similar symptoms especially at early stages of disease development and careful observation is necessary to distinguish them. The pathogen can be easily distinguished on potato dextrose agar by colony colour, growth characters, patterns of sclerotia production, and size (Anon., 1985). *R. solani* is light brown and produces compact, large sclerotia, colonies of *R. oryzae-sativae* are light grayish and produce many small, round, loose sclerotia. Colonies of *R. oryzae* are pinkish and produce salmon-coloured, small, flat sclerotia.

The majority of the strains could be assigned as *R. solani, R. oryzae-sativae* or *R. oryzae* based on previously defined morphological and cultural characters (Anon., 1999). *R. solani* and *R. oryzae-sativae* are somewhat similar in appearance on agar medium while *R. oryzae* is more distinct. However, cultural characteristics may differ considerably between strains of *R. solani,* while those of all three species may differ to some extent when grown on agar substrates.

The morphological traits for *Rhizoctonia* species infecting rice sheaths could be as follows (Anon., 1999) *R. solani* is multinucleated, the slerotial size is 2.5 mm, irregular and dark brown. The perfect state of the fungus is *Thanatephorus cucumeris* with anastomosis group AG 1A. *R. oryzae-sativae* is binucleated with round to irregular sclerotia, 0.5 2mm in size and cream and pale brown in appearance. The perfect state *is Ceratobasidium oryzae-sativae* with anastomosis group AG Bb. *Rhizoctonia oryzae* is multinucleated. Sclerotia irregular, salmon-pink to orange in appearance. The perfect stage is *Waitea circinata* with anastomosis group WAG-O.

The development of sheath blight, bordered sheath spot and aggregate sheath spot caused respectively by *R. solani, R. oryzae* and *R. oryzae-sativae* in ten rice cultivars differing in height and maturity were compared in the greenhouse at IRRI, Philippines by Shahjahan (1991). He found that three pathogens infected rice plants at all growth stages but the symptoms of bordered sheath spot and aggregate sheath spots remained confined to leaf sheath only. Varietal differences in pre- emergence death and varietal as well as disease differences in infection of 15-day old seedlings were evident. Forty-day old seedlings developed 100% sheath blight, 66% sheath spot and 31 % aggregate sheath spot. At this stage the maximum diseased leaf and sheath area due to sheath blight, sheath spot and aggregate sheath spot were 31.5%, 3.90% and 1.01%, respectively hence sheath blight pathogen was more aggressive than the other two pathogens.

Chien and Chang (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 seven cultural type and six physiological races. Tu (1967) studied many strains from Taiwan and noted that strains with less aerial mycelium were more pathogenic. Akai *et al.* (1960) found, conversely, that strains with poor mycelium growth were less pathogenic. Isolates differing in virulence were also reported by Tsai (1973) among 40 single basidiospore cultures and Haque (1975) 25 field isolates.

Kim and Yang (1987) studied the cultural characteristics on PSA medium of 58 *R. solani* isolated from 7 sites grouped them into 7 culture types. They found only isolate type 1a at all sites. No isolate produced severe infection on all 9 test rice varieties used. There were significant differences between varieties in resistance and reaction to isolates and there was a variety x isolate interaction.

Lakshmanan and Nair (1985) observed that isolates of *R. solani* from rice and cowpea were similar in their pathogenicity to 14 test plants and both produced similar symptoms on rice. An isolate from Jack (bean: *Canavalia ensiformis)* produced only very mild symptoms on rice. The cultivation of cowpea as a fallow crop in a rice cropping system could aggravate the problem of sheath blight disease, caused by *R. solani.*

Ali (2002) isolated 30 isolates of *R. solani* from different parts of Bangladesh and studied population diversity using multidisciplinary approaches such as biochemical, molecular diagnostic techniques and pathogenicity test. He found that considerable diversity exists among the *R. solani* isolates and he separated the isolates into 2-3 groups.

2.6 Interaction of fungal pathogens

Akter *et al.* (2003) observed that combined inoculation with the three pathogens (*R. solani, R. oryzae-sativae* and *R. oryzae*) evidenced the highest disease severity. Sheath blight was maximum when rice plant were inoculated with *R. solani* solely or combined with any other two species. *R. oryzae-sativae* has the moderate potential with respect to disease development. The least or no disease was found when rice plant was inoculated with *R. oryzae*. Sheath blight severity was reduced significantly when the plant was inoculated *with R. oryzae* five days before inoculation with *R. solani*. It indicated antagonistic effect of *R. oryzae* against *R. solani* and *R. oryae-sativae* did not show any antagonistic effect against *R. solani*.

Katan *et al.* (2002) studied the interactions of soil-borne pathogens with roots and aboveground plant organs and observed that most cultivated crops are susceptible to one or more soil-borne plant pathogens and might become diseased if appropriate conditions exist. Examples of soil-borne plant pathogens of economic importance are species or pathotypes of the fungi *Aphanomyces, Armillaria, Sclerotium, Gaeumannomyces, Fusarium, Macrophomina, Phytophthora, Pythium,* and *Verticillium*. The types of diseases caused by soil-borne plant pathogens; characteristics of soil-borne plant pathogens and other soil microorganisms are discussed.

Agarwal *et al.* (1977) found *Trichoderma harzianum* as antagonistic against *Sclerotium rolfsii*. They reported that filtrates of *Trichoderma viride* inhibited the growth of *S. rolfsii* on PDA. In pot trial the antagonist controlled seedling death. Culture was more effective when applied to seed rather than soil.

Deshmukh and Raut (1992) observed that *T. harzianum* and *T. viride* overgrew the colonies of *Fusarium oxysporum, Rhizoctonia bataticola* (*Macrophomina phaseolina*), *F. moniliforme* (*Gibberella fujikuroi*), *Collectotrichum gloeosporioides* (*Glomerella cingulata*) and *Curvularia lunata* (*Cochliobolus* *lunatus*). *T. harzianum* was found more aggressive than *T. viride*. In pot trials, *T. harizanum* was effective against *F. oxysporum* in a 1: 1 mixture.

Xu *et al*. (1993) studied the antagonism of *T. harzianum* against soil borne fungi. They observed *T. harzianum* inhibited hyphal growth of soil fungi such as *Fusarium, Penicillium* and *Aspergillus*. Anggraeni and Suharti (1994) recorded that *Trichoderma* was highly antagonistic towards soil inhibiting fungi (*Fusarium, Rhizoctonia* and *Corticium*) causing root and stem rot, and leaf spot disease in forest plantation in Java.

Begum *et al.* (1999) carried out an experiment on the bio-control potential of *T. harzianum* against foot and root rot causing pathogen (*Fusarium oxysporum* and *S. rolfsii*) of food legumes *in vitro* and glass house condition. Interaction among the isolates of *T. harzianum* and the isolates of *F. oxysporum* on PDA resulted that *T. harzianum* inhibited the growth of *F. oxysporum* and also lysed mycelia of *F. oxysporum* out of the ten isolates of *T. harzianum*. The degree of antagonistic activity of *T. harzianum* increased with increasing time. Treatments of legume seeds with conidia of *T. harzianum* (2 x 10^6 conidia/seed) were found to show profound effect in reduction of seed borne *F. oxysporum*.

Inamul and Khan (2000) investigated the interaction of ten fungal isolates from root rot affected cotton plant. They found that *Trichoderma* sp. was the most antagonist against *A. flavus* and *Curvularia* sp. They also observed that *A. flavus* markedly affected the mycelial growth of *Curvularia* sp.

Manka *et al.* (2001) observed that communities of saprotrophic soil fungi could exert considerable effect on growth of soil borne pathogens. They found that soil borne pathogen (*Fusarium* sp.) inhibited the growth of *Aspergillus* sp.

Chapter 3

Materials and Methods

Chapter III

MATERIALS AND METHODS

Two experiments were conducted both in laboratory and experimental field of Plant Pathology Division of Bangladesh Rice Research Institute (BRRI), Gazipur during the period of Boro season 2005- 2006 to study the interaction, disease incidence and severity of three species of *Rhizoctonia*. The materials and methods of these two experiments are presented in this chapter under the following headings -

3.1 *In-vitro* studies on the antagonism among *Rhizoctonia solani, Rhizoctonia oryzae and Rhizoctonia oryzae-sativae*

The experiment was conducted to find out the antagonistic effect among the three *Rhizoctonia* species under the laboratory condition of Bangladesh Rice Research Institute (BRRI), Gazipur during the period of November 2005.

Culture of *R. solani* (Plate 1), *R. oryzae* (Plate 2) *and R. oryzae-sativae* (Plate 3) collected from BRRI, Gazipur. The antagonism among the three fungal pathogens was studied in dual culture in PDA media. A total of 30 petridishes containing PDA media was used for this study.

Ten petridishes were used for the study of each interaction in dual culture. The interaction between *R. solani* verses *R. oryzae*, *R. oryzae* verses *R. oryzae-sativae* and *R. solani* verses *R. oryzae-sativae* were studied.

Two fungal blocks either from *R. solani* and *R. oryzae* or *R. solani* and *R. oryzae-sativae* or *R. oryzae* and *R. oryzae-sativae* was placed in two opposite corners of the petridishes after 6 hours of pouring of PDA media. Radial growth was measured after 48 hours of inoculation of two pathogens in dual culture and it was continued up to 96 hours. Radial growth (mm), time required to fusion and overlapping fungi were recorded in this experiment.

The colony growth ratio (CGR) of test fungi was calculated with the following formula:

Colony growth ratio (CGR) = redial growth of *R. solani* or *R.oryzae-sativae* isolates/Radial growth of *R. oryzae* or *R.oryzae-sativae* isolate.

3.2 Interaction effect among *Rhizoctonia solani*, *Rhizoctonia oryzae* and *Rhizoctonia oryzae-sativae* on the disease incidence, severity and yield of rice

3.2.1 Experimental site

The present piece of research work was conducted to study the interaction among *R. solani*, *R. oryzae* and *R. oryzae-sativae* causing sheath diseases of rice in experimental field of Plant Pathology Division of Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh during the period of November 2005 to May 2006.

