Management of bacterial leaf blight of paddy (Oryza sativa L.) caused by Xanthomonas oryzae pv. oryzae

BY

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PLANT PATHOLOGY

DIVISION OF PLANT PATHOLOGY
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CERTIFICATE – I

This is to certify that the thesis entitled "***Management of bacterial leaf blight of paddy (Oryza sativa L.) caused by Xanthomonas oryzae pv. oryzae*** "submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Plant Pathology),** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu is a record of bonafide research, carried out by **Mr. Prem Chinabi Aryan,** Registration Number **J-14-M-389,** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that such help and assistance received during the course of thesis investigation have been duly acknowledged.

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CERTIFICATE – II

We, the members of Advisory Committee of, **Mr. Prem Chinabi Aryan** Registration No. **J-14 M-398,** a candidate for the degree of **Master of Science in Agriculture (Plant Pathology),** have gone through the manuscript of the thesis entitled "*Management of bacterial leaf blight of paddy (Oryza sativa L.) caused by Xanthomonas oryzae pv. oryzae*" and recommend that it may be submitted by the student in partial fulfillment of the requirements for the degree.

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Prem Chinabi Aryan

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CHAPTER – I

INTRODUCTION

Rice (*Oryza sativa* L.) is the principal staple food for more than two billion people, who live in rural and urban areas of tropical and subtropical Asia. Rice provides about 40 to 70 per cent of the calories consumed by these people (Hosain and Fischer, 1995). Cultivation of rice is an important source of income and employment generation in the rural areas of Asia (Hosain, 1997). Out of 732.0 million tons, of rice production in the world more than 90 per cent is produced and consumed in Asia (FAO, 2011). Rice is grown on millions of small farms with an average size ranging from 0.4 to 3.5 ha, primarily to meet family needs. China and India account for roughly 50 per cent of the world's total rice area and jointly produce 55 per cent of world's rice. There are a number of constrains in rice production among which diseases are the major factors. Bacterial leaf blight is one of the most important rice diseases.

India is the second leading producer of rice in the entire world, next to China with an annual rice production is 147.0 million tons in 42.24 million ha of cultivation (FAO 2011). Rice constitutes 52 per cent of the total food grain production and 60 per cent of the total cereal production in India (Anon.2010).The major rice growing states of India are West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Bihar, Orissa, Assam, and Karnataka. More than 50 per cent of the total rice production comes from the first four states (FCI 2010). Rice accounts for up to 60 per cent of the energy intake of 3 billion Asians (Guyer *et al*., 1998). Indian rice production target for the year 2025 is 140 million ton which can be achieved only by increasing rice production two million ton per year in the coming decade (Anon. 2006).

In Jammu division paddy occupies 116 thousand hectares leading to a yield of 3284 thousand quintals and productivity of 28.31 q/ha (Economic Survey J&K 2013-14). Bacterial leaf blight of paddy mostly appears in lower belt of Jammu region, particularly basmati rice cultivated areas. This disease also causes significant crop loss in the state (Gupta, *et al*. 2012). More than 70 diseases caused by fungi, bacteria, viruses and nematodes are among the most important limiting factors that affect rice production (Song and Goodman, 2001). Rice crop is prone to number of bacterial diseases among which bacterial leaf blight caused by *X. oryzae pv. oryzae* is a serious problem and threat to rice production in both tropical and temperate rice growing regions due to its high epidemic potential (Mew,1987). The disease occurs in the host plant at the seedlings, vegetative and reproductive stages but bacterial leaf blight infection at the tillering stage causes severe blighting of leaves resulting in yield loss up to 75 per cent depending on weather, location and particular rice cultivar used (Ou, 1985).

In India it is a severe problem during the monsoon season. In this season the pathogen spreads rapidly and loss may be up to 6 to 84 per cent in tropical Asia, depending on habitat, climate and variety or cultivar used. According to Liu (2006), loss at the tillering stage by bacterial leaf blight is 50% and yield increases from 10 to 20 per cent (Thind and Bala 2002). Bacterial leaf bilght under mild infection causes yield reduction ranging from 10-12 per cent (Mew *et al.*, 1993) whereas under severe condition, it can be as high as 50 per cent (Ou, 1985).

Keeping in view the importance of the disease, socio economic status of the crop, the losses inflicted to the farmers in terms of remuneration and inadequate research work carried on the disease in the state, the present study was unsertaken with the following objectives:

1. Screening of rice germplasm against bacterial leaf blight of paddy.
2. To work out suitable management strategy against bacterial leaf blight of paddy in Jammu.

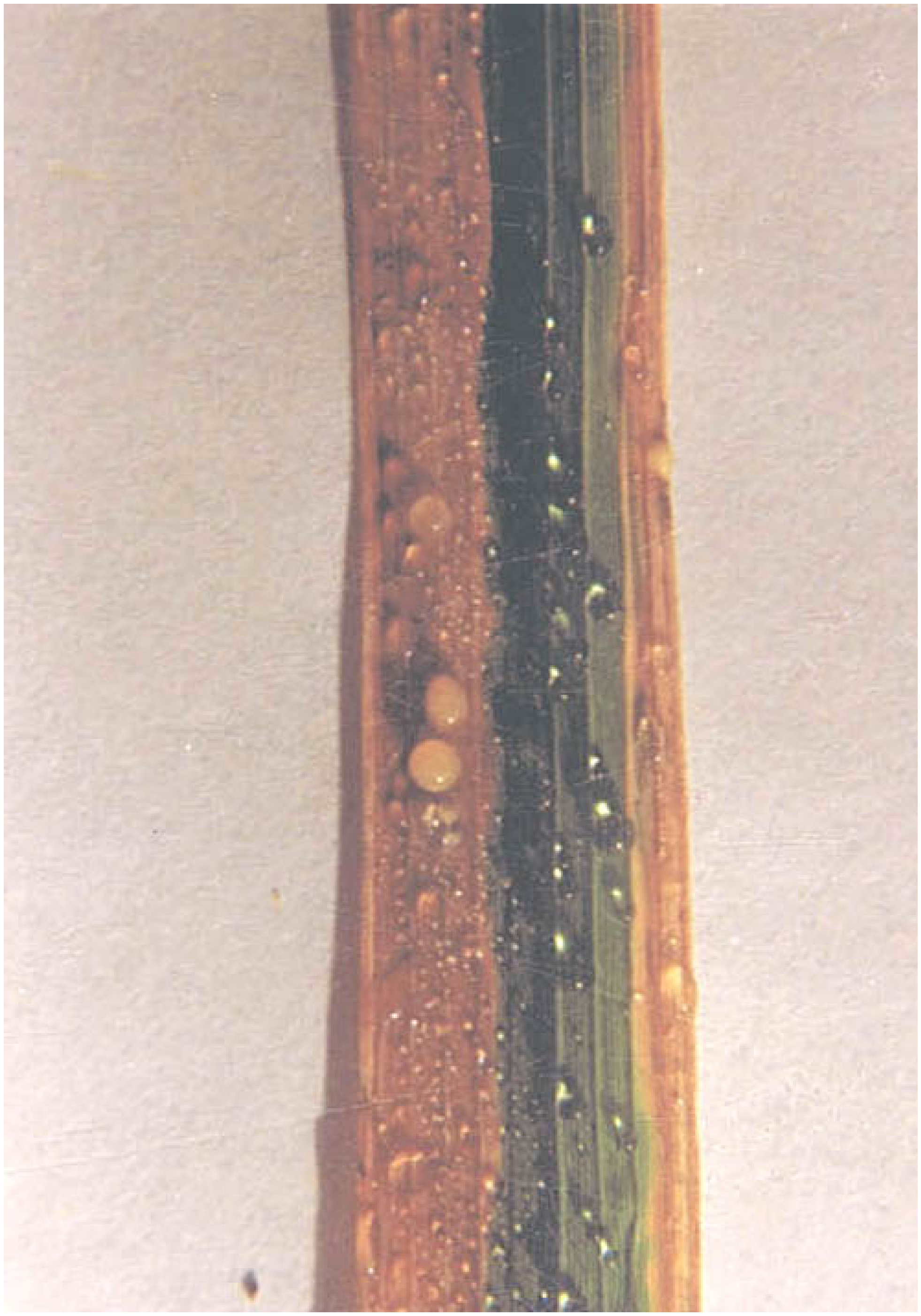

Plate 1: Bacterial ooze on blighted leaf of rice

CHAPTER – II

REVIEW OF LITERATURE

Bacterial leaf blight of rice (BLB), caused by *Xanthomonas oryzae pv. oryzae* (Swings *et al.,* 1990), is one of the most widespread and destructive diseases of rice in tropical rice-growing countries of Asia, Australia, United States, Latin America and Africa (Mew *et al*., 1993; Sere *et al*., 2005). This disease was first noticed by the farmers in Fukuoka prefecture Kyushu Island, Japan in 1884-85 and since then it was called "white withering disease" (Tagami and Mizukami, 1962). Its bacterial nature was established and the bacterium was described in 1922 (Ishiyama, 1922). Studies have shown that the disease is present in most of the rice growing states of India (Mizukami and Wakimoto 1970). The disease is more prevalent in both rain fed and irrigated lands in the wet season mostly so in monsoon. In temperate countries, it is common during the rainy season. Bacterial leaf blight occurs at all stages of rice plant growth and depends on the environmental conditions.

Bacterial leaf blight of rice was reported in several rice growing eco zones of Togo with high incidence and severities (Dewa *et al*., 2011). Reduction in rice yield crop was reported by (Mew *et al*., 1993). BLB was observed to occur in fields with high incidence of 70 to 80 per cent in several West African countries (Sere *et al*., 2005). Yield losses due to bacterial leaf blight ranging from 50 to 90 per cent have been reported (Ou, 1985). Bacterial leaf blight of rice is highly destructive, widespread disease and is a threat to rice production in both temperate and tropical rice growing region due to its high epidemic potential (Mew,1987) it is particularly destructive in Asian countries during heavy rains of monsoon.

X. oryzae pv. oryzae is a seed-borne pathogen, occurring in glumes and occasionally with in the endosperm. Seed collected from heavily diseased field's seedlings grown from such seeds usually shows disease symptoms and die at an early stage (Srivastava and Rao, 1969). The causal organism invades plants through water pores and wounds (Mizukami, 1956, Tabei & Mukoo, 1960).

Manipulating planting dates along with pyramiding disease resistance in high yielding rice cultivars can potentially minimize losses due to bacterial blight (Rafi *et al.*, 2013).Poorly drained areas along rivers or lakes and mountainous basins are conducive for disease development (Mizukami and Wakimoto 1969). Two to three sprays of Bordeaux mixture at booting stage as preventive measure with 8-10 days interval is recommended (Choudhary *et al.*, 2012). Disease management with the use of resistant cultivars is considered to be effective in minimizing the damage, but rice cultivars resistant to BLB are limited. In addition, resistant cultivars with one or two major resistant genes are unsustainable in the field because of the high pathogenic variability of *Xanthomonas oryzae pv. oryzae* under field conditions (Babu *et al*., 2003).

