SURVIVAL OF *Xanthomonas campestris* pv. *oryzae* AND ITS CONTROL IN KUTTANAD

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DECLARATION

I hereby declare that this thesis entitled **"Survival of *Xanthomonas campestris* pv. *oryzae* and its control in Kuttanad"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
30th April, 1996.

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CERTIFICATE

Certified that this thesis entitled **"Survival of *Xanthomonas campestris* pv. *oryzae* and its control in Kuttanad"** is a record of research work done independently by **Smt. C. A. Mary** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

Bacterial blight is one of the most important diseases of rice in South East Asia. In Kerala this disease is prevalent in two of the major rice growing regions such as Palakkad and Kuttanad region comprising Alleppey, Pathanamthitta and Kottayam Districts. In Kuttanad, even though the disease occur both during punja (November-December to February-March) and additional crop (June-July to September-October), it becomes severe only during the additional crop season. Therefore, the main objective of the present investigation was to understand the factors responsible for the recurrence of this disease in a severe form only during this season. The mode of survival of the pathogen during and in between the two major cropping seasons of the region was also studied in detail. An extensive survey was also conducted among 115 farmers in 12 Krishibhavans of Kuttanad taluk for this purpose to collect specific informations on existing cultural practices, crop variety, nature and distribution of weed flora and self sown rice in and around rice fields and on weather data from June 1992 to March 1994. As last part of this investigation, the efficacy of two different methods of spraying, prophylactic and curative, using selected antibiotics, Bactrinol-100 and cowdung extract on the control of bacterial blight disease was tested under field condition at Nedumudi, in Kuttanad. The project was implemented with following technical programme.

1. Survey on the incidence of bacterial blight of rice in Kuttanad.

2. Screening rice varieties for resistance against *Xanthomonas oryzae* pv. *oryzae*.

3. Mode of survival of *Xanthomonas oryzae* pv. *oryzae* in infected seed, plant debris, soil and water, collateral weed hosts and self sown rice.

4. Influence of weather on bacterial blight disease in Kuttanad.

5. Control of bacterial blight of rice.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Bacterial blight caused by *Xanthomonas oryzae* pv. *oryzae* is an important disease of rice occurring in almost all the major rice producing countries of tropical and subtropical Asia (Ou, 1972). It is also reported from South America (Lozano, 1977), and the Sahelian countries of Africa (Awoderu and John, 1984).

In India, bacterial blight of rice was first observed in Khopli area of Maharashtra State during 1951 (Sreenivasan *et al.*, 1959 and Bhapkar *et al.*, 1960). Later a severe epidemic of bacterial blight was recorded from Bihar (Srivastava and Rao, 1964). This disease is now prevalent in most of the rice growing regions of the country. In the production oriented survey organised by All India Co-ordinated Rice Improvement Project (AICRIP) the occurrence of bacterial blight was reported in moderate to severe form in 14 states namely, Andra Pradesh, Bihar, Gujarat, Haryana, Kerala, Karnataka, Maharashtra, Madhya Pradesh, Orissa, Punjab, Tamilnadu, Uttar Pradesh and West Bengal (Reddy, 1983 and Durgapal, 1985).

In Kerala bacterial blight of rice was first observed in 1976 in Palakkad district. Later, Mary and James Mathew (1980) reported that the disease was endemic in the two major rice growing areas of Kuttanad and Palakkad. However, in Kuttanad it was found to recur in an epiphytotic proportion almost

every year during the additional crop season from June-July to September-October (Nair *et al.*, 1990 and Sreekumar, 1991).

The Pathogen

Takaishi (1909) observed that the turbid dew drops from bacterial blight affected rice plants consisted of a mass of bacteria which could reproduce the disease when inoculated into healthy plants. Bokura (1911) isolated a bacterium called *Bacillus oryzae* from such diseased leaves. Ishiyama (1922) reported that bacterial blight was caused by a kind of rod shaped bacterium and named it as *Pseudomonas oryzae* (Uyeda and Ishiyama). This was subsequently renamed as *Xanthomonas oryzae* (Uyeda and Ishiyama) Dowson by Breed *et al.* (1957). In the first comprehensive phenotypic study of the genus *Xanthomonas*, Dye (1962) showed that most species could not be distinguished from *Xanthomonas campestris*. Subsequently, Dye and Lelliot (1974) recorded five species of *Xanthomonas* including *X.oryzae* in *Xanthomonas campestris*. Buchanan and Gibbons (1974) and Dye *et al.* (1980) suggested the pathovar names of *Xanthomonas campestris* according to the International Standards for naming pathovars of phytopathogenic bacteria and identified the pathogen as *Xanthomonas campestris* pv. *oryzae* (Ishiyama 1922). Vanden Mooter and Swings (1990) after a comprehensive phenotypic analysis of strains of *Xanthomonas* and related strains suggested an improved taxonomy of the genus comprising eight taxa viz., *albilineans, axonopodis, campestris, fragariae, graminis, oryzae, populi* and *maltophilia*, the first seven were plant pathogens and the last one *maltophilia* a non pathogen, were distinguishable phenotypically as species.

On the basis of DNA-DNA hybridization technique and other phenotypic data, the name *Xanthomonas oryzae* (ex Ishiyama 1922) Swings *et al.* (1990) was reinstated with two pathovars *X. oryzae* pv. *oryzae* causing the bacterial blight of rice and *X. oryzae* pv. *oryzicola* causing the leaf streak disease of rice (Young *et al.* 1992).

Ishiyama (1922) first described the bacterial blight pathogen as an aerobic, rod shaped, gram negative, non spore forming bacterium with monotrichous flagellation. Breed *et al.* (1957) reported that the pathogen was a rod shaped aerobic bacterium of size ranging from 0.5 to 0.8 x 1.0 to 2.0 µm which produced smooth, circular glistening colonies of yellow colour on nutrient agar medium. It neither liquefied gelatin nor hydrolyzed starch, but produced slightly acidic reaction in milk medium and used sugars such as glucose, lactose and sucrose without production of any gas. However, Pordesimo (1958) reported that an isolate of the bacterial blight pathogen from Philippines liquefied gelatin and hydrolysed starch to some extent.

The earlier observations of Breed *et al.* (1957) were later confirmed by Sulaiman and Ahamed (1965). They also reported that the optimum temperature for growth of the pathogen was between 28 to 30°C with thermal death point at 52-53°C. Reddy (1966) made a comprehensive study of *Xanthomonas oryzae* isolates occurring in India and reported that isolates from rice varieties T141 and PTB 10 were morphologically and culturally similar to the original isolate *Xanthomonas oryzae* but differed from other isolates in their ability to hydrolyse starch and inability to reduce nitrate. This indicated that different strains of *Xanthomonas oryzae* occurred in India.

Reddy (1966) reported that bacterial isolate of pathotype I was characterised by a resistant reaction on DV85 and susceptible reaction on IR8, Kogyoku (Xa-1), Rantai-Emas 2 (Xa-1+Xa-2), Chugoku 45 (Xa-3), IR 20 (Xa-4), IR 1545 (Xa-5), Malaghit Sungsong (Xa-6), Camposelak. The isolates of pathotype II on the other hand were characterised by a resistant reaction on Chugoku 45, Camposelak and Malaghit Sungsong and susceptible reaction on other varieties including DV85. Pathotype I was prevalent in all the bacterial blight endemic regions of the country whereas distribution of pathotype II was restricted to certain areas in Orissa and West Bengal (Reddy *et al.*, 1980).

Chakravarthi and Rangarajan (1967) made a detailed investigation on the physiological and biochemical characters of the pathogen and found that its colonies on nutrient agar were yellow, smooth, slimy and circular with an entire margin. Abundant slime was produced on slants of nutrient agar, potato dextrose agar and yeast extract dextrose agar media. The optimum temperature for the growth of the bacterium was between 28-30°C. The other characters reported were its strict aerobic nature, oxidative metabolism of glucose and ability to liquefy gelatin. Starch hydrolysis was positive and litmus milk was reduced turning the medium blue without coagulation and peptonization. Hydrogen sulphide and ammonia were produced from peptone water. Acid without gas was produced from glucose, galactose, sucrose, xylose, maltose and lactose. Neither urease nor tyrosinase was produced by the bacterium under appropriate growth conditions.

Symptomatology

Mizukami (1956) first described the symptoms of bacterial blight as water soaked lesions which appeared along the margin of the upper leaves. They gradually enlarged along the veins and later turned yellow in colour. As the disease progressed, the lesions became white or greyish white in colour followed by withering of the infected parts. In seedlings, on the other hand, the infected leaves rolled completely and turned yellow before getting dried. This was called the 'kresek' phase and was first observed in Indonesia by Reitsma and Schure (1950). Studies conducted at International Rice Research Institute, Philippines had also revealed that the kresek phase of the disease started one or two weeks after transplanting as greyish discolouration of leaves followed by rolling of leaves along the midrib regions (Anon. 1964).

Goto (1964) described the pale yellow symptom of *Xanthomonas* infection. In this, two or three pale yellow young leaves were found in mature plants. The symptoms resembled very much to that of iron deficiency. But no bacteria could be isolated from pale yellow leaves. The organism was present only in the crown region of infected stem.

Srivastava and Rao (1966) reported the typical symptoms of bacterial blight which appeared one week after artificial inoculation. As in natural infection, the symptoms began as water soaked lesions on both margins of leaves which later extended to leaf sheath and clumps resulting in the death of the tiller or the whole clump. Singh and Saksena (1968) observed poor root growth in plants infected during the early stages of growth. They further

observed poor grain filling and complete prevention of earhead development in severely affected plants.

The extent of yield loss depended on locality, season, weather and cultivar. In places where severe kresek was observed,total crop failure was reported. Ishiyama (1922) reported a reduction of 20 to 30 percent in yield when the infection was moderate and 30 per cent when it was severe. The weight of 1000 grains of unhulled rice was also reduced by the disease. The percentage of husked, sterile, unfilled grains was high in diseased plants (Ikeno, 1958). The average loss in yield due to the disease was 33.1 per cent in T(N) I, 46.8 per cent in Tainan 8 and 74.89 per cent in LT8 under field conditions (Anon. 1967).

Ray and Sengupta (1970) studied the incidence of bacterial blight in Tripura on T(N)I and observed that in summer rice from December to April, the disease severity was mild so that there was no measurable yield loss. However, in transplanted winter and autumn crops from May to September and July to December respectively, the intensity of infection was very severe which resulted in considerable yield loss. According to Rao and Kauffman (1971) the bacterial blight was more severe during monsoon season in dwarf varieties like T(N)I and Jaya with yield loss as high as 50 per cent. Rao and Kauffman (1977) also observed a potential grain loss of 56 per cent from Andra Pradesh in highly susceptible Karuna variety, 10 per cent in moderately susceptible IR8 and insignificant loss in relatively resistant IR22 varieties during the monsoon season under field conditions.

Mohiuddin *et al.* (1977) reported that infection of Co33 variety of rice at the flag leaf stage resulted in 30 to 40 per cent loss in yield.

The influence of *Xanthomonas oryzae* on the yield components of rice cultivars such as Karuna, Sona and T(N)I was also studied by Reddy *et al.*(1978) at the Central Rice Research Institute, Cuttack. They found that when the crop was infected at the panicle initiation stage, the yield reduction was about 72.7 per cent in Karuna and 43 per cent in Sona. The loss in yield due to the disease at flowering stage was only 25 to 28 per cent in Sona and T(N)I.

Srivastava and Kapoor (1982) reported that in rice cultivar Jaya, loss in yield due to bacterial blight varied from 6.3 per cent at infection grade one to 36.8 per cent at infection grade nine. Sharma and Kaul (1984) analysed the yield loss due to bacterial blight on two susceptible and two resistant cultivars and found that all yield components were adversely affected. Yield loss due to reduction in productive tiller number was high in susceptible varieties. Malik and Paroda (1987) studied the performance of 19 varieties under bacterial blight stress and reported that grains per panicle was the character affected by the disease. Lu *et al.* (1990) analysed the effects of bacterial blight on main economic traits in eight hybrids in China. This investigation led to the conclusion that inoculation of susceptible hybrids at the booting stage decreased the number of filled grains per plant, thousand grain weight and grain yield and increased the number of empty husks per plant. Jin *et al.* (1993) evaluated the effect of bacterial blight on grain yield and yield components of 41 resistant cultivars with different levels of

resistance. They found that the yield of plants grown at high nitrogen levels and infected 60-70 days after sowing was less than that of plants infected before 60 or after 70 days of sowing. The reduction was associated with the reduction of panicles per hill, grains per panicle, percentage of filled grains and thousand grain weight. Infection of upper leaves before flowering resulted in reduced harvest index in IR56, IR36 and IR72. However when the fourth leaf was infected, the harvest index was increased. Harvest index in IR56, IR36 and IR72 plants infected after flowering and IR 66 at 70-90 days after sowing was also increased.

Lin (1996) in Taiwan studied the influence of bacterial blight on the yield and quality of rice and reported that the grain yield declined due to a significant decrease in panicle weight, spikelet number per panicle, percentage of filled grains and thousand grain weight. Blight induced a significant decline in grain translucency and an increase in percentage of immature green and dead grains. However, its influence on percentage of brown rice, total milled rice and head rice was not significant. The eating quality of infected rice was reduced slightly.

Screening rice varieties for resistance to bacterial blight

Mahmood and Singh (1970) reported that while rice varieties such as T(N)I, T65 and Padma were highly susceptible to bacterial blight, IR5, IR8, IR48 were moderately resistant and BR7 and N136 were resistant. Rice varieties like IR20 and IR22 which were earlier found to be resistant (Anon, 1970) later became susceptible to a virulent strain of *Xanthomonas oryzae*

(Anon, 1973). Dath *et al.* (1977) found that the build up of bacterial leaf blight was greater in highly susceptible varieties like T(N)I than in moderately susceptible varieties. Wu *et al.* (1981) classified rice varieties resistant to bacterial blight into three categories such as broad spectrum resistant varieties like IR20, IR8, non broad spectrum resistant varieties like Zenith, Tetep and Co22 and non resistant variety like Tadakan.

Mariappan *et al.* (1981) reported a partial resistance of rice cultivar ASD 5 to bacterial blight upto tillering stage to a virulent strain of the pathogen that caused severe damage to most of the improved cultivars of rice. Agarwal and Philip (1982) reported that out of 1201 entries tested, seven were highly resistant and 14 resistant to bacterial blight. Sahu *et al.* (1982) could select 25 out of a total of 6129 rice cultivars as resistant varieties after screening for natural resistance against bacterial blight infection. But Mary and Mathew (1982) while screening 50 popular cultivars of rice in Kerala, could isolate no variety that was resistant to *Xanthomonas oryzae* pv. *oryzae* infection. Ahuja (1984) and Ahuja *et al.* (1984) tested 37 rice donor cultivars and got Latisail and IET 4141 as resistant to both kresek and blight phases of *X. oryzae* pv. *oryzae*. Chand *et al.* (1984) evaluated 177 early to mid season races and found 125 numbers as resistant to *X. oryzae* pv. *oryzae*.

Shukla (1984) found that CB II a tall traditional *indica* type possessed two dominant genes governing resistance to *X. oryzae* pv. *oryzae* to both kresek and blight phases.

Dev and Mary (1985) evaluated 328 entries from the NSNI in 1983 and obtained IET Nos. 8236, 8288, 8314 and 8748 as resistant to *Pyricularia oryzae*, *Rhizoctonia oryzae* and *Xanthomonas oryzae* pv.*oryzae*. Manuel *et al.* (1985) studied the reaction of Ambasamudram varieties and found ASD11 had resistance not only to bacterial blight but also to four other diseases. Pandey *et al.* (1985) found that 37 out of 317 entries which scored 3 on 0-9 scale in six AICRIP trials later became susceptible to bacterial blight when screened under artificial epiphytotic conditions.

Singh and Chand (1986) studied the reaction of 125 early to mid season varieties to *X. oryzae* and obtained RP 2151-175-1 and RP2151-192-1 as resistant to both phases of pathogen infections. Subramanian *et al.* (1986) studied the reaction of IRRI races and reported IR 28118-138-2-3 as most resistant. IR 18349-22-1-2-1-1, IR 21820-154-3-2-2-3 and IR 25587-133-3-2-2-2-2 also combined high yield of 5.3 t/ha with high disease resistance. Malik (1987) screened 30 early, 50 mid season and 52 scented elite lines and found seven early, 15 mid season and 11 scented lines were resistant to bacterial blight.

Saha (1988) studied the reaction of 74 varieties with gene Xa-5 to 4 Philippines races of bacterial blight pathogen and found that all were resistant to races 1, 2 and 3 but only 22 were resistant or moderately resistant to race 4 which came from gene centre 1 comprising Bangladesh, Nepal and North East India and one from Indonesia and Pakistan. Shen *et al.* (1990) screened 99 rice cultivars and lines for resistance to seven pathogenic groups of *X. oryzae* and found that only eight varieties showed resistance to all seven

pathogenic groups. Shen *et al.* (1991) also tested 14,400 cultivars for resistance to *X. oryzae* pv. *oryzae* and reported 18 with resistance to *X. oryzae* pv. *oryzae*.

Hamamatsu *et al.* (1989) analysed the response of 42 *Oryza rufipogon* strains to five Japanese races of *X. oryzae* pv. *oryzae* and reported variation in both general and race specific resistance. When one annual and two perennial *Oryza rufipogon* strains from Thailand and two primitive Chinese *Oryza sativa* land races were investigated for response to three Japanese pathogen races, wide variation was observed in both groups, although the wild strains were generally resistant and land races more susceptible. Resistance to *X. oryzae* strain was also assessed by Yong *et al.* (1991) in Yunnan, China and found that six per cent were resistant. The glutinous varieties were more resistant than non-glutinous varieties.

Saini *et al.* (1992) evaluated 48 Basmati lines against eight Indian pathotypes and reported that all were susceptible to pathotype I and three cultivars and 21 lines were susceptible to all the eight pathotypes.

Kaku (1993) grouped the resistance reactions of rice varieties to *Xanthomonas oryzae* pv. *oryzae* into 3 types- symptomless, browning and small yellow lesion. No symptoms were observed in the resistant reaction controlled by the resistance genes Xa-1, Xa-7, Xa-10 while the reaction controlled by Xa-2, Xa-4, 4a, 5 and Xa-8 was characterised by small yellow to slight yellow lesions. The resistance reaction controlled by Xa-3, Xa-4b, Xa-6 and Xa-9 was characterised by brown necrosis.

Rana *et al.* (1994) evaluated 500 rice varieties for resistance to *Xanthomonas oryzae* pv. *oryzae* using IR54 as resistant check and T(N)I as susceptible check. They also found nine varieties as resistant to bacterial blight disease. Sha *et al.* (1994) reported that out of 30 cultivars tested for resistance to eight strains of *Xanthomonas oryzae* pv. *oryzae* from Japan, IRRI Philippines and China, six were resistant to all strains and 18 were resistant to between one and seven strains.

Koch and Parlevliet (1990) compared various assessment methods for quantitative resistance in rice cultures to *Xanthomonas oryzae* pv.*oryzae* and found that no significant correlation existed between lesion length and leaf dimensions. This indicated that leaf size did not affect the spread of the disease once the infection had been initiated. Lesion length was therefore an acceptable parameter for assessing resistance to *Xanthomonas oryzae* pv. *oryzae*.

Survival of the pathogen

Chattopadhyay and Mukherjee (1971) reported that in naturally infected seeds, *Xanthomonas oryzae* survived for 30 to 160 days after harvest depending on the variety. Kauffman and Reddy (1975) reported that the presence of the pathogen could be detected in infected seeds by the concentrated suspension technique method and the phage technique up to two months after harvest. Singh and Rao (1977) demonstrated the presence of *Xanthomonas oryzae* in and on the seeds for a period up to 11 months after harvest.

Durgapal *et al.* (1980) studied the mode of infection of rice seeds by *Xanthomonas oryzae* pv. *oryzae*. Systemic infection in culms of rice cultivar T(N) I resulted in the production of infected panicles. Seed infection occurred through the vascular system. Bacterial streaming was detected in the vascular strands at the panicle base and in seed pedicels. Singh *et al.* (1980a) observed that the bacterium could survive for about ten months at room temperature and the seeds retained enough infection until the next season to cause an epidemic under favourable conditions. Active inoculum was present in 90 per cent of infected seeds immediately after harvest. Severe vascular infection in panicle branches resulted in chaffiness of seeds.

Raina *et al.* (1981) reported that the bacteria overwinter to next crop season not only through infected seeds but also in the rhizosphere of wheat and other non host plants. Pal *et al.* (1982) studied the survival of *Xanthomonas oryzae* on varieties like Pusa 33 and T(N)I and found that about 35 to 36 per cent of the infection was noticed when the seeds were stored in plastic jars at room temperature. However, the bacterium was not detected after three months of storage. Reddy (1983a) monitored the movement of the bacterium upward in rice seedlings grown from infected seed and showed that the disease was transmitted through seed. Singh *et al.* (1983) could demonstrate the successful seed transmission of bacterial blight in T(N)I seed samples in Copen hagen, Burma, Malaysia and Thailand.

According to Murthy and Devadath (1984) in kharif season, the pathogen survived for 170-180 days in 54 per cent of infected seeds while in the rabi season it survived only in 45 per cent of infected seeds. They also

suggested that the infected seed may serve as a source of inoculum from season to season even if they did not produce symptoms directly.

According to Jain *et al.* (1985), the bacterial streaming test revealed greater than two per cent seed infection in eight test cultivars with a disease score of nine. The cultivars varied in per cent seed infection. They also showed that the fluorescence technique was not good for detecting the bacterium in the seeds. Pandey (1985) reported the inadequacy of germling ooze test in detecting *Xanthomonas oryzae* pv. *oryzae* in rice seeds. Unnamalai *et al.* (1986) observed that direct immunofluorescence was the most sensitive technique for detection of 10^2 c.f.u./ml of *Xanthomonas oryzae* pv. *oryzae* in rice seeds.

Raj and Pal (1988) reported that infected leaves seemed to provide primary inoculum for the next crop, since the pathogen remained viable in leaves irrespective of the storage condition over nine months. Sunder and Dodan (1989) studied the cross season perpetuation of bacterial blight pathogen in Haryana and reported that *Xanthomonas oryzae* pv. *oryzae* remained infective in stored rice leaves but not in grains when tested both under pot culture and field condition using three cultivars.

According to Chattopadhyay and Mukherjee (1975), the residue from harvested crops provided the inoculum for subsequent crop, particularly when two crops were raised in a year. Mary and Mathew (1980) reported that the pathogen could survive for 28 days in infected plant debris and crop residue. Trimurthy *et al.* (1982) observed that the pathogen survived in diseased stubbles on soil surface for 190 days, in diseased leaves for 130 days,

in stubbles buried in soil for 110 days and in leaves buried in soil for 60 days respectively. Flooding of infected material reduced the extent of survival of the pathogen. Further, in double cropped areas infected stubble was a source of inoculum for the next crop.

Singh (1971) reported that *Xanthomonas oryzae* pv. *oryzae* did not survive in unsterilized soil for a week or over summer in the field, in manure or compost pits. Murthy and Devadath (1982) studied the survival of *X.oryzae* pv. *oryzae* in different soils and reported that survival was influenced by the type of soil. In acid sulphate and saline soils, the pathogen survived for less than 10 days. However, the pathogen survived better in alluvial soils than in black calcareous and laterite soils. Besides, the rate of survival was more in sterilized than in unsterilized soil. Murthy and Devadath (1982a) in another study reported that *Xanthomonas oryzae* pv.*oryzae* and its phage survived longer at 15-25°C than at 30-45°C.

Dath and Devadath (1983) did not get any disease development in seedlings of susceptible T(N)I when the inoculum of *Xanthomonas oryzae* pv. *oryzae* was added to irrigation water. However, when the level of water was increased, blight developed in plants with leaves in contact with the infected irrigation water. But Kresek disease developed in seedlings grown in soil to which 1/10 and 1/100 dilution of bacterial inoculum had been added but not when 1/1000 dilution was used.

Murthy and Devadath (1981a) gave evidence that volunteer plants may be the source of primary inoculum for the next crop especially under low land conditions in double cropped areas.

Trimurthy *et al.* (1982) observed typical symptoms of bacterial blight on perennial wild rice (*Oryza perennis*) in December-August. Although the leaves died during summer, blight symptoms appeared in new leaves long before the onset of the disease on newly transplanted rice seedlings in adjacent fields.

Nayak and Reddy (1985) reported that sporadically occurring individual plants infected by *Xanthomonas oryzae* pv. *oryzae* served as focal centres of primary infection, spreading the disease to neighbouring healthy plants. According to Durgapal (1985a) self sown rice plants from bacterial blight infected rice seeds served as a source of primary infection in North West India. He observed that seeds infected with bacterial blight which were buried to a depth of 25 cm in soil could retain viability and inoculum through the rabi season under both cultivated and non cultivated conditions. Partial shade, as under trees in fields, provided ideal situation for the successful establishment of the disease in self sown plants. Although the number of such sources of primary infection was less, it was sufficient to initiate an outbreak of bacterial blight in rice crops.

Devadath and Dath (1985) observed that when infected chaff was dumped near threshing floors, the developing self sown rice seedlings had bacterial blight symptoms. Similarly when rice seedlings were raised in soil to which infected chaff material was incorporated, there was development of bacterial blight symptoms.

Duan *et al.* (1979) observed that the pathogen of bacterial blight could survive in the roots of *Digitaria sanguinalis, Plantago major, Paspalum*

distichum and *Cyanadon dactylon*. These weeds from infected rice fields induced leaf blight in healthy rice seedlings when planted together in pots eventhough no symptoms were present in above ground parts of such weeds. Li *et al.* (1985) reported that *Paspalum distichum, Cyanadon dactylon, Leersia japonica* and *Zizania caduciflora* could induce infection on rice plants. However, the extent of infection varied with the plant part used as a source of pathogen, the maximum being the roots and stems of *Z. caduciflora*.