3.2.2 Characteristics of soil

The soil of the experimental area was loamy and belongs to the Madhupur tract (UNDP, 1988) under AEZ 28. The selected plot was medium high land. The characteristics of the soil under the experimental plot were analyzed and details of the soil characteristics are presented in Appendix I.

3.2.3 Weather condition of the experimental site

Details of the metrological data of air temperature, relative humidity, rainfalls and sunshine during the period of the experiment was collected from the Weather Station of Bangladesh Rice Research Institute, Gazipur and have been presented in Appendix II.

3.2.4 Selection of cultivar

A high yielding but normally sheath blight susceptible cultivar BRRI dhan29 was selected for this experiment.

Plate 1. Colony of *R. solani* in PDA media

Plate 2. Colony of *R. oryzae* in PDA media

Plate 3. Colony of *R. oryzae-sativae* in PDA media

3.2.5 Seed bed preparation and raising of seedlings

A small piece of medium low land at BRRI Gazipur was selected for raising seedlings. The land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth condition. The land was marshy and no fertilizers were applied to the seed bed. Clean and healthy matured seeds were soaked in tap water for 24 hours and incubated for 48 hours for germination before sowing in the seed bed which was earlier prepared.

3.2.6 Treatments

The experiment was conducted to determine the interaction among *R. solani*, *R. oryzae* and *R. oryzae-sativae* on the disease incidence, severity and yield of rice during Boro season (November 2005 to May 2006). Eight treatments were maintained under natural field condition. The treatments are given below –

T_1 : *Rhizoctonia solani* + *Rhizoctonia oryzae* + *Rhizoctonia oryzae-sativae*

T_2 : *Rhizoctonia oryzae* + *Rhizoctonia oryzae-sativae*

T_3 : *Rhizoctonia solani* + *Rhizoctonia oryzae*

T_4 : *Rhizoctonia oryzae-sativae* + *Rhizoctonia oryzae*

T_5 : *Rhizoctonia solani* alone

T_6 : *Rhizoctonia oryzae* alone

T_7 : *Rhizoctonia oryzae-sativae* alone

T_8 : Control (non-inoculated)

3.2.7 Layout of the experiment

The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment is shown in Figure 1. There were total of 24 plots, each measuring 2 m × 3 m. The 8 treatments of the experiment were assigned at random into 8 plots of each replication. The distance between two plots was 50 cm and between blocks was 75 cm.

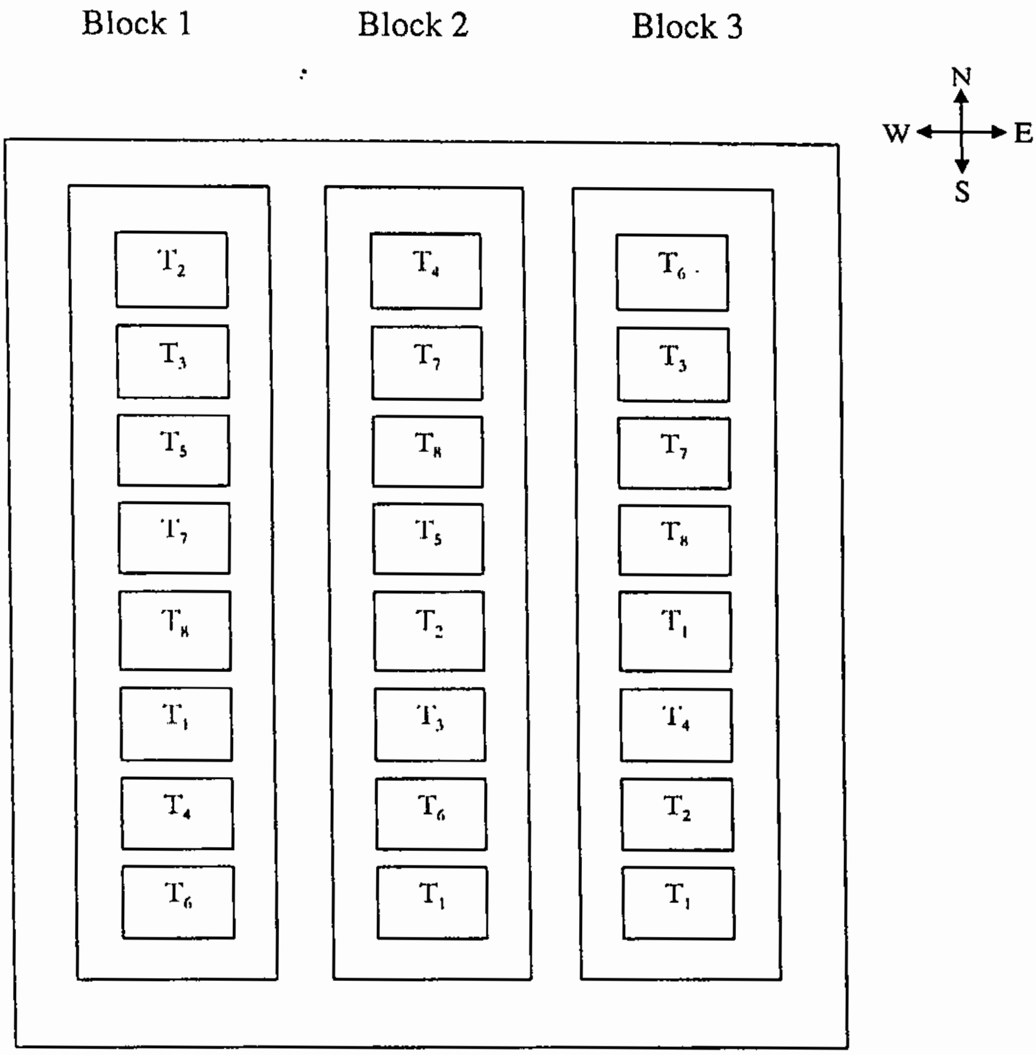

Figure 1. Layout of the experimental plot

3.2.8 Land preparation

The plot selected for the experiment was opened in the last week of January 2006 with a power tiller, and was exposed to the sun for a week, after one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth condition. Weeds and stubbles were removed, and finally obtained a desirable tilth of soil for transplanting of rice seedlings. The experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in 3.2.7. Recommended doses of well-rotten cowdung manure and chemical fertilizers as indicated in 3.2.9 were mixed with the soil of each unit plot.

3.2.9 Application of fertilizer

The sources of fertilizers used for N, P, K, S and Zn were urea, TSP, MP, Gypsum and zinc sulphate were applied, respectively. The entire amounts of TSP, MP, Gypsum and Zinc sulphate were applied during the final preparation of land. Urea was applied in three equal installments at 15, 35 and 55 days of transplanting. The dose and method of application of fertilizer are shown in Table 1.

Table 1. Dose and methods of application of fertilizers in rice field

Fertilizers	Dose (kg/ha)	Application (%) top dressing			
		Basal	First	Second	Third
Urea	299	0	33.33	33.33	33.33
TSP	77	100	--	--	--
MP	80	100	--	--	--
Gypsum	55	100	--	--	--
Zinc sulphate	5	100	--	--	--

Source: Adhunik Dhaner Chash, 2003.

3.2.10 Transplanting of seedling in the main field

After preparing the land 40 days old seedlings of BRRI dhan29 were uprooted carefully to avoid root injury. The seedlings were transplanted in the experimental plot 8th February 2006 using 2-3 seedlings/hill. The distance between hill to hill and row to row were 20 cm.

3.2.11 Intercultural operation

After transplanting various intercultural operations were accomplished for better growth and development of rice.

3.2.12 Evaluation of sheath disease incidence and severity

Percent tiller infection and percent relative lesion height (%RLH) for all the three diseases were recorded at flowering, hard dough and maturity stage.

3.2.13 Inoculation of pathogens

Cultures of *R. oryzae*, *R. solani* and *R. oryzae sativae* were grown in rice: rice hull medium was used as inocula. At maximum tillering stage, 15 central hills of each plot were inoculated with 10 days old culture of *R. solani*, *R. oryzae* and *R. oryzae-sativae* on rice: rice hull medium in different combinations. Each hill was inoculated by 50 gm of inocula. Altogether 8 treatments including uninoculated control were maintained in the experiment.

3.2.14 Data recording

The crop was harvested at full ripening stage on 22 May 2006. Previously selected 20 hills were harvested from each plot. Data on following characters were recorded at different growth stages of rice on the following parameters :

a. Infected tiller (%)

b. Relative lesion height (%)

c. Effective tiller/hill

d. Panicle length (cm)

e. Filled grain/panicle

f. Unfilled grain/panicle

g. Spikelet/panicle

h. 1000-grain weight (g)

i. Yield (t/ha)

3.2.15 Analysis of data

The data obtained for different characters were statistically analyzed to find out the significance of the difference among the treatments. The mean values of all the characters were evaluated and analysis of variance was performing by the 'F' (variance ratio) test. The significance of the difference among the treatments means was estimated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4
Results

Chapter IV

RESULTS

Two experiments were conducted both in laboratory and experimental field of Plant Pathology Division of Bangladesh Rice Research Institute (BRRI), Gazipur during the period of Boro season, 2005- 2006 to study the interaction among three species of R*hizoctonia* namely, R*hizoctonia solani, Rhizoctonia oryzae and Rhizoctonia oryzae-sativae* and disease incidence and severity of rice sheath diseases caused by them. The analysis of variance (ANOVA) of the data is given in Appendix III to IV. The results have been presented and discussed here in the following headings:

4.1 *In-vitro* studies on the antagonism among *Rhizoctonia solani, Rhizoctonia oryzae and Rhizoctonia oryzae-sativae*

In laboratory condition, the antagonism among *R. solani* (Rs), *R. oryzae* (Ro) *and R. oryzae-sativae* (Ros) were studied in dual culture method. For all the cases, it was found that the increasing of time (48-96 hours), radial growth also increased (plate 4, plate 5 and plate 6). In case of Rs vs Ro interaction, it was found that the mean radial growth of Rs was always higher than the growth of Ro starting from 48 hours to 96 hours (Table 2).