Literature pertaining to etiology to induce resistance, symptoms, characters, damages, chemical, organic and biological managements have been reviewed in this chapter.

1. Occurrence and Distribution of BLB

Tagami and Mizukami (1962) and Yamanuki *et al.* (1962) reported that bacterial leaf blight (BLB) of rice was first seen by farmers in Fukuoka prefecture, Kyushu island Japan in 1884-1885 and it was distributed from central to south western parts of Japan from 1908 to 1910.

Occurrence of BLB was then reported from Korea (Takeuchi, 1930), Indonesia, Mainland China (Fang *et al*, 1957) and Thailand (Jalavicharana, 1958).

Bacterial leaf blight of paddy being destructive in tropical and sub-tropical parts of Asia has also been reported from Taiwan (Hoshioka, 1951) Philippines, Indonesia, Thailand (Goto, 1964), China (Fang *et al*., 1956) and India (Bhapkar *et al*., 1960; Shekhawat and Srivastava, 1968; Srivastava and Rao, 1964; Srivastava, 1967).

In tropical Asia losses had been reported on higher than in temperate countries (Ou, 1972). The disease was also observed in Latin America and Africa (Lozano, 1977).The disease was first reported from India by Srinivisan *et al.* (1959) from Maharashtra where it was reported to wide spread and destructive since 1951 (Bhapkar *et al.* 1960).However, in 1963 for the first time a severe epidemic was recorded in Bihar and its prevelance in other states was recorded (Srivastava and Rao, 1963; Durgapal, 1985).

The disease caused by *X. oryzae* was also reported from Sri Lanka (Seneviratne, 1962), the Philippines; (Goto. 1964); Bangladesh (Alim, 1967); Vietnam, Malaysia (Hashioka, 1969); and Pakistan (Mew and Majiid, 1977).

Lozano (1977) reported the disease from tropical America including Caribbean region (Mexico, Costa Rica, Honduras, Salvador and Panama) and South America (Colombia, Venezuela and Bolivia).

Buddenhagen *et al.* (1979) reported the incidence of bacterial leaf blight in West Africa from Mali, Consequently it was found in Senegal (1980), Niger (1988), Gabon (1984) and Cameroon (Janes et al. 1991).

2. Damage or Yield loss

Reddy *et al.* (1979) stated that in tropical Asia, the yield losses of rice varied from 2 to 74 per cent (depending on location, season, weather conditions and cultivars), whereas Reddy and Shukla (1978) estimated 72.7 per cent loss in Koruna and 43 per cent in Sona when both the varieties were infected with BLB at panicle initiation stage. Inoculation of flag leaf with two isolates of *X. oryzae pv. oryzae* resulted in 38 per cent to 40 per cent loss of yield. Inoculation of susceptible hybrids at the booting stage decreased the number of filled grains per plant, 1000-grain weight, grain yield and increased the number of empty husks plant-1.

Ashrafuzzaman (1992) reported that the severity of BLB, (the most damaging disease of rice) in tropical Asia (South East Asia) was high and losses varied from 6-60 per cent.

Mew *et al.* (1993) reported that the field losses in individual affected fields were 20 per cent or 20-30 per cent while in severely affected fields losses were over 50 per cen per cent. The severe infection at the tillering stage of rice could lead to yield loss of 50 per cent or total crop losses.

3. Symptoms of Bacterial Leaf Blight

According to Tabei and Mukoo (1960), the causal organism invades the rice plant through water pores located on the margin of the upper part of the leaf; the lesions usually start from the leaf margin near the top. In the case of bacterial leaf blight disease, the pathogen chiefly enters through hydathodes as suggested by electron microscopic studies (Horino, 1984, Mew *et al.,* 1984).

It is a vascular disease whereby *Xanthomonas oryzae* continues to grow until the xylem vessels are clogged with bacterial cells and extracellular polysaccharides (Gang *et al.*, 2009). The typical characteristics of a diseased leaf blade are: dead, V-shaped yellow leaf area at the leaf tip, followed by water-soaked leaf area and green leaf area at the leaf base.

However, according to Tagami and Mizukami (1962), as the disease advances, the lesion may cover the entire blade, turn white and later become greyish from the growth of a various saprophytic fungi.

4. Etiology and Taxonomy

Nishida (1909) reported that the diseased leaves in the field applied with ammonium sulphate, exuded dew drops which were acidic in reaction, while the drops from healthy leaves in the same field were not acidic. Takaishi (1909) reported that the acid soil was the most favourable factor of the diseases and application of soybean cake often increases the disease by acidifying soil and he observed that the dew drops with yellow bacterial masses on diseased leaves resulted in the infection of healthy leaves.

Bokura (1911) reported that the disease was caused by a bacterium named *Bacillus oryzae.* Ishiyama (1933) after further studies identified the bacterium as *Pseudomonas oryzae*. Later, the name *X. oryzae* was reviewed to *X. campestris pv. oryzae* (Ishiyama, 1933) in the list of pathovars presented by the committee on Taxonomy of Phytopathogenic Bacteria of the International Society for Plant Pathology.

According to Tagami and Mizukami (1962), in the early stage of the study in Japan in 1901, the bacterial leaf blight of rice was believed to be of physiological origin, mainly due to soil acidity.

Swings *et al.* (1990) recently considered the bacterium to be a distinct species from *X. campestris* on the basis of phenotypic, genotypic and chemotaxonomic data, and proposed the name *X. oryzae* pv. *oryzae*. This name is now being used widely by researchers of bacterial blight of rice.

Morphologically, according to Ishiyama (1933), the causal organism is short and rod-shaped, with round ends, 0.5-0. 8xl-2.0nm (0.8-1 .Ox 1,7lim in host), with monotrichous flagellum of 6-8^m, gram negative and non-spore-forming.

Yoshimura (1963) reported by electron microscopic observation that the size of the bacterial cells was 0.55-0.75x1.35-2.17 nm in culture, and 0.45-0.60x0.65-1.40^m in host tissue.

According to Swings et al. (1990), physiologically the bacterium is obligatory aerobic of which catalase, indole formation, 2-ketogluconate formation, urease, egg yolk, reaction, nitrate reduction, and oxidase tests are all-negative.

5. Transmission of the pathogen

Irrigation water is considered to contribute to the spread of this disease over large areas of cultivated land, as it carries the bacterial ooze that drop into rice field water. However, the role of water as a primary mode of transmission has been disputed as the pathogen survives only for 15 days in field water (Tagami *et al*., 1963). The bacterial leaf blight pathogen is seed-borne, although the extent to which it is transmitted through the seed has been questioned (Unnamalai *et al*., 1988).

A PCR assay for amplification of *Xoo* DNA using primers derived from a repetitive mobile element IS1113 could not detect the pathogen DNA from seeds collected from infected plants (Gnanamanickam *et al.,* 1995). The controversy over seed transmission of the bacterial leaf blight pathogen has resulted due to the fact that sowing seeds from a diseased field into a disease-free field did not always lead to a disease outbreak and most of the experimental evidences for seed transmission were obtained from the bacteriophage technique and not from the direct isolation method. Moreover, the seed-borne transmission of infection either in the nursery or in the field has not been positively proved (Unnamalai *et al*., 1988, Gnanamanickam *et al.,* 1995, Murty and Devadath, 1984).

6. Pathogenic Variability and Host Resistance

Resistance to BLB is widely different with pathogenic races and the cultivars. As chemical controls have an adverse effect on the environment and is costly, growing resistant cultivars is the most safe and feasible control measures against the disease.

Kaku (1980) reported that the primary method of evaluating resistance was to grow cultivars in the field and expose them to natural infection or artificial inoculation. He also reported that the leaf clipping was the artificial inoculation method through which the leaves of each plant were grasped and the tops of all leaves were clipped by a pair of scissors wetted with bacterial suspension, so that the cut ends of the leaves were inoculated with the bacteria. This method was useful not only for qualitative resistance but also quantitative resistance.

Ikeda and Busto (1990) evaluated 198 rice accessions including 10 wild species and 22 natural hybrids against six races of BLB caused by *X. campestris pv. oryzae*. Reactions to the BLB races were tested using the clipping method. Five seedlings/pot per accession were inoculated at booting to heading stage. Resistance was measured using the lesion length of less than 10cm and susceptibility was measured using lesion length of more-than 20 cm. Lesion lengths were measured at 18 DAL.

Lin (1993) reported that at the booting stage, the flag leaves were inoculated with 5 Taiwanese *X. oryzae pv. oryzae* isolates by the clipping method. Disease lesion percentage, yield and yield components were measured. Among the varieties, Taichung 65, Tainung 70, Hosinchu 64 and Kaohsiung 139 were relatively less susceptible. There was a significant reduction in the grain yield of all varieties except Kaohsiung 139 and Kaohsiung 141 upon infection.

Kumar *el al.* (1995) reported that a high yielding variety, Kranti, susceptible to bacterial blight was used to study the induction of resistance against *Xanthomonas oryzae pv. oryzicola* by differentially killed cells of the same bacterium. Two criteria were used one was the development of disease by re-inoculation with live bacteria 7 after pre-treatment and the another was the concentration of orthodihydric phenols. Pretreatment of plants with killed bacteria did not induce resistance to the disease and orthodihydric phenol levels did not increase.

Xiao *et al.* (1998) investigated the changes in phenylamine amonia lyase (PAL), peroxides (POX), superoxides dismutase (SOD), glutathione (GSH), Ascorbic acid (ASA), malodialdihede (MDA), Plasma membrane permeability, fatty acid composition and CHL content in hybrid rice seedling and leaves following inoculation with *X. oryzae* pv. *oryzae*. The response of the 2 combinations of hybrid rice to bacterial leaf blight differed.

Jalaluddin *et al.* (1998) screened and evaluated fourteen advanced mutants along with five check varieties of rice for their resistance to bacterial leaf blight (*X. oryzae pv. oryzae*) and sheath blight (*Rhizoctina solani*) during four consecutive transplanted (T) aman seasons from 1994-1997. For bacterial blight, flag leaves were inoculated with the causal bacterium (10^8 cell/ml) by clipping method. All the induced mutants and the check varieties TKM6, Binasail, BR9 and BR 14 were moderately susceptible to bacterial leaf blight.

Jalaluddin *et al.* (1999) screened and evaluated four somaclonal progenies of rice variety BR3 along with four check varieties for their resistance to bacterial leaf blight (BLB) caused by *X. oryzae pv. oryzae* and sheath blight caused by *Rhizoctonia solani* during the Aman and Boro seasons of 1990-1993. All the somaclonal progenies were moderately susceptible to BLB in both Aman and Boro season.