Valluvaparidasan and Mariappan (1989) confirmed the susceptibility of *Pennisetum scrobiculatum, Cyperus rotundus* and *Leersia hexandra* to bacterial blight pathogen. They also identified *Cenchrus ciliaris, Bajra napier* hybrid 2, *Echinochloa crusgalli, Brachiaria mutica* and *Panicum maximum* as alternate hosts of bacterial blight pathogen.

Gonzalez *et al.* (1991) observed that the perennial weed, *Leersia hexandra* in rice fields could act as a symptomless alternate host for *Xanthomonas oryzae* pv. *oryzae*. Brar and Thind (1994) reported that *Echinochloa colonum* could act as a host to *Xanthomonas oryzae* pv. *oryzae*. However, Rakesh Mehra and Thind (1994) found that none of the seven weeds namely *Cyperus difformis, C. iria, C. rotundus, Digitaria ciliaris, Echinochloa colonum* commonly seen in and around bacterial blight infected rice fields, produced disease symptoms either naturally or under artificial inoculation.

Environmental factors

Soga (1918) observed that an endemic area to bacterial blight was one with acidic soil, poor drainage, relatively high underground water level and

frequent flooding. Kuwazuka (1942) concluded that the disease was most prevalent in areas with more than 20 mm of rainfall in July and an annual mean temperature of 14°C and above. Goto *et al.* (1955) reported that a combination of rainy weather, stormy winds and a tempeature of 22-26°C favoured an outbreak of bacterial blight disease. Sulaiman and Ahamed (1965) reported the critical conditions for the incidence of bacterial blight in the month of July. These were maximum temperature of 29°C, minimum temperature of 24°C, rainfall of 1394.6 mm and relative humidity of 91 per cent. In August, the disease was optimum with a maximum tempeature of 30°C, minimum temperature 23.4°C, rainfall of 60.7 mm and relative humudity of 93 per cent. However, in October, the conditions became adverse with maximum temperature of 34°C, minimum temperature of 22.4°C. Investigations made at International Rice Research Institute showed that a temperature of 25-35°C was most favourable for disease development (Anon. 1974).

Reddy and Pillai (1974) reported that a well distributed rainfall and a relative humidity of 90 per cent and above for 15 hours per day favoured the outbreak of bacterial blight. Mohiuddin *et al.* (1977) concluded from seven years of observation that more than 27 rainy days during August, September and October (total rainfall 200 mm) contributed to greater incidence of bacterial blight disease in rice.

Dath *et al.* (1980) studied the meteorological factors associated with lesion development and found that temperature was the most critical factor influencing lesion development after infection. Thus,crops planted from June to early October and from January to early February showed relatively longer

lesions. Srinivasan and Singh (1983) reported that a combination of weather conditions like maximum temperature of 30 to 35°C, minimum temperature of 24 to 26°C, relative humidity of 64 to 68 per cent and a heavy well distributed rainfall associated with short sunny days favoured a severe occurrence of bacterial blight of rice. A similar observation was also made by Nair and Sreelatha (1988). They correlated the recurrence of bacterial blight in Kuttanad during the additional crop season (June-September) with the specific weather conditions during the period. Huang *et al.* (1989) analysed the factors affecting the epidemic fluctuation of bacterial blight disease during 1955-85 in the pearl river delta Guangdong and found that the susceptibility of varieties and typhoon rains were the principal factors involved in the outbreak of the disease. Diekmann and Bogyo (1992) found that mean daily maximum temperature in month one after planting, mean daily minimum temperature in month two and mean precipitation in month three were the climatic parameters which were important in disease occurrence.

Control of bacterial blight

Hashioka (1951) found that spraying with Bordeaux mixture partly controlled bacterial blight if applied before typhoon. However,it was not effective enough for practical use because of the copper sensitiveness of many rice varieties. Jain *et al.* (1965) reported that spraying with Coppesan at 2.8 kg/ha reduced the infection of *Xanthomonas oryzae* pv. *oryzae*. Pal and Singh (1978) reported that Brestanol was translocated from roots to leaves through stem and leaf sheath and was sufficient to inhibit the growth of *Xanthomonas oryzae* pv. *oryzae*.

Wakimoto and Mukoo (1963) reported that chloramphenicol was best for the control of bacterial blight disease. Swarup *et al.* (1965) found that penicillin G (100 ppm) gave maximum inhibition of *Xanthomonas oryzae* pv. *oryzae* under *in vitro* conditions. Desai *et al.* (1967) reported that seventeen species of *Xanthomonas* was inhibited by streptocycline at concentration of 25 to 250ppm in *in vitro*. Pal and Oas (1968) observed that spraying with Agrimycin at the rate of 15g/112 l of water completely checked the spread of bacterial blight of rice. Shetty and Rangaswami (1968) found that streptocycline at 25-50 ppm was inhibitory to three isolates of *Xanthomonas oryzae* pv. *oryzae* and was lethal at 50-100 ppm. According to Krishnappa and Singh (1977) TF 130 followed by Agrimycin-500 gave good control of this disease. Singh *et al.* (1977) had also reported that Agrimycin was effective in controlling bacterial blight of rice.

Balaraman and Soumini Rajagopalan (1978) found that among the antibiotics tried, tetracycline gave the largest inhibition zone followed by ledermycin, erythromycin and chloramphenicol.

Chauhan and Vaishnav (1980) observed that the best method for control of *Xanthomonas oryzae* pv. *oryzae* was the application of streptocycline along with copper containing compounds.

Singh *et al.* (1980) reported that terramycin, Brestanol, Agrimycin-100 at 500 ppm and a combination of Agrimycin-100 and Fytolan gave effective control of blight phase of the disease. Durgapal *et al.* (1981) found that on agar medium, Thiram effectively inhibited growth of *Xanthomonas*

oryzae pv. *oryzae* at 250 ppm. Thiram + Agrimycin 100 and Thiram + streptocycline were highly effective against *Xanthomonas oryzae* pv. *oryzae*.

Mary and Mathew (1982) observed that penicillin at 500 ppm was inhibitory for the growth of *Xanthomonas oryzae* pv. *oryzae* under *in vitro* conditions. Pencillin or Agrimycin-100 (250 ppm) applied as post inoculation sprays, were equally effective in reducing the disease intensity in rice. Durgapal (1983) found that the most suitable means for controlling *Xanthomonas oryzae* pv. *oryzae* was to submerge the seedlings for 24 h in 500 ppm Agrimycin-100, Dicrystin-S or streptocycline before transplanting.

Singh and Dhilip Monga (1985) reported that treatment with Duter and Captan dissolved in dichloro methane and Blitox, terramycin and Benlate in acetone effectively eliminated the pathogen from seed. Swain *et al.* (1985) observed that seed treatment with Plantomycin (0.03%) alone or in combination with carbendazim (0.3%) showed the highest efficiency in controlling bacterial blight. Mariappan *et al.* (1986) reported that Agrimycin 100 along with copper oxychloride and Agrimycin-100 alone gave good control of bacterial blight disease. Valluvaparidasan and Mariappan (1986) also attempted to control bacterial blight using chemicals applied as prophylactic and curative sprays. Of the prophylactic sprays, Plantomycin + Fytolan, Paushamycin + Fytolan and Agrimycin + Fytolan reduced the disease incidence by 50 per cent. Among the curative sprays tested, bromidiol white vitrol and Plantomycin + Fytolan were effective in reducing the disease but in both the treatments, chemical methods were ineffective in totally eradicating the disease.

Hu *et al.* (1987) reported that application of cytosine antibiotic 16A-6 gave about 70 per cent control of rice bacterial blight, with yield increase of 10-20 per cent. This treatment was effective even when rain followed soon after spraying and also after floods.

Chandrasekharan and Vidhyasekharan (1988) reported that chloramphenicol was superior to streptomycin, oxytetracycline, streptocycline and their various combinations in controlling bacterial blight of rice.

Choi *et al.* (1988a) reported that wild type strains of the rice bacterial blight pathogen, including parental strains of the mutants, were sensitive to nine different antibiotics, including rifampicin at 20 µg/ml. In another report, Choi *et al.* (1988b) also reported that most isolates of *Xanthomonas oryzae* pv. *oryzae* were sensitive to antibiotics such as streptomycin, novobiocin, erythromycin, oleandomycin, vancomycin, rifampicin and oxymycin at 5 µg/ml medium. The minimum inhibitory concentration of Penicillin G was <4 µg/ml.

Mahto *et al.* (1988) found that among two antibiotics and eight fungicides tested against *Xanthomonas oryzae* pv. *oryzae*, maximum inhibition was produced by streptocycline. A similar observation was made earlier by Sreelatha (1985).

Park *et al.* (1988) screened 2050 strains of *Streptomyces* spp. collected from 485 soil samples for antibiosis against *Xanthomonas oryzae* pv. *oryzae*. High level of control was obtained with 13 strains and these were further

investigated in green house tests. Strain 74-4 gave the maximum control of 56 per cent.

Other methods of disease control

Bacteriophage specific for *Xanthomonas oryzae* was first isolated by Yoshii *et al.* (1953). Wakimoto (1954) named it as *Xanthomonas oryzae* sp. bacteriophage. Nilpanit *et al.* (1984) isolated bacteriophage strains of *Xanthomonas campestris* from parts of Thailand. They suggested the bacteriophage technique to forecast bacterial blight outbreaks. Phage population determined by plaque counting also gave an indication of the population density of the host bacterium *Xanthomonas oryzae* pv. *oryzae* in irrigation water.

Iwata *et al.* (1979) extracted an unknown aminoacid with the formula $C_5H_7NO_2$ from the cultures of *Streptomyces zaomyceticus* str.SFI836 and the compound was found effective against *Xanthomonas oryzae* pv. *oryzae* when applied directly to the roots of potted rice plants but was ineffective under *in vitro* conditions.

Philip and Devadath (1980) isolated phylloplane fungal and bacterial flora of bacterial blight tolerant and susceptible rice and found only one species of *Aspergillus* and *Penicillium* having antagonism to *Xanthomonas oryzae* pv. *oryzae*.

Uno *et al.* (1980) observed that methyl coffeate isolated from dwarf diseased mulberry leaves showed antibacterial activity against six bacteria

including *Xanthomonas oryzae* pv. *oryzae*. Lin and Yu (1981) suggested an integrated technique for control of bacterial blight disease which included growing disease resistant cultivars, selecting disease free areas for nursery site with good drainage, irrigation with shallow water frequently at seedling and tillering stage, avoiding excessive use of N and the use of sufficient P,K and organic manure as basal dressing. Padmanabhan (1983) also suggested an integrated approach based on host tolerance, judicious use of fertilizers, adoption of appropriate agronomic practices, direct control with biocides and use of biological antagonists to minimise losses due to bacterial blight.

Gossele *et al.* (1984) studied the effect of 235 organic and inorganic compounds against the rice pathogen *Xanthomonas oryzae* pv. *oryzae*. Among them, the most active were zinc oxide, 8-hydroxy quinoline, methyl glyoxal, D-phenanthroline and formaldehyde. Salts of copper, nickel and cobalt were inhibitory for all strains at concentrations between 0.001 per cent and 0.005 per cent. Hoa *et al.* (1984) observed that spraying with ammonium sulphate five days before glasshouse inoculation (prophylactic spraying) decreased the intensity of bacterial blight in moderately resistant and susceptible cultivars.

Grainge *et al.* (1985) found that extracts of *Artabotrys uncinatus* and *Allium sativum* inhibited *Xanthomonas oryzae* pv. *oryzae* under *in vitro* conditions.

Sivaswamy and Mahadevan (1985) studied in detail the effect of stable bleaching powder on bacterial blight of paddy at different stages of plant growth and concluded that it did not control effectively the bacterial blight

disease. However, Sivaswamy and Mahadevan (1986) reported that stable bleaching powder was toxic for the growth of *Xanthomonas oryzae* pv. *oryzae* at concentration > 100 µg/ml. The bacterial respiration was inhibited at 50 µg/ml. Hence the addition of stable bleaching powder to soil reduced survival and population of the pathogen.

Takahi and Shirahagen (1985) reported the development of a new bactericide namely techlofthalam for the control of bacterial blight. Although it did not kill the bacteria, it was very effective in rice plants. Liao and Chien (1987) reported that in the laboratory 10 per cent techlofthalam inhibited the growth *Xanthomonas oryzae* pv. *oryzae* more effectively than oryzamate. In field trials, 1000 ppm techlofthalam gave the best control, reducing the progress of the disease.

Mary *et al.* (1986) observed that a foliar spray of cowdung extract (20 g/l) controlled bacterial blight equivalent to that given by penicillin (100 ppm), paushamycin (250 ppm) and streptomycin (100 ppm). Sreekumar and Nair (1990) reported that even though under *in vitro* conditions, cowdung extract failed to produce any typical growth inhibition zone, under pot culture conditions, cowdung extract was better than some of the chemical treatments like terramycin, streptocycline and Bactrinol-100. They also studied the effect of spraying with Bactrinol-100, oxytetracycline, streptocycline and cowdung extract on the control of bacterial blight disease under field conditions. The reduction in disease intensity was maximum after spraying with terramycin followed by Bactrinol-100, streptocycline and cowdung extract. The grain yield was also maximum in plants sprayed with terramycin. However, the increase in yield obtained by spraying with Bactrinol-100 and cowdung extract

was higher than that of plants sprayed with streptocycline. Further, the increase in thousand grain weight and straw yield was maximum in plants sprayed with cowdung extract.

Sakthivel *et al.* (1986) isolated several strains of *Pseudomonas fluorescens* from plant rhizosphere and identified them as biotypes C and G. These siderophore producing strains showed antagonism under *in vitro* tests to several plant pathogens including *Fusarium oxysporum* f. sp. *cubense*, *Rhizoctonia solani*, *Sarocladium oryzae* and *Xanthomonas campestris* pv. *oryzae*. Anuratha and Gnanamanickam (1987) also studied the effect of *Pseudomonas fluorescens* (biotype III) on *Xanthomonas oryzae* pv. *oryzae*. *Pseudomonas fluorescens* (10^8 c.f.u./ml) was initially mixed with one per cent solution of sterile carboxymethyl cellulose and powdered vermiculite and dried overnight at room temperature (28°C). Rice seeds coated with this mixture showed 40 to 60 per cent reduction in bacterial blight severity.

Sreekumar and Nair (1990) observed that Bactrinol-100 gave good control of bacterial blight in rice varieties Jyothy and C-153. Bactrinol-100 gave about 55 per cent disease reduction in Jyothy and 59 per cent in C-153 under field conditions. Moreover, the grain weight, straw yield and thousand grain weight were found to increase significantly by spraying with Bactrinol-100.

Yoshida *et al.* (1990) reported that N-Cyano methyl-2-chloro isonicotinamide controlled both bacterial leaf blight and rice blast under field conditions.

Zhu and Li (1990) reported that an isolate of *Bacillus subtilis* B826, from the phylloplane of squash, was strongly inhibitory to several isolates of *Xanthomonas oryzae* pv. *oryzae*. A protein B826-11 was purified from the crude extracts of cell free cultures of B826 and this protein had the same inhibitory spectrum as B826.

Saikia and Chowdhury (1993) also investigated the influence of phylloplane microflora on bacterial leaf blight development using a range of concentration and inoculation methods. *Erwinia heribicola* was found to be most effective and gave 90 per cent disease reduction.

MATERIALS AND METHODS

MATERIALS AND METHODS

Survey on the incidence of bacterial blight of rice in Kuttanad

Survey on the incidence of bacterial blight of rice caused by *Xanthomonas oryzae* pv. *oryzae* was conducted in Kuttanad Taluk during 1992-1994. One hundred and fifteen farmers distributed over 12 Krishibhavans were randomly selected for this purpose (Fig.1). The first survey was conducted during the additional crop season (June-July to September-October) of 1992 followed by punja season (November-December to February-March) of 1992-1993, additional crop of 1993 and the punja of 1993-1994. Informations on the incidence and intensity of bacterial blight at different locations and details regarding crop variety were collected. The nature of weeds and the presence or absence of self sown rice in and around the infected fields were also recorded. The weather data for the survey period from June 1992 to March 1994 were collected from the Rice Research Station of Kerala Agricultural University at Moncompu, Alleppey District.

Location selected for the survey on the incidence of bacterial blight of rice in Kuttanad.

Sl. No.	Name of Krishi Bhavan	Taluk	District
1.	Champakulam	Kuttanad	Alleppey
2.	Edathua	Kuttanad	Alleppey
3.	Kainakary	Kuttanad	Alleppey
4.	Kavalam	Kuttanad	Alleppey
5.	Muttar	Kuttanad	Alleppey
6.	Nedumudi	Kuttanad	Alleppey
7.	Neelamperoor	Kuttanad	Alleppey
8.	Pulinkunnu	Kuttanad	Alleppey
9.	Ramankari	Kuttanad	Alleppey
10.	Thakazhi	Kuttanad	Alleppey
11.	Thalavadi	Kuttanad	Alleppey
12.	Veliyanadu	Kuttanad	Alleppey

Proforma used for the survey on the incidence of Bacterial blight of rice in Kuttanad

Name of the farmer

Name of padasekharam :

Address

Name of Krishi bhavan :

Season	Rice varieties	Age of crop	Area	Disease		Additional information
				Score (0-9)	Incidence (0-100%)	
Additional crop-1992 Punja crop 1992-93 Additional crop 1993 Punja crop 1993-94						1. Weed population. 2. Self sown rice 3. Weather data 4. Off season cultivation of rice

Pathogen

Xanthomonas oryzae pv. *oryzae* the causal organism of bacterial blight of rice was isolated from plants in an infected field at Nedumudi in Kuttanad taluk during the additional crop season of 1992 by routine standard procedures (Rangaswami and Soumini Rajagopalan, 1973). The pathogen was isolated on Potato Sucrose Agar (PSA) medium of following composition.

Potato Sucrose Agar + medium (PSA)

Potato	—	300 g
$Ca(NO_3)\ 4H_2O$	—	0.5 g
Na_2HPO_4	—	2 g
Peptone	—	5 g
Sucrose	—	20 g
Agar agar	—	15 g
Distilled water	—	1000 ml
pH	—	6.8 to 7.0

A bacterial colony showing typical characters of *Xanthomonas oryzae* pv. *oryzae* was selected. The culture was checked for purity by restreaking on PSA medium and by gram staining. A pure culture of the same was maintained on PSA slants at 4°C in a refrigerator for further studies.

The different morphological and physiological characters of the pathogen like colony characters, gram staining (Hucker, 1927) and production of acid from sugars (Dye, 1962) were studied by routine standard procedures. The different media were used as described by the Society of American bacterioligist (Anon, 1957) and methods described by (Dye, 1962) with modifications.

Growth on glucose agar medium

Production of capsular slime was tested by streaking on glucose agar medium of following composition.

Glucose agar medium

Beef extract	—	5.0 g
Peptone	—	5.0 g
Glucose	—	10.0 g
Agar agar	—	20.0 g
Distilled water	—	1000 ml
pH	—	6.8

The plates were incubated at 30 ± 1°C in an incubator. The observations were taken after 72 h of culture growth.

Urease production

The medium of Christensen's urea agar (Christensen, 1946) was used for this test.

Christensen's urea agar medium

Peptone	—	1.0 g
NaCl	—	5.0 g
KH_2PO_4	—	2.0 g
Glucose	—	1.0 g
Agar agr	—	20.0 g
Phenol red (0.2 per cent solution)	—	6.0 ml
Distilled water	—	1000 ml
pH	—	6.8

To 90 ml pre sterilized aliquots of above medium, 10 ml of filter sterilized twenty per cent urea solution was added. Five ml of the media was dispensed in 10 ml test tubes. The slants were streaked with a 48 h old culture of *Xanthomonas oryzae* pv.*oryzae* and incubated at 30 ± 1°C in an incubator. Observations were taken periodically for any change in colour of the medium from yellow to red which indicated a positive urease activity.

Action on milk

Both unskimmed and skimmed milk were used for this purpose. A 1:3 dilution of skimmed milk in water was prepared and bromocresol purple was added to a final concentration of 0.002 per cent. (Clark and Lubs, 1917). Unskimmed milk containing approximately three per cent fat was also prepared in this manner. Five ml of both the milk samples were distributed in 10 ml test tubes and sterilized by steaming for 30 minutes for three successive days in an Arnold steam sterilizer. These were inoculated with a 48 h old culture of the pathogen and incubated at 30 ± 1°C for 30 days in an incubator. Three replications were maintained for each sample. Observations were taken at regular intervals for acidic or alkaline reaction, curdling and peptonization of both the milk samples. A change in colour from blue to yellow indicated an acidic reaction and an alkaline reaction was shown by the development of violet colour. Curdling was indicated by heterogeneous clump formation due to precipitation of milk and peptonization by partial clearing of milk.

Production of hydrogen sulphide

The ability of the culture to produce hydrogen sulphide was tested using peptone water of following composition.

Peptone water

Peptone	—	10.0 g
NaCl	—	5.0 g
Distilled water	—	1000 ml
pH	—	7.0

Five ml of the medium was dispensed in test tubes and sterilized in an autoclave at 121.6°C for fifteen minutes. Lead acetate paper strips of 5 x 50 mm size were prepared by soaking in a saturated solution of lead acetate. After drying, these strips were autoclaved and once again dried properly. The tubes were inoculated with a 48 h old culture of *Xanthomonas oryzae* pv. *oryzae* and lead acetate strips were inserted aseptically between the plug and inner wall of each tube. These were incubated at 30 + 1°C in an incubator. Observation on any blackening of lead acetate paper strips due to hydrogen sulphide production was taken after 14 days of culture growth.

Tolerance to different concentrations of sodium chloride

Modified peptone water containing 2, 2.5, 3 and 6 per cent sodium chloride was used for this purpose.

Modified peptone water

Peptone	—	1.0 g
Distilled water	—	100 ml

The medium was dispensed in 10 ml test tubes, autoclaved and inoculated with a 48 h old culture of the pathogen. The presence or absence of growth at different concentrations of sodium chloride were recorded over a period of seven days after incubation at 30 ± 1°C in an incubator.

Gelatin liquefaction

Nutrient gelatin medium of the following composition was used.

Nutrient gelatin medium

Peptone	—	10.0 g
Beef extract	—	5.0 g
Gelatin	—	120.0 g
Distilled water	—	1000 ml
pH	—	7.0

Gelatin was mixed with all other ingredients and heated over a water bath until it was completely dissolved. The sterilized medium was aseptically poured in petriplates. After solidification,it was streaked with a 48 h old, culture of the pathogen and incubated at 30 ± 1°C for 48 hours. The plates were flooded with a saturated solution of ammonimum sulphate. Gelatin

liquefaction was indicated by the formation of a clear halo around bacterial colonies.

Starch hydrolysis

The ability of *Xanthomonas oryzae* pv. *oryzae* to hydrolyse starch was tested using a medium containing 0.2 per cent soluble starch (Difco) and the following ingredients.

Starch medium

Peptone	—	10.0 g
Beef extract	—	5.0 g
Starch soluble	—	2.0 g
Agar agar	—	20.0g
pH	—	7.0
Distilled water	—	1000ml

A 48 h old culture of the pathogen was aseptically spot inoculated on the surface of starch agar medium in petriplates. They were incubated for four days at 30 ± 1°C in an incubator and flooded with lugol's iodine solution. A colourless or reddish zone around bacterial growth in contrast to a blue background of the medium indicated positive starch hydrolysis.

Testing of virulence of the isolated culture of *Xanthomonas oryzae* pv. *oryzae*

The isolate of *Xanthomonas oryzae* pv. *oryzae* was tested for virulence by inoculating healthy seedlings of a highly susceptible rice variety

T(N)1 at maximum tillering stage. Artificial inoculation was done by the clip inoculation technique using a 48 h old aqueous suspension (10^9/ml) of the pathogen grown on PSA medium.

The inoculation was done by clipping the leaf tip of T(N)1 plants using a pair of scissors dipped in the above bacterial suspension. It was also applied on the entire leaf surface using a cotton swab. Three replications were maintained in pots. The plants were covered with polythene bags and a high level of humidity was maintained by sprinkling with water twice a day so that a favourable microclimate was created to initiate infection.

The typical symptoms of bacterial blight first appeared as water soaked lesions which later turned to yellow. These lesions spread gradually downwards from the tip of the leaves. After seven days, the pathogen was reisolated on PSA medium by the method described earlier. This virulent culture was used for all subsequent studies such as screening of rice varieties for resistance to *Xanthomonas oryzae* pv. *oryzae* and for the *in vitro* screening of various antibiotics, Bactrinol-100 and cowdung extract for the control of bacterial blight of rice under field conditions.

SCREENING RICE VARIETIES FOR RESISTANCE AGAINST *Xanthomonas oryzae* pv. *oryzae*

Two pot trials were conducted to screen 21 rice varieties/ cultivars for resistance against infection by *Xanthomonas oryzae* pv. *oryzae*. The first pot trial was conducted at College of Agriculture, Vellayani and the second at Rice Research Station, Moncompu of Kerala Agricultural University.

Rice varieties/cultivars screened for resistance against *Xanthomonas oryzae* pv. *oryzae*

Sl. No.	Varieties/Cultivar		Duration (days)
Short duration			
1.	Aruna (MO8)		100 — 110
2.	Jyothy		110 — 120
3.	Makam (MO9)		100 — 110
4.	Red Triveni		100 — 105
5.	T(N)1 (Susceptible check)		110 — 115
Medium duration			
6.	Asha (MO5)		115 — 120
7.	Bhadra (MO4)		125 — 130
8.	Cul. 38-4-1 (MR1)	Multiple resistant cultures	120 — 125
9.	Cul. 38-4-2 (MR2)		
10.	Cul. 38-8-1 (MR3)		
11.	Cul. 48-11-1(MR6)		
12.	Kanakam (MO11)		120 — 130
13.	Karthika (MO7)		115 — 120
14.	Mahavira		115 — 120
15.	MO1-10-4-1 (M1)	Mutants	120 — 125
16.	MO1-10-8-1 (M2)		
17.	MO1-20-3-1 (M3)		
18.	MO1-20-19-4 (M10)		
19.	Pavizham (MO6)		115 — 118
20.	Remya (MO10)		115 — 120
21.	DV 85 (Resistant check)		120 — 125

Pot evaluation trials

These experiments were laid out in completely randomised design with three replications each during 1992 in the months of June to September at College of Agriculture, Vellayani and in 1993 at Rice Research Station, Moncompu during the additional crop season of rice in Kuttanad. NPK fertilizers were applied as per package of practices recommendations of Kerala Agricultural University (1993) for short duration and medium duration rice varieties.