In case of Rs vs Ros interaction, it was recorded that the increasing of time increased the radial growth for both Rs and Ros and the growth of Rs was always higher than Ros. In Ro vs Ros interaction, it was recorded that in progressing of time radial growth for both Ro and Ros also increased and but the growth rate of Ro was always similar to Ros. The radial growth rate of Rs, Ro and Ros was not inhibited in dual culture in comparison with Rs, Ro and Ros alone, respectively. In interactions, Rs vs Ro and Rs vs Ros, the colony growth ratios (CGR) of Rs over Ro and Ros were higher compared to control at 72 and 90 hrs after inoculation while the CGR of Ros over Ro was not increased

Table 2. Antagonism effect among *R. solani*, *R. oryzae*, *R. oryza- sativae* under laboratory condition

Interaction / Time	Rs vs Ro (mm)			Rs vs Ros (mm)			Ro vs Ros (mm)			Control					
	Rs	Ro	CGR (Rs / Ro)	Rs	Ros	CGR (Rs / Ros)	Ro	Ros	CGR (Ros / Ro)	Rs alone (mm)	Ro alone (mm)	Ros alone (mm)	CGR (Rs/ Ro)	CGR (Rs/ Ros)	CGR (Ros/ Ro)
48 hours	45.5	14.8	3.07	40.9	15.7	2.61	16.1	17.2	1.07	44.2	15.0	16.4	2.95	2.63	1.06
72 hours	54.0	17.7	3.05	52.5	20.9	2.51	32.0	34.9	1.09	53.3	32.8	35.1	1.60	2.12	1.07
96 hours	59.5	19.0	3.13	58.4	24.1	2.42	35.2	38.0	1.07	58.9	35.5	38.3	1.66	1.54	1.08

Colony growth ration (CGR)= Radial growth of fast growing fungus/Radial growth of slow growing fungus;

Rs- *R. solani*, Ro- *R. oryzae*, Ros- *R. oryzae sativae*

Vs- Versus

in interaction compared to control at three different time intervals. The higher colony growth ratio compared to control indicated the higher antagonistic effect. Rs showed antagonistic effect on Ro and Ros at 72 and 96 hrs respectively. On the other hand, Ros did not show any antagonistic effect on Ro (Table 2).

In Rs vs Ro and Rs vs Ros interactions, Rs fused with Ro and Ros within 24 hrs and was slightly overlapping on Ro and Ros respectively at 72 hrs (Plate 4 and 5). Both Ro and Ros were comparatively slow growing fungi. Ro fused with Ros at 96 hrs but no overlapping was recorded within this period (Plate 6) (Table 3).

Table 3. Time required for fusion and overlapping among *Rhizoctonia solani* (Rs), *Rhizoctonia oryzae* (Ro) *and Rhizoctonia oryzae-sativae* (Ros)

Interactions	Time required for fusion (hr)	Overlapping of fungus at 96 hrs
Rs vs Ro	24	Rs slightly overlapping on Ro
Rs vs Ros	24	Rs slightly overlapping on Ros
Ro vs Ros	96	No overlapping

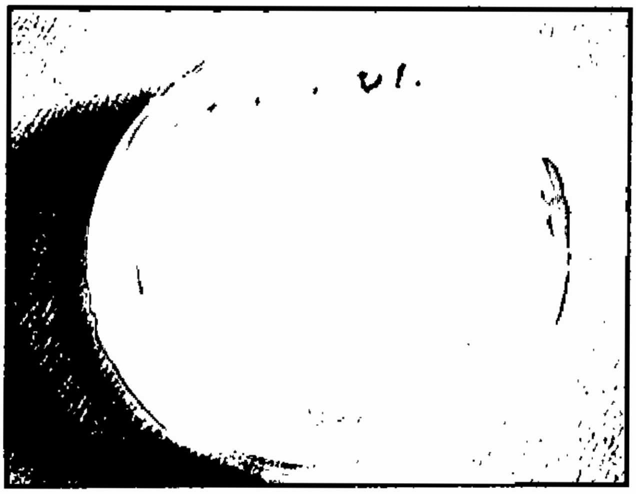

Plate 4. Interaction between *R.* solani and *R.* oryzae at 72 hrs in dual culture

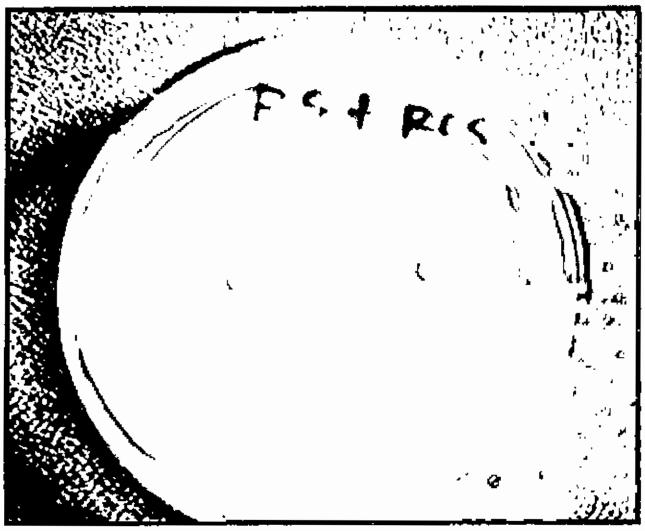

Plate 5. Interaction between *R. solani* and *R. oryzae-sativae* at 72 hrs in dual culture

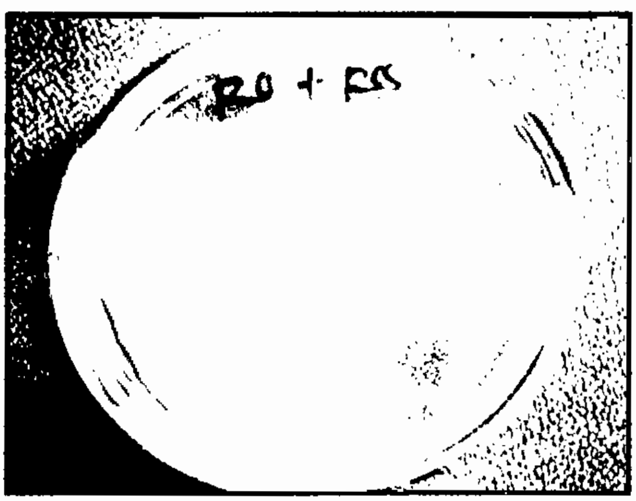

Plate 6. Interaction between *R. oryzae* and *R. oryzae-sativae* at 72 hrs in dual culture

4.2 Interaction among *Rhizoctonia solani, Rhizoctonia oryzae* and *Rhizoctonia oryzae-sativae* on the disease incidence, severity and yield of rice

4.2.1 Effect of treatments

4.2.1.1 Disease severity and incidence of sheath blight

The percentages of RLH and infected tiller had significant variations among *R. solani* (Rs), *R. oryzae* (Ro) *and R. oryzae-sativae* (Ros) and also their different combinations, (Table 4 and appendix IV). The highest % RLH (55.08%) was recorded in treatment, Rs alone which was statistically identical (53.73%) in treatment Rs+Ros+Ro and in consideration of % infected tiller, the highest (60.07%) was recorded in the same treatment, Rs alone. On the other hand the lowest % RLH (31.06%) was recorded in treatment Ros+Ro which was statistically insignificant (31.91%) with control and in case of % infected tiller, the lowest (7.29%) was recorded in Ros+Ro treatment which was statistically similar (7.66%) with control condition (Table 4).

Plate 7. Symptom caused by *R. solani* on rice cultivar BRRI dhan 29

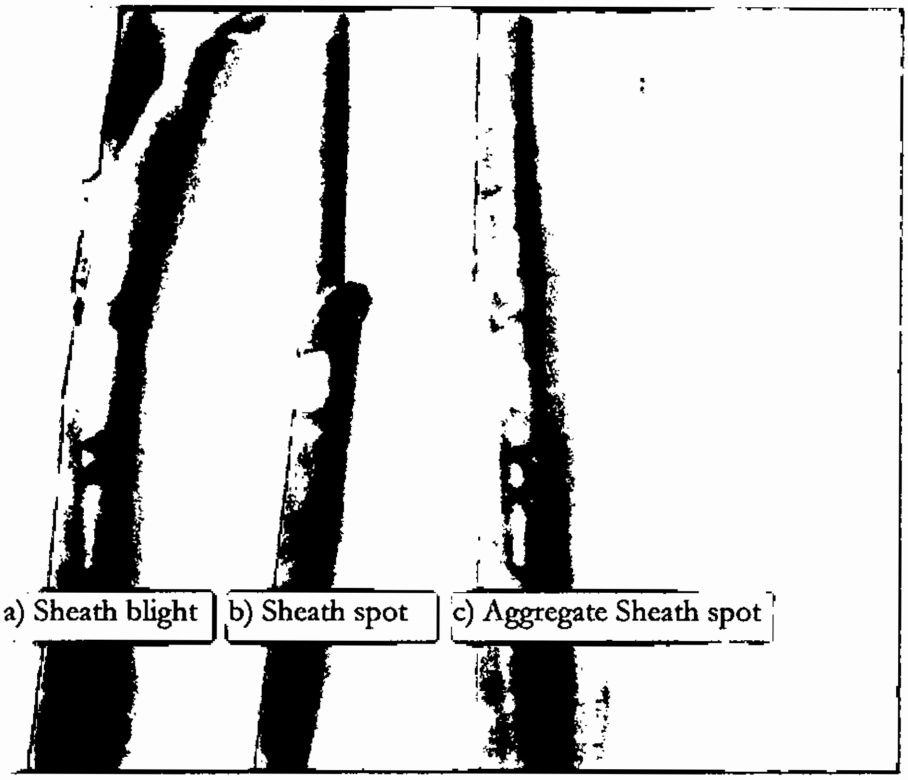

Plate 8. Showing the symptoms of a) Sheath blight b) Sheath spot and c) Aggregate sheath spot on rice cultivar BRRI dhan 29