Zhang *et al.* (1999) reported that Yuanjing 7, the new late maturing variety selected from progeny of an irradiated cross between R9063 and Xiushui 861caused the variation of mean yield between 6187.5kg and 9375 kg per hectare, total panicles per hills, 1000 grain weight between 24.4-25.8 gm. when a single crop late rice trials was conducted in 1996 and 1997 respectively. Yuanjing 7 had moderate resistance to bacterial leaf blight.

Tasleem-uz-zaman *et al*. (2000) conducted an experiment and reported that some 104 local rice varieties/lines were evaluated for resistance to BLB pathogen (*X. oryzae* pv. *oryzae*) under field condition at Kala shah kuku during 1996 to 1998. None of the varieties/lines showed complete resistance to BLB. IR64, IR8 and shadab were moderately resistant while 50, 44 and 7 genotypes showed moderately susceptible, susceptible and highly susceptible reaction, respectively. This indicated scarcity of resistance in most of the local varieties/ lines against BLB disease of rice.

Liu (2001) reported that resistance of 213 rice varieties (lines) to bacterial leaf blight (*X. oryzae* pv. *oryzae)* was evaluated in regional tests in Jiangsu Province in 1996-2000. The varieties 94-44, 96218, Zhendao 272, Shanyoukang 63, Shanyou 084, Jinyou 63, 109, 701, 7057, 9510, 9619, 5-172, 92-133, Yangjing 7057, Sidao 98-3789, Xin 108, Zhebdai-99,s 44/157 and 9522 had high levels of disease resistance. Based on the results, the pathogenic rate of the strain Zhe 173 (PT. TV) of *Xanthomonas oryzae pv. oryzae* was greater than other strains. This coincided with the assumption that PT JV is the major bacterial strain of *Xanthomonas oryzae pv. oryzae* affecting Jiangsu Province.

Cheng *et al.* (2001) cited that hybridization between indica and glutinous rice was conducted. From the F1 generation, directional breeding was designed to eliminate the glutinous lines and retain the indica lines. By continuous selection, the new variety Zhanglong 9104 was developed. It shows strong tillering, high and consistent yield, good performance and grain quality. It possesses resistance to both rice blast and rice plant sheath blight, and medium resistance to bacterial leaf blight. In the rice yielding trials in Fujian in 1994-95, the average yield was 2.73 and 2.81% higher than that of Jinnou 6 and Shanyougui 32, respectively. It was registered in 1999 in Fujian Province.

Lan (2002) reported that zhenhui 084 was a restorer line of indica rice and was bred during 1992-2001 in Jiangsu, China, by the pedigree selection from cross 912156 x R19. It contained the broad-spectrum and high resistance gene Xa-7 and the resistant gene Xa-4 to bacterial leaf blight caused by *Xanthomonas oryzae pv. oryzae*. Zhenhui 084 showed highly resistance to bacterial leaf blight, good plant type, large panicles, good combining ability and fine grain quality. It was registered as the national protective variety in July 2001. The hybrid combination II you 084 (II-32A x Zhenhui 084) was examined and approved by the crop variety committee of Jiangsu province in April, 2001.

Babu *et al.* (2003) reported that rice plants (CV.TR 50) pre-treated with BTH showed resistance to a challenging infection with *Xanthomonas oryzae pv. oryzae*. Approximately 50% reduction in disease intensity was observed in plants treated with BTH at 100 Hg/ml. Immunoblot analysis using barley chitinase antiserum revealed the induction of a 35 kda chitinase in rice in response to BTH treatment. The results indicated that the BLB resistance can be induced even in genetically-susceptible cultivars through application of BTH.

Babu *et al.* (2004) reported that clip inoculation of *Xanthomonas oryzae pv. oryzae* showed resistance against BLB to rice under greenhouse conditions. Rice plants when clip inoculated with *Xanthomonas oryzae pv. oryzae* showed the maximum (65.5%) increase in activity of phenolics in the resistant cultivar BJI compared to the susceptible cultivar IR50 until 3 days after inoculation (DAI). The enzyme activity was maximum (84.7%) in BJI on the fifth day after inoculation. However, in IR50, the enzyme activity decreased on the second day after inoculation.

Jalaluddin *et al.* (2005) identified 23 races of *Xanthomonas oryzae pv. oryzae* in Bangladesh using 11 near isogenic lines and rice varieties IR24, Taichung Native-1, Asominori and M95 each carrying a specific BLB resistance gene (Xa-gene) and found that there was high level of virulence diversity among the race populations. Among the races, nine (race 1 to 9) were virulent on 9 to 14 of 15 different rice varieties. Two highly aggressive races (race 1 and race 2) have overcome the resistance of 14 different rice varieties. Among the differential varieties and the near-isogenic lines, only the induced mutant M95 was resistant to all the races of *Xanthomonas oryzae pv. oryzae* except race I. The resistance gene(s) in M95 is not yet identified.

Jalaluddin (2005) conducted an experiment for the evaluation of 22 exotic rice mutant/varieties which revealed that the Indonesian rice mutant Atomita- 4, was resistant to bacterial leaf blight and moderately susceptible to sheath blight. The Vietnamese rice Tai Nguyen, was susceptible to BLB during aman season. The rice strains THBB, DM-25, TNDB-100, 3027 and RD- 2586 along with Binadhan5 and Binadhan6 were moderately resistant to sheath blight but susceptible to BLB during boro season.

7. Chemical management

Spraying copper oxychloride (Sulaiman and Ahmed, 1965) and streptomycin solution at short intervals was recommended to control this disease (Seki and Mizukami, 1956).

Chlorinating irrigation water with stable bleaching powder was also reported to be effective in minimizing the disease (Chand *et al.,* 1979).

Seed treatment with hot water at 57°C for 10 min or disinfecting with mercury compounds was suggested earlier to eradicate seed-borne inoculum (Tagami and Mizukam, 1962).

Synthetic organic bactericides such as nickel dimethyl dithiocarbamate, dithianone, phenazine and phenazine N-oxide were also recommended (Fukunaga, 1966).

Spraying techlofthalam was more useful than soil application and it translocated readily and inhibited bacterial multiplication in rice plants (Nakagami *et al.,* 1980a, Nakagami *et al.*, 1980b).

Plants grown in soil containing potash levels greater than 183 ppm are more BB resistant (Mondal and Miah, 1985). Similarly, supplements of phosphorous fertilizers resulted in a BB incidence of 5 on a 0–9 scale, but brought about reduction in the number of diseased tillers (Thiagarajan *et al.*, 1986). Also, plants that received nitrogen supplements at tillering, showed high vigour and produced kresek-free tillers (Devadath and Dath, 1987).

Tagami & Mizukami (1962) reported the efficacy of various copper fungicides including that containing organ mercury compound but their utility was not much different from Bordeaux mixture. They also reported that spraying of chloramphenicol appeared to be as effective as streptomycin and less phytotoxic than the latter.

Sivaswamy (1985) reported that the rice seeds treated with *Xanthomonas oryzae pv. oryzae* or seedlings inoculated by root treatment, leaf tip pruning and foliar spray were subsequently treated with stable bleaching powder. Generally, disease incidence was low, and in the inoculated seedlings it was less than in the controls. Plants treated with stable bleaching powder showed improved height and weight and increased grain and straw yields, but disease incidence was not reduced and in a few treatments it was increased. Soil drenching reduced the disease index. It was concluded that stable bleaching powder did not control bacterial leaf blight.

Asai and Nakai (1988) reported that when chemical mutagens were used as seed treatments, the concentration of ethylamine (EI) and ethyl methansulfonate (EMS) giving 50% Ml seed fertility (D50) were 0.35- 0.4% and 0.7% (V/V), respectively. The frequencies of chlorophyll mutants with these doses in the M2 generation were 5% and 2.2% (EMS). M2 plants at young seedling and flag leaf stages were inoculated by clipping leaf tips with scissors dipped in a suspension of *Xanthomonas oryzae pv. oryzae* race l(one) and scored for disease severity 2 weeks later. Frequencies of resistant mutants in M2 seedlings were 0.18% for ET and 0.05% for EMS. The M3 and control (C3) lines from selected M2 (C2) plants, grown in the experimental field, were inoculated on their flag leaves with races 1, III and IV. Of these, 9 resistant lines in ET and 4 in EMS treatments were selected with resistance to all 3 races. Since the selected resistant mutant lines were changed in other agronomical traits they could be used directly in the field, but were suitable as materials for crossing in further resistance breeding trials.

Natrajan (1988) reported that various chemical sprays were tested to control *Xanthomonas oryzae pv. oryzae* on rice plants. Applications were made at 30 and 45 days after transplanting (DAT) the crop. Bleaching powder was the most effective in reducing bacterial leaf blight followed by plantomycin, paushamycin + copper oxychloride and paushamycin alone.

Mariappan (1988) conducted an experiment to control the bacterial leaf blight of rice through the combination of antibiotic and fungicide which reported that agrimycin

100 + copper oxychloride and agromycin 100 alone gave equal control and were significantly superior to control with treatments involving paushamycin and streptomycin.

Valluvaparidasan (1988) made some attempts to control bacterial leaf blight (*Xanthomonas oryzae pv. oryzae*) using various chemicals applied as prophylactic and curative sprays. Of the prophylactic sprays, plantomycin + fytolan, paushamycin + fytolan, and agrimycin + fytolan reduced the disease by up yp 50%. Of the curative sprays tested, bromidiol, white vitrol and plantomycin + fytolan were effective in reducing the disease, but in both treatments chemical methods were ineffective in totally eradicating the disease.

Baruah *et al.* (1991) conducted the research work of the nitrogen management for wet land rice in bacterial leaf blight endemic areas which resulted that basal application of urea in the form of neem cake coated urea and mussoorie rock phosphated urea reduced disease incidence and gave higher grain yields than 3 split applications of prilled urea and basal placement of urea super granules which increased incidence.

Rakesh (1994) evaluated the different seed treating agents for the control of bacterial leaf blight of rice and concluded that bleaching powder (100ml), Blitox-50 W (copper oxychloride) (62.5mg dissolved in 15 ml of acetone for 25g of seeds), streptocycline (100ml) and zinc sulfate (2%) reduced the intensity of bacterial leaf blight of rice, caused by *Xanthomonas oryzae pv. oryzae* when evaluated as seed treatments in the glasshouse and in the field. The seed as treatment did not increase yield.

Zhang (1998) conducted an experiment to control bacterial leaf blight (*Xanthomonas oryzae pv. oryzae*) of rice and concluded that when rice seeds were soaked in a 50 mg/kg solution of zhongshengmycin in water for 48 hours before sowing in the field, disease severity was significant reduced.

Mahto (2001) conducted a field experiment in Nepal during the 1994 and 1995 cropping seasons which resulted that BLB incidence significantly increased with leaf injury together with increasing rates of N. Rice grain yield was high at high N rates. That also increased the disease incidence. At the same N rate, Sabitri showed less infection compared to Masuli.