Artificial inoculation of different rice varieties/cultivars with a virulent culture of *Xanthomonas oryzae* pv.*oryzae* (10^9/ml) was done by the clip inoculation technique described earlier. Observations on disease intensity was taken after 21 days of inoculation using the standard evaluation system developed by International Rice Research Institute, Philippines (1980).

Standard score chart for bacterial blight of rice developed by IRRI, Philippines.

Score		Description
0	—	No blighting of leaves
1	—	Less than 1% of leaf area blighted
3	—	1 to 5 % leaf area blighted
5	—	6 to 25 % of leaf area blighted
7	—	26 to 50 % of leaf area blighted
9	—	51 to 100 % of leaf area blighted

According to the disease score obtained, the varieties/cultivars were grouped based on the general scale in the standard evaluation system for rice (IRRI, 1980).

Score		Reaction
0	—	Highly Resistant (HR)
0-1	—	Resistant (R)
> 1-3	—	Moderately resistant (MR)
> 3-5	—	Moderately susceptible (MS)
> 5-7	—	Susceptible (S)
> 7-9	—	Highly Susceptible (HS)

Observations were also recorded on the lesion length (cm) produced in each variety.

Statistical analysis of the data for each year was conducted followed by combined analysis.

MODE OF SURVIVAL OF *Xanthomonas oryzae* pv. *oryzae*

Seeds, straw and stubbles from bacterial blight infected 2rice variety Red Triveni, soil and water from infected fields, weeds and self sown rice plants growing in and around infected fields were closely monitered to find out the mode and extent of survival of *Xanthomonas oryzae* pv. *oryzae*. The various samples were collected from ten different locations such as

Champakulam, Edathua, Kainakary, Kavalam, Muttar, Nedumudi, Pulinkunnu, Ramankari, Thakazhi and Veliyanadu of Kuttanad Taluk.

Survival in infected seed

About 500 g of infected seeds each were collected from various locations of Kuttanad Taluk during additional crop season of 1993. They were stored at room temperature in brown paper covers for seven weeks. These samples were tested for the presence of *Xanthomonas oryzae* pv. *oryzae* under *in vivo* conditions by sowing 100 seeds from each lot in earthern pots at weekly intervals upto a total period of seven weeks. The emerging seedlings were closely observed for the occurrence of typical symptoms of bacterial blight till the harvest stage. Data on the percentage of infected seedlings were recorded separately for each location.

The data were analysed by analysis of variance described by Snedecor and Cochran (1967) and the trend was described by adopting a statistical model prepared by Yamane (1969). The details of the model are given below:

Modified exponential form

$$y = k + ab^x$$

where, y denotes per cent survival

k denotes asymptote

x denotes weeks codified as 0, 1, 2.... etc.

b denotes rate of change

a denotes constant

Infected straw and stubbles

The infected straw and stubbles were also collected from the same locations from where the infected seed samples were collected. Two hundred and fifty grams of straw and five hundred grams of stubbles were collected and stored at room temperature for 120 days for straw and 63 days for stubbles. The survival of *Xanthomonas oryzae* pv. *oryzae* was monitored by inoculating the leaves of T(N)1 rice variety at maximum tillering stage by using an aqueous suspension containing chopped straw or stubbles. The clip inoculation was done periodically at 15 days interval for straw and at seven days interval for stubbles for a total period of 120 days for straw and 63 days for stubbles. Three replications were maintained for each location. Observations were made on the occurrence of typical symptoms of bacterial blight such as yellowing and marginal blighting of leaves after seven days of inoculation. The final data were recorded as positive or negative for the development of symptoms of bacterial blight disease.

In addition to the above experiments, the survival of *Xanthomonas oryzae* pv.*oryzae* in infected stubbles under field conditions was also studied. For this, the bacterial blight infected stubbles were maintained under natural field conditions both under dry and wet land conditions at four different locations such as Champakulam, Nedumudi, Pulinkunnu and Ramankari. Here also, the survival of the pathogen was monitored by inoculating the leaves of T(N)1 rice variety at the maximum tillering stage by using an aqueous

suspension containing chopped stubbles at weekly intervals upto a maximum period of 28 days. Three replications were maintained for each location. Observations were made on the occurrence of typical symptoms of bacterial blight after seven days of inoculation and the final data was recorded as positive or negative for the development of symptoms of bacterial blight disease in T(N)1.

Infected soil and water

The soil and water samples were collected from the same locations from where the infected seed, straw and stubbles were collected earlier during the additional crop season of 1993. They were tested within 48 h for the presence of pathogen by clip inoculating a suspension of the same on the leaves of T(N)1 at maximum tillering stage. Three replications were maintained for each sample. The final data was recorded as positive or negative for the development of typical symptoms of bacterial blight disease after seven days of inoculation.

In addition to this, the survival of *Xanthomonas oryzae* pv. *oryzae* in soil was also monitored by collecting soil samples from infected field at Nedumudi during the additional crop of 1992 and 1993 and punja of 1992-93 and 1993-94. The samples were tested for the presence of pathogen by serial dilution and plating technique using a selective medium for isolation of *Xanthomonas oryzae* from soil samples.

SX agar medium (Schaad and White,1974)

Soluble potato starch	—	10.0 g
Beef extract	—	1.0 g
Ammonium oxalate	—	5.0 g
Potassium diphosphate	—	2.0 g
Methyl violet B	—	1.0 g (1% solution in 20% ethanol)
Methyl green	—	2.0 ml (1% solution)
Cycloheximide	—	0.25 g
Agar	—	15 g
Distilled water	—	1000 ml
pH	—	6.8

Three replications were maintained for each soil sample. The petriplates were incubated at 30 ± 1°C in an incubator for 72 h and examined for the presence of typical colonies of *Xanthomonas oryzae* pv. *oryzae*.

Survival of *Xanthomonas oryzae* pv. *oryzae* in weeds

The data on the nature and type of weeds occurring in and around rice fields in Kuttanad were collected at the time of initial survey on the incidence of bacterial blight. These weeds usually grew on the main field bunds, on the sides of water channels and in aquatic waste lands.

Screening weeds for susceptibility to *Xanthomonas oryzae* pv. *oryzae* under natural conditions

Eighteen prominent weeds were screened for susceptibility to infection by *Xanthomonas oryzae* pv. *oryzae* under natural conditions at Mathur padasekharam Nedumudi, Kuttanad during additional crop season of 1993. The selected weeds were planted in rows of one metre length. Each row having ten plants were interpolated with a bacterial blight susceptible rice variety T(N)1.

The different weeds were closely observed for the appearance of bacterial blight symptoms when a natural incidence of the disease was noticed in T(N)1 at panicle initiation stage. They were further tested for symptom less carrier of the pathogen by the ooze test. The data was recorded as presence or absence of bacterial blight symptoms on leaves of different weeds. The results of ooze test was recorded as positive or negative for the presence of bacterial blight. The symptoms on positive weeds were studied in detail and the pathogen was isolated on PSA medium. The pathogenicity was also confirmed by re-inoculation on the host weed and also on the highly susceptible rice variety T(N)1.

Survival in self sown rice plants

Self sown rice plants normally grew from rice seeds falling here and there around rice field during harvesting, threshing and transporting

Weeds screened for susceptibility to infection by *X. oryzae* pv. *oryzae* under field conditions

Sl. No.	Scientific Name	Vernacular name
	A. Grasses	
1.	*Cyanadon dactylon* Pers.	'Karuka'
2.	*Echinochloa colona* (L.) Link.	'Kavada'
3.	*E. crusgalli* (L.) Beauv.	'Kavada'
4.	*E. stagnina* (Retz.) Beauv.	'Kambi kavada'
5.	*Isachne dispa*	'Karimadi pullu'
6.	*Oryza rufipogon* Griff.	'Wild rice'
7.	*Oryza sativa* var. *fatua*	'Varinellu'
8.	*Panicum repens* L.	—
9.	*Paspalum conjugatum* Berg.	—
10.	*Saccolepis interrrupta* (Willd) Stap. f.	'Pindipullu', 'Pothalu'
	B. Sedges	
1.	*Fimbristylis dichotoma*	'Korah'
2.	*Cyperus distance*	'Minukkan'
	C. Broad leaf weeds	
1.	*Limnophila heterophylla* (Roxb) Benth.	'Mullan'
2.	*Ludwigia parviflora*	'Kandathil kanthari'
3.	*Monochoria vaginalis* (Burm. f.) Presl. ex. Kunth.	'Kakkapola'
4.	*Sphenoclea zeylanica* Gaertn.	'Cheera'
	D. Ferns	
1.	*Marselia quadrifoliata* L.	'Nalilakudakan'
2.	*Salvinia molesta* Mitchell	'African payal'

operations. They also came up from seeds getting scattered while being carried away by insects, rodents and birds. Some of them also originated as ratoon plants. They were seen on the main field bunds, on the sides of water channels and in aquatic waste lands. Observations on the presence and absence of self sown rice plants in and around rice fields, stage of its growth in relation to main crop and whether there was any incidence of bacterial blight in these plants even before the occurrence of this disease in the main crop were taken at the time of initial survey. These data were used to interpret the role of such plants in the possible perpetuation of bacterial blight pathogen from season to season in Kuttanad.

CONTROL OF BACTERIAL BLIGHT OF RICE

A. *In vitro* evaluation of antibiotics, Bactrinol- 100 and Cowdung extract against *Xanthomonas oryzae* pv. *oryzae*

The effect of five antibiotics such as ambistryn-s, chloramphenicol oxytetracycline, penicillin and streptocycline, Bactrinol - 100 and fresh cowdung extract on growth of *Xanthomonas oryzae* pv. *oryzae* was studied under *in vitro* conditions. Sterile filter paper discs of 10 mm diameter dipped in appropriate concentrations of various antibiotics, Bactrinol-100 and cowdung extract were aseptically placed in the centre of petriplates containing PSA medium pre seeded with a 48 h old virulent culture of the pathogen. Three replications were maintained for each treatment. Observations on the zone of growth inhibition in centimeters were recorded after 72 h of incubation at 30 $\pm$ 1°C in an incubator.

Concentrations of antibiotics, Bactrinol-100 and cowdung extract used for *in vitro* evaluation against *Xanthomonas oryzae* pv. *oryzae*

Sl. No.	Test substance	Manufacturing company	Active ingredient	Concentration (ppm)	Diluent for stock solution
1.	Penicillin	Alembic chemical Works Co. Ltd.Baroda	Procaine Penicillin G and Penicillin G sodium	250,500,750	Sterile distilled water
2.	Ambistryn-S	Sarabhai chemicals Wadi,Wadi Baroda	Streptomycin	250,500,750	-do-
3.	Oxytetracycline	Pfizer Ltd. 307,311 GIDC Estate, Ankleshwar	Oxytetracycline hydro chloride	100,250,500	-do-
4.	Chloramphenicol	Parke-Davis Sakinaka, Bombay	Chloramphenicol	100,250,500	-do-
5.	Streptocycline	Hindustan antibiotics, Ltd, Pimpri, Poona	Streptomycin sulphate 90% and Tetracycline hydrochloride 10%	100,250,500	-do-
6.	Bactrinol-100	Merlin laboratories,Madras	2-Bromo-2-nitropropane 1-3-diol	250,500,750	-do-
7.	Cowdung extract	—	—	20,50 and 100 g/l	-do-

B. *In vitro* evaluation of varying proportions of oxytetracycline and streptomycin on growth of *Xanthomonas oryzae* pv. *oryzae*

Nine different proportions of oxytetracycline and streptomycin were initially prepared by dissolving appropriate quantities of both the antibiotics in sterile distilled water. This experiment was done mainly to find out whether any change in the existing ratio of 9:1 (streptomycin and oxytetracycline) currently used in the manufacture of phytoantibiotics will be more effective for the control of bacterial blight under field conditions. The *in vitro* screening with various proportions of the above antibiotics were done by the method described earlier. Observations on the growth inhibition zone in centimeters were recorded after 72 h of incubation at 30 ± 1°C in an incubator.

C. Control of bacterial blight under field conditions

Two separate field experiments were conducted in a farmer's field at Mathur padasekharam, Nedumudi, Kuttanad during additional crop season of 1992 and 1993 to study the effect of spraying with selected concentrations of antibiotics, Bactrinol-100 and cowdung extract on the control of bacterial blight. The different concentrations selected on the basis of *in vitro* screening were as follows.

1. Streptocycline : 500 ppm
2. Mixture of streptomycin and oxytetracyline (1:9) : 250 and 500 ppm

3. Bactrinol-100 : 500 ppm

4. Fresh Cowdung extract : 20g/l

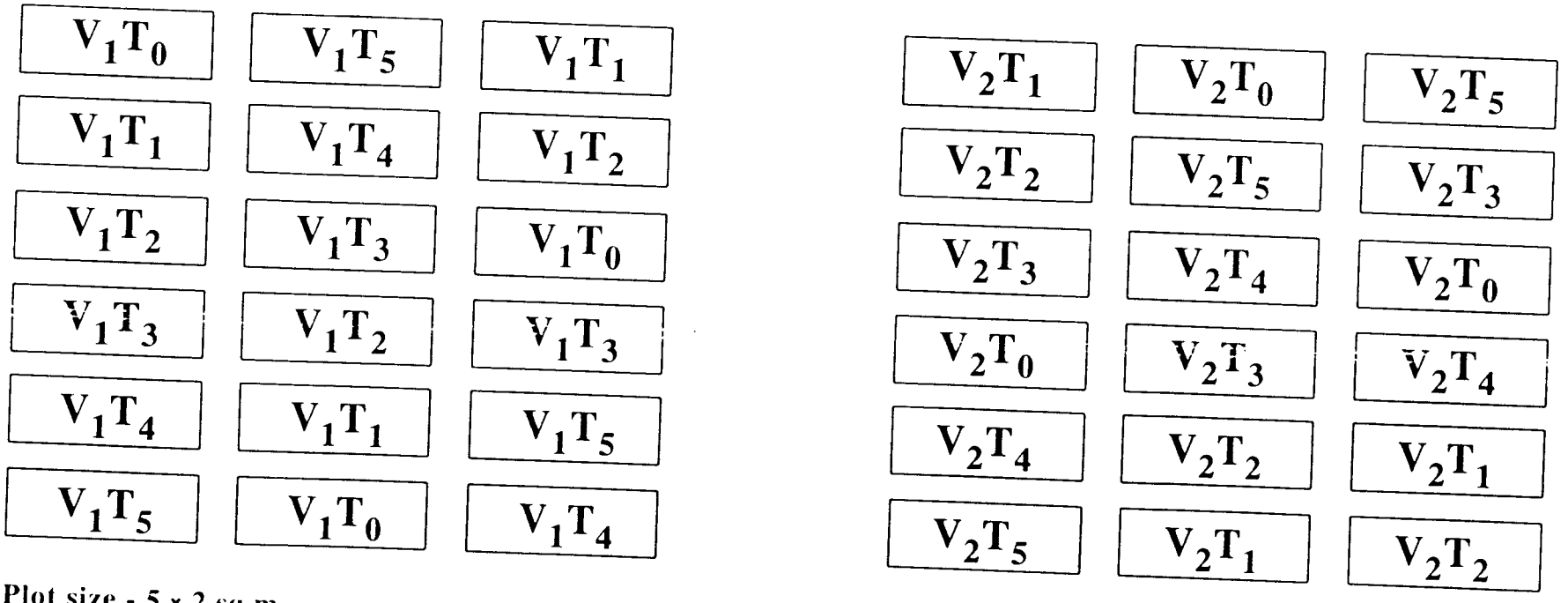
5. Control

Two different spray schedules, prophylactic and curative were adopted. A highly susceptible variety of rice, T(N)1 along with a variety cultivated by the farmer, Jyothy were used. The experiment was laid out in RBD in plots of 2x5 m^2 size. (Fig. 2 and 3). NPK fertilizers at the rate of 70:35:35 were applied in two split doses. Half the dose of N and K and the full dose of P were applied at the time of final ploughing. The remaining dose of N and K fertilizers was added as top dressing at 50 DAS. Lime was applied at the rate of 600 Kg/ha in two split doses, 350 kg as basal dose at the time of final ploughing and 250 kg as top dressing one month after sowing. Hand weeding was done to remove the weeds at 30 and 45 days after sowing.

The prophylactic sprayings were given at 25 and 40 DAS in T(N)1 and 30 and 45 DAS in Jyothy. The curative sprayings were given only after the onset of bacterial blight disease. These were given at 55 and 70 DAS in T(N)1 and 60 and 75 DAS in Jyothy.

In the case of prophylactic spraying, observations were taken on the time of disease incidence. The disease intensity was scored (as per the International Rice Research Institutes (IRRI) evaluation system) at 85 DAS in T(N)1 and 90 DAS in Jyothy.

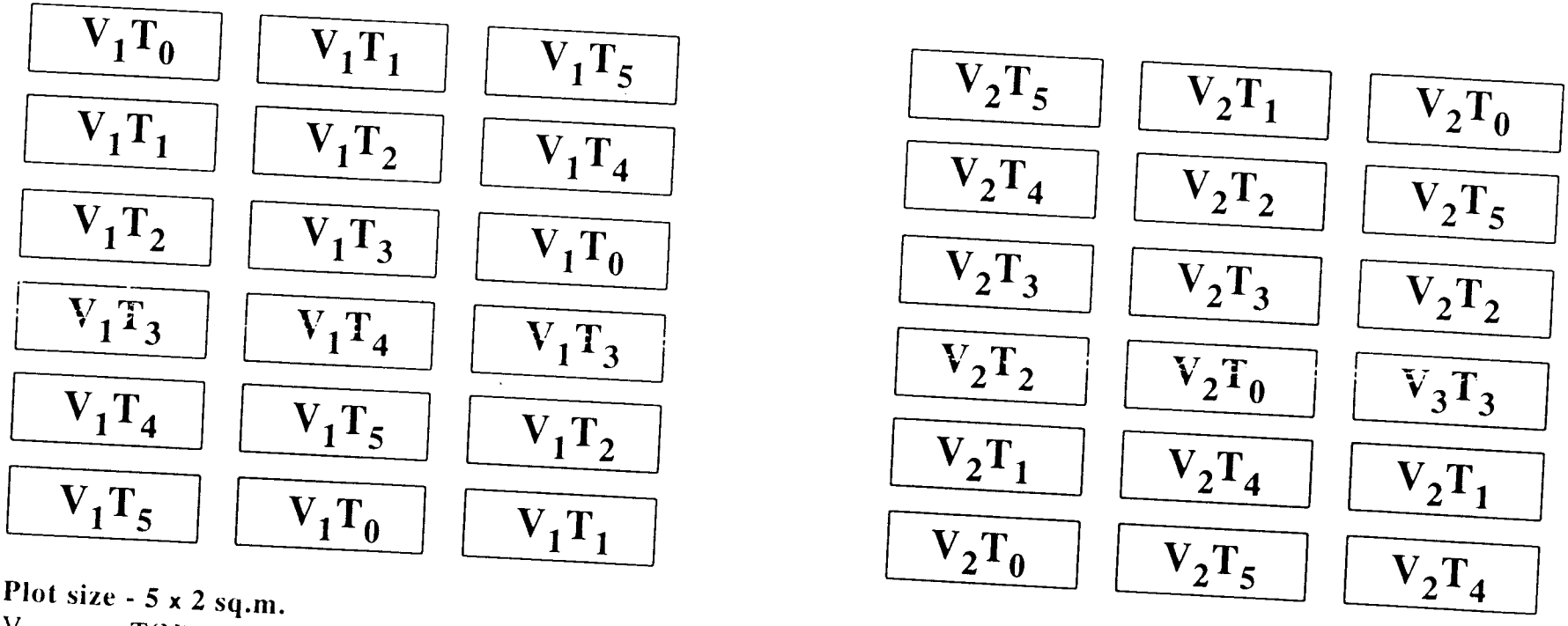
Fig. 2. Layout of the field experiment with prophylactic spraying against bacterial blight at Nedumudi



Plot size - 5 x 2 sq.m.

V_1 - T(N)1
V_2 - Jyothy
T_0 - Control
T_1 - Streptocycline - 500 PPM
T_2 - Oxytetracycline + streptomycin (9:1) - 250 PPM
T_3 - Oxytetracycline + streptomycin (9:1) - 500 PPM
T_4 - Bactrinol - 100 - 500 PPM
T_5 - Cowdung Extract - 20g/l

Fig. 3. Layout of the field experiment with curative spraying against bacterial blight at Nedumudi



Plot size - 5 x 2 sq.m.

V_1 - T(N)1
V_2 - Jyothy
T_0 - Control
T_1 - Streptocycline - 500 PPM
T_2 - Oxytetracycline + streptomycin (9:1) - 250 PPM
T_3 - Oxytetracycline + streptomycin (9:1) - 500 PPM
T_4 - Bactrinol - 100 - 500 PPM
T_5 - Cow dung Extract - 20g/l

Using the disease score, the per cent disease index was calculated by the formula :

$$\% \text{ Disease index} = \frac{\text{Sum of individual ratings}}{\text{Totai number of leaves observed}} \times \frac{100}{\text{Maximum disease score}}$$

At the time of harvest, various yield parameters specified below were recorded.

1. Grain and Straw yield

Each plot was harvested separately and the grain and straw weights were determined after drying the samples in the sun for three days. The final data were expressed in terms of t/ha grain and straw yield.

2. Thousand grain weight

Thousand fully formed grains were separated from each treatment and the weight was determined using a mettler balance.

3. Chaff percentage

The main culm panicles from 12 randomly selected hills were separated, threshed and the number of filled grains (f), number of unfilled

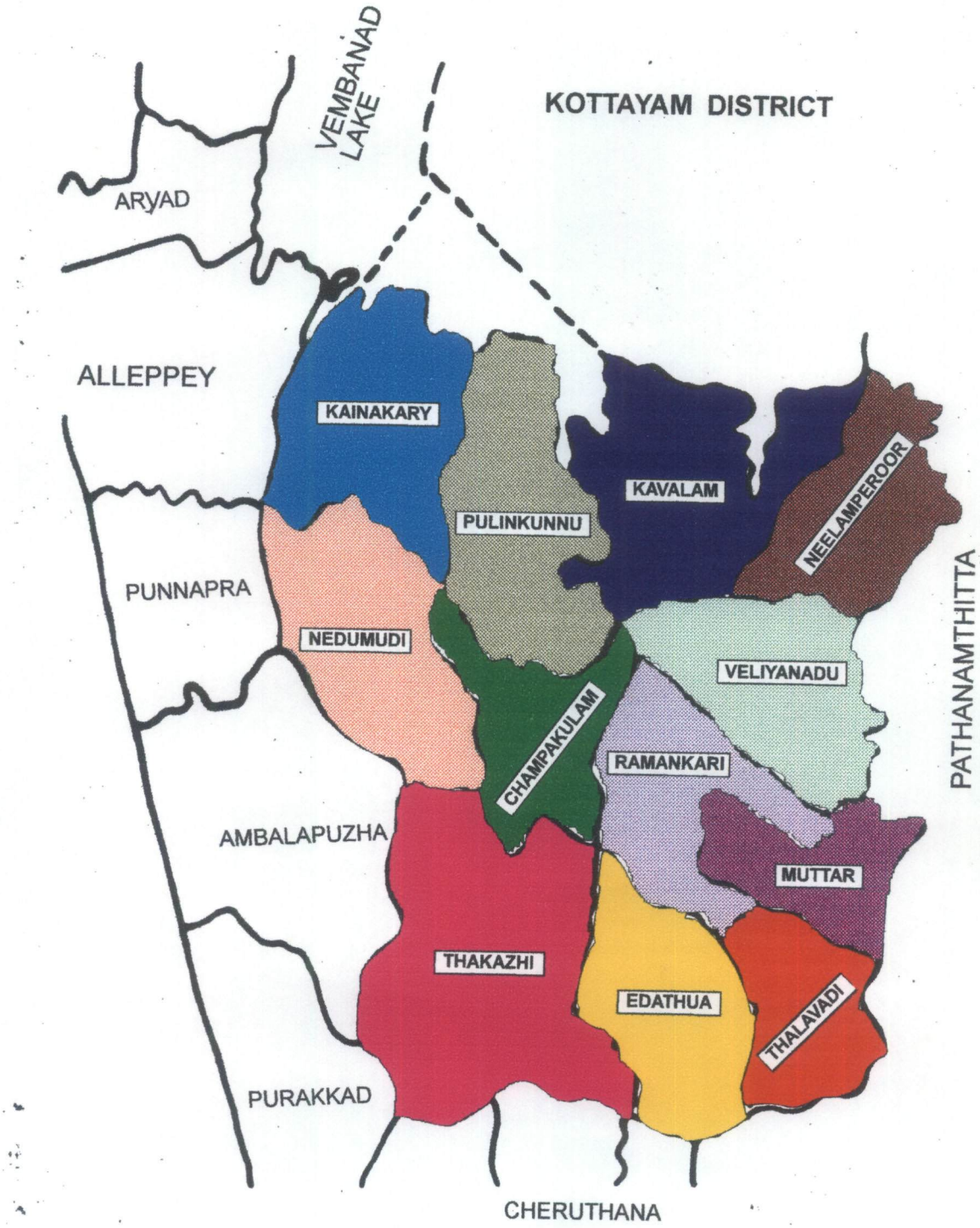


Fig. 1. Locations selected for the survey on incidence of bacterial blight disease of rice in Kuttanad

grains (u) and the weight of filled grains (w) were determined. The rest of the panicles from all 12 hills were also threshed and the number of unfilled grains (U) and the weight of filled grains (W) were assessed. From the data, the percentage of unfilled grains was worked out by using the formula of Gomez (1972).

$$\text{Percentage of unfilled grains} = \frac{U + u}{f\,(W+w)/W+U+u} \times 100$$

In the case of curative spraying, in addition to various yield parameters specified above, observations on initial disease scores before the spray and disease score 15 d after the second spray were also recorded.