Table 4. Effect of treatments on % RLH and % infected tiller on sheath blight, sheath spot and aggregated sheath spot

Treatment	Sheath blight		Sheath spot		Aggregate sheath spot	
	%RLH	% infected tiller	%RLH	% infected tiller	%RLH	% infected tiller
Rs+Ros+Ro	53.73 ab	41.29 b	31.19 b	12.17 b	34.99 b	12.57 b
Rs+Ros	50.52 bc	47.03 b	14.54 c	2.69 c	31.86 c	10.64 c
Rs+Ro	47.54 cd	57.06 a	31.43 b	19.79 a	0.00 e	0.00 e
Ros+Ro	31.06 f	7.29 d	30.55 b	10.12 b	34.32 bc	12.03 bc
Rs alone	55.08 a	60.07 a	0.00 d	0.00 c	0.00 e	0.00 e
Ro alone	42.12e	15.25 c	37.02 a	20.97 a	20.01 d	6.49 d
Ros alone	45.63 d	20.07 c	0.00 d	0.00 c	44.06 a	22.75 a
Control	31.91 f	7.66 d	0.00 d	0.00 c	0.00 e	0.00 e
LSD	3.445	6.70	3.832	3.255	3.023	1.723

In a column mean followed by a common small letter (s) are not different significantly at 5% level by LSD.

(Rs-*R. solani*, Ro-*R. oryzae* and Ros-*R. oryzae-sativae*)

4.2.1.2 Disease severity and incidence of sheath spot

In case of % RLH and infected tiller for sheath spot, statistically significant variations were recorded among *R. solani* (Rs), *R. oryzae* (Ro) *and R. oryzae-sativae* (Ros) and also their different combinations (Table 4 and appendix IV). The highest % RLH for sheath spot (37.02%) was recorded in treatment Rs alone which was closely followed by treatment, Rs+Ro (31.43%). In case of infected tiller, the highest (20.97%) was recorded in treatment Ro alone which was statically identical (19.79%) with the treatment Rs+Ro. On the other hand lower % RLH for sheath spot (0.00%) was recorded in treatments Rs alone, Ros alone and control condition. No infected tiller (0.00%) was recorded for Rs alone, Ros alone and control condition (Table 4).

4.2.1.3 Disease severity and incidence of aggregate sheath spot

In aggregate sheath spot, % RLH and infected tiller were statistically significant among *R. solani* (Rs), *R. oryzae* (Ro) and *R. oryzae-sativae* (Ros) and also their different combinations which was applied as treatments (Appendix IV). The highest % RLH (44.06%) and infected tiller (22.75%) for aggregate sheath spot were recorded in treatment. On the other hand, the lowest % RLH in aggregate sheath spot (0.00%) was recorded for treatments Rs+Ro, Rs alone and also control. In case of % infected tiller, the lowest (0.00%) was recorded from Rs+Ro, Rs alone, Ros alone and control condition (Table 4).

4.2.2 Effect on growth stage

42.2.1 Disease severity and incidence of sheath blight

In case of % RLH and infected tiller for sheath blight, statistically significant variations were found among the growth stages (Table 5 and appendix IV). The highest % RLH (66.06%) was recorded at maturity followed by hard dough (44.69%) and flowering stage (23.37%). The percentage of infected tiller followed the same trend (Table 5).

Table 5. Effect of growth stage on % RLH and % infected tiller on sheath blight, sheath spot and aggregated sheath spot

Growth stage	Sheath blight		Sheath spot		Aggregate sheath spot	
	% RLH	% infected tiller	% RLH	% infected tiller	% RLH	% infected tiller
Flowering	23.37 c	20.03 c	11.51 c	5.46 c	11.51 c	5.46 c
Hard dough	44.69 b	31.77 b	20.50 b	8.04 b	20.50 b	8.04 b
Maturity	66.06 a	44.10 a	29.96 a	10.68 a	29.96 a	10.68 a
LSD	1.211	1.074	1.022	0.298	0.775	0.577

In a column mean followed by a common small letter (s) are not different significantly at 5% level by LSD.

4.2.2.2 Disease severity and incidence of sheath spot

In consideration of % RLH and infected tiller for sheath spot, statistically significant variations were found among the growth stages. The highest % RLH (29.96%) was recorded at maturity stage while in % infected tiller (10.68%) was also in the same stage. Again the lowest % RLH (11.51%) was recorded at flowering stage while % infected tiller was the lowest (5.46%) for the same stage (Table 5).

4.2.2.3 Disease severity and incidence of aggregate sheath spot

The percentages of RLH and infected tiller for sheath spot were statistically significant among the growth stages (Table 5 and appendix IV). The highest % RLH (29.96%) was recorded at maturity stage while % infected tiller was also the highest (10.68%) in the same stage. Again the lowest % RLH (11.51%) and infected tiller (5.46%) were recorded at flowering stage (Table 5).

4.2.3 Interaction between treatments and growth stages

4.2.3.1 Disease severity and incidence of sheath blight

In case of interaction between treatments and growth stages, a statistically significant variation was recorded for % RLH and infected tiller in sheath blight (Appendix IV). The highest % RLH (80.24%) was obtained in Rs+Ro treatment at maturity stage. On the other hand, at maturity stage, the highest % infected tiller (82.56%) was obtained in Rs alone (Figure 1). Again the lowest % RLH (17.68%) was recorded in Ros+Ro treatment at flowering stage while the lowest % infected tiller (5.25%) was recorded in control condition at flowering stage (Figure 2).

4.2.3.2 Disease severity and incidence for sheath spot

Interaction between treatments [*Rhizoctonia solani* (Rs), *Rhizoctonia oryzae* (Ro) *and Rhizoctonia oryzae-sativae* (Ros) and also their different combination] and growth stages was statistically significant for % RLH and infected tiller in sheath spot (Appendix IV). The highest % RLH (53.65%) was obtained in Ro alone treatment at maturity stage. On the other hand, % infected tiller was the highest (26.05%) in Ro alone at the same stage (Figure 3). Again the lowest % RLH (0.00%) was recorded from Ro alone, Ros alone and control condition for three stages while % infected tiller was the lowest (0.00%) in Ro alone, Ros alone and control condition for three stages (Figure 4).

4.2.3.3 Disease severity and incidence for aggregate sheath spot

A significant interaction effect between treatments [*R. solani* (Rs), *R. oryzae* (Ro) *and R. oryzae-sativae* (Ros) and also their different combination] and plant growth stages for % RLH and infected tiller of aggregate sheath spot was recorded (Appendix IV). The highest % RLH (65.71%) and infected tiller (30.23%) was recorded for Ros alone treatment at maturity stage (Figure 5). Again the lowest % RLH (0.00%) was recorded in Rs+Ro, Rs alone and control condition for three stages. In case of % infected tiller, the lowest (0.00%) was recorded in Rs+Ro, Ros alone and control condition for three stages (Figure 6).

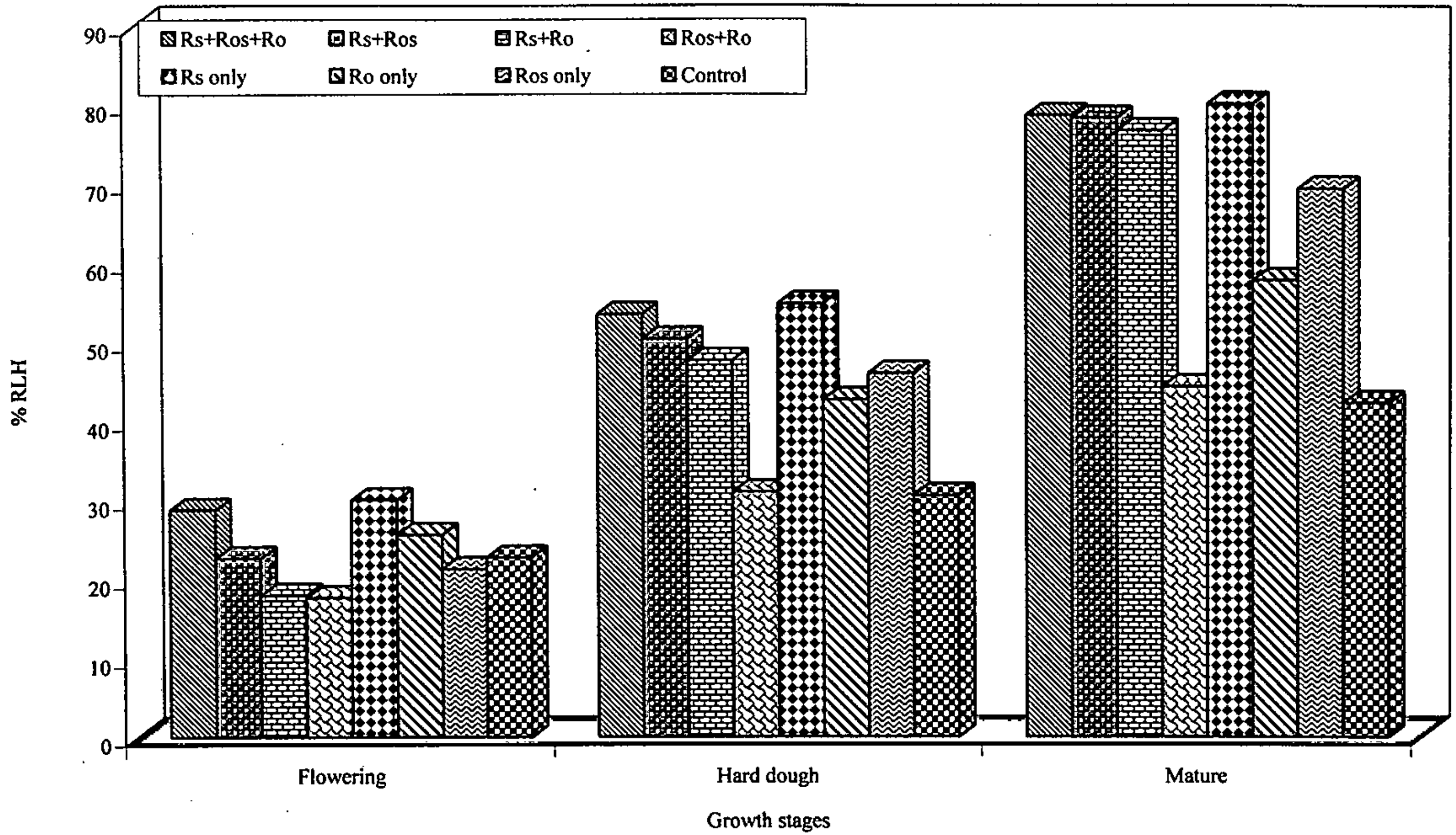

Figure 1. Interaction effect between treatments and growth stages on % RLH for sheath blight of rice (Rs: *R. solani*; Ro: *R. oryzae* and Ros: *R. oryzae-sativae*)