8. Cultural and physical management

Bhagawati *et al.*, (1993) reported that under normal high intensity, lesions caused by *Xanthomonas oryzae pv. oryzae* were longer on old leaves than on younger ones, light enhanced the leaf tissue sugar and increased disease intensity; 8 days after inoculation, lesions were longer on young leaves exposed to light than on old ones in the dark. Artificial manipulation of sugar level in rice leaves confirmed that higher leaves were correlated with disease intensity.

Zhao *et al.*, (1994) investigated field trials and found that the cultural methods produced high yield of rice (>500 kg/MU). The results were simulated by a computer model. The following factors were considered to be crucial: timely sowing; optimum plant densities; proper management of water and fertilizers; and the control of rice Bacterial Leaf Blight (*Xanthamonas campestris pv. oryzae*).

Zhang (1998) reported that the control of rice bacterial leaf blight (Xanthomonas oryzae) using a new agricultural antibiotic, Zongshengmycin was investigated when infected rice seeds were soaked in a 100 mg/kg solution (at 58°C, cooling to room temperature) of the antibiotic for 48 hours, bacteria on the surface and inside the seeds were completely killed. This removed the source of seed infection. When rice seeds were soaked in a 50 mg/kg solution of Zhongshengmycin in water (at 55-60°C, cooling down to air temperature) for 48 hours before sowing in the field, disease severity was significantly reduced. However, when disease was severe, it was necessary to apply a spray of 15 mg/kg solution of the fungicide (Zongshengmycin) during early August.

Zhang *et al.* (1999) reported that in single crop late rice trials in 1996 and 1997, mean yield varied between 6187.5 and 9375 kg/ha, in each case higher than the control varieties by between 4.4 and 16.6%. Total panicle numbers were 3.555-3.645 million per ha, with 95.5-103.9 grains per panicle and a 1000-grain weight of 24.4-25.8 g. The rice (Yuanjing 7) had moderate resistance to bacterial leaf blight (*Xanthomonas oryzae*) and good resistance to blast while sown as double cropping, late rice, Yuanjing 7 took 141 days to reach maturity and 162 days when sown as single crop late rice. Seeds were soaked in a sterilizing solution before sowing and nitrogen fertilizers were applied prior to culm extension.

Ahammad (2005) conducted an experiment for the induction of BLB resistance in rice plants and reported that the lowest BLB severities were induced and the highest grain yield was obtained in plants where leaf clipping was done at early or maximum tillering stages of rice growth.

As there is no single most effective control measure available against this disease, some cultural practices may minimize disease incidence (Chaudhary *et. al*., 2009).

Plate 2: a) Bacterial blighted leaves of rice
b) Bacterial blight infested seeds

CHAPTER – III

MATERIALS AND METHODS

The field experiments of the present investigation on "Management of bacterial leaf blight of paddy (*Oryza sativa L.*)" were conducted at University Research farm, Faculty of Agriculture, Chatha during the year 2015. Materials and methodologies adopted for field experimentation are described as below:

1. Survey of disease

Surveys of rice growing areas of Jammu, Kathua and Samba districts was conducted to see the incidence of disease and to collect the diseased material. Diseased plants affected with BLB were identified by specific symptoms i.e. blight symptoms appeared on leaves of young plants, as pale-green to grey-green water-soaked streaks near the leaf tip and margins.

Five fields in each location were selected for estimation of disease incidence and collection of diseased samples. Samples were taken at five places randomly. At each place four plants were examined. For collection of samples upper three leaves of each plant were collected. The disease incidence was calculated by using the formula of (IRRI 1996).

$$\text{Percent disease incidence} = \frac{\text{Number of bacterial blight infected plants}}{\text{Total number of plants examined}} \times 100$$

2. Design, Layout and Treatments

The experiment was laid out in a split-plot design with three replications. The rice cultivar Basmati-370 was tested. Three dates of transplanting (5^{th}, 15^{th} and 25^{th} July) were in main plots and three irrigation schedule(I_1- Stagnant water, I_2- Water drained out after tillering stage, I_3- Water drained out two days after transplanting and after tillering stage) and chemicals the treatments (streptomycin and copper oxychloride) were tested in sub plots of size 0.76 x 0.76 m^2 each. The treatments were randomly assigned to experimental units.

R_1

T_1I_1	TO	T_2F_1
T_1I_2	T_2F_1	T_3A
T_1I_3	T_3A	TO
T_2F_1	T_1I_3	T_1I_2
T_3A_1	T_1I_2	T_1I_1
T O	T_1I_1	T_1I_3

R_2

T_2F_1	TO	T_1I_1
T_3A	T_2F_1	T_1I_2
TO	T_3A	T_1I_3
T_1I_2	T_1I_3	T_2F_1
T_1I_1	T_1I_2	T_3A_1
T_1I_3	T_1I_1	T O

R_3

T_2F_1	T_1I_1	TO
T_3A	T_1I_2	T_2F_1
TO	T_1I_3	T_3A
T_1I_2	T_2F_1	T_1I_3
T_1I_1	T_3A_1	T_1I_2
T_1I_3	TO	T_1I_1

Experimental Design: Split-plot (variety in main plot and treatments in subplot) with 3 replications.

Factor A: Varieties: V = Basmati-370.

Factor B: Treatments: T_1 = 5th July 2015, T_2 = 15th July, T_3 =25th July, T_4 =Stagnant water level, T_5 = Water drained out after tillering stage, T_6 = Water drained out two days after transplanting and after tillering stage, T_7 = Spray of copper oxycloride @ 3gm/litre of water at the time of disease appearance, T_8 = Spray of streptomycin @ 100 ppm at the time of disease appearance, T_9 = Control.

Plot size: 0.76 m x 0.76 m

R_1,R_2,R_3 = Replications.

Location: Field of Plant Pathology Division, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu.

3. Seed Bed Preparation and Raising of Seedlings

The land was ploughed and after each ploughing planked was done. The land was marshy and rich in organic matters and therefore, no fertilizers were applied to the seed bed. Seeds of Basmati-370 were collected from the Plant Pathology Division, SKUAST-J. 30 days old seedlings were transplanted in a well-puddle field.

Plate 3: Bacterial blighted field of rice

4. Land Preparation and fertilizer application

The land was thoroughly ploughed with a tractor driven disc plough followed by harrowing. Weeds and stubbles were removed from the field for transplanting of rice seedlings. Fertilizers for N P K were applied in the plots at the rate of 30, 20 and 10 kg per hectare. Half quantity of N and whole quantity of P and K was applied as basal dose and half in two split doses as top dressing.

5. Screening

Sixteen rice genotypes viz. PUSA-1121, B-370, PR-113, RR-8585, PC-19, IET-1410, SJR-5, Jaya, PB-1, IARI-1460, Ranbir basmati, Saanwal basmati, Basmati-564, IR-10, Basmati-385 and Ratna collected from different sources were grown under field conditions for resistance against BLB and the incidence of disease was recorded . Screening was done in the field to screen of paddy genotypes against *Xanthomonas oryzae* pv. *oryzae*. Data of severity was recorded as percentage of tissue area infected out of total leaf area examined. Percentage average lesion area of 15 leaves collected was measured for disease severity in each plot using the following scale (Chaudhry, 1996):

Disease Rating	Lesion size (% of leaf length)	Disease Reaction
0	0	Immune
1	1-10	Resistant
3	11-30	Moderately Resistant
5	31-50	Moderately Susceptible
7	51-75	Susceptible
9	76-100	Highly Susceptible

$$\text{Disease Index} = \frac{n(1) + n(3) + n(5) + n(7) + n(9)}{tn}$$

Where:

n (1), n (3), n (5), n (7) and n (9) = Number of leaves showing severity score of 1, 3, 5, 7 and 9.

tn = Total number of leaves scored

6. Management

For management of disease two chemicals viz. streptomycin and copper oxychloride 100 ppm and 0.3 per cent respectively were applied along with three irrigation schedules (I_1- Stagnant water, I_2- Water drained out after tillering stage, I_3- Water drained out two days after transplanting and after tillering stage) on three dates of transplanting viz 5th July,15th July and 25th July. The lesion length was measured after 2 and 3 weeks and for maintaining optimal humidity for infection development adequate water was supplied as per schedule.

7. Yield and yield parameters

The crop was harvested at maturity stage and plants of each sub plots were harvested separately to obtain yields. All harvested plants of individual sub plots were threshed separately and the grains were dried (12 per cent moisture content) before recording the weight of the grains. The data for the important agronomic parameters such as number of tillers/hill; plant height, panicle length, and yield kg per quintal were recorded.

8. Analysis of data

The data were subjected to statistical analysis. Analysis of variance was done following split-plot design for the concerned field experiment with the help of computer package O.P Stat followed by calculator.

CHAPTER – IV

EXPERIMENTAL RESULTS

I. SURVEY

In order to determine the prevalence of bacterial leaf blight of paddy in Jammu, Kathua and Samba districts of Jammu division of Jammu and Kashmir, an exhaustive survey was conducted during *kharif* 2015 at boot leaf stage of the crop and data presented in Table 1, revealed that the disease incidence in Jammu district, ranged from 34.10 to 45.33 per cent with the mean of 34.59 per cent. In Kathua district disease incidence ranged from 15.21 to 40.13 per cent with mean of 29.67 per cent while in Samba district the incidence ranged from 15.23 to 40.21 per cent with mean of 36.35 per cent. Maximum disease incidence was recorded in Kulian (45.33 per cent) of Jammu district and minimum at Jagatpur (15.21 per cent) of Kathua district. Overall disease incidence for all three districts was 33.53 per cent.

Three varieties viz. Basmati-370, Pusa-1121and IET-1410 were grwon at different locations of Jammu district. Maximum disease incidence (45.33 per cent) was recorded IET-1410 whereas minimum incidence (34.10 per cent) was recorded in Basmati-370. In Kathua district, five varieties IET-1410, Pusa-1121, Neha, PHB-71, and Basmati-370 were grown. Maximum and minimum incidence of 40.13 per cent and 15.21 per cent respectively was recorded in IET-1410 and Neha. In Samba district, three varieties i.e. Basmati-370, Neha and Ratna were grown by most of the farmers. Maximum disease incidence 40.21 per cent was recorded in Ratna while minimum incidence 15.23 per cent was recorded in Neha.

II. SCREENING

Sixteen varieties were grown in order to determine the severity for bacterial leaf blight of paddy. The data presented in Table 2 revealed that maximum severity was observed on Jaya (60.22 per cent) whereas, minimum severity was observed on Pusa-1121 (25.21 per cent). Four varieties i.e. PUSA-1121, PR-113, PB-1 and IR-10 were found as moderately resistant, eleven varieties viz. B-370, RR-8585, PC-19, IET-1410, SJR-5, IARI-1460, Ranbir basmati, Saanwal basmati, Basmati-564, Basmati-385, Ratna as moderately susceptible and one Jaya as susceptible. Out of twenty varieties none of the variety was found immune.