The data were statistically analysed using the analysis of variance for factorial RBD experiments (Snedecor and Cochran, 1967) and significance was tested by 'F' test (Cochran and Cox, 1965).

ECONOMIC BENEFITS OF CONTROLLING BACTERIAL BLIGHT OF RICE

The relative economic benefits of prophylactic and curative sprayings were calculated on the basis that the presen t cost of paddy cultivation is Rs. 7500/- per ha and the current market rates for one kilogram of grain and straw are Rs. 3.50 and Rs. 1.40 respectively. The cost per gram of various bactericidal agents like streptocycline, streptomycin, oxytetracycline and

Bactrinol-100 was Rs. 2.45, Rs. 8.00, Rs. 13.00 and Rs. 2.50 respectively and cowdung was available free of cost.

The net return per rupee invested was calculated by the formula

$$\text{Net return per rupee invested} = \frac{X - Y}{Y}$$

where,

X = value of the product (grain/straw)

Y = total cost of production including treatment.

RESULTS

1. SURVEY ON THE INCIDENCE OF BACTERIAL BLIGHT OF RICE IN KUTTANAD

Survey on the incidence of bacterial blight of rice in Kuttanad was conducted in 115 farmers field distributed over 12 different Krishibhavans during 1992 to 1994. The mean data on disease score and percentage of disease incidence for each location are given in Tables 1, 2 and 3 and Figs. 4 and 5. The individual data for various locations are given separately in Appendix 1-12.

The survey indicated that the area coming under Ramankari and Nedumudi Krishibhavans was more susceptible to bacterial blight disease in Kuttanad. The data for four seasons gave a disease score of 5.20 and 4.98 with a percentage disease incidence of 29.93 and 31.33 (Table 3) for these locations. Further, between the two major cropping seasons the disease incidence was more during additional crop season. For Ramankari, the mean disease score and percentage of disease incidence during this season were 6.35 and 39.30 respectively. The corresponding values for the Punja season were only 4.05 and 20.55 (Table 1 and Table 2). A similar trend was also observed in all other locations except in Neelamperoor and Thalavadi, where there was no incidence of bacterial blight during the survey period of 1992-94.

Table 1. Incidence of bacterial blight disease in Kuttanad Taluk during additional crop season

Name of Krishi Bhavan	Number of locations surveyed	Disease score and percentage of disease incidence					
		Additional 1992		Additional 1993		Mean	
		Score	Incidence	Score	Incidence	Score	Incidence
Champakulam	10	4.2	43.5	4.5	25.0	4.35	34.25
Edathua	10	4.8	31.2	5.0	38.0	4.90	34.60
Kavalam	10	2.0	25.5	3.8	24.1	2.90	24.80
Kainakary	10	4.5	17.4	4.9	34.7	4.70	26.05
Muttar	10	4.2	25.0	5.0	33.0	4.60	29.00
Nedumudi	10	6.2	45.8	5.9	40.0	6.05	42.90
Pulinkunnu	10	4.1	29.1	5.6	30.5	4.83	29.80
Ramankari	10	5.9	32.1	6.8	45.9	6.35	39.30
Thakazhi	5	4.6	17.0	4.6	36.0	4.60	26.50
Veliyanadu	10	4.5	25.5	4.8	42.0	4.65	33.75
Mean		4.5	29.2	5.7	34.9	5.10	32.05
Neelamperoor	10	Nil	Nil	Nil	Nil	Nil	Nil
Thalavadi	10	Nil	Nil	Nil	Nil	Nil	Nil

Table 2. Incidence of bacterial blight disease in Kuttanad Taluk during punja season

Name of Krishi Bhavan	Number of locations surveyed	Disease score and percentage of disease incidence					
		Punja 1992–1993		Punja 1993 – 1994		Mean	
		Score	Incidence	Score	Incidence	Score	Incidence
Champakulam	10	2.9	5.2	0.8	2.0	1.85	3.60
Edathua	10	3.5	17.9	3.0	18.0	3.25	17.95
Kavalam	10	2.1	6.4	1.8	6.0	1.95	6.20
Kainakary	10	0.9	2.2	0.71	2.6	0.82	2.40
Muttar	10	1.2	4.5	1.3	10.0	1.25	7.25
Nedumudi	10	4.4	18.6	3.4	20.9	3.90	19.75
Pulinkunnu	10	1.5	6.0	2.8	15.5	2.15	10.75
Ramankari	10	4.3	21.1	3.8	20.0	4.05	20.55
Thakazhi	5	2.0	5.0	2.6	12.0	2.30	8.50
Veliyanadu	10	2.2	16.2	3.0	18.5	2.60	19.35
Mean		2.50	10.30	2.30	12.50	2.40	11.43
Neelamperoor	10	Nil	Nil	Nil	Nil	Nil	Nil
Thalavadi	10	Nil	Nil	Nil	Nil	Nil	Nil

Table 3. Mean disease score and percentage of bacterial blight disease incidence in Kuttanad Taluk

Name of Krishi Bhavan	Disease score and percentage of disease incidence					
	Additional (Mean)		Punja (Mean)		Mean	
	Score	Incidence	Score	Incidence	Score	Incidence
Champakulam	4.35	34.25	1.85	3.60	3.10	18.93
Edathua	4.90	34.60	3.25	17.95	4.08	26.28
Kavalam	2.90	24.80	1.95	6.20	2.43	15.50
Kainakary	4.70	26.05	0.82	2.40	2.76	14.23
Muttar	4.60	29.00	1.25	7.25	2.93	18.13
Nedumudi	6.05	42.90	3.90	19.75	4.98	31.33
Pulinkunnu	4.85	29.80	2.15	10.75	3.50	28.28
Ramankari	6.35	39.30	4.05	20.55	5.20	29.93
Thakazhi	4.60	26.50	2.30	8.50	3.45	17.50
Veliyanadu	4.65	33.75	2.60	19.35	3.63	26.55
Mean	5.10	32.05	2.40	11.43	3.75	21.74
Neelamperoor	Nil	Nil	Nil	Nil	Nil	Nil
Thalavadi	Nil	Nil	Nil	Nil	Nil	Nil

RESULTS

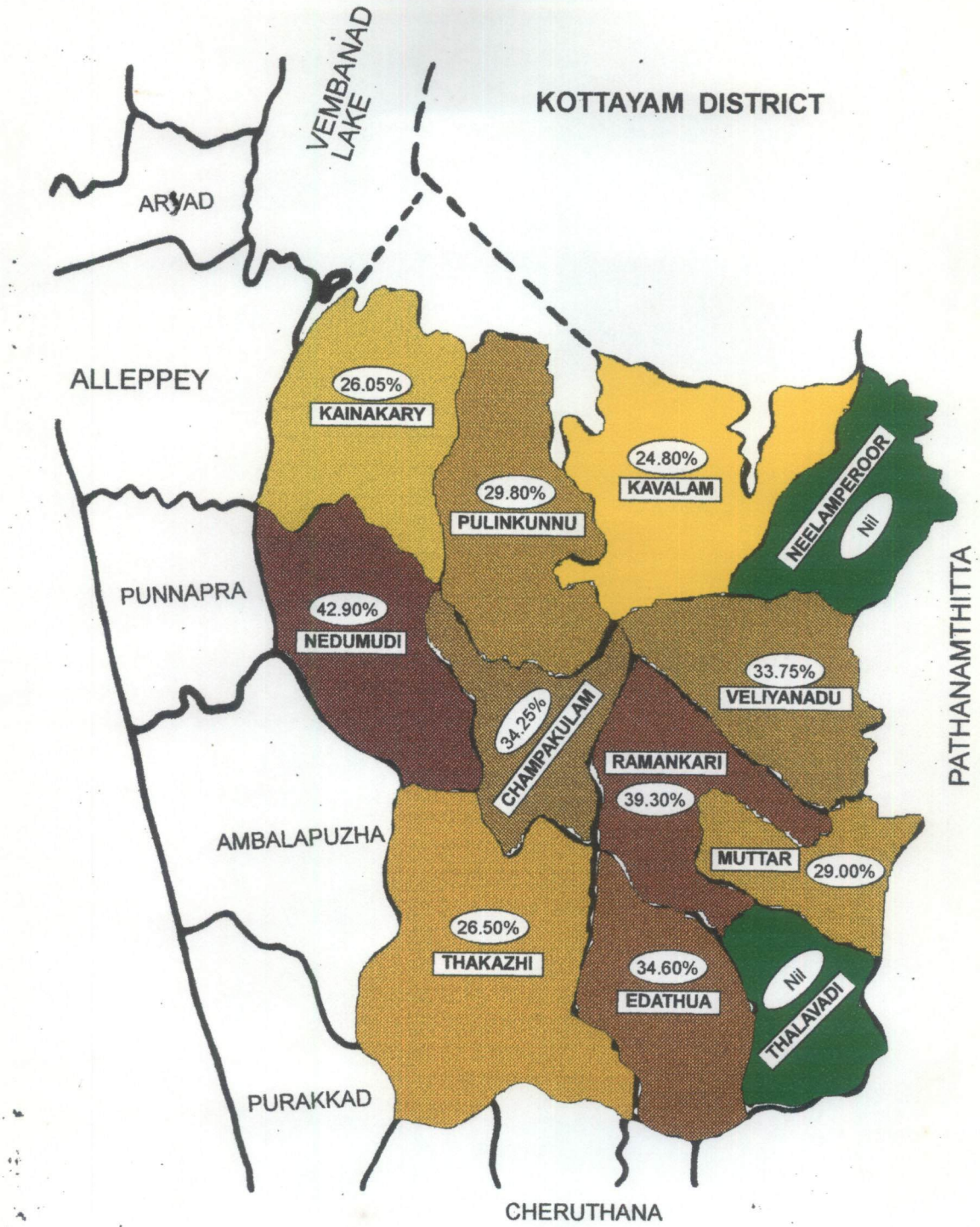


Fig. 4. Incidence of bacterial blight of rice in Kuttanad during additional crop season

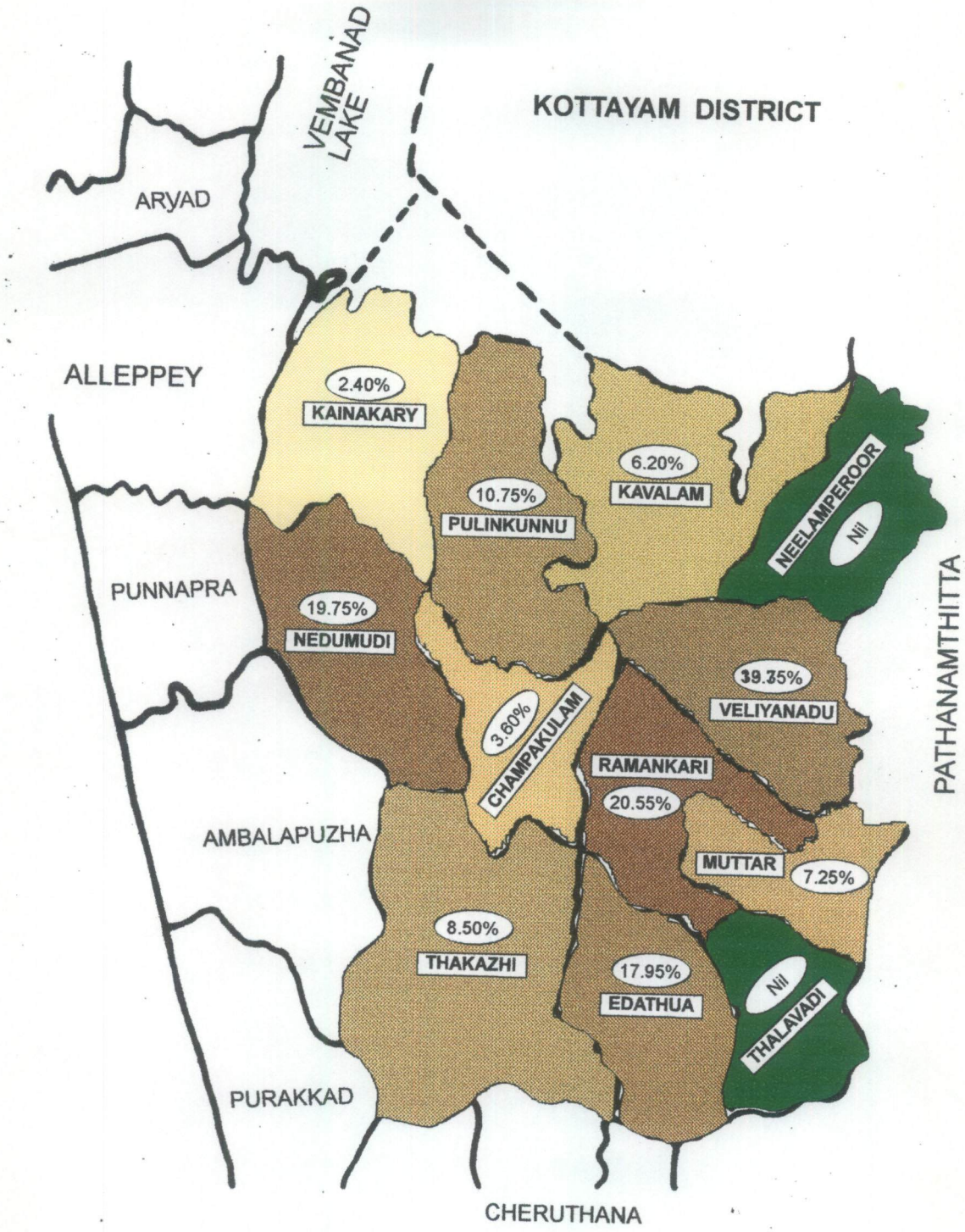


Fig. 5. Incidence of bacterial blight of rice in Kuttanad during punja crop season

Some of the locations like Kavalam, Kainakary and Muttar had a less severe incidence of bacterial blight disease (Table 1, 2 and 3). In these locations, the mean disease score and percentage of disease incidence varied from 2.43 to 2.93 and from 14.23 to 18.13 respectively.

1.1. Susceptibility of rice varieties cultivated by farmers to bacterial blight disease

The survey data on rice varieties cultivated by different farmers in the 12 Krishibhavans of Kuttanad Taluk are given in Appendix 1-12. It was observed that during the additional crop of 1992, 50 per cent of farmers cultivated the variety Red Triveni followed by Jyothy (25.47 %) and other varieties like Pavizham, Jaya, Cul. 1280, Sindhuram, Asha etc (24.53 %) (Fig. 6). The result of Chi-square test of significance to find out the association between variety and disease score is given in Table 4. The $X^2_{2x2} = 15.76$ showed a significant association between rice varieties cultivated and disease score. The variety Red Triveni was most susceptible to this disease. (Plate 1).

During the punja season of 1992-93, most of the farmers (47.66%) cultivated the variety Red Triveni followed by Jyothy (34.58%) and other varieties like Pavizham, Sindhuram, Cul.1280, Asha etc. (17.76%) (Fig.7). Here also, the $X^2_{2x3} = 13.09$ showed a significant association between the variety cultivated by the farmers and disease score (Table 5). The variety Red Triveni was again found to be most susceptible to bacterial blight disease.

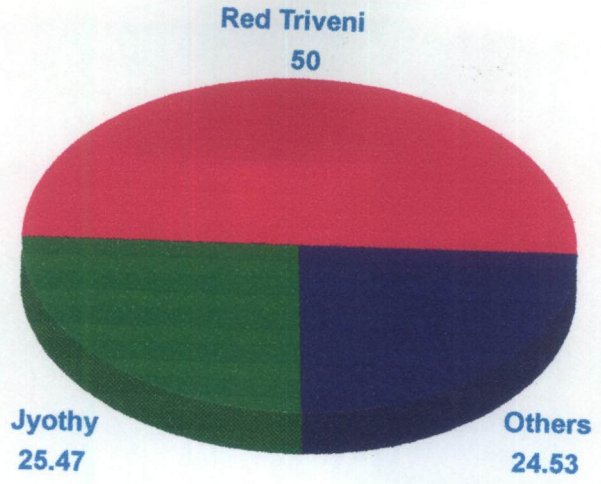


Fig. 6. Rice varieties cultivated during additional crop of 1992

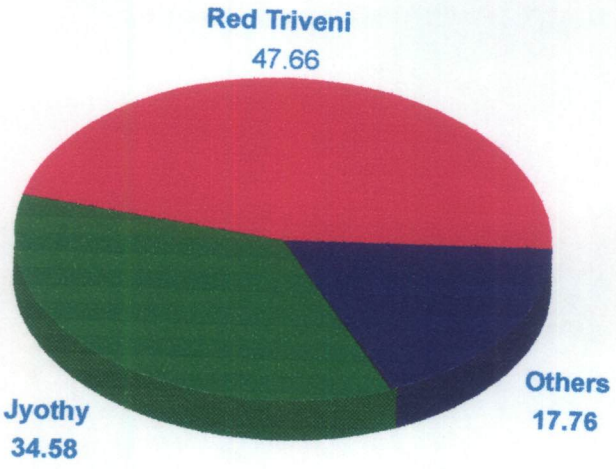


Fig. 7. Rice varieties cultivated during punja crop of 1992-93

Table 4. Susceptibility of rice varieties to bacterial blight disease-additional crop 1992

Varieties	Disease score observed frequency			Total
	1-3	5	7	
Red Triveni	10	27	16	53
Jyothy	15	10	2	27
Other varieties	10	14	2	26
Total	35	51	20	106

$X^2_{2\times2} = 15.76^{**}$

** Significant at 1 per cent level.

Table 5. Susceptibility of rice varieties to bacterial blight disease-punja crop 1992-93

Varieties	Disease score observed frequency				Total
	0	1-3	5	7	
Red Triveni	0	36	10	5	51
Jyothy	9	22	4	2	37
Other varieties	2	15	2	0	19
Total	11	73	16	7	107

$X^2_{2\times3} = 13.09^{**}$

** Significant at 1 per cent level.

Plate I. Severe infection of bacterial blight disease in rice variety Red Triveni

In the additional crop season of 1993 also,46.4 per cent of the farmers cultivated Red Triveni followed by Jyothy (24.1%), Parijatha (14.3%) and other varieties like IR 100, Pavizham, Sindhuram, Jaya etc. (15.2%) (Fig.8). Here also, the X^2_6 = 76.24 (Table 6) revealed a significant association between varieties cultivated and disease score with Red Triveni being the most susceptible variety.

However, during the punja season of 93-94 , when nearly 34.66 per cent farmers cultivate Red Triveni, 31.68 per cent white Triveni, 24.75 per cent Jyothy and 8.91 per cent other varieties like Pavizham, Bhadra and Sindhuram (Fig. 9), the Chi square X^2_3 = 3.85 (Table 7) was not significant.

2. THE PATHOGEN

Xanthomonas oryzae pv. *oryzae* was initially isolated on PSA medium from a sample of bacterial blight infected leaf of rice variety, Red Triveni. The isolate produced light yellow, circular, slimy and raised colonies both on PSA and GA media. It was an aerobic, gram -ve, rod shaped bacterium with an optimum temperature for growth at 30 ± 1°C. Acid production without gas formation was observed in the utilization of sugars such as glucose, galactose and mannose. While the urease activity was negative, the culture was capable of both starch hydrolysis and gelatin liquefaction. It produced an alkaline reaction in milk without any coagulation or peptonization. Hydrogen sulphide was produced from peptone water. The growth of the bacterium was not inhibited at lower concentrations of sodium chloride such as 2, 2.5 and 3 per cent, but it was inhibited at 6 per cent concentration of sodium chloride in peptone water.

Table 6. Susceptibility of rice varieties to bacterial blight disease-additional crop 1993

Varieties	Disease score observed frequency			Total
	1-3	5	7	
Red Triveni	1	27	24	52
Jyothy	23	3	1	27
Parijatha	0	4	12	16
Other varieties	5	6	6	17
Total	29	40	43	112

X^2

$3 \times 2 = 76.24^{**}$

**Significant at 1 per cent level

Table 7. Susceptibility of rice varieties to bacterial blight disease-punja crop 1993-94

Varieties	Disease score observed frequency		Total
	1-3	5 - 7	
Red Triveni	25	10	35
White Triveni	28	4	32
Jyothy	22	3	25
Other varieties	7	2	9
Total	82	19	101

X^2

$1 \times 3 = 3.85$

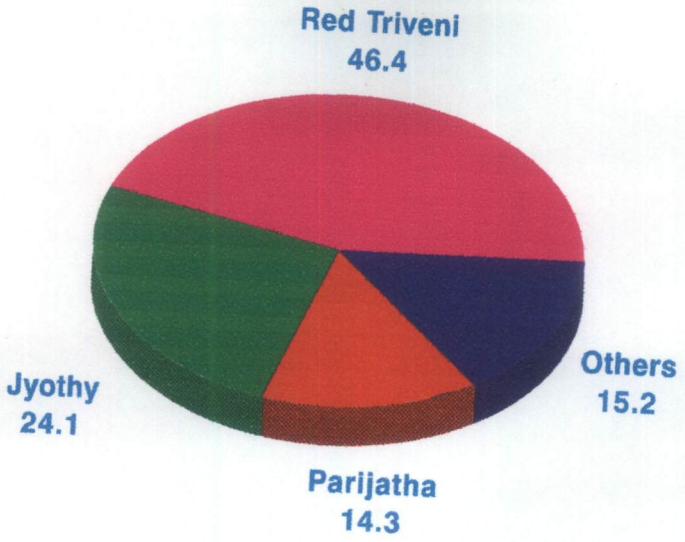


Fig. 8. Rice varieties cultivated during additional crop of 1993

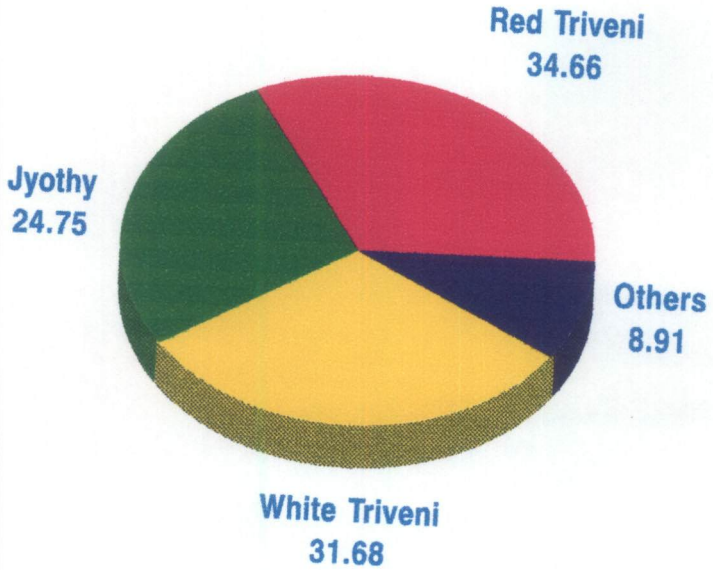


Fig. 9. Rice varieties cultivated during Punja crop of 1993-94

2.1. Testing the virulence of isolated culture of *Xanthomonas oryzae* pv. *oryzae*

The pathogenicity of the isolate was tested on a highly susceptible check variety of rice T(N)1 using a 48h old aqueous suspension of the pathogen by clip inoculation method. The initial symptom appeared as water soaked lesions at the clip end of the leaves after three days of inoculation. They soon changed to yellow colour and spread downwards through the leaf margin. These lesions later changed to straw colour and by about 15 days more than 50 per cent of the leaf area was affected. Finally by the third week of infection, the whole leaf got blighted and dried. The induction of typical symptoms of bacterial blight in T(N)1 proved the virulent nature of the isolate. The pathogen was reisolated on PSA medium and a pure culture of the same was maintained on PSA slants for further studies.

3. SCREENING RICE VARIETIES FOR RESISTANCE AGAINST *Xanthomonas oryzae* pv. *oryzae*

Twenty one rice varieties/cultivars were screened under pot culture conditions for resistance to infection by *Xanthomonas oryzae* pv. *oryzae*. The first experiment was conducted at College of Agriculture, Vellayani during 1992 in the month of June to September which corresponded with the additional crop season of Kuttanad. The second pot trial was conducted at Rice Research Station, Moncompu during the additional crop season of 1993. The bacterial blight resistant variety DV 85 and highly susceptible variety T(N)1 were used as check varieties. Data on disease score and lesion length were recorded 21 days after inoculation.

The disease score varied from 0.82 in the bacterial blight resistant check variety DV 85 to 8.66 in Red Triveni. Based on the critical difference and as per the International Rice Research Institute score chart, the different rice varieties were grouped as resistant (0-1), moderately resistant (>1-3), moderately susceptible (>3-6), susceptible (>6-7) and highly susceptible (>7-9) varieties to bacterial blight disease. (Table 8 and Fig.10). It was observed that none of the rice varieties screened could be grouped either as resistant or moderately resistant to bacterial blight disease. Twelve varieties such as Aruna, Asha, Cul 38-4-1, Cul 38-4-2, Cul 38-8-1, Cul 48-11-1, Makam, Mahavira, MO1-10-4-1. MO1-10-8-1, MO1-20-3-1 and Remya were found to be moderately susceptible, while five varieties like Bhadra, Jyothy, Kanakam, Karthika and Pavizham were susceptible varieties. Three varieties, such as MO1-20-19-4, T(N)1 and Red Triveni were highly susceptible to bacterial blight disease.