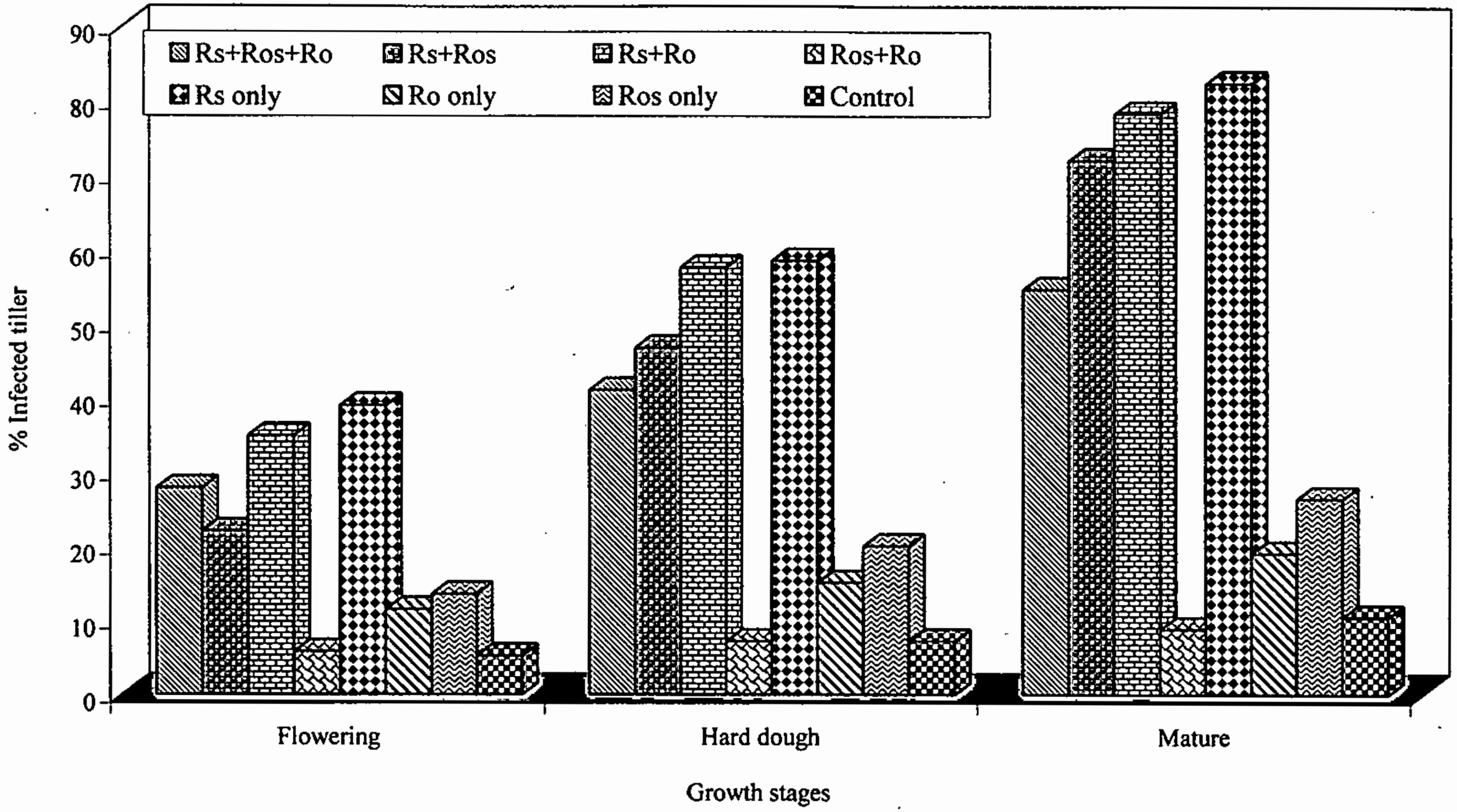

Figure 2. Interaction effect between treatments and growth stages on % infected tiller for sheath blight of rice (Rs: R. solani; Ro: R. oryzae and Ros: R. oryzae-sativae)

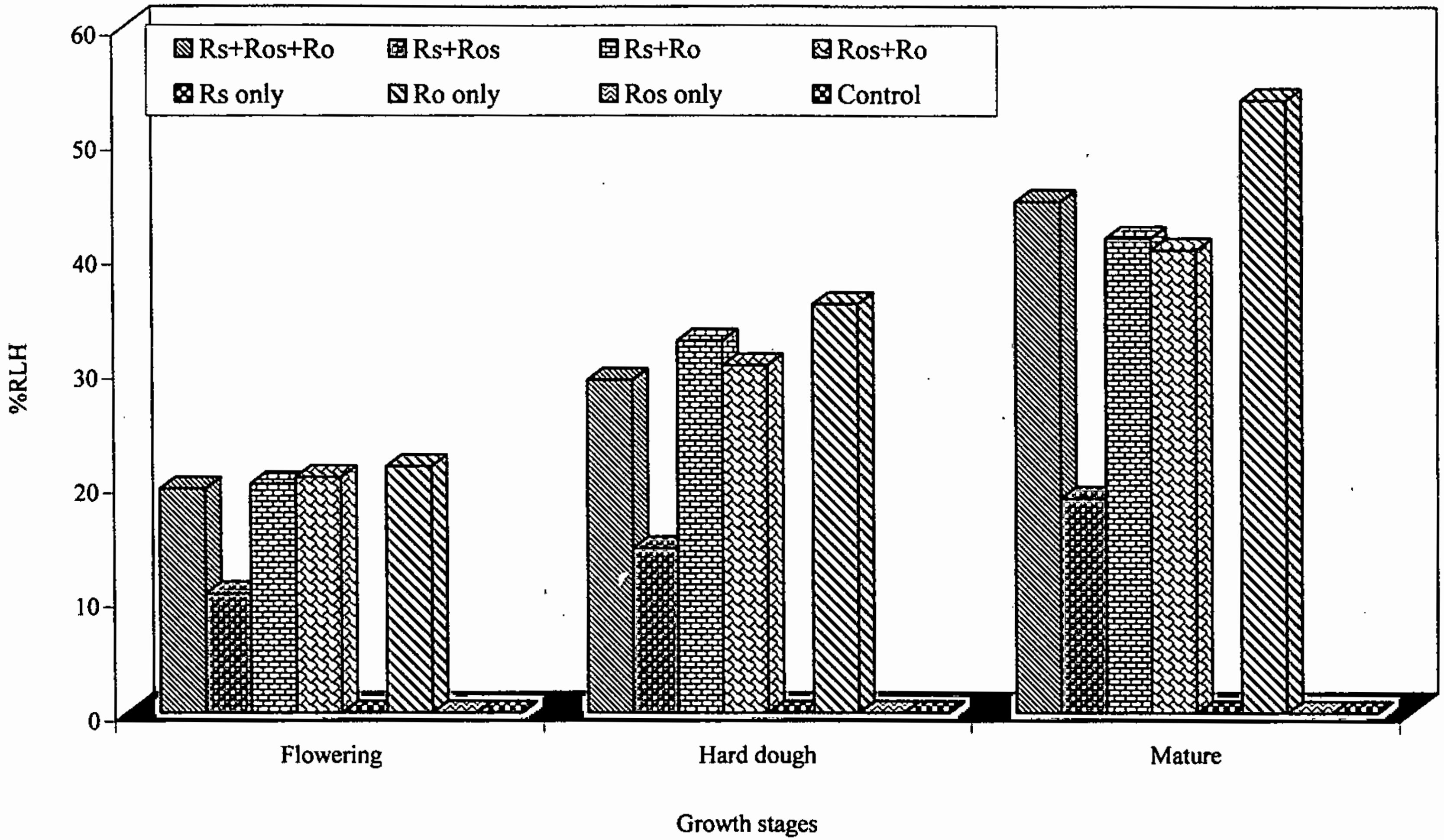

Figure 3. Interaction effect between treatments and growth stages on % RLH for sheath spot of rice (Rs: R. solani; Ro: R. oryzae and Ros: R. oryzae-sativae)