Table 1: Disease incidence of bacterial leaf blight on paddy in Jammu Division

S.No.	District	Location	Variety	PDI (%)
I	**Jammu**			
1		Udheywala	B-370	40.21
2		B.Bramhana	B-370	38.11
3		Bhor Camp	B-370	34.10
4		Gagian	Pusa-1121	15.21
5		Kulian	IET-1410	45.33
6	Mean			34.59
7	Range			34.10-45.33
II	**Kathua**			
1		Nagari	IET-1410	40.13
2		Kalibari	Pusa-1121	17.15
3		Jagatpur	Neha	15.21
4		Rathwal	PHB-71	39.33
5		Bhujwal	B-370	36.56
6	Mean			29.67
7	Range			15.21-40.13
III	**Samba**			
		Ramgarh	B-370	37.11
1		Koh Bramhana	Neha	15.55
2		Raiper	Ratna	40.21
3		Sordi	Ratna	35.34
4		Bainglarh	Neha	15.23
5		ChakSalarian	B-370	38.32
6	Mean			36.35
7	Range			15.23-40.21
	Overall mean			33.53

Plate 4: 0-9 scale used for BLB screening

Table : 2 Disease reaction of different paddy genotypes against bacterial leaf blight

S.No.	Variety	Disease severity (%)	Score	Disease reaction
1	PUSA-1121	25.21	3	MR
2	B-370	38.11	5	MS
3	PR-113	27.45	3	MR
4	RR-8585	39.34	5	MS
5	PC-19	42.77	5	MS
6	IET-1410	42.21	5	MS
7	SJR-5	45.33	5	MS
8	Jaya	60.22	7	S
9	PB-1	30.55	3	MR
10	IARI-1460	40.65	5	MS
11	Ranbir basmati	35.22	5	MS
12	Saanwal basmati	38.33	5	MS
13	Basmati-564	40.72	5	MS
14	IR-10	27.22	3	MR
15	Basmati-385	38.33	5	MS
16	Ratna	45.21	5	MS

III. Effect of disease management on yield and yield components

The effects of the different treatments on yield and yield attributes such as number of tillers, plant height, and panicle length are presented in Table 3, 4 and 5. The effects of the treatments were recorded as follows:

Table 3: Effect of agronomic inputs on the severity of BLB and yield components of paddy

DOT	I_1				I_2				I_3				Mean			
	NT	PH	PL	Y	NT	PH	PL	Y	NT	PH	PL	Y	NT	PH	PL	Y
D1	7.33	106.00	19.33	25.20	8.67	109.66	20.83	25.22	9.00	106.67	19.56	25.23	8.33	107.44	19.90	25.21
D2	8.00	121.67	25.50	36.11	11.33	123.33	26.43	39.21	10.00	121.67	25.77	34.44	9.77	122.22	25.90	36.58
D3	6.33	91.33	20.60	30.30	8.33	94.33	21.43	31.25	7.00	92.33	20.80	32.45	7.22	92.66	20.94	31.32
Mean	7.22	106.33	21.82	30.53	9.44	109.11	22.90	31.88	8.67	106.88	22.04	30.70	-	-	-	-
CD (p=0.05)	0.53	0.60	0.32	0.11	-	-	-	-	-	-	-	-	0.94	0.59	0.60	0.20

NT = No. of tillers, PH = plant height (cm), PL = panicle length (cm), Y = Yield (q/ha), DOT = Date of transplanting, I_1, I_2, I_3 = irrigation schedule, D1 = 5th July, D2 = 15th July, D3 = 25th July

I_1- Stagnant water, I_2- Water drained out after tillering stage, I_3- Water drained out two days after transplanting and after tillering stage

Effects on effective number of tillers

Maximum number of effective tillers (11.33) were recorded during second date of transplanting (15^{th} July) and second irrigation schedule(Water drained out after tillering stage) while the minimum 6.33 tillers were recorded in plants grown on third date of transplanting (25^{th} July) with first irrigation schedule (Stagnant water). Whereas numbers of tillers were significantly affected in all treatments. Mean number of tillers ranged from 7.22 to 9.77 in different dates of transplanting.

Effects on plant height

Plant height ranged from 106.33 to 109.11 cm in different irrigation schedules. The maximum plant height of 123.33 cm was recorded in plants grown on second date of transplanting and second irrigation schedule while minimum plant height 91.33 cm was recorded in plants grown on third date of transplanting (25^{th} July) and first irrigation schedule stagnant water in sub plot. Mean plant height ranged from 92.66 to 122.22 cm in different dates of transplanting.

Effects on panicle length

Panicle lengths were significantly affected in all treatments. Mean of panicle lengths ranged from 21.82 to 22.90 cm in different irrigation schedule. The maximum panicle length 26.43 cm was recorded in plants grown on second date of transplanting (15^{th} July) and second irrigation schedule (water drain out after tillering stage) while the minimum panicle length 19.33 cm was recorded in plants grown on first date of transplanting(5^{th} July) and first irrigation schedule.

Effects on yield

Yield was significantly affected by different treatments (Table 3). Mean yield ranged from 30.53 to 31.88 q/ha in irrigation schedule. The maximum 39.21 q/ha yield was recorded in plants grown on second date of transplanting and second irrigation schedule while the lowest yield of 25.20 q/ha was recorded plants grown on first date of transplanting (5^{th} July) and first irrigation schedule. Mean yield ranged from 31.32 to 36.58 q/ha in dates of transplanting in different dates of sowings.

Table 4: Effect of cultural and chemical management on the severity (%) of bacterial leaf blight of paddy

DOT	Irrigation schedule				Chemical			
	I_1	I_2	I_3	Mean	Streptomycin 100ppm	Copper oxychloride 0.3%	Control	Mean
D1	24.33	19.33	20.67	21.44	13.33	16.00	27.67	19.00
D2	17.33	14.33	14.33	15.33	11.33	17.33	19.33	16.00
D3	17.33	14.33	14.33	15.33	21.67	28.33	43.33	34.25
Mean	19.67	16.00	16.44	-	15.44	20.56	30.11	-
CD P=0.05	1.19	-	-	1.52	2.03	-	-	1.73

I_1-Stagnant water, I_2-Water drained out after tillering stage, I_3-Water drained out two days after transplanting and after tillering stage, D1 = 5th July, D2 = 15th July, D3 = 25th July

Results from Table 4 revealed that there was significant effect due to transplanting dates, irrigation schedules and chemicals on the severity of bacterial leaf blight of paddy. Mean severity due to transplanting dates ranged from 15.33 to 21.44 per cent. Maximum disease severity 24.33 percent was recorded from first date of transplanting (5th July) and in irrigation schedule first (stagnant water) whereas all other dates of transplanting and irrigations schedule were at par (14.33% disease severity).

Results for chemical management of the disease showed that the chemicals tested were significantly superior in comparison to control. Maximum disease severity 43.33 per cent was recorded in control sub-plot whereas minimum severity 11.33 per cent was recorded in streptomycin treated plots 16.00 per cent in copper oxychloride treated plots.

Table 5: Effect of cultural and chemical management on the yield and yield related parameters of paddy

DOT	Streptomycin 100ppm				Copper oxychloride 0.3%				Control				Mean			
	NT	PH	PL	Y	NT	PH	PL	Y	NT	PH	PL	Y	NT	PH	PL	Y
D1	9.67	114.00	22.67	29.13	9.00	111.33	20.33	27.25	6.33	105.33	18.23	22.46	8.33	110.22	20.41	26.28
D2	11.67	124.67	27.43	41.34	10.67	122.67	26.30	37.14	8.67	120.33	24.50	27.54	10.33	122.56	26.07	35.34
D3	8.67	99.00	22.80	35.46	8.00	96.00	22.40	35.23	6.33	91.00	20.80	28.72	7.67	95.33	22.00	33.13
Mean	10.00	112.56	24.30	35.31	9.22	110.00	23.01	33.20	7.11	105.56	21.17	26.24	-	-	-	-
CD (P=0.05)	0.42	0.92	0.57	0.13	-	-	-	-	-	-	-	-	1.15	0.85	0.94	0.50

NT= No. of tillers, PH = plant height (cm), PL = panicle length (cm), Y = Yield (q/ha), DOT = Date of Transplanting, D1 = 5th July, D2 = 15th July, D3 = 25th July

Application of chemicals had significant effects on number of tillers, plant height, panicle length, and yield. Mean no. of tillers ranged from 7.11 to 10.00. Maximum 11.67 tillers were recorded when streptomycin was sprayed and sub plot was transplanted on 15^{th} of July and minimum number of tillers 6.33 were recorded in control sub plot, except sub plot which was transplanted on 15^{th} of July . Plant height mean ranged from 105.56 cm to 112.56cm in all treatments. Maximum, minimum plant height plant height and mean panicle length of 124.67 cm, 91.00 cm and from 21.17 cm to 24.30 cm was recorded when streptomycin was sprayed on 15^{th} of July and 25^{th} of July respectively. Maximum panicle length 27.43 cm was observed in sub plots sprayed with streptomycin and transplanted on 15^{th} July and minimum panicle length 18.23 cm was observed in control sub plot transplanted on 5^{th} July. However, maximum yield of 41.34 q/ha was recorded in sub plots sprayed with streptomycin and transplanted on 15^{th} of July and minimum yield 22.46 q/ha was recorded in control sub plot which was transplanted on 5^{th} July.

With regards to different dates of transplanting maximum number of tillers, plant height, panicle length, and yield were observed in second date of transplanting D2 (15^{th} July) and minimum number of tillers and plant height were recorded in third date of transplanting D3 (25^{th} July) while panicle length and yield were observed in first date of transplanting D1(5^{th} July).

CHAPTER – V

DISCUSSION

Bacterial leaf blight (BLB) caused by *Xanthomonas oryzae pv. oryzae* is a serious disease reducing grain yield to varying levels depending on the stage of the crop, degree of cultivar susceptibility and a great extent to the conduciveness of the environment in which it occurs (Akhtar *et al*., 2011). Seed-borne bacterial leaf blight of rice, caused by *X. oryzae pv. oryzae* (Ishiyama) (Swings *et al.,* 1990), is the major limiting factor in rice production. In India, the yield loss due to this was reported upto 81.3 per cent (Srivastava, 1967; Sonti, 1998; Gnanamanickam *et al.,* 1999; Veena *et al*., 2000).