The mean lesion length in different rice varieties varied from 0.45 cm in the resistant variety DV 85 to 23.59 cm in Red Triveni (Table 9). Based on the critical difference for lesion length, these varieties were grouped into five. The first group consisted of the resistant check variety DV 85 and the fifth group consisted of the highly susceptible variety, Red Triveni. Eventhough there were significant variations in lesion length due to infection by *Xanthomonas oryzae* pv.*oryzae*, there was no correlation between lesion length and disease score except in Red Triveni where a high disease score of 8.66 was associated with maximum lesion length. Similarly, in DV 85, a low disease score of 0.82 was associated with minimum lesion length of 0.45 cm.

Table 8. Reaction of rice varieties for resistance to bacterial blight disease - Pooled data on disease score at Vellayani and Moncompu

Sl. No.	Name of variety/ cultivar	Bacterial blight disease# score (0-9)		Mean
		Vellayani	Moncompu	
A. Resistant				
1.	DV 85 (Resistant check)	0.63 (1.28)*	1.00 (1.41)	0.82 (1.35)
B. Moderately Resistant				
	Nil	—	—	—
C. Moderately Susceptible				
1.	Aruna	5.0 (2.45)	7.0 (2.83)	6.0 (2.64)
2.	Asha	4.29 (2.30)	5.00 (2.45)	4.65 (2.37)
3.	Cul 38-4-1 (MR1)	7.00 (2.83)	3.62 (2.15)	5.31 (2.49)
4.	Cul 38-4-2 (MR2)	4.89 (2.43)	5.00 (2.45)	4.95 (2.44)
5.	Cul 38-8-1 (MR3)	7.00 (2.83)	5.00 (2.45)	6.00 (2.64)
6.	Cul 48-11-1 (MR6)	4.89 (2.43)	6.30 (2.70)	4.56 (2.56)
7.	Makam (MO9)	5.00 (2.45)	5.00 (2.45)	5.00 (2.45)
8.	Mahavira	5.00 (2.45)	5.00 (2.45)	5.00 (2.45)
9.	MO 1-10-4-1 (M1)	5.00 (2.45)	7.00 (2.83)	6.00 (2.64)

Contd....

Table 8 (Contd....)

Sl. No.	Name of variety/ cultivar	Bacterial blight disease# score (0-9)		Mean
		Vellayani	Moncompu	
10.	MO 1-10-8-1 (M2)	5.00 (2.45)	7.00 (2.83)	6.00 (2.64)
11.	MO 1-20-3-1 (M3)	3.00 (2.00)	4.29 (2.30)	3.65 (2.15)
12.	Remya	5.00 (2.45)	5.00 (2.45)	5.00 (2.45)
D. Susceptible				
1.	Bhadra	8.31 (3.05)	4.29 (2.30)	6.30 (2.68)
2.	Jyothy	7.00 (2.83)	7.00 (2.83)	7.00 (2.83)
3.	Kanakam	5.00 (2.45)	9.00 (3.16)	7.00 (2.81)
4.	Karthika	7.64 (2.94)	5.00 (2.45)	6.32 (2.69)
5.	Pavizham	7.00 (2.83)	6.30 (2.70)	6.65 (2.77)
E. Highly susceptible				
1.	MO 1-20-19-4 (M10)	7.64 (2.94)	7.00 (2.83)	7.32 (2.88)
2.	Red Triveni	8.31 (3.05)	9.00 (3.16)	8.66 (3.11)
3.	T(N)1	7.64 (2.94)	8.31 (3.05)	7.98 (3.00)

C.D. 0.578 (0.05 level)

* Figures in parentheses are $\sqrt{x + 1}$ values of disease score.

Mean of three replications.

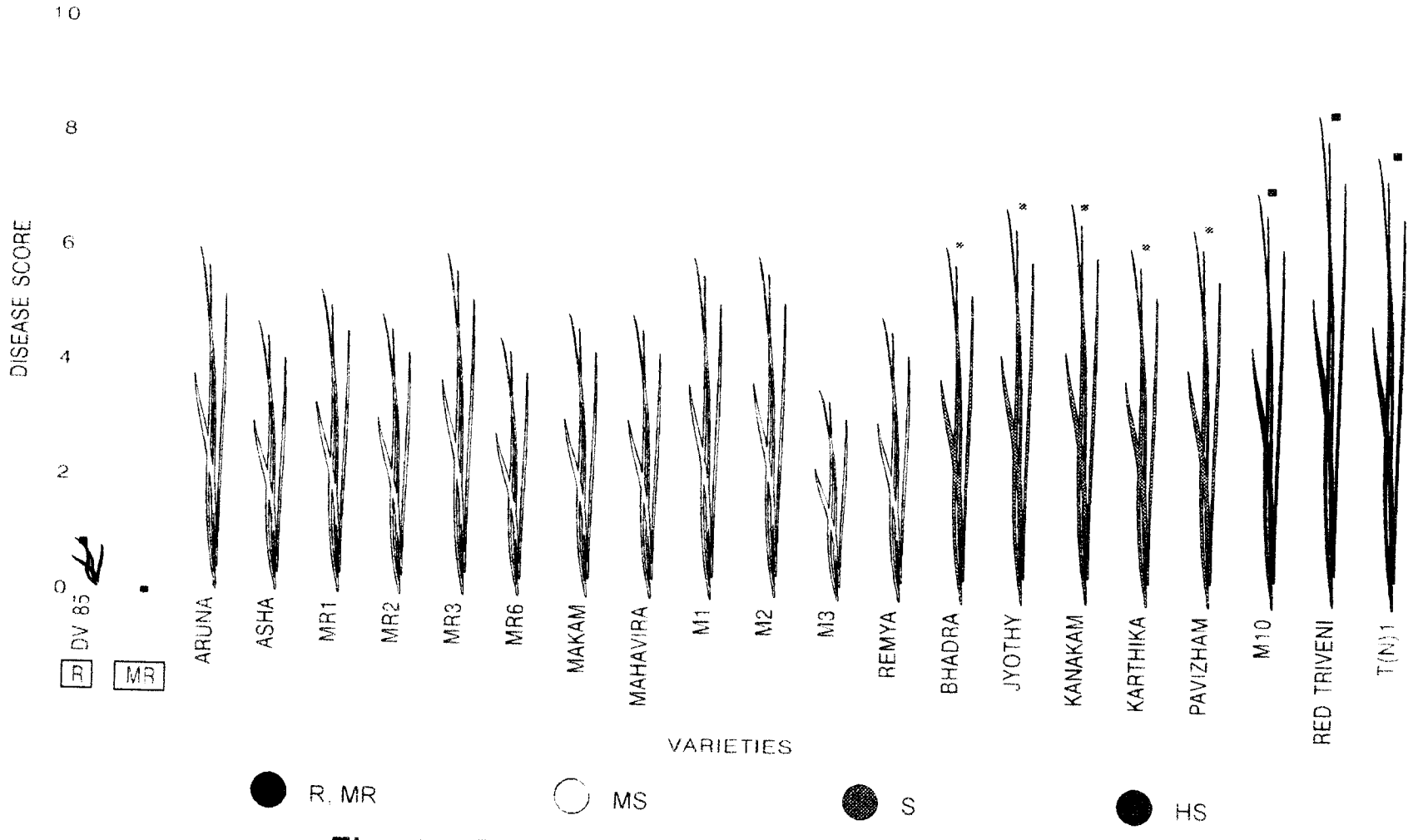


Fig. 10. Reaction of rice varieties against bacterial blight disease

Table 9. Reaction of rice varieties for resistance to bacterial blight disease - Pooled data on lesion length at Vellayani and Moncompu

Sl. No.	Name of variety/cultivar	Bacterial blight lesion length* (in cm)		
		Vellayani	Moncompu	Mean
Group I				
1.	DV 85	0.37	0.53	0.45
Group II				
1.	Bhadra	10.09	12.55	11.32
2.	Karthika	13.60	12.07	12.84
3.	Mahavira	14.21	12.39	13.30
4.	MO 1-10-4-1	14.39	12.95	13.67
Group III				
1.	Aruna	17.07	16.60	16.83
2.	Asha	15.15	15.30	15.23
3.	Cul 38-4-1	15.87	13.77	14.82
4.	Cul 38-4-2	13.15	13.37	13.26
5.	Cul 48-11-1	19.68	14.37	17.03
6.	Makam	15.57	15.60	15.59
7.	MO 1-20 3-1	19.12	13.54	16.33
8.	Pavizham	16.51	16.48	16.50
9.	Remya	15.43	15.52	15.48
10.	T(N)1	15.37	17.88	16.63
Group IV				
1.	Cul 38-8-1	17.19	19.20	18.20
2.	Jyothy	18.17	18.03	18.10
3.	Kanakom	20.23	16.30	18.27
4.	MO 1-20-19-4	18.12	18.18	18.15
Group V				
1.	MO 1-10-8-1	23.15	18.20	20.68
2.	Red Triveni	25.18	22.20	23.59

CD - 3.505. (0.05 level)

* Mean of three replications.

4. MODE OF SURVIVAL OF *Xanthomonas oryzae* pv. *oryzae*

4.1. Survival in infected seed :

The survival of *Xanthomonas oryzae* pv. *oryzae* in infected seed was studied under pot culture conditions by sowing at weekly intervals one hundred infected seeds collected from ten different locations. The data were recorded in terms of percentage of seedlings getting infected by bacterial blight disease. There was significant reduction in the extent of survival of the pathogen with increase in the period of storage at room temperature. Seedlings showing the typical symptoms of bacterial blight were obtained for most of the locations upto six weeks. However, in some locations such as Muttar and Thakazhi, the pathogen was found to survive only up to a maximum period of three weeks. The above observation was confirmed by bivariate regression technique (Table 10 and Fig. 11).

A decreasing trend in the survival of bacterial blight pathogen was observed with respect to the period of storage of infected seed material. This trend was described in a modified exponential form given by,

$y = k + ab^x$ where,

$y = -10.3215 + 53.8515 \times 0.7019^x$

y = per cent survival

k = asymptote

x = weeks codified as 0,1,2 etc.

a = constant

b = rate of change

Table 10. Survival* of *Xanthomonas oryzae* pv. *oryzae* in infected seed

Locality	Number of seeds sown	Percentage of seedlings showing disease symptoms						
		Storage period after harvest (in weeks)						
		1	2	3	4	5	6	7
Champakulam	100	60	36	22	12	7	2	0
Edathua	100	31	25	12	8	0	0	0
Kainakary	100	49	37	28	10	7	1	0
Kavalam	100	49	35	20	8	3	1	0
Muttar	100	28	10	5	0	0	0	0
Nedumudi	100	56	50	20	17	9	2	0
Pulinkunnu	100	42	34	18	10	4	1	0
Ramankari	100	58	37	20	10	5	2	0
Thakazhi	100	18	12	5	0	0	0	0
Veliyanadu	100	48	40	20	11	5	0	0
Mean		43.53 #(41.26)	30.73 (33.65)	16.21 (23.73)	6.89 (15.21)	2.75 (9.55)	0.68 (4.73)	0

CD (0.05) for treatments 2.936
SE = 3.258 CV = 15.290

Figures in parentheses are transformed percentages in degrees
* Mean of three replications.

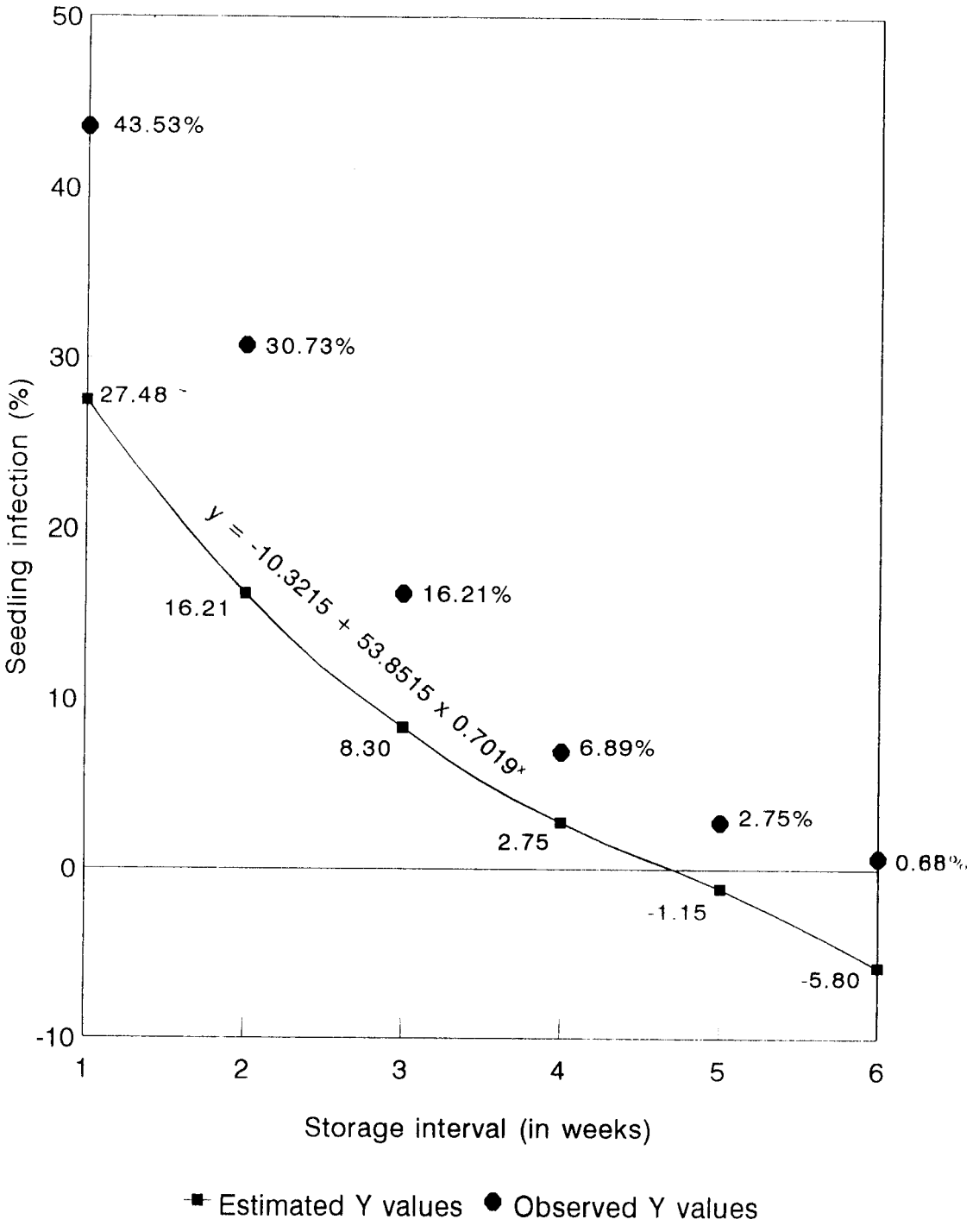


Fig. 11. Trend in the survival of Xanthomonas oryzae pv. oryzae in seed

4.2. Survival in infected straw

The survival of *Xanthomonas oryzae* pv. *oryzae* in infected straw was studied by inoculating the leaves of T(N)1 at maximum tillering stage with an aqueous suspension of chopped infected straw stored for different periods at room temperature. The inoculation was done at 15 day intervals upto 120 days. Observations on the occurrence of typical symptoms were recorded after seven days of each inoculation. The disease incidence was uniform with infected straw up to 75 days of storage irrespective of the location from where they were collected (Table 11 Fig. 12). However, thereafter, the disease incidence was at random up to 105 days. This showed that the pathogen was capable of surviving in infected straw only upto a maximum period of 105 days.

4.3. Survival in infected stubbles

The survival of *Xanthomonas oryzae* pv. *oryzae* in infected stubbles was also studied by inoculating the leaves of T(N)1 at maximum tillering stage with an aqueous suspension of chopped infected stubbles stored at different periods in sterile water at room temperature. The inoculation was done at seven days interval up to 63 days. Observations on the occurrence of typical symptoms were recorded after seven days of each inoculation. The disease incidence was uniform with infected stubbles upto 35 days of storage irrespective of the location from where they were collected. (Table 12 and Fig. 13). However, thereafter, the disease incidence was at random up to 56 days. This showed that the pathogen was capable of surviving in infected stubbles for a maximum period of 56 days.

Table 11. Survival* of *Xanthomonas oryzae* pv. *oryzae* in infected paddy straw collected from different location

Sl. No.	Locations	Disease incidence in T(N)1							
		Storage period of infected straw (days)							
		15	30	45	60	75	90	105	120
1.	Champakulam	+	+	+	+	+	+	+	–
2.	Edathua	+	+	+	+	+	–	–	–
3.	Kainakary	+	+	+	+	+	+	–	–
4.	Kavalam	+	+	+	+	+	–	–	–
5.	Muttar	+	+	+	+	+	–	–	–
6.	Nedumudi	+	+	+	+	+	+	+	–
7.	Pulinkunnu	+	+	+	+	+	–	–	–
8.	Ramankari	+	+	+	+	+	+	+	–
9.	Thakazhi	+	+	+	+	+	–	–	–
10.	Veliyanadu	+	+	+	+	+	+	–	–

* Mean of 3 replications

\+ Pathogen present

– Pathogen absent.

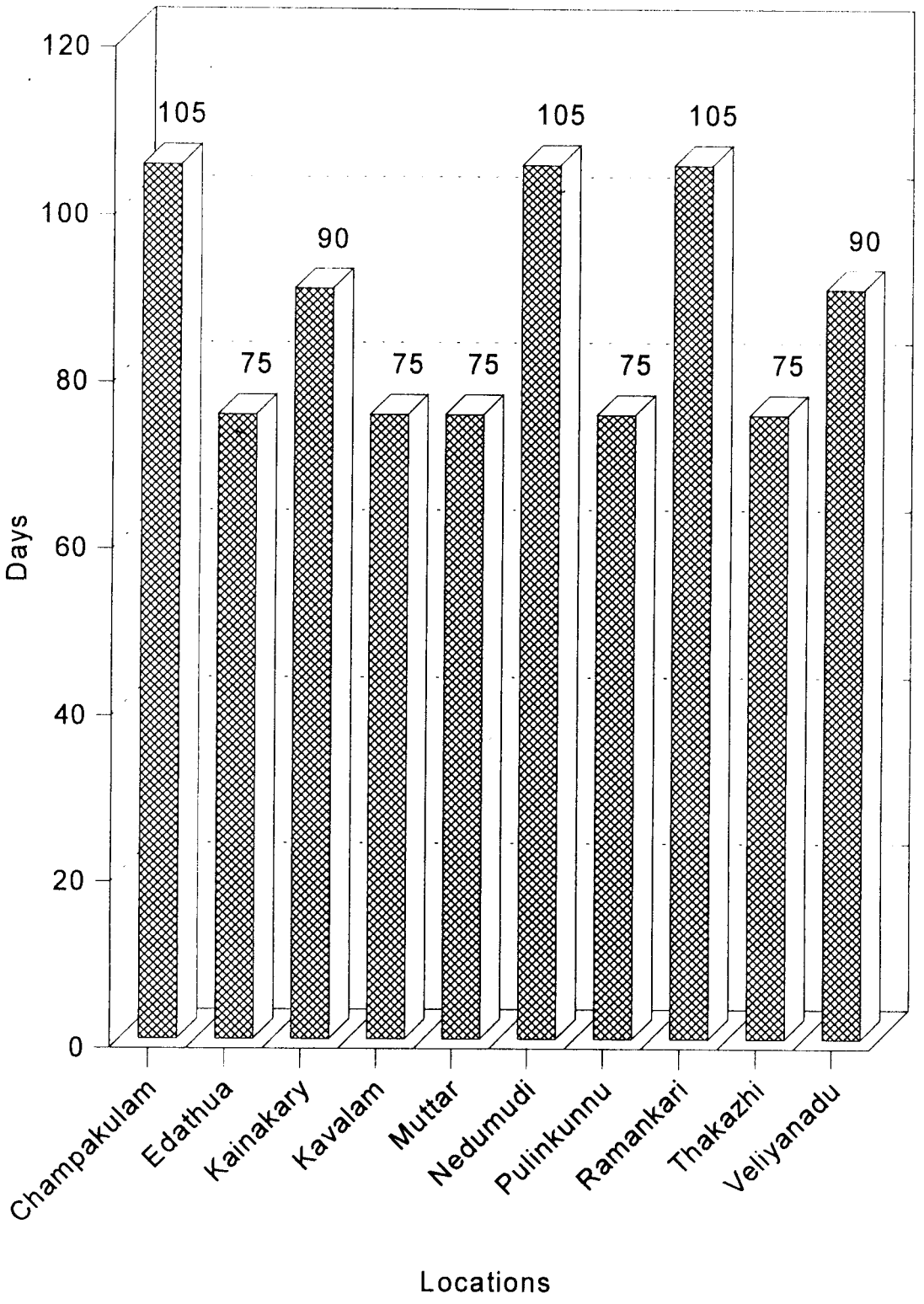


Fig. 12. Survival of Xanthomonas oryzae pv. oryzae in infected straw

Table 12. Survival* of *Xanthomonas oryzae* pv. *oryzae* in infected stubbles stored at room temperature

Sl. No.	Locations	Disease incidence in T(N)1								
		Storage period of infected stubbles (days)								
		7	14	21	28	35	42	49	56	63
1.	Champakulam	+	+	+	+	+	+	+	+	–
2.	Edathua	+	+	+	+	+	–	–	–	–
3.	Kainakary	+	+	+	+	+	+	+	–	–
4.	Kavalam	+	+	+	+	+	+	+	–	–
5.	Muttar	+	+	+	+	+	–	–	–	–
6.	Nedumudi	+	+	+	+	+	+	+	+	–
7.	Pulinkunnu	+	+	+	+	+	+	+	–	–
8.	Ramankari	+	+	+	+	+	+	+	+	–
9.	Thakazhi	+	+	+	+	+	–	–	–	–
10.	Veliyanadu	+	+	+	+	+	+	+	–	–

* Mean of 3 replications
\+ Pathogen present
-- Pathogen absent.

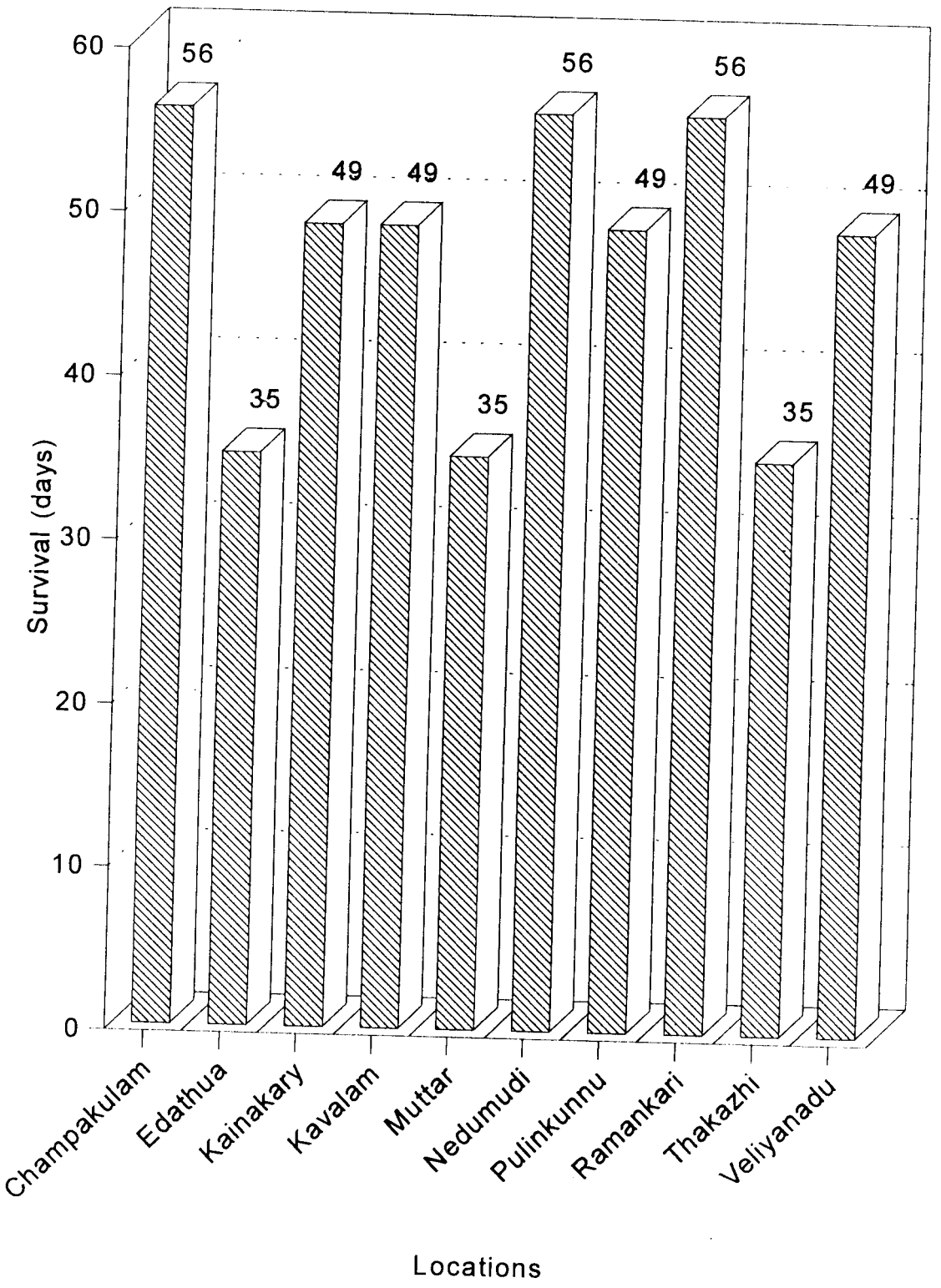


Fig. 13. Survival of Xanthomonas oryzae pv. oryzae in infected stubbles stored at room temperature

4.4. Survival in infected stubbles under field conditions.

Xanthomonas oryzae pv. *oryzae* was found to survive in infected stubbles remaining in the field (Plate II) under dry land condition for 28 days after harvest of the infected crop. However, under submerged conditions, the pathogen survived only for 14 days (Table 13 and Fig. 14)

4.5. Survival in infected soil and water

The survival of *Xanthomonas oryzae* pv. *oryzae* in infected soil and water was studied by inoculating the leaves of T(N)1 at maximum tillering stage with a suspension of soil and water collected from infected field at different locations in Kuttanad. The inoculation was done within 48 h to detect the presence of pathogen. Observation on the occurrence of typical symptoms of bacterial blight was recorded after seven days of inoculation (Table 14). But no incidence of this disease was observed.