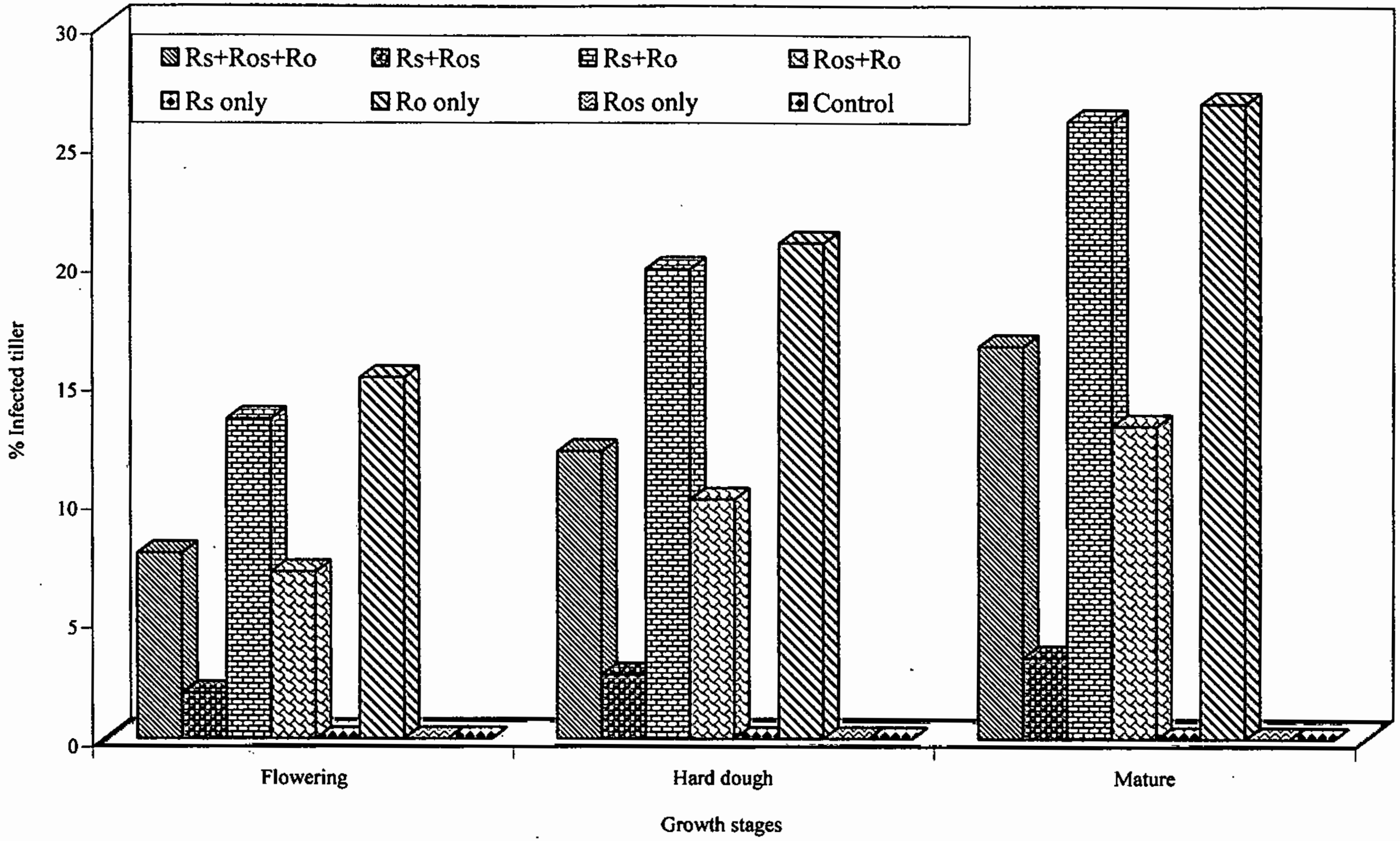

Figure 4. Interaction effect between treatments and growth stages on % infected tiller for sheath spot of rice (Rs: R. solani; Ro: R. oryzae and Ros: R. oryzae-sativae)

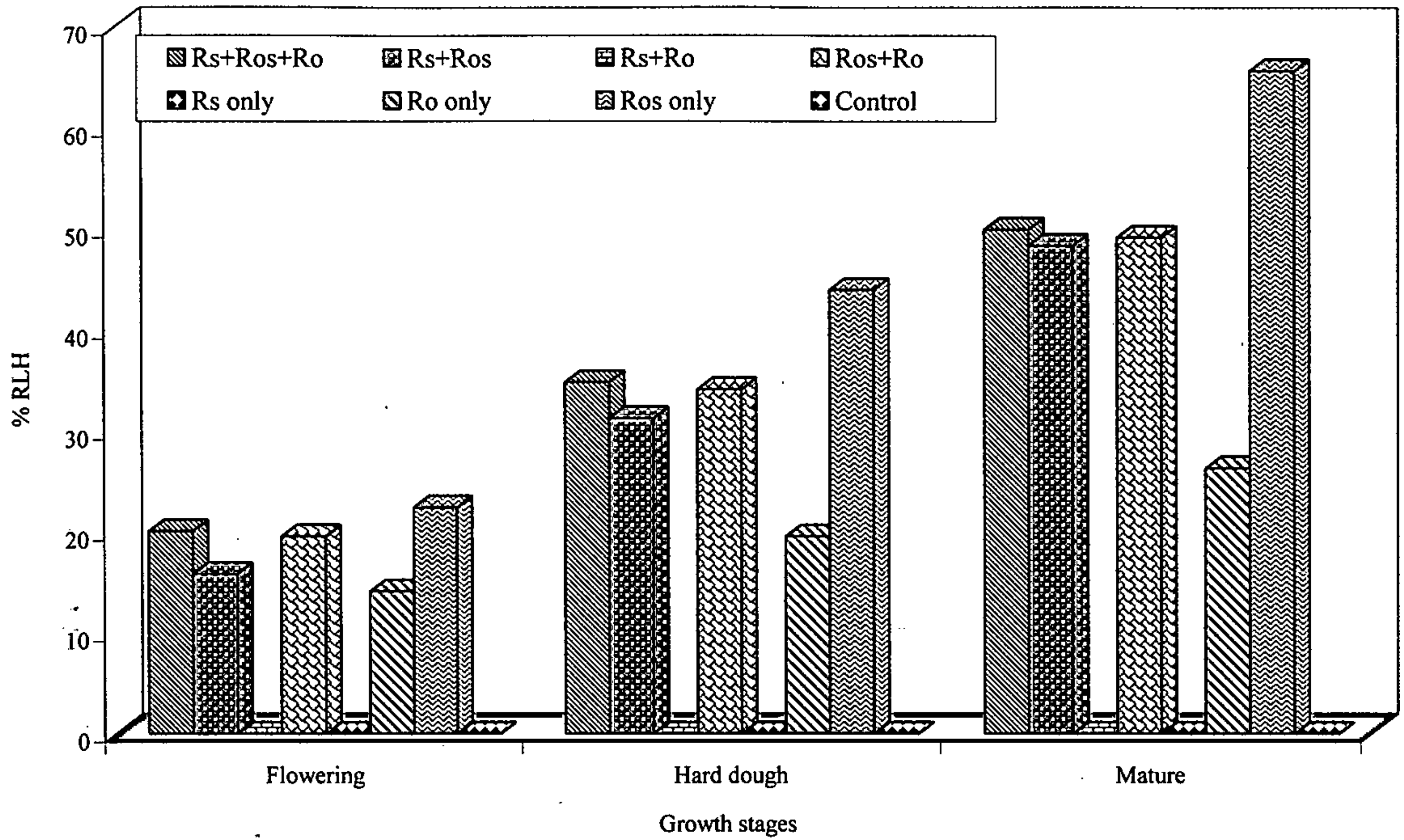

Figure 5. Interaction effect between treatments and growth stages on % RLH for aggregated sheath spot of rice
(Rs: R. solani; Ro: R. oryzae and Ros: R. oryzae-sativae)

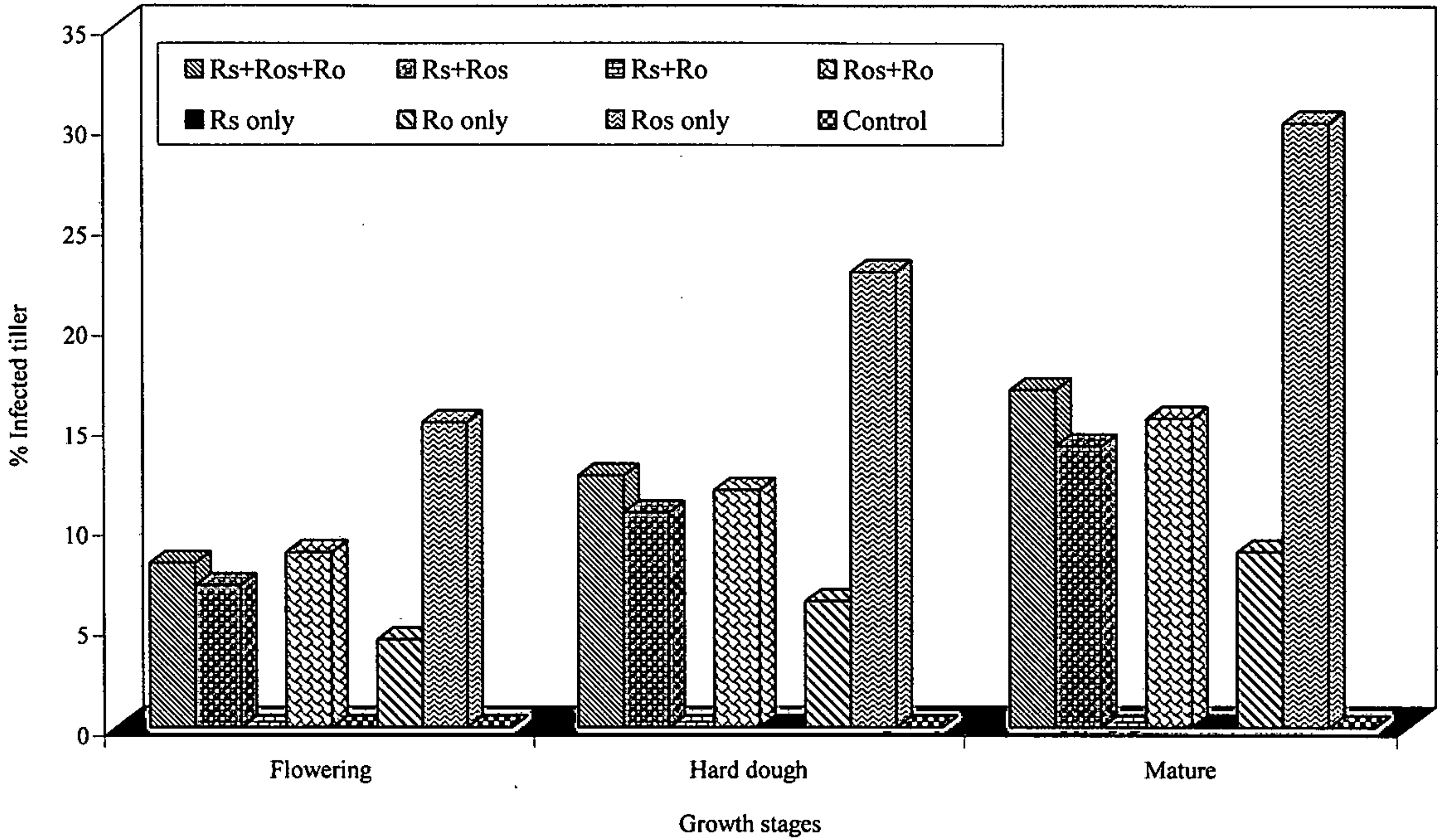

Figure 6. Interaction effect between treatments and growth stages on % infected tiller for aggregated sheath spot of rice (Rs: R. solani; Ro: R. oryzae and Ros: R. oryzae-sativae)