A survey was conducted during *kharif* season of 2015 to ascertain the status of bacterial leaf blight in paddy in sub-tropics of Jammu division. It was observed that the per cent disease incidence varied from 34.10 to 45.33 per cent with the mean of 34.59 per cent in Jammu district and in Kathua the disease incidence was reported from 15.21 to 40.13 per cent with mean of 29.67 per cent. Disease incidence in Samba district ranged from 15.23 to 40.21 per cent with mean of 36.35 per cent. Maximum 45.33 per cent disease incidence was recorded in Kulian village of Jammu district and minimum 15.21 per cent at Jagatpur of Kathua district. Overall average disease incidence for all three districts was 33.53 per cent. These findings are with accordance to the finding of Singh, (1999) who reported, that average maximum disease incidence of bacterial leaf blight in Jammu and Kathua districts were 65.11 and 65.81 per cent, respectively and maximum disease incidence was reported in Pounichak (84.00 per cent) and minimum at Bhore camp 36.50 per cent of Jammu district. In Kathua district maximum disease incidence was reported from Nagari village 81.50 per cent and minimum in Bhujwal 15.15 per cent.

It was observed during survey in Jammu and Kathua districts maximum 45.33 per cent disease incidence was recorded in IET-1410 whereas, minimum incidence was 34.10 per cent in Basmati-370 in Jammu district. While variety Neha was found to have minimum disease incidence in both Samba and Kathua districts 15.23 per cent and 15.21 per cent respectively. Ali *et al*., (2009) reported that 26.50 per cent disease incidence in

Basmati-385, 20.70 per cent in IR-6, 27.27 per cent in Kashmir Basmati and 26.80 per cent in Basmati–370 at Malakand in Pakistan.

Sixteen varieties were screened to find out the resistance source against the bacterial leaf blight, out of them Jaya was found susceptible with 60.22 per cent disease severity. Whereas minimum 25.21 per cent disease severity was observed in Pusa-1121. While PUSA-1121, PR-113, PB-1 and IR-10 were moderately resistant, and varieties Basmati-370, RR-8585, PC-19, IET-1410, SJR-5, IARI-1460, Ranbir basmati, Saanwal basmati, Basmati-564, Basmati-385, Ratna were moderately susceptible. These findings are in accordance with the finding of Khan *et al*., (2009) was screened basmati 385 and basmati 370 found moderately susceptible reactions against *X. oryzae pv oryzae*. Similarly results were also reported by Shah (2008), who evaluated the basmati 385 against *X. oryzae pv. oryzae* in Pakistan. Similar findings have been reported by Singh, (1999) that, cultivars IR-8, Jaya, Parmal and PC-19 are being grown on commercial scale in the entire rice growing sub tropical belt of Jammu these varieties are having known susceptibility to *Xoo* and is the region for the high incidence of disease in the area. Gupta *et al*., 2012 reported that bacterial leaf blight caused by *X. campestris pv.* o*ryzae* mostly appears in lower belt of Jammu region, particularly basmati rice cultivated areas. This disease also causes significant crop loss in the state. All the commercial basmati varieties cultivated in Punjab are found moderately susceptible to highly susceptible to BLB disease (Cheema *et al*., 1998, Khan *et al*., 2000a; Khan *et al*., 2000b; Akhtar *et al*., 2008 and Khan *et al*., 2008).

To evaluate antibiotic and chemicals on three dates of transplanting so as to observe appropriate time of transplanting in view of less disease incidence of the disease, it was found that there were significant effects due to transplanting dates, irrigation schedules and chemicals on the severity of bacterial leaf blight of paddy. Mean severity due to transplanting dates ranged from 15.33 to 21.44 per cent. Maximum mean of severity 21.44 percent was recorded from first date of transplanting whereas minimum mean severity 15.33 per cent was recorded from both second and third dates of transplanting.

In case of chemicals evaluation it was observed that mean of disease severity due to application of chemicals ranged from 15.44 to 30.11 per cent. Maximum disease severity of 30.11 per cent was recorded in control plot, whereas minimum severity 15.44 per cent was recorded in streptomycin sprayed sub plot followed by copper oxychloride sprayed sub plot (20.56 per cent disease severity) were significant effects on severity of bacterial leaf blight of paddy in comparison to control. Mean of disease severity due to irrigation schedule ranged from 15.99 to 19.66 per cent. Maximum disease severity of 19.66 per cent was recorded in irrigation schedule first (stagnant water) whereas minimum severity 15.99 per cent was recorded in second irrigation schedule (water drain out after tillering stage). It was observed that all three schedule of irrigations significantly different to each other. Biswas *et al*., (2009) found that the seed treatment with streptocycline (100 ppm) along with foliar spray of streptocycline in combination of copper oxychloride (100ppm+500ppm) gave the best management strategies for minimizing bacterial leaf blight in all three consecutive years showing 10.97 per cent, 9.76 per cent and 10.18 per cent disease intensity, respectively.

The results of effectiveness of dates of transplanting and irrigation schedules on the yield and growth parameters were recorded which were maximum 11.33 numbers of tillers per hill, plant height 123.33 cm, panicle length 26.43 cm and yield 39.21 q/ha were recorded in second date of transplanting (15th July) and second irrigation schedule (Water drained out after tillering stage) while the minimum 6.33 tillers per hill and plant height 91.33 cm were recorded in plants grown on third date of transplanting (25th July) with first irrigation schedule (Stagnant water). While the lowest panicle length 19.33 cm was recorded in plants grown on first date of transplanting (5th July) and first irrigation schedule whereas lowest yield 25.20 q/ha was recorded in first irrigation schedules on first date of transplanting. Mean yield ranged from 25.21 to 31.32 q/ha in dates of transplanting. It was observed that yield and growth parameters were significantly affected in all treatments. Our findings contradiction with the findings of Rafi *et al.*, 2013 reported that higher grain yield was observed when planting was done on 15th June, while lower grain yield was recorded for early sowing (5th June). Our results are in contradiction to Ranjan *et al*., (2012) who reported that the highest yields and low disease severity were observed in first sown crops i.e. 8 June, in all the four varieties, followed by second sown i.e. 23 June and third sown 8 July. Environmental factors influence the disease severity. The first sown crops escape the disease severity resulting in highest yield. Mizukami and Wakimoto (1969) reported that to escape the bacterial leaf blight nursery should be well drained, no flooding should occur in a heavy downpour, avoid deep irrigation water, or sow in an upland nursery if possible.

CHAPTER – VI

SUMMARY AND CONCLUSION

The present studies on "Management of bacterial leaf blight of paddy (*Oryza sativa L.*) caused by *Xanthomonas oryzae pv. oryzae"* were undertaken in order to determine the status of the bacterial leaf blight of paddy in Jammu Division, role of irrigation and drainage in disease development, screening of varieties to identify the resistant source and determination of transplanting date to escape the disease and evaluate different management strategies for disease management. The results are summarized and concluded as under –

- During the course of investigation, the disease was noticed in all the surveyed areas *viz*. Jammu, Samba and Kathua districts of Jammu division during the year 2015. Maximum disease incidence was recorded in Kulian (45.33 per cent) of Jammu district and minimum in Jagatpur (15.21%) of Kathua district. Overall average disease incidence for all three districts was 33.53 per cent.

- Sixteen germplasm were screened under field condition against bacterial leaf blight, and no germplasm was found immune or resistant to the disease. PUSA-1121, PR-113, PB-1 and IR-10 were moderately resistant, whereas Basmati -370, RR-8585, PC-19, IET-1410, SJR-5, IARI-1460, Ranbir basmati, Saanwal basmati, Basmati-564, Basmati-385, Ratna were moderately susceptible. However, Jaya was found to be susceptible.

- Results of studies on chemical evaluation fungicide and antibiotic for disease management revealed that minimum disease severity of 15.44% was recorded in streptomycin followed by copper oxychloride (20.56 % disease severity) second date of transplanting (15^{th} July) and second irrigation schedule (water drained out after tillering stage) was found most effective among all the treatments of disease management with maximum 11.33 numbers of tillers per hill, plant height of 123.33 cm, panicle length of 26.43 cm and yield of 39.21 q/ha which was recorded in second date of transplanting (15^{th} July) and second irrigation schedule (water drained out after tillering stage) while the first date of transplanting (5th July) with first irrigation schedule (stagnant water) was least effective treatment among all irrigation schedule and dates of transplanting with 7.33 tillers per hill and plant height 106.00 cm and panicle length 19.33 cm along with 25.20 q/ha yield.

REFERENCES

Ahmad, M. M. 2005. *Effect of Bacterial Inoculum for the induction of BLB resistance in rice*. M.Sc. Thesis, Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh. 40 pp.

Akhtar, M. A., Rafi, A. and Hameed, A. 2008. Comparisons of methods of inoculation of *Xanthomonas oryzae pv. oryzae* in rice cultivars. *Pakistan Journal of Botany.* **40** (5): 2171-2175.

Akhtar, M. A., Abbasi, F. M., Ahmad, H., Shahzad, M.,. Shah, M. A and Shah A. H. 2011. Evaluation of rice germplasm against *X. oryzae* causing bacterial leaf blight, *Pakistan Journal of Botany*, **43**(6): 3021-3023.

Amjad, A., Khan, M.H., Bano, R., Rashid, H., Raja, N. I., Iqbal. and Chaudhry, Z. 2009. Screening of Pakistani rice (*Oryzae sativa*) Cultivars against *X. oryza* pv. *oryzae Pakistan Journal of Botany*. **41**(5): 2595-2604.

Alim, A. 1967. Breeding of rice for resistance to major diseases in East Pakistan. In: Proceedings of the symposium on rice diseases and their control by growing resistant varieties and other measures, Tokyo, **pp**.199-207.

Anonymous. 2006. *Survey of Indian Agriculture*. The Hindu.

Anonymous. 2010. *Economic Survey, Agriculture and Food Management.* Ministry of Finance, Government of India.

Asai, T. and Nakai, H. 1988. *Induction of mutants of rice resistant to bacterial leaf blight through mutagenesis with chemicals*: Bulletin 38, 9th edition. pp 53-59 Faculty of Agriculture, Shizuoka-University Japan.

Ashrafuzzaman, H. 1992. *Disease of crops,* Bangla Academy publisher, Dhaka, Bangladesh. pp. 203-207

Babu, R. M., Sajeena, A., Samundeeswari, A. V., Sreedhar, A., Vidhyasekeran, P. and Reddy, M. S. 2003. Induction of bacterial blight (*X. oryzae* pv. *oryzae*) resistance in rice by treatment with acibenzolar Smethyl. *Annual Applied Biology*, **143**: 333-340.

Babu, R. M., Sajeena, A., Seetharaman, K., Ebenezar, E. G., Raja, A. S., Biji, K. R. and Prakash, M. S. 2004. Induction of phenols in rice bacterial leaf blight resistance. *Journal of Ecobiology*, **16** (1): 53-56.

Baruah, B. P., Saikia, L., Ali, S. and Senapoty, D. 1991. Nitrogen management for wet land rice in bacterial leaf blight endemic areas. *Oryzae*. **28**: 507-508.

Bhagawati, R. and Bhagawati, K. N. 1993. Interaction of light intensity and Bacterial leaf blight of rice. *Journal of Plant Pathology*, **35**(6): 289-293.