4.6. Survival in infected soil

The survival of *Xanthomonas oryzae* pv. *oryzae* in infected soil was studied by serial dilution and plating technique using a selective medium. The soil samples were collected from an infected field in Nedumudi, Kuttanad during the additional crop season of 1992 and 93 and punja season of 1992-93 and 93-94. However, no pathogen could be isolated from any of the samples plated.

Table 13. Survival* of *Xanthomonas oryzae* pv. *oryzae* in infected paddy stubbles under field conditions

Sl. No.	Location	Disease incidence in T(N)1					
		Under dry land condition (days)				Under wet land condition (days)	
		7	14	21	28	7	14
1.	Champakulam	+	+	+	+	+	+
2.	Nedumudi	+	+	+	+	+	+
3.	Pulinkunnu	+	+	+	+	+	+
4.	Ramankari	+	+	+	+	+	+

* Mean of 3 replications.

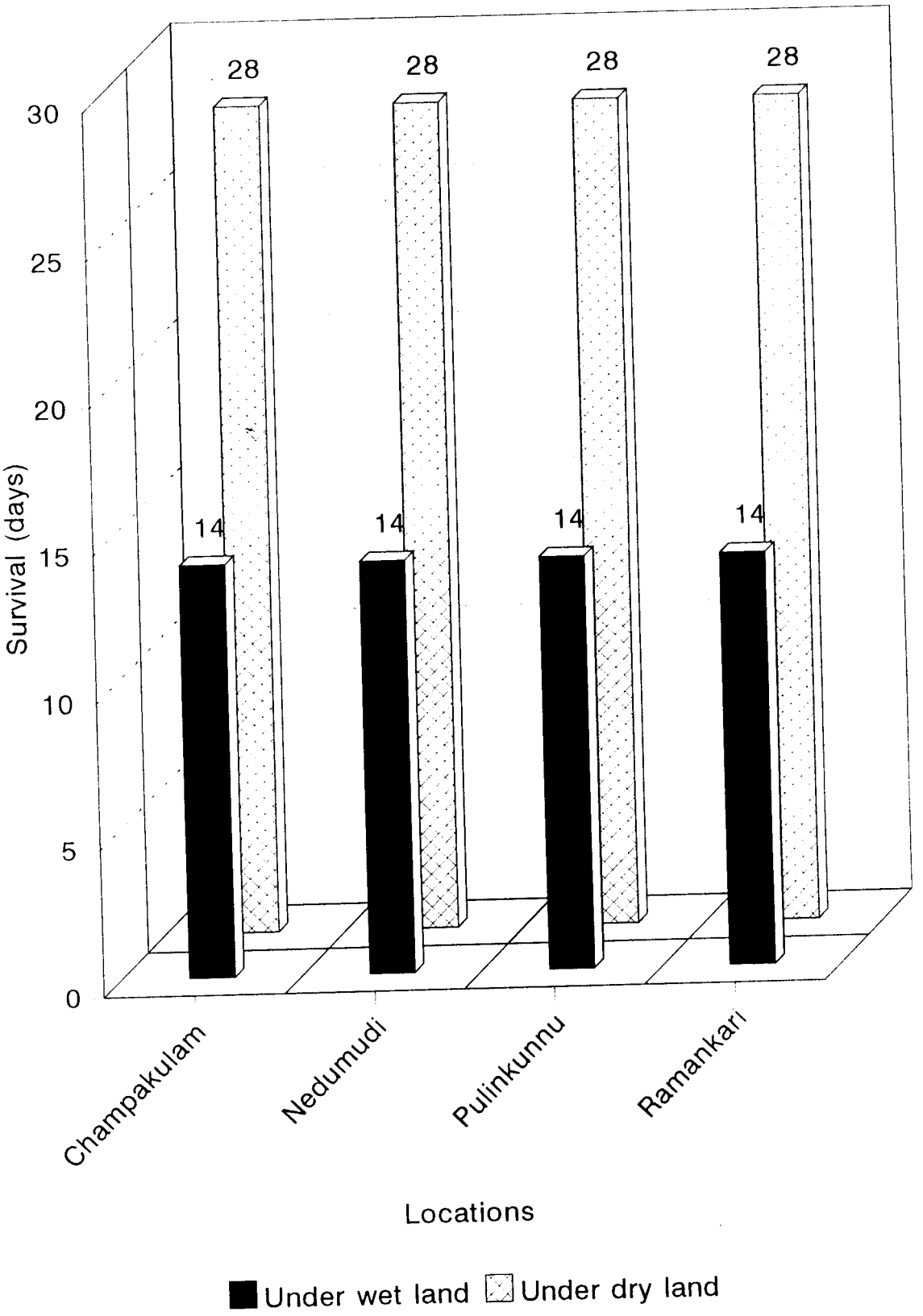


Fig. 14. Survival of Xanthomonas oryzae pv. oryzae in infected stubbles under field conditions

Plate II. Bacterial blight infected stubbles of rice variety Red Triveni

Table 14. Survival* of *Xanthomonas oryzae* pv. *oryzae* in infected soil and water samples collected from different locations

Sl. No.	Locality	Disease incidence on T(N)1
1.	Champakulam	—
2.	Edathua	—
3.	Kainakary	—
4.	Kavalam	—
5.	Muttar	—
6.	Nedumudi	—
7.	Pulinkunnu	—
8.	Ramankari	—
9.	Thakazhi	—
10.	Veliyanadu	—

— Pathogen absent
* Mean of three replications

4.7. Survival of *Xanthomonas oryzae* pv.*oryzae* in weeds

4.7a. Nature of weed population in Kuttanad

The weed flora of Kuttanad consisted of grasses, sedges, broad leaf weeds and ferns. Out of these, the grass weeds caused the major problem to rice crop. The prominent weeds in and around the rice fields (Plate III) and aquatic waste lands spread over twelve Krishibhavans of Kuttanad Taluk were surveyed during the additional and punja crop seasons of 1992 to 1994. The list of these weeds is given in Table 15.

Plate III. Occurrence of different weeds in and around rice fields

Table 15. Prominent weeds in Kuttanad surveyed during 1992 to 1994

Sl. No.	Scientific name	Vernacular name	Density No./Sq.m.		
			Additional season	Punja season	Aquatic waste lands
A. Grasses					
1.	*Cyanadon dactylon* Pers.	'Karuka'	10	10	4
2.	*Echinochloa colona* (L.) Link.	'Kavada'	10	2	2
3.	*E.crusgalli* (L.) Beauv.	'Kavada'	9	9	2
4.	*E. Stagnina* (Retz.) Beauv.	'Kambikavada'	25	25	4
5.	*Isachne dispa*	'Karimadipullu'	10	4	10
6.	*Oryza rufipogon* Griff.	Wild rice	10	10	0
7.	*Oryza sativa* var. *fatua*	'Varinellu'	14	14	0
8.	*Panicum repens* L.	—	Thick on bunds	Thick on bunds	6
9.	*Paspalum* sp.	'Kadakal'	0	0	Big clumps covering 2 sq.m area
10.	*Paspalum conjugatum* Berg.	—	4	4	2

Contd....

Table 15 (Contd...)

Sl. No.	Scientific name	Vernacular name	Density No./Sq.m.		
			Additional season	Punja season	Aquatic waste lands
11.	*Saccolepis interrupta* (Willd) Stap. f.	'Pindipullu', 'Pothalu'	5	2	4
12.	*Tragus* sp.	'Padarpan'	2	6	0
B. Sedges					
1.	*Cyperus distance*	'Minukkan', 'Chellippullu', 'Kudappullu'	17	19	10
2.	*Eleocharis plantaginea*	'Kathira'	6	0	9
3.	*Fimbristylis dichotoma*	'Korah'	20	28	4
C. Broad leaf weeds					
1.	*Eichornia crassipes* Solms.	'Venappacha'	10	5	14
2.	*Limnocharis flava* (L.) Buch.	'Nagappola'	3	1	1

Contd...

Table 15 (Contd...)

Sl. No.	Scientific name	Vernacular name	Density No./Sq.m.		
			Additional season	Punja season	Aquatic waste lands
3.	*Limnophila heterophylla* (Roxb) Benth.	'Mullan'	Fully covering soil surface	0	0
4.	*Ludwigia parviflora*	'Kandathil Kanthari'	12	13	6
5.	*Monochoria vaginalis* (Burm.f.) Presl. ex Kunth.	'Kakkapola'	6	3	60
6.	*Nymphea nouchali* (Burm.f.)	'Aambal'	0	0	5
7.	*Schenoplectus* sp.	'Mutti'	6	9	0
8.	*Sphenoclea zeylanica Gaertn.*	'Cheera'	3	3	0
D. Ferns					
1.	*Marselia quadrifoliata* L.	'Nalilakudakan'	6	9	3
2.	*Salvinia molesta* Mitchell	'African payal'	7	5	Fully covering water surface

Out of these, weeds like *Cyanadon dactylon, Echinochloa stagnina, E. crusgalli, Oryza rufipogon, Oryza sativa var. fatua, Panicum repens, Paspalum conjugatum, Cyperus distance, Fimbristylis dichotoma, Ludwigia parviflora* and *Salvinia molesta* (Plate IV) were dominant during both the cropping seasons. However, some of the weeds like *Echinochloa colona and Eleocharis plantaginea* were present in large numbers only during the additional crop season. Similarly, weeds like *Tragus* sp., *Schenoplectus* sp. and *Marselia quadrifoliata* were more prominent during punja season. Some of the weeds like *Salvinia molesta, Monochoria vaginalis, Nymphea nouchali and Paspalum* sp. were mostly seen in aquatic waste lands along with other weeds like *Isachne dispa, Cyperus distance* and *Eichornia crassipes.*

4.7b. Screening of weeds under natural conditions for bacterial blight disease

In all, eighteen dominant weeds occurring during the additional and punja crop seasons were observed for the presence of typical symptoms of bacterial blight disease. Only two weeds (Table 16) *Oryza sativa* var. *fatua* and *Paspalum conjugatum* showed symptoms in leaves similar to that of bacterial blight disease.

Symptoms on *Oryza sativa* var. *fatua* ('Varinellu')

The symptoms started as yellowing from the tip of leaves and progressed downwards. These lesions later changed to straw colour. The symptoms were usually observed at panicle initiation stage (Plate V)

Plate IV. Occurrence of *Salvinia molesta* in a bacterial blight infected rice field.

Table 16. Screening weeds under natural conditions for bacterial blight infection

Sl. No.	Scientific Name	Bacterial Blight	
		Natural infection	Ooze test
A. Grasses			
1.	*Cyanadon dactylon* Pers.	–	–
2.	*Echinochloa colona* (L.) Link.	–	–
3.	*E. crusgalli* (L.) Beauv.	–	–
4.	*E. stagnina* (Retz.) Beauv.	–	–
5.	*Isachne dispa*	–	–
6.	*Oryza rufipogon* Griff.	–	–
7.	*Oryza sativa* var.*fatua*	+	+
8.	*Panicum repens* L.	–	–
9.	*Paspalum conjugatum* Berg.	+	+
10.	*Saccolepis interrupta* (Willd) Staf. f.	–	–
B. Sedges			
1.	*Fimbristylis dichotoma*	–	–
2.	*Cyperus distance*	–	–
C. Broad leaf weeds			
1.	*Limnophila heterophylla* (Roxb) Benth.	–	–
2.	*Ludwigea parviflora*	–	–
3.	*Monochoria vaginalis* (Burm. f.) Presl. ex. Kunth.	–	–
4.	*Sphenoclea zeylanica* Gaertn.	–	–
D. Ferns			
1.	*Marselia quadrifoliata* L.	–	–
2.	*Salvinia molesta.* Mitchell.	–	–

Plate V. *Oryzae sativa* var. *fatua* ('varinellu') showing typical symptoms of bacterial infection.

and were quite conspicuous on the boot leaf extending to the panicle base. There was profuse ooze of bacterium when the cut ends of the infected leaves were observed under microscope in a drop of water.

The pathogen was isolated on PSA medium where it produced light yellow, smooth, round, raised, and slimy colonies characteristic of *Xanthomonas oryzae* pv. *oryzae*. This isolate reproduced disease symptoms on reinoculation not only in the weed but also in T(N)1 plants.

The weed 'Varinellu' belonged to the same family as that of cultivated rice and usually grew along with rice crop in the mainfield. But it could be distinguished from rice by its tall habit, long internodes, early flowering behaviour, narrow long leaves and awned grains. Natural infection of this weed with bacterial blight pathogen was observed during both the cropping seasons in Kuttanad.

Symptoms on *Paspalum conjugatum*

In *Paspalum conjugatum*, the initial symptoms of bacterial blight infection appeared as yellowing of leaves. As the disease progressed, infected leaves turned black in colour and soon dried. The symptoms were first seen on lower leaves which spread later to upper leaves (Plate VI). Profuse bacterial ooze was obtained from cut end of the leaves. However, the pathogen could not be isolated on PSA medium. But, when a suspension of chopped infected leaves was used for inoculation, it produced typical symptoms of bacterial

Plate VI. *Paspalum conjugatum* showing typical symptoms of bacterial blight infection.

blight disease not only in the weed but also in T(N)1. Natural infection of this weed with the bacterial blight pathogen was observed during both the cropping seasons in Kuttanad.

4.8. Survival in self sown rice

In Kuttanad, bacterial blight infected self sown rice plants originating from seeds or ratoons could be observed on field bunds, (Plate VII), chira, sides of water channels, 'Kalam' and in aquatic waste lands near cultivated field. The details regarding self sown rice with typical symptoms of bacterial blight are given in Table 17, 18, 19 and 20. They were seen at different stages of growth of main crop such as maximum tillering, panicle initiation, booting, flowering, dough and harvest stage in the months of March, April, May, June, July, August and December. The disease score due to bacterial blight infection in these plants varied with location and it ranged from three to seven.

The data (Table 17, 18, 19 and 20) indicated that the presence of self sown rice with bacterial blight infection in the months of July, August and December was critical since it could serve as a source of inoculum to the main crop at its most susceptible stages like maximum tillering and panicle initiation stages. The presence of such plants in the months of March, April, May and June could also be of significance as these plants can serve as an alternate host for the survival of the pathogen during and in between the main cropping seasons of Kuttanad.

Plate VII. Self sown rice showing severe infection of bacterial blight disease.

Table 17. Occurence of self sown rice in Nedumudi with bacterial blight disease

Sl. No.	Krishibhavan/ Location	Self sown rice			Main Crop	
		Month	Stage of growth	Disease score	Stage of growth	Incidence bacterial blight
A. Nedumudi						
1.	Mathurpadam	March	flowering	5	Harvest	+
2.	Mathurpadam	April	flowering	3	fallow	–
3.	Mathurpadam	May	flowering	5	fallow	–
4.	Mathurpadam	June	flowering	5	seedling	–
5.	Poopallypadam	June	flowering	5	seedling	–
6.	Pookuttukara padam	August	Harvest	7	Panicle initiation	+
7.	Varamavu varambinakam	December	flowering	5	Panicle initiation	+

Table 18. Occurence of self sown rice in Kainakary with bacterial blight disease

Sl. No.	Krishibhavan/ Location	Self sown rice			Main Crop	
		Month	Stage of growth	Disease score	Stage of growth	Incidence bacterial blight
B. Kainakary						
1.	Meenappally	March	Booting	3	Harvest	+
2.	Meenapally	April	Flowering	3	Fallow	–
3.	Meenapally	May	Maximum tillering	3	Fallow	–
4.	Aarupankari	June	Panicle initiation	3	Seedling	–
5.	Meenapally	June	Panicle initiation	3	Seedling	–
6.	Kakkanattukary	June	Panicle intitiation	3	Seedling	–
7.	Meenapally	August	Flowering	7	Panicle initiation	+
8.	Kakkanattukary	December	Flowering	5	Panicle initiation	+

Table 19. Occurence of self sown rice in Ramankari and Champakulam with bacterial blight disease

Sl. No.	Krishibhavan/ Location	Self sown rice			Main Crop	
		Month	Stage of growth	Disease score	Stage of growth	Incidence bacterial blight
C. Ramankari						
1.	Illimuri thekketholl ayiram	March April May	Harvest Dough Flowering	3 5 5	Harvest Fallow Fallow	+ – –
2.	Chempody	July	Flowering	7	Maximum tillering stage	–
3.	Kanjickel	December	Booting	7	Flowering	+
D. Champakulam						
1.	Thekkae thollayiram	March	Flowering	7	Harvest	+
2.	Chembumpuram	April	Harvest stage	3	Fallow	–
3.	Chembumpuram	June	Panicle initiation	5	Seedling	–
4.	Chembumpuram	December	Panicle initiation	5	Flowering	+

Table 20. Occurence of self sown rice in Pulinkunnu, Edathua and Muttar with bacterial blight disease

Sl. No.	Krishibhavan/ Location	Self sown rice			Main Crop	
		Month	Stage of growth	Disease score	Stage of growth	Incidence bacterial blight
E. Pulinkunnu						
1.	Thadam	March	Dough stage	5	Harvest	+
2.	Irupathirandum padam	July	Panicle initiation	5	Maximum tillering	–
3.	Vadakkekari madathani kari	July	Maximum tillering	5	Maximum tillering	–
		December	Panicle initiation	3	Panicle initiation	+
F. Edathua						
1.	Vypissery	April	Dough stage	3	Fallow	–
2.	Vakara edas serykonam	April	Dough stage	3	Fallow	–

Contd...

Table 20. (Contd...)

Sl. No.	Krishibhavan/ Location	Self sown rice			Main Crop	
		Month	Stage of growth	Disease score	Stage of growth	Incidence bacterial blight
3.	Padijarakili yanveli	June	Dough stage	1	Seedling	–
4.	Edasserykonum	December	Panicle initiation	1	Panicle initiation	+
G. Muttar						
1.	Thengumba llykari	April	Maximum tillering	5	Fallow	–
2.	Kuzhiyanady	July	Flowering	5	Maximum tillering	–
3.	Nendrakari	December	Flowering	5	Panicle initiation	+

4.9 Survival due to off season cultivation of rice in Kuttanad

The months of April and May are generally considered as off seasons for rice cultivation in Kuttanad. However, due to certain specific reasons particularly as a result of variations in the pattern of rainfall and flooding, the cultivation practices were often found to extend beyond the normal cropping seasons in Kuttanad. Consequently,it was observed that the chances of survival of bacterial blight pathogen, *Xanthomonas oryzae* pv. *oryzae* were considerably enhanced due to the presence of rice crop particularly the susceptible varieties such as Red Triveni or Jyothy in one location or another in Kuttanad. This could also contribute for the endemic occurrence of bacterial blight disease in the region.

5. INFLUENCE OF WEATHER ON BACTERIAL BLIGHT DISEASE IN KUTTANAD

The weather data on maximum and minimum temperature, relative humidity, total rainfall and wind velocity for two major cropping seasons were collected from Rice Research Station, Moncompu (Table 21 and 22). The data on the incidence of bacterial blight disease at different locations in Kuttanad are already given earlier (Table 1, 2 and 3). The average maximum and minimum temperature, relative humidity, total rainfall and wind velocity for the two additional crop seasons were 30.4°C, 23.9°C, 88.2%, 504.45 mm and 3.2 km/h respectively. During this season, the mean disease score and percentage of disease incidence were 5.1 and 32.05 respectively. Similarly during the punja season of 1992-93 and 1993-94, the mean maximum and minimum temperature, relative humidity, total rainfall and wind velocity were 32.6°C, 23.2°C, 82.0%, 68 mm and 2.7 km/h. respectively. The mean disease score and percentage of disease incidence were 2.4 and 11.43 respectively (Figs. 15, 16 and 17).

Table 21. Weather in Kuttanad during the additional crop season of 1992 and 1993

Year/Month		Max. temp. (°C)	Min. temp. (°C)	Relative humidity (%)	Total rainfall (mm)	Wind velocity (Km/h)
June	1992	30.7	23.8	92.0	654.8	5.3
July	1992	30.7	22.6	91.0	586.8	3.1
August	1992	30.0	23.0	92.0	461.0	3.4
September	1992	30.1	24.7	85.2	324.2	2.4
October	1992	30.7	24.0	86.2	383.0	2.4
Mean		30.4	23.6	89.3	482.0	3.3
June	1993	29.4	23.8	85.2	911.5	3.1
July	1993	29.4	23.4	92.2	780.8	3.2
August	1993	30.4	24.5	90.2	177.0	3.5
September	1993	31.3	24.2	81.1	161.2	2.8
October	1993	31.0	24.0	86.7	604.1	2.6
Mean		30.3	24.2	87.1	526.9	3.0
Grand mean		30.4	23.9	88.2	504.45	3.2

Table 22. Weather in Kuttanad during the Punja crop season of 1992-93 and 1993-94

Year/Month		Max. temp. (°C)	Min. temp. (°C)	Relative humidity (%)	Total rainfall (mm)	Wind velocity (Km/h)
November	1992	32.5	24.9	85.0	322.6	3.3
December	1992	32.9	22.4	75.2	6.2	2.4
January	1993	31.2	19.5	77.3	Nil	2.1
February	1993	32.5	21.4	77.3	2.0	2.7
March	1993	33.4	24.4	79.6	1.0	3.5
Mean		32.5	22.5	78.9	66.4	2.8
November	1993	32.2	24.1	87.2	203.5	2.4
December	1993	32.4	23.6	82.6	35.6	2.4
January	1994	32.9	22.8	81.9	4.6	2.4
February	1994	32.9	24.0	87.5	40.4	2.6
March	1994	33.3	24.3	86.1	59.0	2.9
Mean		32.7	23.8	85.1	68.6	2.5
Grand mean		32.6	23.2	82.0	68.0	2.7

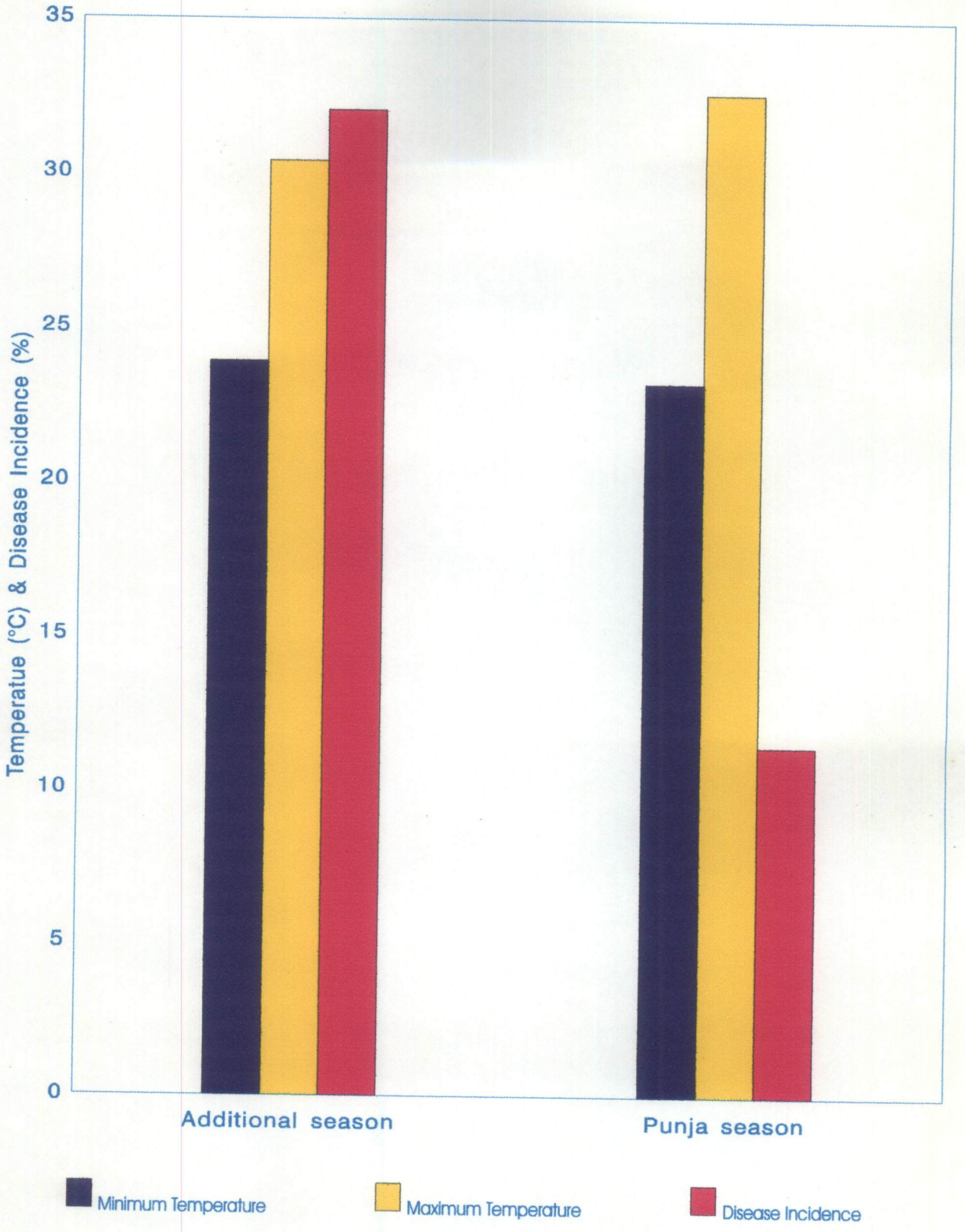


Fig. 15. Influence of temperature on bacterial blight disease during additional and punja crop seasons in Kuttanad