4.2.4 Yield contributing characters and yield

4.2.4.1 Effective tiller/m^2

In respect of effective tiller/m^2, there was no significant difference among *R. solani* (Rs), *R. oryzae* (Ro) and *R. oryzae-sativae* (Ros) and also their different combinations which were applied as treatments (Table 6 and Appendix IV). The number of effective tiller/m^2 varied from 406.33 to 335.67. The maximum effective tiller/m^2 (406.33) was recorded in Rs+Ros treatment which was closely followed by treatment Rs+Ro (405.33) and the minimum (335.67) was recorded in treatment Ro alone which was closely followed by Rs alone (336.33) (Table 6).

4.2.4.2 Panicle length (cm)

No significant variation was found among the treatments (Table 6). But the highest panicle length (24.67 cm) was recorded in control condition which was closely followed by treatment Ros+Ro and Rs+Ros treatment and the lowest panicle length (23.33 cm) was recorded in treatment, Ros alone (Table 6).

Table 6. Effect of three *Rhizoctonia* species on yield and yield contributing characters

Treatment	Effective tiller/m^2	Panicle length (cm)	Filled grain/ panicle	Unfilled grain/ panicle	Spikelet /panicle	1000 grain weight (g)	Yield	Yield loss (%)
Rs+Ros+Ro	368.33	23.67	81.67	69.33	151.00	22.00ab	3.07	18.13
Rs + Ros	406.33	24.00	83.33	53.67	137.00	21.66b	3.04	18.93
Rs + Ro	405.33	23.67	102.00	70.00	172.00	21.00b	3.23	13.86
Ros + Ro	371.33	24.33	99.67	73.67	173.33	22.33ab	3.69	1.60
Rs alone	345.00	23.67	86.33	78.00	164.33	22.00ab	3.06	18.40
Ro alone	336.00	23.67	84.33	74.00	158.33	22.00ab	3.72	0.80
Ros alone	335.67	23.33	82.00	86.33	168.33	22.00ab	3.72	0.80
Control	369.33	24.67	107.33	56.00	163.33	23.30a	3.75	--
LSD Value	94.97^{NS}	1.85^{NS}	38.05^{NS}	37.18^{NS}	61.04^{NS}	1.55	0.919^{NS}	--
CV (%)	14.77	2.84	23.91	21.79	15.59	2.89	15.78	--

(Rs-*R. solani*, Ro-*R. oryzae* and Ros-*R. oryzae-sativae*)

In a column mean followed by a common small letter (s) are not different significantly at 5% level by LSD; NS- Non significant

4.2.4.3 Filled grain/panicle

In case of filled grain/panicle, no statistically significant difference was recorded among the treatments. The number of filled grain/panicle varied from 81.67 to 107.33 (Table 6).

4.2.4.4 Unfilled grain/panicle

Unfilled grain/panicle had no significant variation among the treatments. The highest number of unfilled grain/panicle (86.33) was recorded in Ros alone treatment which was close to treatment Rs alone (78.00). On the other hand the minimum number of unfilled grain (53.67) was recorded in treatment Rs+Ros alone which was similar to control condition (56.00) (Table 6).

4.2.4.5 Spikelet/panicle

Spikelet/panicle had no significant variation among *R. solani* (Rs), *R. oryzae* (Ro) *and R. oryzae-sativae* (Ros) and also their different combinations. The number of spikelet varied from 137.00 to 168.33. The highest number of spikelet/grain (173.33) was recorded in Ros+Ro treatment which was similar to treatment Rs+Ro (172.00) (Table 6).

4.2.4.6 1000 grain weight (g)

A statistically significant variation was recorded among the treatments, *R. solani* (Rs), *R. oryzae* (Ro) and *R. oryzae-sativae* (Ros) and also their different combinations. The highest 1000 grain weight (23.30 g) was found in control condition. The lowest 1000 grain weight (21.00 g) was recorded in Rs+Ro treatment which were statistically similar with the treatment Rs+Ros (21.66) (Table 6).

4.2.4.7 Grain yield

In case of given yield there was no significant difference was found among the treatments. The grain yield varied from 3.04 to 3.84 t/ha. The highest grain yield (3.75 t/ha) was recorded in control condition and the minimum grain yield (3.04

t/ha) was recorded in treatment Rs+Ros (Table 6). The percent yield losses due to three species of *Rhizoctonia* and their different combination was varied. The higher percentages of yield losses (13.86-18.93) occurred in Rs or Rs+Ros or Rs+Ros+Ro treatment compared to other treatments. alone Rs and it's different combinations contributed yield losses of rice.

Chapter 5
Discussion

Chapter V

DISCUSSION

Subsequently two experiments were conducted both in laboratory and experimental field of Plant Pathology Division of Bangladesh Rice Research Institute (BRRI), Gazipur during the period of Boro season, 2005-2006 to study the interaction among disease incidence and severity of three species of *Rhizoctonia* namely, *R. solani, R. oryzae and R. oryzae-sativae.*

In laboratory condition, the interaction between *R. solani* versus *R. oryzae*, *R. solani* versus *R. oryzae-sativae* and *R. oryzae* versus *R. oryzae-sativae* was observed in dual culture and found that the radial growth of *R. solani* was always higher than the growth of *R. oryzae* and *R. oryzae-sativae* starting from 48 to 96 hours after inoculation. But the growth of *R. oryzae* or *R. oryzae-sativae* was more or less similar or followed by each other.

In *R. solani* versus *R. oryzae* and *R. solani* versus *R. oryzae-sativae* interactions, *R. solani* fused with *R. oryzae* or *R. oryzae-sativae* within 24 hours and was slightly overlapping on *R. oryzae* and *R. oryzae-sativae*, respectively at 96 hours. Both *R. oryzae* and *R. oryzae-sativae* were comparatively slow growing fungi. *R. oryzae* fused with *R. oryzae-sativae* at 96 hours but no overlapping was recorded within this period. In interactions, *R. solani* versus *R. oryzae* and *R. solani* versus *R. oryzae sativae,* the colony growth ratios (CGR) of *R. solani* over *R. oryzae* and *R. oryzae sativae* were higher compared to control at 72 and 90 hrs after inoculation while the CGR of *R. oryzae sativae* over *R. oryzae* was not increased in interaction, *R. oryzae* vs *R. oryzae sativae* at three different time intervals. The higher colony growth ratio compared to control indicated the higher antagonistic effect. *R. solani* showed antagonistic effect on *R. oryzae* and *R. oryzae sativae* at 72 and 96 hrs respectively, on the other hand, *R. oryzae sativae* did not show any antagonistic effect on *R. oryzae*. The antagonistic effect was reported earlier between *Rhizoctonia solani* with other soil borne fungi (Das and Hazarika, 2000; Bari *et al.* 2000; Sharma *et al.* 1999; Elad *et al.*, 1980, Vijayan *et al.*, 1994; Dev and Mary, 1986).

In case of % RLH and infected tiller, significant differences were found among *R. solani, R. oryzae and R. oryzae-sativae* and also their different combinations. The % RLH and infected tiller in sheath blight were higher in *R. solani* alone compared to other treatments. In case of aggregate sheath spot, %RLH and infected tiller were also higher in *R. oryzae-sativae* alone compared to mixed with both *R. solani* and *R. oryzae* or any of them. Similar trend was followed in sheath spot disease. This result corroborated with result of Akter *et al.* (2003) with respect to disease incidence.

The highest percentages of RLH and infected tiller were found at maturity followed by hard dough and flowering stage. The development of these three diseases was higher during the later stages of crop growth. This finding is accordance with the findings of Sharma and Teng (1996). Miah *et al.* (1984) reported that plant inoculated with inocula of *R. solani* at maximum tillering, panicle initiation, booting and flowering stages and control without inoculation indicated that sheath blight disease severity were significantly higher when inoculated at booting stage than inoculated at other stages.

The disease severity and incidence were also increased with increasing of plant growth after inoculation of *Rhizoctonia* species. Disease severity appeared high in dense canopy. The reasons for this matter may be the dense plant canopy with near to the soil developed favorable microclimate for disease development. Similarly the varieties with high tiller number help to increase plant population per unit area favoring microclimate for disease development. The above results explain that disease severity become high if the plant canopy becomes dense, increased tiller number per unit area related with high tiller number as reported by Kozaka (1961). Shahjahan *et al.* (1987) carried out an experiment and found that the rice variety is always susceptible to sheath blight and development of relative lesion height (RLH) and percent area infected (PAI) by *R. solani* and the influences was apparent alone at later stages of lesion development. These findings showed the similar results of the present investigation.