Bhapkar, D. G., Kulkarni, N. B. and Chavan, V. M. 1960. Bacterial blight of paddy. *Poona Agriculture College Magazine*, **51**: 34-46.

Biswas, S. K., Rai, M. and Srivastava, S. S. L. 2009. Evaluation of antibiotics and their suitable use against bacterial blight of paddy [*X. oryzae pv. Oryzae* (Ishiyama) Dye]. *Indian Phytopath*. 62(1): 126-128.

Bokura, U. 1911. Bacterial leaf blight of rice. *Teikoku* **2:** (9): 62-66.

Buddenhagen, I. W., Vuong, H. H. and Ba, D. D. 1979. Bacterial Blight found in Africa. *International Rice Research Newsletter*, **4** (1): 11.

Chand, T., Singh, N., Singh, H. and Thind, B. S., 1979. *International Rice Research Newsletter*, **4:** 12.

Chaudhary, S. U., Hussain, M., Iqbal, J and Ali, M. A. 2009. Effect of nitrogen doses on incidence of bacterial leaf blight in rice. *Journal of Agriculture Research*, **47**(3): 253-258.

Chaudhary, R.C. 1996. Internationalization of elite germplasm for farmers: Collaborative mechanisms to enhance evaluation of rice genetic resources. In: New Approaches for Improved use of Plant Genetic Resources; Fukuyi, Japan; pp. 26.

Chaudhary, S. U., Iqbal, J. and Hussain, M. 2012. Effectiveness of fungicides and antibiotics against bacterial leaf blight in rice. *Journal of Agriculture Research*, **50**:

109-117.

Cheema, A. A., Awan, M. A. and Ali, Yousaf, 1998. Screening of Basmati rice mutants against prevalent diseases in the Punjab province. *Pakistan Journal of Phytopathology*. **10**(1):39-41.

Cheng, Q. F. T., Lin, X. P., Feng, J. C., Guo, F. T. and Lin, X. P. 2001. Breeding of a new indica rice variety Zahanglong-9104. *Fujian Journal of Agricultural Sciences*, **16**(4): 5-8.

Devadath, S. and Dath, A. P., 1987. *International Rice Research Newsletter*, **12**: 30.

Dewa, K. M. K., Banito, A., Onasanya, A., Kpemoua, K. E. and Sere, Y. 2011. Rice bacterial blight in Togo: Importance of the Disease and Virulence of the pathogen. *Current Research Bacteriology*, **4**(3): 94-100.

Durgapal, J. C. 1985. High virulence of *Xanthomonas compestris pv oryzae* a factor in 1980 epiphytotics in the non-traditional rice growing regions of North -West India. *Indian Journal of Agriculture*, **5**(2): 133-135.

Fang, C. R., Lin, C. F. and Chu, C. L. 1956. A preliminary study on the disease cycle of the bacterial leaf blight of rice. *Acta Phytotaxonomica Sinica*, **2**: 173–185.

Fang, C. T., Ren, H. C., Chen, T. Y., Chu, Y. K., Faan, H. C. and Wu, S. C. 1957. A comparison of the rice bacterial leaf blight organisms or rice and *Lersia hexandra Swartz*. *Acta Phytopathol Sinica*, **3**(2): 99-124.

FCI (Food Corporation of India) 2010. Status of rice cultivation. *Current Science*, **90**: 6.

Food and Agriculture Organization, 2011. Agridata, Rome.

Fukunaga, K., in XIth *Pacific Science Congress*, Tokyo, 1966.

Gang, L., Cong-Fengs, Xiao-Miap, Yuey and Jin-Shengw 2009. Analysis of pathotypic and genotypic diversity of *X. oryzae* pv. *oryzae* in China. *Journal of Phytopathology*, **157**: 208-218.

Gnanamanickam, S. S., Sakthivel, N., Nelson, R., Alvarez, A. M. and Leach, J. E. 1995.

Detection of Plant Pathogens and their Management (eds Jeevan, P. Verma, A. Varma and D. Kumar), Anchor Publ. (P) Ltd., New Delhi, pp. 159–172.

Gnanamanickam, S.S., Priyadarshani, B., Narayanan, N.N., Vasudevan P., Kavitha, S., 1999. An over view of bacterial leaf blight disease of rice and strategies for its management. *Current Science*, **77**(1): 1435-1444.

Goto, M. 1964. Kresek and pale yellow leaf, systemic symptoms of bacterial leaf blight of rice caused by *Xanthomonas oryze* (Uyeda & Ishiyama) Dowson. *Plant Div. Rep*. **48**: 858-861.

Gupta, B. B., Salgotra, R. K. and Bali, A. S. 2012. Status paper on rice in Jammu and Kashmir, **pp.**15-16.

Guyer, D., Tuttle, A. S., Johnson, M., potter, S., Gorlach, J., Forff, S. and Land, C. L. 1998. Activation of latent transgenes in Arabidopsis using a hybrid transcription factor. *Genetics*, **149**: 633-639.

Hashioka, Y. 1969. Rice diseases in the world. III. Bacterial diseases. *Riso*. **18**(3): 189-204.

Horino, O. 1984. *Annual of Phytopathology Society of Japan*, **50**: 72–76.

Hoshioka, Y. 1951. Bacterial leaf blight of rice and its control. *Agriculture Horticulture*, **26**: 644-648.

Hossain, M**.** 1997. Rice-supply demand in Asia: A socioeconomic and biophysical analysis. In: Applications of systems approach at the farm and regional levels. (Teng, P.S., Kropff, M.J., ten Berge, H.F.M, Dent, J.B., Lansigan, F.P. and van Laar, H.H. eds). Kluwer Academic Publishers. UK. 263-279.

Hossain, M. and Fischer, K.S. 1995. Rice research for food security and sustainable development in Asia: Achievements and future challenges. Geo journal **35** (3): 286-298.

Ikeda, R. and Busto, G. A. 1990. Resistance of wild rice's to bacterial blight (BB). *International Rice Research Newsletter*, **15**(3): 14.

IRRI: International Rice Research Institute, 1996. Standard Evaluation System for Rice. International Rice Testing Program PO Box 933, Manila, Philippines.

Ishiyama, S. 1922. Studies on the white leaf disease of rice plants. *Rep. Agric. Expt. Sin. Tokyo*, **45**: 233-251.

Ishiyama, S. 1933. Studies on bacterial leaf blight of rice. *Rep. Agric. Exp. Stn. Tokyo*, **45**(3): 233-261.

Jalaluddin, M. 2005. Evaluation of exotic mutants/varieties of aman rice for BLB and sheath blight resistance. Annual report (June). BINA, Mymensingh. **pp**. 210.

Jalaluddin, M., Kashem, M. A., Azam, M. A. and Hasna, M. K. 1998. Evaluation of some advanced mutants of rice for resistance to bacterial leaf blight and sheath blight. *Bangladesh Journal of Agriculture Science*, **28**(1): 33-37.

Jalaluddin, M., Kashem, M. A., Hasna, M. K. and Khalil, M. I. 1999. Screening of some somaclonaling progenies of rice resistance to sheath blight and bacterial leaf blight. *Bangladesh Journal of Crop Science*, **11**(1-2): 39-42.

Jalaluddin, M., Yamamoto, T., Nakai, H. and Tsuyumu, S. 2005. Pathogenic variability and DNA fingerprinting *of Xanthomonas oryzae pv. oryzae* from Bangladesh. *SABRAO Journal of Breeding and Genetics*, **37**(1): 1-10.

Jalavicharana, K. 1958. Occurrence of bacterial blight of rice. *FAO Plant Prot. Bull*, **6**(8): 126.

Janes, M. P., Jeutong, F. and Tehatchoua, J. 1991. Disease of rice in Cameroon. *International Rice Research Newsletter*, **16**(1): 19-20.

Kaku. 1980. Clipping inoculation method for evaluating quantitative resistance of rice varieties to bacterial leaf blight. *Kinki-Chugoku Agriculture Research*, **54**: 17-18.

Khan, J. A., Arshad, H. M. I., Jamil F. F. and Hasnain, S. 2009. Evaluation of rice genotypes against bacterial leaf blight (blb) disease. *Pak. J. Phytopathol.,* **21**(1): 26-30.

Khan, J. A., Arshad H. M .I., Jamil F. F. and Hasnain S. 2008. Screening of rice germplasm against Bacterial leaf blight disease. *Pakistan Journal of Phytopathology.* **20** (1): 48-51.

Khan, J. A., Jamil, F. F. and Gill, M. A. 2000a. Screening of rice germplasm against Bakanae and Bacterial leaf blight. *Pakistan Journal of Phytopathology*. **12**(1): 6-11.

Khan, T. Z., Gill M. A. and Khan M. G.. 2000b. Screening of rice varieties/lines for resistance to resistance to bacterial leaf blight. *Pakistan Journal of Phytopathology*. **12**(1):71-72.

Kumar, A., Verulkar, S. B. and Kotashane, A. S. 1995. Failure of induced resistance in rice against BLB of paddy pretreated with killed bacteria *(Xoo). Advances in P. Sci. India*, **8**(2): 297-300.

Lan, S. S. 2002. Breeding and utilization of Indica rice restorer line Zhenhui 084. *Hybrid Rice*, **17**: 2.

Lin, C. S. 1993. Tolerance of twelve rice varieties against *Xanthomonas campestris pv. oryzae* the bacterial leaf blight pathogen. *Bulletin of Taichung-district-Agricultural-Temprovement Station*, **41**: 43-54.

Liu, D. 2006. *Xanthomonas oryzae pv. oryzae:* Model pathogen of a model crop. *Molecular Plant Pathology*, **7:** 303-324.

Liu, Y. F. 2001. Analysis on resistance of rice varieties (lines) to bacterial leaf blight in Jiangsu Province. *Plant-Protection*, **27**(5): 3-6.

Lozano, J. C. 1977. Identification of bacterial leaf blight in rice, caused by *Xanthomonas oryzae*, in America. *Plant Disease Rep*, **61**: 644- 648.

Mahto, B. N. 2001. Effect of nitrogen doses and leaf injury on bacterial leaf blight of rice. *Annals of Agricultural Research*, **22**(2): 198-200.

Mariappan, V. 1988. Antibiotice-fungicide combination in the control of bacterial leaf blight of rice. *Advances in research on plant*.

Mew, T. W. 1987. Current status and future prospects of research prospects of research on bacterial blight of rice. *Annual Review of Phytopathology*, **25**: 359-382.

Mew, T. W. and Majid, A. 1977. Bacterial blight of rice in Pakistan. *IRRN*, **2**(1): 5.

Mew, T. W., Alvarez, A. M., Leach, J. E. and Swing, J. 1993. Focus on bacterial blight of rice. *Plant Diseases*, **77**: 5–12.

Mew, T. W., Mew, I. C. and Huang, J. S. 1984. *Phytopathology*, **74:** 635–641.