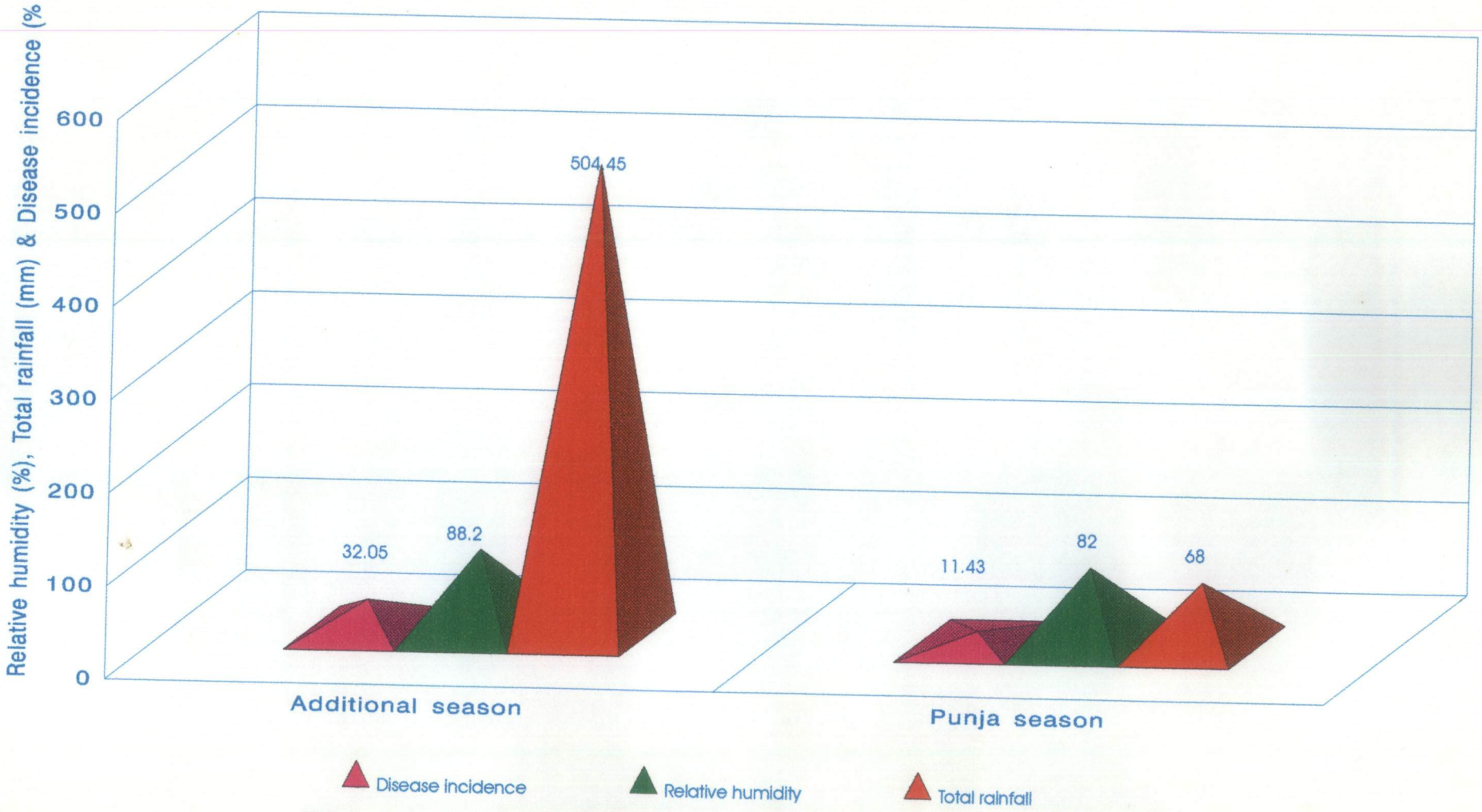


Fig. 16. Influence of humidity and total rainfall on bacterial blight disease during additional and punja crop seasons in Kuttanad

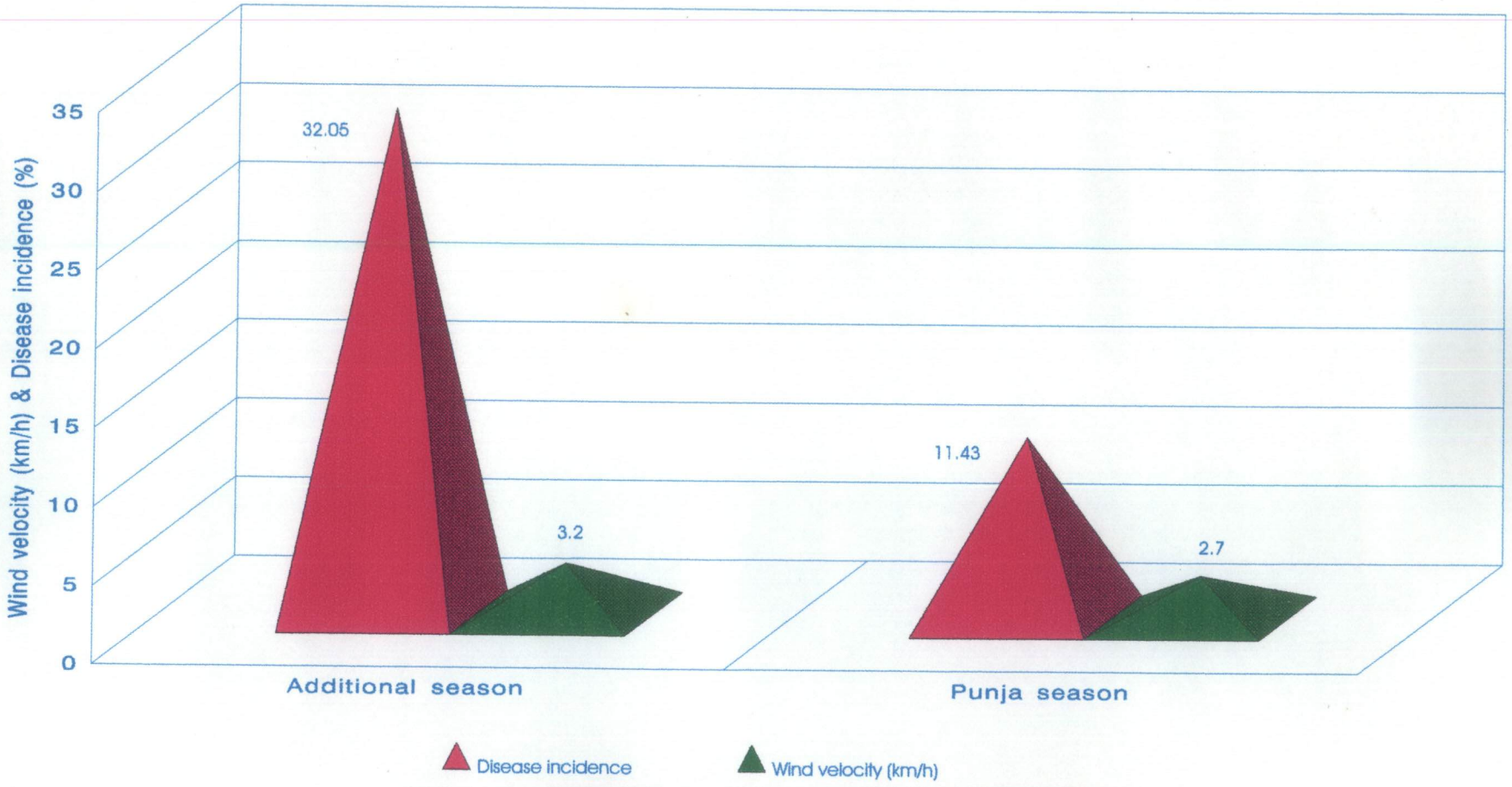


Fig. 17. Influence of wind velocity on bacterial blight disease during additional and punja crop seasons in Kuttanad

6. CONTROL OF BACTERIAL BLIGHT OF RICE

6.1 *In vitro* evaluation of antibiotics, Bactrinol-100 and cowdung extract against *Xanthomonas oryzae* pv. *oryzae*.

The results of the *in vitro* evaluation of antibiotics, Bactrinol-100 and cowdung extract against *Xanthomonas oryzae* pv. *oryzae* are presented in Table 23 and Fig. 18. The antibiotic oxytetracycline was most effective in inhibiting the growth of the pathogen. The mean zone of growth inhibition of 3.16 cm was significantly higher than all other bactericidal agents except chloramphenicol. Here the zone of growth inhibition produced 2.91 cm was statistically on par with the above treatment. The effect of streptocycline, the commercially produced phytoantibiotic and streptomycin was on par with that of chloramphenicol. The zone of growth inhibition increased with increasing concentration of various antibiotics from 250 to 750 ppm as in the case of streptomycin and from 100 to 500 ppm with respect to oxytetracycline, chloramphenicol and streptocycline. However, the extent of growth inhibition obtained with Bactrinol-100, an organic bactericidal agent was not significant. Further, the use of different concentrations of penicillin and cowdung extract did not inhibit the growth of the pathogen on PSA medium.

6.2. *In vitro* evaluation of varying proportions of oxytetracycline and streptomycin on growth of *Xanthomonas oryzae* pv. *oryzae*.

Since oxytetracycline was found most effective in inhibiting the growth of the pathogen under *in vitro* conditions and in phytoantibiotic preparations such as streptocycline, it is used only in the ratio of 1:9 along with streptomycin, a separate study was conducted to study the effect of increasing concentration of oxytetracycline in combination with streptomycin on the growth of *Xanthomonas oryzae* pv. *oryzae*.

Table 23. Sensitivity of *Xanthomonas oryzae* pv. *oryzae* to different antibiotics, Bactrinol-100 and cowdung extract under *in vitro* conditions

Sl. No.	Bactericides used	Growth inhibition (cm)			Mean
		250 ppm	500 ppm	750 ppm	
1.	Penicillin	0 (1.0)*	0 (1.0)	0 (1.0)	0 (1.0)
2.	Streptomycin	2.53 (1.88)	2.70 (1.92)	2.93 (1.98)	2.72 (1.93)
3.	Bactrinol-100	1.27 (1.51)	1.67 (1.47)	2.28 (1.81)	1.74 (1.60)
		100 ppm	250 ppm	500 ppm	
4.	Oxytetracycline	2.80 (1.95)	3.20 (2.05)	3.47 (2.11)	3.16 (2.04)
5.	Chloramphenicol	2.50 (1.87)	2.60 (1.90)	3.62 (2.15)	2.91 (1.97)
6.	Streptocycline	2.23 (1.80)	2.62 (1.90)	3.30 (2.07)	2.72 (1.92)
		20 g/l	50 g/l	100 g/l	
7.	Cowdung	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)
8.	Control	0 (1.0)	0 (1.0)	0 (1.0)	0 (1.0)

C.D. for treatments 0.100 (0.05 level) SE = 0.060

C.D. for levels of bactericides 0.058 (0.05 level) CV = 3.730

* Figures in parentheses are $\sqrt{x+1}$ values.

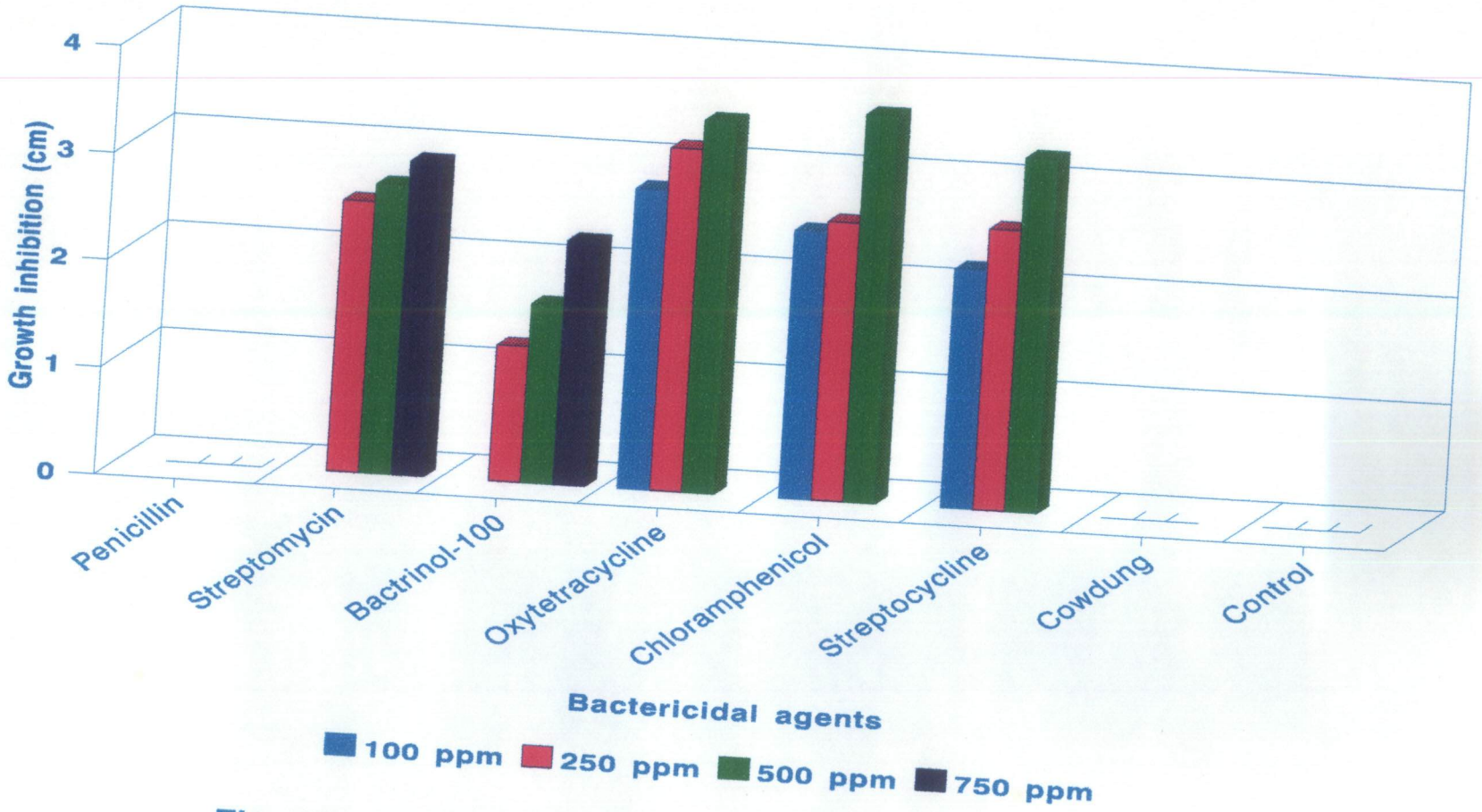


Fig. 18. Sensitivity of Xanthomonas oryzae pv. oryzae to different bactericidal agents

The zone of growth inhibition increased not only with the concentration of antibiotic from 100 to 500 ppm but also with increasing concentration of oxytetracycline. (Table 24, Fig. 19 and Plate VIII). Thus, the mean zone of growth inhibition obtained with higher proportion of oxytetracycline in the mixture when compared with the normal proportion of 9:1 was significantly high. The maximum zone of growth inhibition of 3.43 cm was obtained with 1:9 proportion of streptomycin and oxytetracycline. Two levels of the same, 250 and 500 ppm were selected for further field evaluation trials.

7. CONTROL OF BACTERIAL BLIGHT UNDER FIELD CONDITIONS

Two separate field experiments were conducted to study the effect of spraying with selected concentrations of antibiotics, Bactrinol-100 and cowdung extract on the control of bacterial blight during the additional crop seasons of 1992 and 1993 at Nedumudi in Kuttanad Two rice varieties T (N)1 and Jyothy and two different spraying methods prophylactic and curative were used for these trials. The pooled data on various observations such as per cent disease index, grain and straw yield, thousand grain weight and chaff per cent are presented in Tables 25 to 44.

Table 24. Sensitivity of *Xanthomonas oryzae* pv. *oryzae* to different proportions of streptomycin and oxytetracycline under *in vitro* conditions

Sl. No.	Proportion of streptomycin to oxytetracycline	Growth inhibition in cm			Mean
		100 ppm	250 ppm	500 pm	
1.	9:1	2.06 (1.73)*	2.26 (1.81)	2.73 (1.93)	2.35 (1.83)
2.	8:2	2.13 (1.77)	2.63 (1.91)	3.20 (2.05)	2.65 (1.91)
3.	7:3	2.50 (1.87)	3.03 (2.01)	3.40 (2.10)	2.98 (1.99)
4.	6:4	2.39 (1.84)	3.00 (2.00)	3.27 (2.07)	2.89 (1.97)
5.	5:5	2.83 (1.96)	2.76 (1.94)	3.59 (2.15)	3.06 (2.01)
6.	4:6	2.20 (1.80)	2.66 (1.91)	3.27 (2.07)	2.71 (1.93)
7.	3:7	2.60 (1.90)	3.03 (2.01)	3.10 (2.03)	2.91 (1.98)
8.	2:8	3.33 (2.08)	3.33 (2.08)	3.53 (2.13)	3.40 (2.10)
9.	1:9	3.07 (2.02)	3.43 (2.11)	3.79 (2.19)	3.43 (2.11)

C.D between proportions 0.098 (0.05 level) SE = 0.060

C.D within proportions 0.057 (0.05 level) CV = 3.130

* Figures in parentheses are $\sqrt{x}$ values.

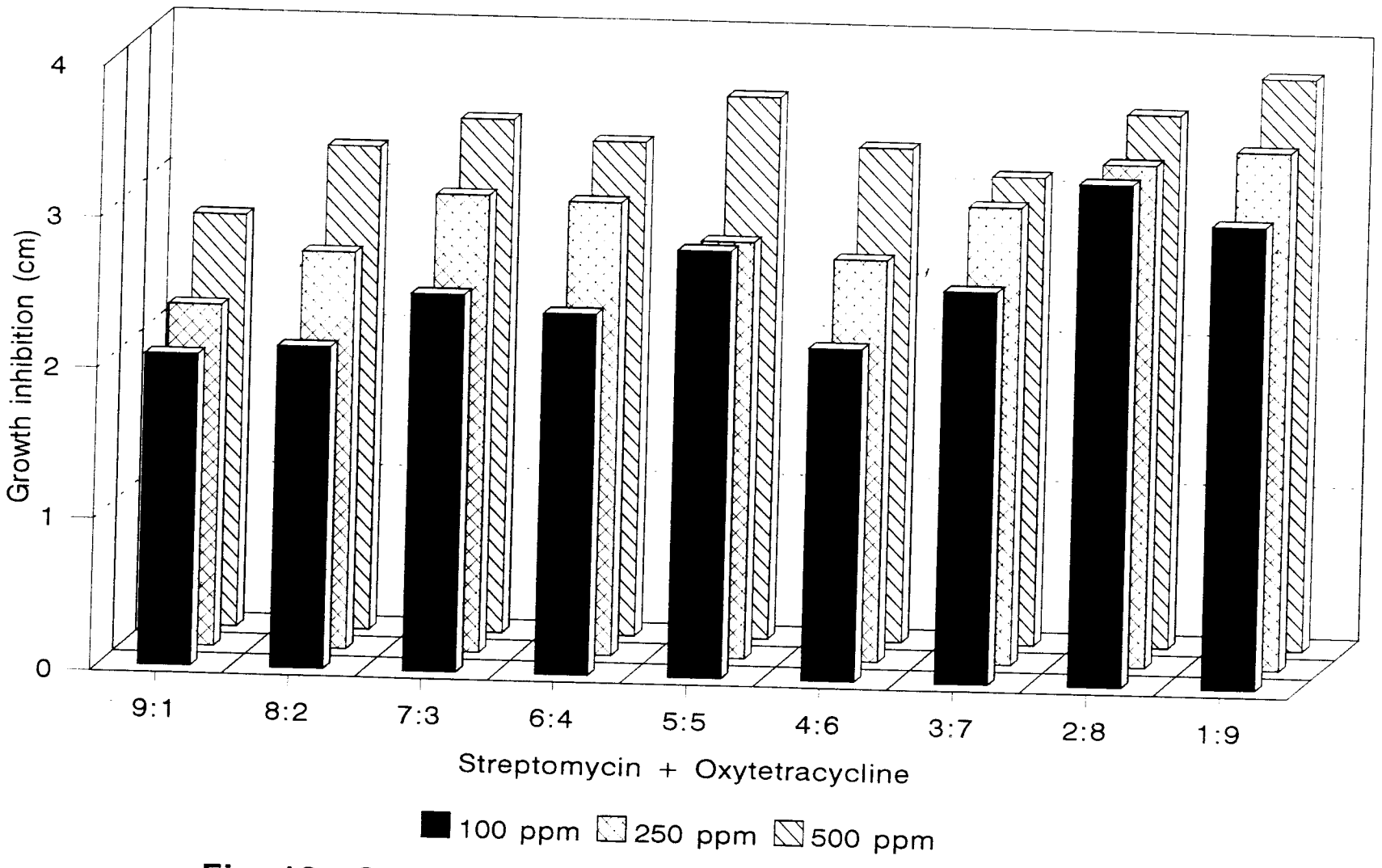
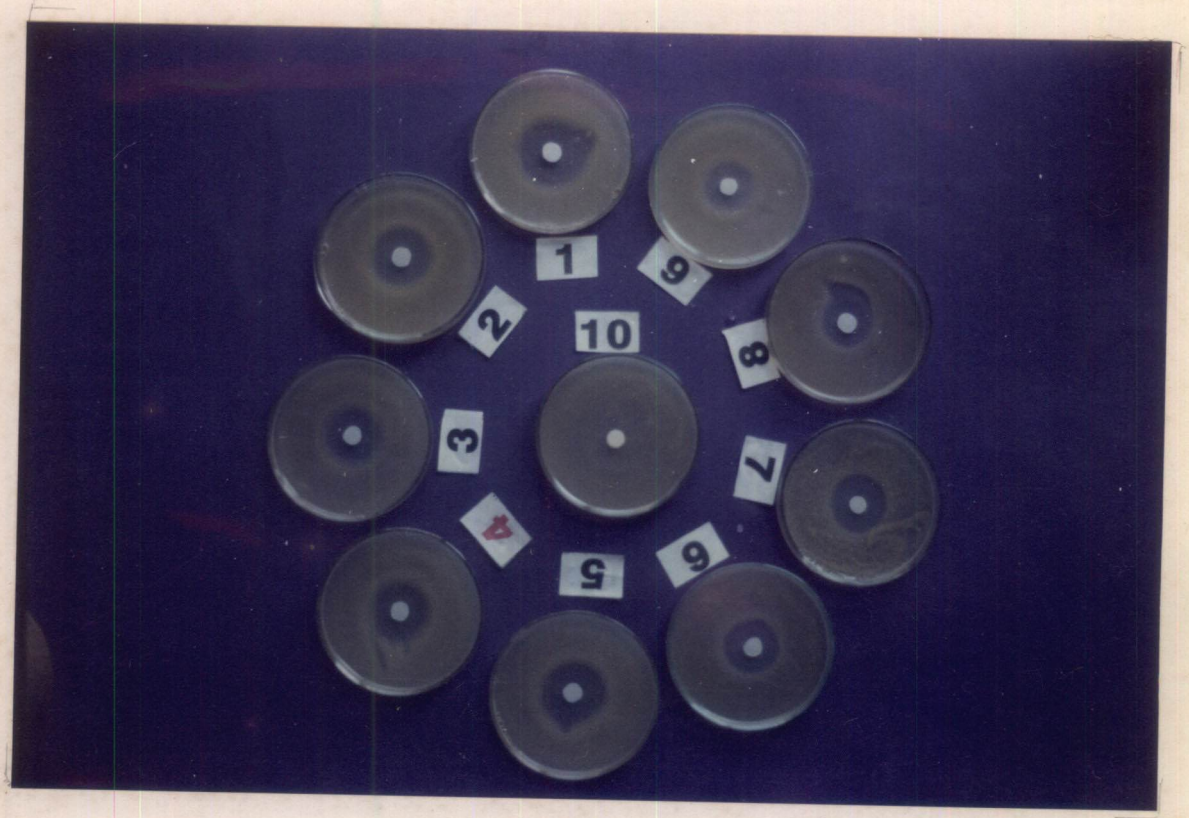


Fig. 19. Sensitivity of Xanthomonas oryzae pv. oryzae to different proportions of streptomycin + Oxytetracycline

Plate VIII. Growth inhibition of *Xanthomonas oryzae* pv. *oryzae* by increasing proportion of oxytetracycline under *in vitro* conditions.

1. Oxytetracycline + streptomycin (9:1) 500 ppm.
2. Oxytetracycline + streptomycin (8:2) 500 ppm.
3. Oxytetracycline + streptomycin (7:3) 500 Ppm.
4. Oxytetracycline + streptomycin (6:4) 500 Ppm
5. Oxytetracycline + streptomycin (5:5) 500 Ppm
6. Oxytetracycline + streptomycin (4:6) 500 Ppm
7. Oxytetracycline + streptomycin (3:7) 500 Ppm
8. Oxytetracycline + streptomycin (2:8) 500 Ppm
9. Oxytetracycline + streptomycin (1:9) 500 Ppm
10. Control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7.1 Effect of prophylactic spraying on per cent disease index in T(N)1 and Jyothy

The prophylactic spraying with 500 ppm streptocycline, Bactrinol-100, and 250 and 500 ppm 1:9 streptomycin and oxytetracycline mixture and cowdung extract (20 g/l) were given at 25 and 40 DAS in T(N)1 and 30 and 45 DAS in Jyothy. The incidence of bacterial blight occurred at panicle initiation stage of the crop in both the varieties. The per cent disease index was recorded at 85 DAS in T(N)1 and 90 DAS in Jyothy.