Interactions between treatments [*R. solani* , *R. oryzae* and *R. oryzae-sativae* and their different combinations] and growth stages for %RLH and infected tiller showed significant differences. The severity and incidence were greater in sheath blight, sheath spot and aggregate sheath spot, when *R. solani*, *R. oryzae* and *R. oryzae sativae* respectively inoculated alone. The severity and incidence of each disease were hindered very slightly by the inoculum mixed with three or two pathogens. Different growth stages of rice had showed same phenomenon. Our results slightly differed with the results of Akter *et al.* (2003). In her report, she mentioned that combined inoculation with the three pathogens (*R. solani, R. oryzae-sativae* and *R. oryzae*) evidenced the highest disease severity. Sheath blight was maximal when rice plant were inoculated with *R. solani* solely or combined with any other two species. *R. oryzae-sativae* has the moderate potential with respect to disease development. The least or no disease was found when rice plant was inoculated with *R. oryzae*. In the earlier, Minian (1984) established a linear relationship between different growth stages and sheath diseases causing *Rhizoctonia* spp. Shahjahan *et al.* (1990) found that the development of rice sheath blight caused by *R. solani* under different cultural condition. Plants appeared to the most susceptible at panicle initiation to booting stage with more severity in symptoms and extent of damage during Aus season. The rate of lesion length development is high during the three days immediately after initiation of infection and it decreased with time after infection.

No significant variation was recorded due to the interaction between *Rhizoctonia solani, Rhizoctonia oryzae and Rhizoctonia oryzae-sativae* and also their different combination on yield and yield contributing characters except a few cases. The highest (numerically) yield was recorded in control treatment. As the disease severity of three sheath diseases increased considerably in later rice growth stages (at maturity). So yield loss was not statistically significant as compared to control. These findings corroborate with the findings of several investigators in our country and abroad. (Anonymous, 1988, Tsai, 1974, and Miah *et al.*, 1983). They reported that severe yield loss occurred in sheath blight when pathogen attacks severely in vegetative or reproductive phage.

Ahn and Mew (1986) reported a relation between rice sheath blight and yield and no significant yield reduction was found when RLH was less than 20%. If lesion reached the 3rd sheath from the sheath bearing the flag leaf and if RLH was about 30% a significant yield loss was found. A 46% yield loss is possible in milled rice if sheath blight lesion reaches 90% of RLH.

Among the three diseases, the higher % of yield losses occurred when *R. solani* inoculated alone or mixed with both *R. oryzae sativae* and *R. oryzae* or any of them. Probably sheath blight caused by *R. solani* played a major role for causing yield loss of rice. A very little amount of yield losses occurred due to sheath spot and aggregate sheath spot respectively.

Chapter 6
Summary & Conclusion

Chapter VI

SUMMARY AND CONCLUSION

In order to find out the interaction effect among the three species of *Rhizoctonia* namely, *R. solani, R. oryzae and R. oryzae-sativae*, subsequently two experiments were conducted both in laboratory and experimental field of Plant Pathology Division of Bangladesh Rice Research Institute (BRRI), Gazipur during Boro season, 2005- 2006.

In laboratory condition, the antagonism among the three fungal pathogens was tested in dual culture method. The interaction between *R. solani* versus *R. oryzae*, *R. solani* versus *R. oryzae-sativae* and *R. oryzae* versus *R. oryzae-sativae* was observed in dual culture in petridishes and found that the radial growth of *R. solani* was always higher than the growth of *R. oryzae* and *R. oryzae-sativae* starting from 48 to 96 hours period of time. But the growth of *R. oryzae* or *R. oryzae-sativae* was more or less similar or followed by each other.

In *R. solani* versus *R. oryzae* and *R. solani* versus *R. oryzae-sativae* interactions, *R. solani* fused with *R. oryzae* or *R. oryzae-sativae* within 24 hours and was slightly overlapping on *R. oryzae* and *R. oryzae-sativae*, respectively at 96 hours. Both *R. oryzae* and *R. oryzae-sativae* were comparatively slow growing fungi. *R. oryzae* fused with *R. oryzae-sativae* at 96 hours but no overlapping was recorded within this period. In interactions, *R. solani* versus *R. oryzae* and *R. solani* versus *R. oryzae sativae*, the colony growth ratios (CGR) of *R. solani* over *R. oryzae* and *R. oryzae sativae* were higher compared to control at 72 and 90 hrs after inoculation while the CGR of *R. oryzae sativae* over Ro was not increased in interaction, *R. oryzae* versus *R. oryzae sativae* at three different time intervals. The higher colony growth ratio compared to control indicated the higher antagonistic effect. *R. solani* showed antagonistic effect on *R. oryzae* and *R. oryzae sativae* at 72 and 96 hrs respectively, on the other hand, *R. oryzae sativae* did not show any antagonistic effect on *R. oryzae*.

In field experiment, eight treatments were tested under natural field condition. The treatments were *Rhizoctonia solani* + *Rhizoctonia oryzae* + *Rhizoctonia oryzae-sativae*, *Rhizoctonia oryzae* + *Rhizoctonia oryzae-sativae*, *Rhizoctonia solani* + *Rhizoctonia oryzae*, *Rhizoctonia oryzae-sativae* + *Rhizoctonia oryzae*, *Rhizoctonia solani* alone, *Rhizoctonia oryzae* alone, *Rhizoctonia oryzae-sativae* alone and control condition.

In case of % RLH and infected tiller, significant differences were found among the treatments. The % RLH and infected tiller in sheath blight were higher in *R. solani* alone compared to *R. solani*+*R. oryzae-sativae*+*R. oryzae*, *R. solani*+*R. oryzae* and *R. solani*+*R. oryzae-sativae* treatments. In case of aggregate sheath spot, %RLH and infected tiller were also higher in *R. oryzae-sativae* alone compared to mix with both *R. solani* and *R. oryzae* or any of them. Similar trend was followed in sheath spot disease.

The highest percentages of RLH and infected tiller were found at maturity followed by hard dough and flowering stage. The development of these three diseases was higher during the later stages of crop growth. Interactions between treatments and growth stages for %RLH and infected tiller showed significant differences. The severity and incidence were greater in sheath blight, sheath spot and aggregate sheath spot, when *R. solani*, *R. oryzae* and *R. oryzae sativae* respectively inoculated alone. The severity and incidence of each disease were hindered very slightly by the inoculum mixed with three or two pathogens in different growth stages of rice.

No significant variation was observed on yield and yield contributing characters except 1000 grain weight. The highest (numerically) yield was recorded in control treatment. Among the three diseases, the higher % of yield losses occurred when *R. solani* inoculated alone or mixed with both *R. oryzae sativae* and *R. oryzae* or any of them. Probably sheath blight caused by *R. solani* played a major role for causing yield loss of rice. A very little amount of yield losses occurred due to sheath spot and aggregate sheath spot respectively.

The findings of the present study indicated that *R. solani*, showed antagonistic effect on *R. oryzae-satiave* and *R. oryzae*. The severity and incidence of each disease were less when two or three pathogens inoculums were mixed in different growth stages of rice.

Considering the situation and limitations of the present investigation, further studies in the following areas may be suggested:

- Repetition of the same experiment is necessary to get definite conclusion.
- Regional trails may be performed in order to find out the location variation.
- Differences of cropping season may be evaluated.

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Appendices

APPENDICES

Appendix I. Results of mechanical and chemical analysis of soil of the experimental plot

Mechanical analysis

Constituents	Percent
Sand	33.50
Silt	60.20
Clay	6.20
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.08
Organic carbon (%)	1.3
Total nitrogen (%)	0.08
Available P (ppm)	20
Exchangeable K (%)	0.2

Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from November 2005 to May 2006

Month	Air temperature (^0C)		RH (%)		Total rainfall (mm)	Sunshine (hrs/day)
	Maximum	Minimum	9 am	2 pm		
November 05	29.5	18.7	76.1	59.6	5.2	7.0
December 05	27.5	14.4	73.1	52.6	0.0	7.5
January 06	25.5	12.4	78.8	45.9	0.0	6.7
February 06	31.1	18.4	76.0	45.3	0.0	7.2
March 06	33.6	20.1	67.8	39.8	0.0	8.4
April 06	33.6	22.8	77.7	61.0	95.2	7.6
May 06	34.0	24.8	77.3	62.8	465.0	6.4

Appendix III. Analysis of variance of the data on % RLH and % infected tiller on sheath blight, sheath spot and aggregated sheath spot pooled over three growth stages

Sources of variation	Degrees of freedom	Mean square					
		Sheath blight		Sheath spot		Aggregate sheath spot	
		%RLH	% infected tiller	%RLH	% infected tiller	%RLH	% infected tiller
Replication	2	2.335	17.335	0.356	19.153	11.260	1.982
Treatment (A)	7	755.61**	4305.8**	3149.1**	705.8**	3016.1**	586.2**
Error	14	11.613	44.433	14.362	10.364	8.938	2.581
Growth stage (B)	2	10933.8**	3477.4**	1760.9**	154.0**	2043.1**	163.6**
Interaction	14	157.49**	285.02**	254.56**	21.72**	228.46**	20.92**
Pooled error	32	4.240	3.335	3.022	0.256	1.739	0.963

** : Significant at 0.01 level of significance

Appendix IV. Analysis of variance of the data of three *Rhizoctonia* species on yield and yield contributing characters of rice

Sources of variation	Degrees of freedom	Mean square						
		Effective tiller	Panicle length (cm)	Filled grain/ panicle	Unfilled grain/ panicle	Spikelet /panicle	1000 grain weight (g)	Yield
Replication	2	1435.17	0.125	102.125	55.167	28.042	1.167	0.022
Treatment	7	2335.04	0.565	322.66	362.28	445.31	1.280*	0.256
Error	14	2941.31	0.458	472.125	233.976	630.61	0.405	0.143

* : Significant at 0.05 level of significance