Mizukami, S. and Wakimoto, S. 1970. Epidemiology and control of bacterial leaf blight of rice. *Annual Review of Phytopathology*, **8:** 259-280.

Mizukami, T. 1956. Studies on the bacterial leaf blight of rice plant on the entrance and multiplying portion of the pathogen upon the rice plant leaves (preliminary report). *Agricultural bulletin of Saga University*, **4**: 169-175.

Mizukami, T. and Wakimoto, S. 1969. Epidemiology and control of bacterial leaf blight of rice. *Annual Review of Phytopathology*, **7**: 51-72.

Mondal, A. H. and Miah, S. A. 1985. *International Rice Research Newsletter*, **10**: 12–13.

Murty, V. S. T. and Devadth, S. 1984. Role of seed in survival and transmission of *Xanthomonas campestris* pv. *oryzae* causing bacterial blight of rice. *Phytopathologische Zeitschrift*, **110**: 15–19.

Nakagami, K., Tanaka, H., Ishida, M. and Koremura, M. 1980. *Journal of Pestic. Sciences*, **5:** 237–242.

Nakagami, K., Tanaka, H., Yamaoka, K. and Tsujino, Y. 1980. *Journal of Pestic. Sciences*, **5**: 607–609.

Natrajan, S. **1988.** Chemical control of bacterial leaf blight of rice. *Advances in research on plant pathogenic bacteria based on the proceedings of the National*

Symposium on Phytobacteriology **held** at the University of Madras, Madras, India during March **14- 15. 1986.** Department of Plant Pathology, Tamil Nadu Agricultural University, Coimatiore, **641003,** India. **87-89: 6.**

Nishida, T. 1909. Bacteril leaf of rice. *Noji Zappo*, Japan. **127**: 68-75.

Ou, S. H. 1972. Varietal resistance and variability of *Xanthomonas oryzae*. In: *Rice Breeding*. International Rice Research Institute, Laos Banos, Philippines **pp** 297-300.

Ou, S. H. 1985. Bacterial leaf blight in Rice diseases. Common wealth Microbiological institutes, *Cambrian News*, Aberystwyth, U.K. 70-74.

Ou, S. H. 1985. Rice Diseases, 2nd Ed. CMI, Kew, **pp** 380.

Rafi, A., Hameed, A., Akhtar, A.M., Akmal, M., Bibi, A.,Ali, M.,Rehman, H., and Junaid, M. 2013. Effect of planting dates on bacterial leaf blight incidence and yield performance of rice cultivars in different location of Khyber Pakhtunkhwa, Pakistan,. *Sarhad Journal of Agriculture.* **29**(3): 407-414.

Rakesh, M. 1994. Evaluation of different seed treating agents for the control of bacterial blight of rice. *Crop Research Hisar*, **7**(2): 288-291.

Ranjan, R. K., Rai, Bimla, Chaudhari, P. K. and Rai, R. C. 2012. Effect of different dates of sowing on bacterial leaf blight of rice disease (*Xanthomonas oryzae* pv. *oryzae*). *Envirnent and Ecology* **30**(3): 586-589.

Reddy, A.P.K., Katyal, J.C, Rouse, D.I. and Mackenzie, D.R 1979. Relationship between nitrogen fertilization, bacterial leaf blight severity and yield of rice. *Phytopatholgy*, **69**: 970–973.

Reddy, P. R. and Shukla, S. N. 1978. Bacterial leaf blight disease Syndrime in rice. *India Phytopathology*, **39**(2): 190-193.

Seneviratne, S. N. 1962. Bacterial blight of rice. *Tropical of Agriculture*, **118**: 123.

Sere, Y., Onasanya, A., Verdier, V., Akator, K., Ouedraogo, L. S., Segda, Z., Mbare, M.

M., Sido, A. Y. and Basso, A. 2005. Rice bacterial leaf blight in West Africa: Preliminary studies on disease in farmer's fields and screening released varieties for resistance to the bacteria. *Asian Journal of Plant Science*, **4**: 577-579.

Shah, M. A. 2008. Morphological, molecular and resistance (bacterial blight and leaf folder) characterization of wild species of rice and F1 hybrids. Ph.D. Thesis submitted to NWFP Agriculture University, Peshawar.

Shekhawat, G. S. and Srivastava, D. N. 1968. Variability of Indian isolates of *Xanthomonas oryzae* (Uyeda et. Ishiyama) Dowson, the incitant of bacterial leaf blight of rice. *Annals of Phytopathology Society of Japan*, **34**: 289-297.

Singh, S.J., *1999.*Studies on Variability an d epidemiology of *Xanthomonas oryzae* pv. *oryzae (Ishiyama) Comb. Nov .Causing Bacterial Blight of Rice in Jammu region.* M.Sc. thesis **pp** *35-51.* SKUAST-Jammu.

Sivaswamy, S. N. 1985. Effect of stable bleaching powder on bacterial leaf blight of paddy. *Oryza*. **22**(3-4): 203-213.

Song, F. and Goodman, R. 2001. Molecular biology of disease resistance in rice*. Physiol. Mol. Plant Pathology*, **59**: 1-11.

Sonti, R.V., 1998. Bacterial leaf blight of rice: New insights from molecular genetics. *Current Science*, **74**(3): 206-212.

Srinivasan, M. C., Thirmulachar, M. J. and Patel, M. K. 1959. *Bacterial blight of rice. Current Science*, **28**: 469-470.

Srivastava, D. N. 1967. Epidemiology and control of bacterial blight of rice in India. T*ropical Agriculture Research Series*, **1**:11-18.

Srivastava, D. N. and Rao, Y. P. 1963. Epidemic of bacterial blight disease of rice in North India. *Indian Phytopathology*, **16**: 393-394.

Srivastava, D. N. and Rao, Y. P. 1964. Seed transmission and epidemiology of bacterial blight disease of rice in North India. *Indian Phytopathology*, **17**: 77–78.

Srivastava, D.N. and Rao, Y.P. 1969. Seed infection and transmission of bacterial leaf streak of rice. Indian Phytopathology **17**: 77-78.

Sulaiman, M. and Ahmed, L. 1965. *Indian Farming*. Controlling bacterial blight in paddy in Maharastra. **15:** 27–29.

Swings, J., Van-den-moooter, M., Vauterian, L., Hoste, B., Gillis, M., Mew, T. W. and Kersters, K. 1990. Reclassification of the causal agents of bacterial blight (*Xanthomonas campestris* pv. *oryzae)* and bacterial leaf streak (*Xanthomonas campestris* pv. *oryzicola)* of rice as pathovars of *Xanthomonas oryzae* (ex Ishiyama 1922) sp. nov, nom. *Rev. Int. J. Syst. Bacterial*, **40**: 309-311.

Tabei, H. and Mukoo, H. 1960. Anatomical studies of rice plant leaves affected with bacterial leaf blight, in particular reference to the structure of water exudation system. *Bulletin National Institute of Agricultural Science*, **11**: 37-43.

Tagami, Y. and Mizukami, T. 1962. Historical review of the researches of bacterial leaf blight of rice caused by *Xanthomonas oryzae* (Yueda et Ishiyama) Dowson. Special report of the plant diseases and insect pests forecasting services No. 10. Plant protection division, Ministry of Agriculture and Forestry, Tokyo, Japan, **pp**. 112.

Tagami, Y., Kuhara, S., Kurita, T., Fujii, H., Sekiya, N., Yoshimura, S., Sato, T. and Watanabe, B. 1963. *Bulletin Kyushu Agriclture. Experiment. Station* **9**: 89–122.

Takaishi, M. 1909. Studies on bacterial leaf blight of rice, first report, Dainihon Nokaiho, Japan. **340**: 53-59.

Takeuchi, H. 1930. Occurrence of bacterial leaf blight of rice. *Bull. Chosen Sotokufu Agric. Exp. Stn*, **5**(1): 62-64.

Tasleem-uz-Zaman, K., Gill, M. A. and Khan, M. G. 2000. Screening of rice varieties for resistance to BLB. *Pakistan Journal of Phytopathology*, **12**(1): 71-72.

Thiagarajan, P., Ramanathan, K. M. and Mariappan, V. 1986. *International Rice Research Newsletter*, **11**: 22.

Thind, B. S. and Bala, G. S. 2002 Effect of cultural practices on seed plant trans-mission of *Xanthomonas oryzae pv. oryzae* in rice. *Journal of Mycology and Plant Pathology*, **32**: 90-91.

Unnamalai, M., Mew, T. W. and Gnanamanickam, S. S. 1988. *Advance Research in Plant Pathogenic Bacteria*, 73–82.

Valluvaparidasan, V. 1988. Control of bacterial leaf blight disease of rice. *Advances in research on Plant Pathology, Bacteria based on the proceedings of the National Symposium on Phytobacteriology* held at the University of Madras, Madras, India during March 14- 15, 1986. Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore 641 003, India. 17: 99-103.

Veena, M.S., Shetty, H.S., Mortensen C.N. and Mathur, S.B. 2000. Bacterial leaf blight of rice. Technical Bulletin, Department of Studies in Applied Botany, University of Mysore, India and Danish Government Institute of Seed pathology for Developing Countries, Denmark, **pp**. 16.

Xiao, Y. S., Wang, Z. Z. and Guo, S. C. 1998. Effect of *Xanthomonas oryaze* pv. *oryzae* activated oxygen Scavengers in the seedling leaves of hybrid rice. *Acta Agronomica Sinica*, **24**(1): 122-188.

Yamanuki, S., Nakamura, K., Kayano, M., Narita, T. and Iwata, T. 1962. First occurrence of bacterial leaf blight of rice in Hokkaido. *Annuals of Phytopathology Sciety. Japan*, **27**: 264.

Yoshimura, S. 1963. Diagnostic and ecological student of rice bacterial leaf blight, caused by *Xanthomona oryzae* (Yeda et Ishiyama) Dowson. *Bull. Hokuriky Agric. Exp. Stn*, **5**: 27-182.

Zhang, M. X. and Zhang, M. X. 1999. Characteristics and main cultural techniques of new late japonica rice variety Yuanging No.7 Zhejinag Nongye Kexue, **4**: 154-155.

Zhang. 1998. Evaluation of resistance to bacterial blight in wild rice species. *Scence. Agriculture Sinica*, **27**(5): 1-9.

Zhao, X. H., Shen, Y., Shu, P. P. and Yuan, X. P. 1994. Reaction of foreign rice varieties (lines) to Pathotypes of Bacterial Leaf Blight and their utilization, Entomological Knowledge. *China National Research Inst. China*, **31**(1): 2-3.

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Certificate - IV

Certified that all the necessary corrections as suggested by the external examiner/ evaluator and the Advisory committee have been duly incorporated in the thesis entitled "***Management of bacterial leaf blight of paddy (Oryza sativa L.) caused by Xanthomonas oryzae pv. oryzae***" submitted by **Mr. Prem Chinabi Aryan,** Registration No. **J-14-M-398.**

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