There was significant reduction in the per cent disease index after spraying with various bactericidal agents except Bactrinol-100 (Table 25 and Fig. 20). The percentage of reduction over control 34.42 in T(N)1 and 34.13 in Jyothy was maximum after spraying with cowdung extract at the rate of 20 g/l. The extent of reduction with 500 ppm streptomycin and oxytetracycline mixture in Jyothy was also on par with above treatment.

7.2 Effect of curative spraying on per cent disease index in T(N)1 and Jyothy

Unlike prophylactic spraying, curative sprayings were given only after the incidence of bacterial blight disease.

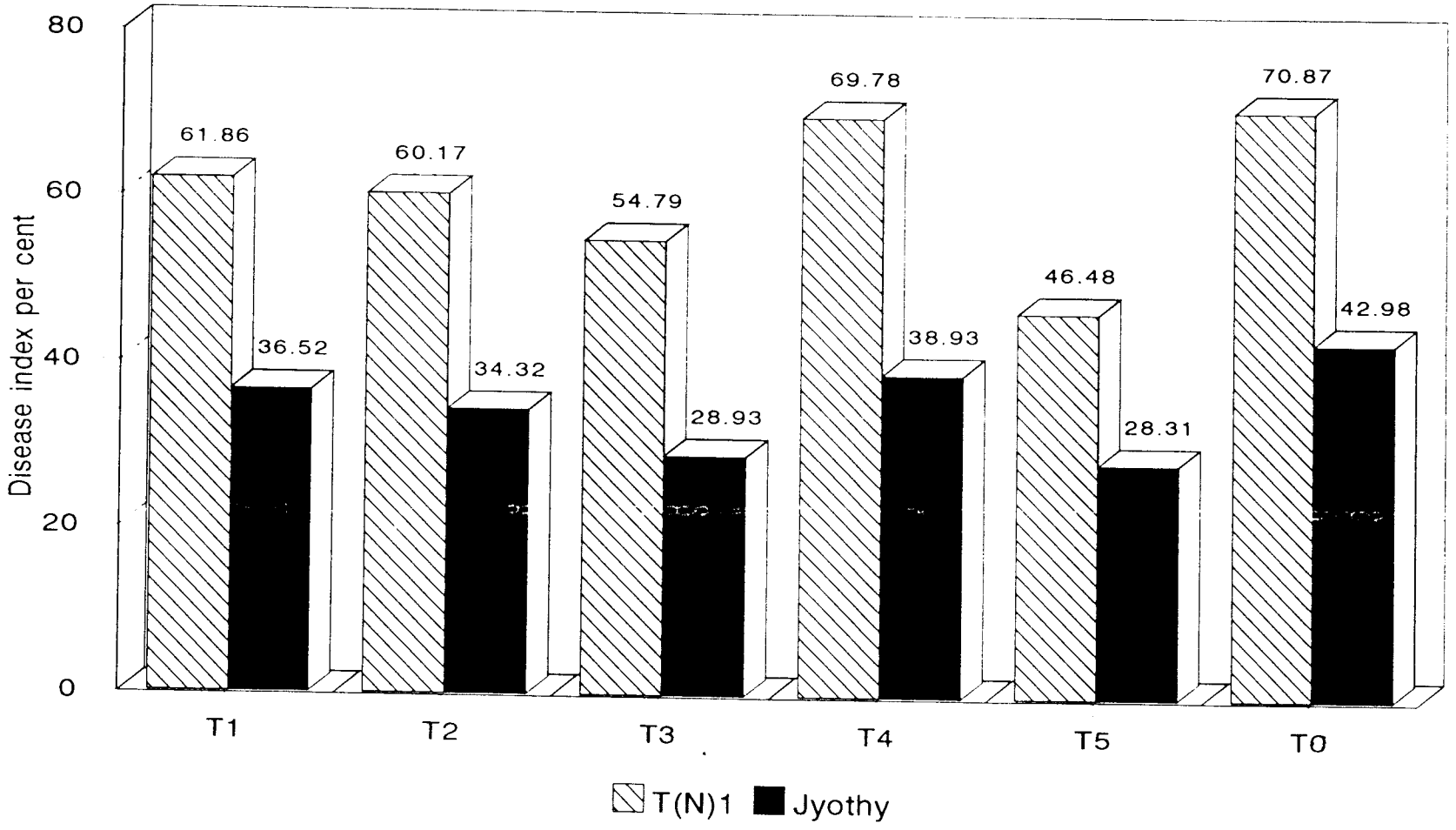
The mean disease index in T(N)1 and Jyothy before spraying with different bactericidal agents was 18.28 and 22.74 respectively. Here also, there was significant reduction in the per cent disease index after spraying with various plant protection chemicals except Bactrinol-100 in Jyothy (Table 26 and Fig. 21).

Table 25. Effect of prophylactic spraying on per cent disease index in T(N)1 and Jyothy - Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			% Disease index	% Reduction over control	%Disease index	%Reduction over control
1.	Streptocycline	500	61.86 (51.87)*	12.71	36.52 (36.35)	15.03
2.	Streptomycin + oxytetracycline (1:9)	250	60.17 (50.90)	15.10	34.32 (34.77)	20.15
3.	Streptomycin + oxytetracycline (1:9)	500	54.79 (47.78)	22.69	28.93 (31.62)	32.69
4.	Bactrinol-100	500	69.78 (56.79)	1.54	38.93 (37.97)	9.42
5.	Cowdung extract	20g/l	46.48 (42.95)	34.42	28.31 (31.18)	34.13
6.	Control	No spray	70.87 (57.70)		42.98 (40.48)	

C.D for treatments (0.05 level) = 3.78

* Figures in parentheses are transformed percentages in degrees.



T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

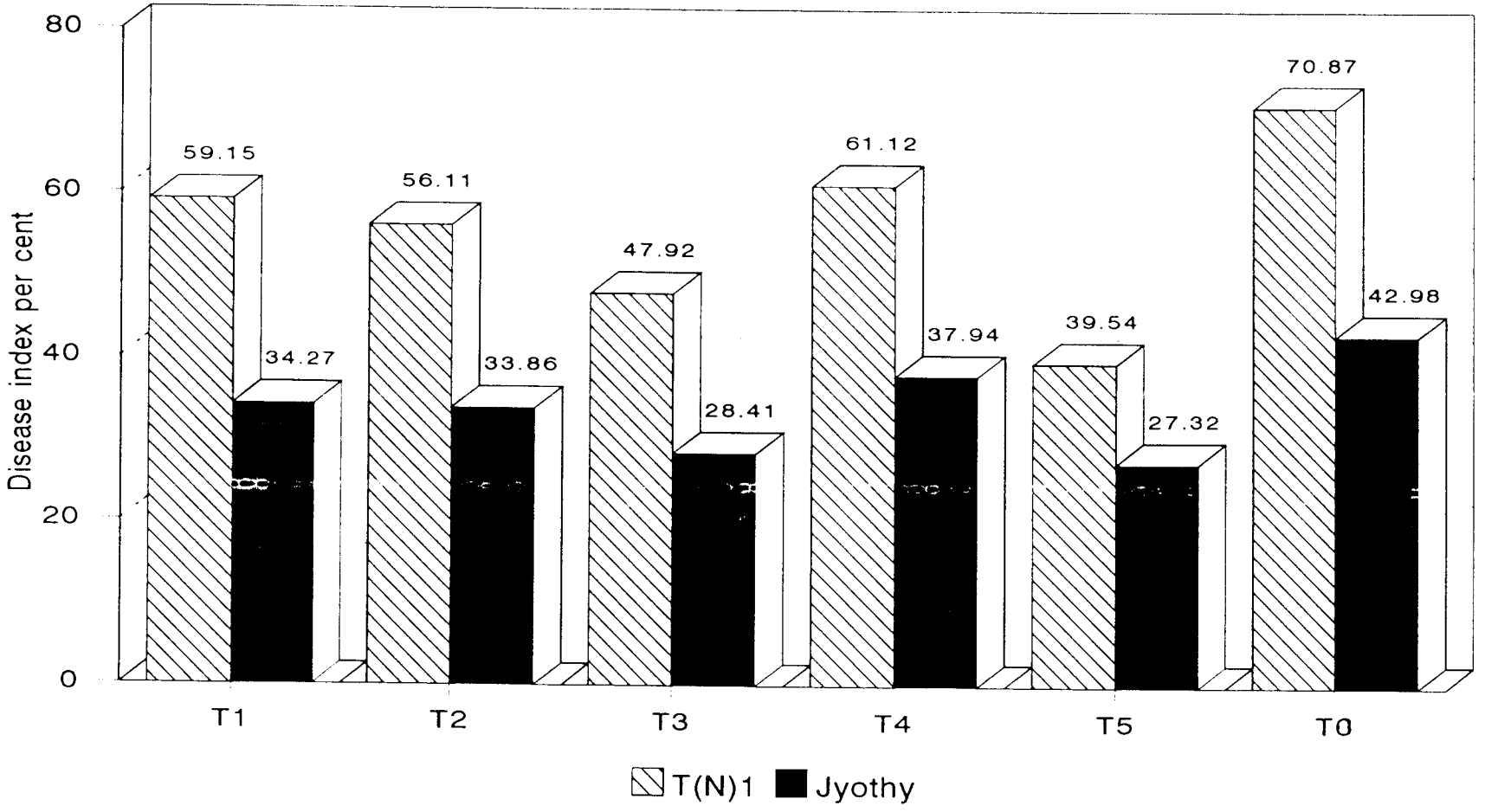
Fig. 20. Effect of prophylactic spraying on per cent disease index in TN(1) and Jyothy

Table 26. Effect of curative spraying on per cent disease index in T(N)1 and Jyothy - Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			% Disease index	% Reduction over control	%Disease index	%Reduction over control
1.	Streptocycline	500	59.15 (50.27)*	16.54	34.27 (34.79)	20.27
2.	Streptomycin + oxytetracycline (1: 9)	250	56.11 (48.51)	20.83	33.86 (34.49)	21.22
3.	Streptomycin + oxytetracycline (1: 9)	500	47.92 (43.80)	32.38	28.41 (31.36)	33.90
4.	Bactrinol-100	500	61.12 (51.43)	13.76	37.94 (37.35)	12.65
5.	Cowdung extract	20g/l	39.54 (38.91)	44.21	27.32 (30.70)	36.44
6.	Control	No spary	70.87 (57.70)		42.98 (40.48)	

C.D. for treatments (0.05 level) = 3.78

* Figures in parentheses are transformed percentages in degrees.



T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

Fig. 21. Effect of curative spraying on per cent disease index in TN(1) and Jyothy

The per cent reduction of 44.21 in T(N)1 and 36.44 in Jyothy was maximum after spraying with cowdung extract at the rate of 20 g/l. The extent of reduction after spraying with 500 ppm streptomycin and oxytetracycline mixture in Jyothy was also on par with above treatment.

7.3 Interaction between variety and method of spraying on per cent disease index in T(N)1 and Jyothy

The mean disease index was significantly low in Jyothy when compared to the highly susceptible rice variety T(N)1. The per cent disease index was 34.06 and 48.32 respectively (Table 27). As regard to the two method of spraying, significant reduction in per cent disease index was obtained with curative spraying. The mean per cent disease index of 40.16 was significantly low as compared to 42.22 resulting from prophylactic sprayings.

Table 27. Interaction between variety and method of spraying on per cent disease index in T(N)1 and Jyothy

Variety	Methods of spraying		Mean (variety)
	Prophylactic	Curative	
T(N)1	50.06	46.58	48.32
Jyothy	34.38	33.75	34.06
Mean (Method)	42.22	40.16	

CD for Varieties (0.05 level) 1.19
CD for Methods (0.05 level) 1.19
CD for Variety x Method (0.05 level) 1.69.

In the interaction between variety and method of spraying, significant reduction in per cent disease index was obtained only in T(N)1 due to curative spraying. Here the disease index was only 46.58 when compared to 50.06 after prophylactic spraying. In Jyothy, however, the interaction between variety and method of spraying was not significant.

7.4 Interaction between variety and treatments on per cent disease index in T(N)1 and Jyothy

The extent of disease reduction was significantly high in Jyothy as compared to T(N)1. The per cent disease index in these varieties was 34.06 and 48.32 respectively (Table 28). In both T(N)1 and Jyothy, the best treatment for the control of bacterial blight was spraying with cowdung extract at the rate of 20 g/l. The disease index in these varieties was 40.93 and 30.94 respectively (Table 28). In the rice variety Jyothy, it was also observed that the effect of spraying with streptomycin and oxytetracycline mixture at 500 ppm also reduced the disease index. This was statistically on par with the treatment of cowdung extract.

7.5 Effect of prophylactic spraying on grain yield in T(N)1 and Jyothy

There was no significant difference between treatments in grain yield in both T(N)1 and Jyothy affected with bacterial blight after prophylactic spraying with different bactericidal agents (Table 29 and Fig. 22). The yield increase of 6.20 and 12.96 per cent was maximum after spraying with 20g/l of cowdung extract. This corresponded to a net yield of 5.14 and 5.58 t/ha respectively. A slight reduction in yield was also observed in both T(N)1 and Jyothy after spraying with Bactrinol-100.

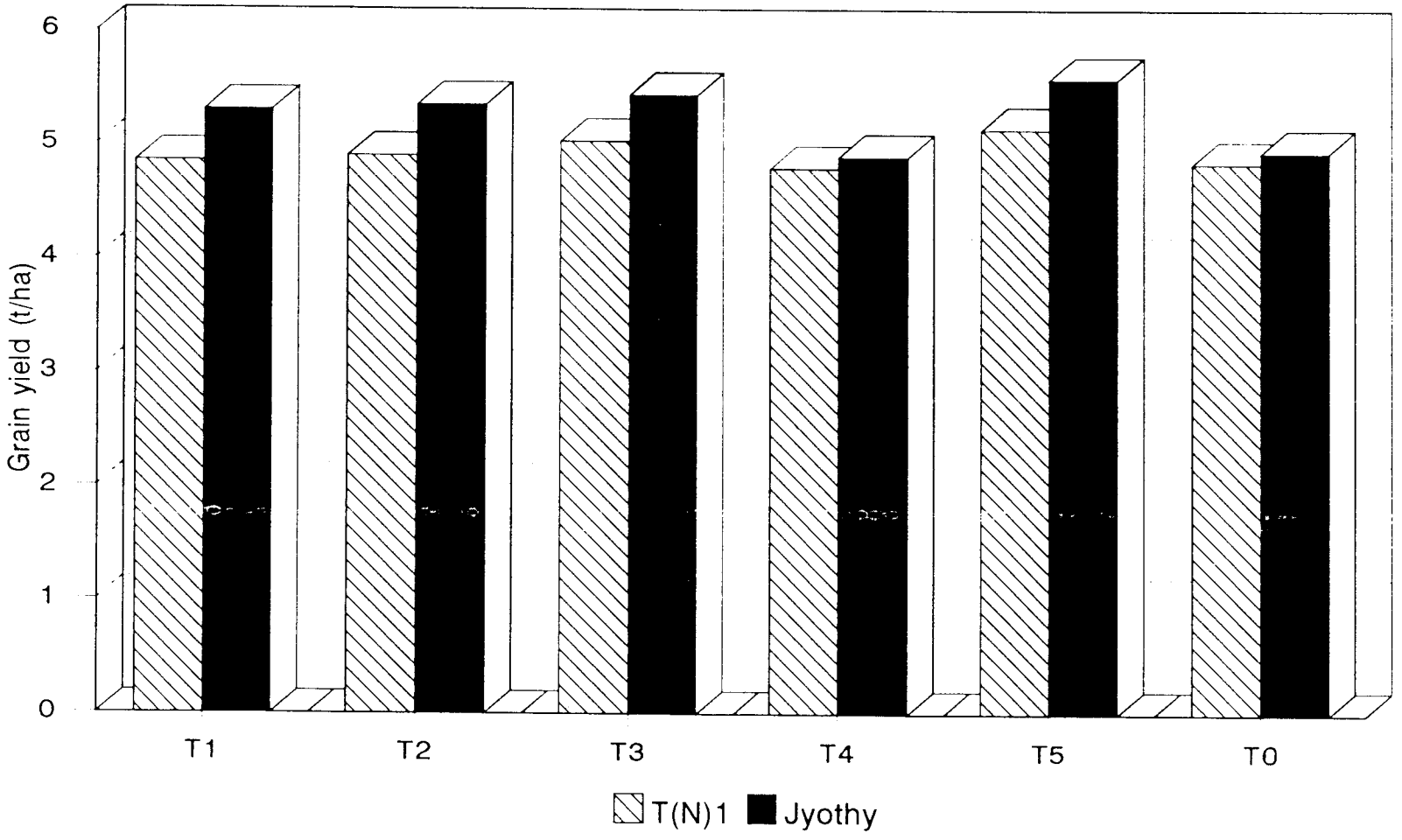
Table 28. Interaction between variety and treatment on per cent disease index in T(N)1 and Jyothy

Treatments	Concentration (ppm)	Disease index (%)		Mean (treatment)
		T(N)1	Jyothy	
Streptocycline	500	51.07	35.57	43.32
Streptomycin + oxytetracycline (1:9)	250	49.70	34.63	42.17
Streptomycin + oxytetracycline (1:9)	500	45.79	31.49	38.64
Bactrinol-100	500	54.11	37.66	45.89
Cowdung extract	20g/l	40.93	30.94	35.93
Mean (variety)		48.32	34.06	
CD for treatments (0.05 level)	1.89			
CD for varieties (0.05 level)	1.19			
CD for variety x treatment (0.05 level)	2.67			

Table 29. Effect of prophylactic spraying on grain yield in T(N)1 and Jyothy-Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			Grain yield (t/ha)	% Increase over control	Grain yield (t/ha)	% Increase over control
1.	Streptocycline	500	4.85	0.21	5.30	7.29
2.	Streptomycin + oxytetracycline (1: 9)	250	4.90	1.24	5.35	8.30
3.	Streptomycin + oxytetracycline (1: 9)	500	5.03	3.93	5.44	10.12
4.	Bactrinol-100	500	4.80	-0.83	4.90	-0.81
5.	Cowdung extract	20g/l	5.14	6.20	5.58	12.96
6.	Control	No spray	4.84		4.94	

C.D for treatments (0.05 level) 0.66.



T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

Fig. 22. Effect of prophylactic spraying on grain yield in TN(1) and Jyothy

7.6 Effect of Curative spraying on grain yield in T(N)1 and Jyothy

As in the previous experiment, there was no significant difference between treatments in grain yield in T(N) 1. However, in Jyothy, the increase in grain yield was significant in all the treatments except with Bactrinol-100 (Table 30 and Fig. 23). The maximum per cent increase over control among these treatments was 31.78 after spraying with 500 ppm streptomycin and oxytetracycline mixture.

7.7 Interaction between variety and method of spraying on grain yield in T(N)1 and Jyothy

The mean grain yield was significantly high in Jyothy when compared to T(N)1. These were 5.63 and 4.99 t/ha respectively (Table 31). As regard to the two method of spraying,significant increase in grain yield was obtained after curative spraying. The mean yield of 5.50 t/ha was significantly higher than that of prophylactic spraying. In the interaction between variety and method of spraying, significant increase in yield was obtained only in Jyothy due to curative spraying. Here, the mean grain yield of 5.95 t/ha was significantly higher than that of prophylactic spraying.

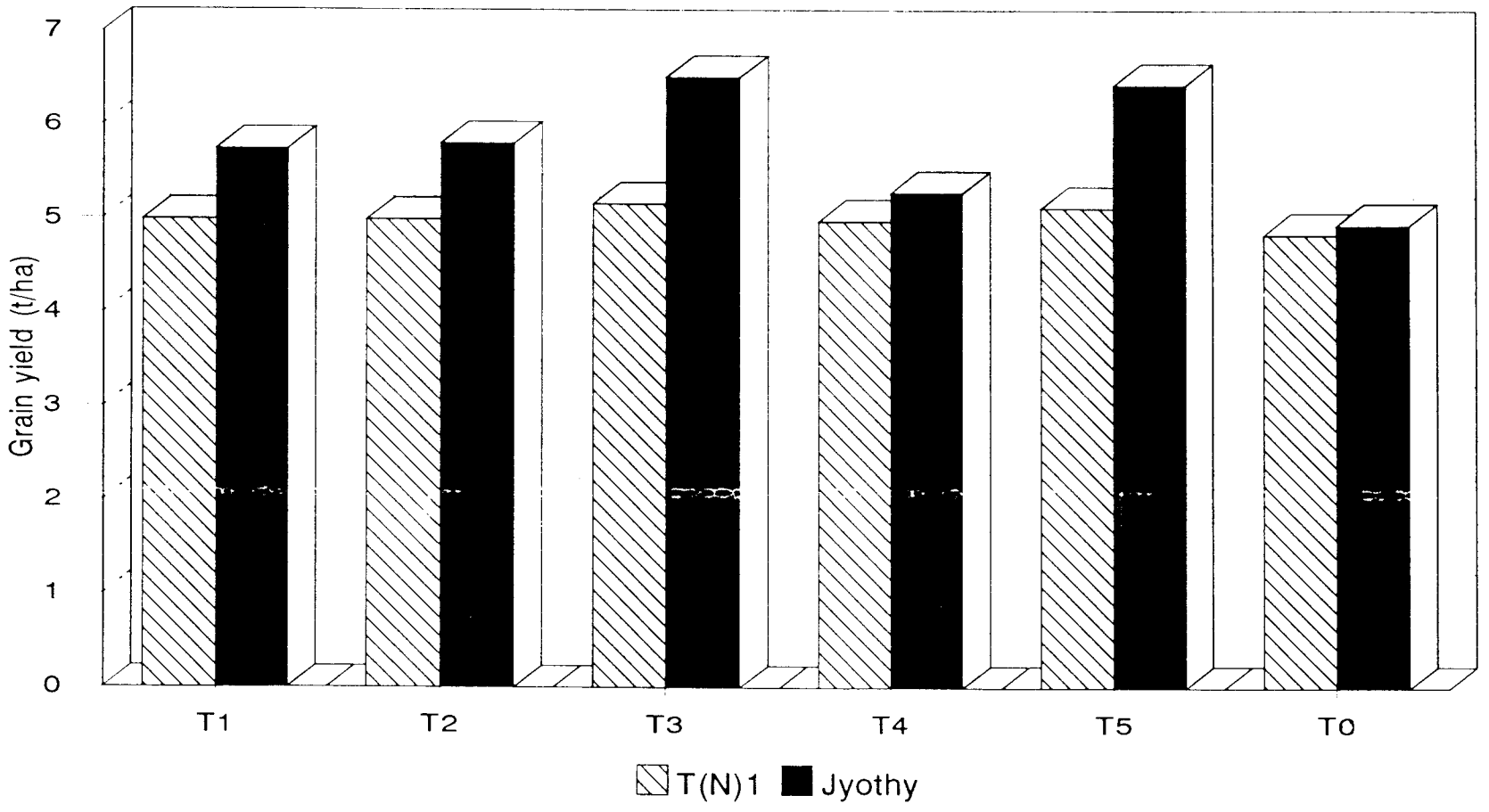
7.8 Interaction between variety and treatments on grain yield in T(N)1 and Jyothy

The mean grain yield of 5.63 t/ha was significantly high in Jyothy when compared to T(N)1. In both these varieties, the grain yield was maximum after spraying with cowdung extract at the rate of 20 g/l (Table 32).

Table 30. Effect of curative spraying on grain yield in T(N)1 and Jyothy-Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			Grain yield (t/ha)	% Increase over control	Grain yield (t/ha)	% Increase over control
1.	Streptocycline	500	4.99	3.10	5.74	16.19
2.	Streptomycin + oxytetracycline (1: 9)	250	4.99	3.10	5.80	17.41
3.	Streptomycin + oxytetracycline (1: 9)	500	5.16	6.61	6.51	31.78
4.	Bactrinol-100	500	4.98	2.89	5.28	6.88
5.	Cowdung extract	20g/l	5.12	5.79	6.43	30.16
6.	Control	No spray	4.84		4.94	

C.D for tretments 0.66.
(0.05 level)



T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

Fig. 23. Effect of curative spraying on grain yield in TN(1) and Jyothy

Table 31. Interaction between variety and method of spraying on grain yield in T(N) 1 and Jyothy

Variety	Method of spraying		Mean (Variety)
	Prophylactic	Curative	
T (N) 1	4.94	5.05	4.99
Jyothy	5.31	5.95	5.63
Mean (Method)	5.13	5.50	

C.D for Varieties (0.05 level) = 0.21

C.D for Methods (0.05 level) = 0.21

C.D for Variety x Method (0.05 level) = 0.29

Table 32. Interaction between variety and treatment on grain yield in T(N)1 and Jyothy

Treatment	Concentration ppm	Variety		Mean (Treatment)
		T(N) 1	Jyothy	
Streptocycline	500	4.92	5.51	5.21
Streptomycin + oxytetracycline (1:9)	250	4.94	5.57	5.26
Streptomycin + oxytetracycline (1:9)	500	5.10	5.97	5.53
Bactrinol - 100	500	4.89	5.08	4.99
Cowdung extract	20g/l	5.13	6.00	5.57
Mean (Variety)		4.99	5.63	

C.D. for Varieties (0.05 level) = 0.21

C.D. for Treatments (0.05 level) = 0.33

The grain yield after spraying with the mixture of streptomycin and oxytetracycline at 250 and 500 ppm, 5.26 and 5.53 t/ha respectively was statistically on par with the cowdung extract treatment. However, the interaction between variety and treatment was not significant.

7.9 Effect of prophylactic spraying on straw yield in T(N)1 and Jyothy

There were significant differences between treatments in straw yield in both T(N)1 and Jyothy affected with bacterial blight after prophylactic spraying with different bactericidal agents. The straw yield of 5.16 and 5.14 t/ha in T(N)1 after spraying with streptomycin and oxytetracycline mixture of 500 ppm and cowdung extract and 5.07, 5.13, 5.28 and 5.39 t/ha in Jyothy after spraying with streptocycline, streptomycine and oxytetracycline mixture of 250 and 500 ppm and cowdung extract were significantly higher than that of the respective control treatments (Table 33 and Fig. 24).

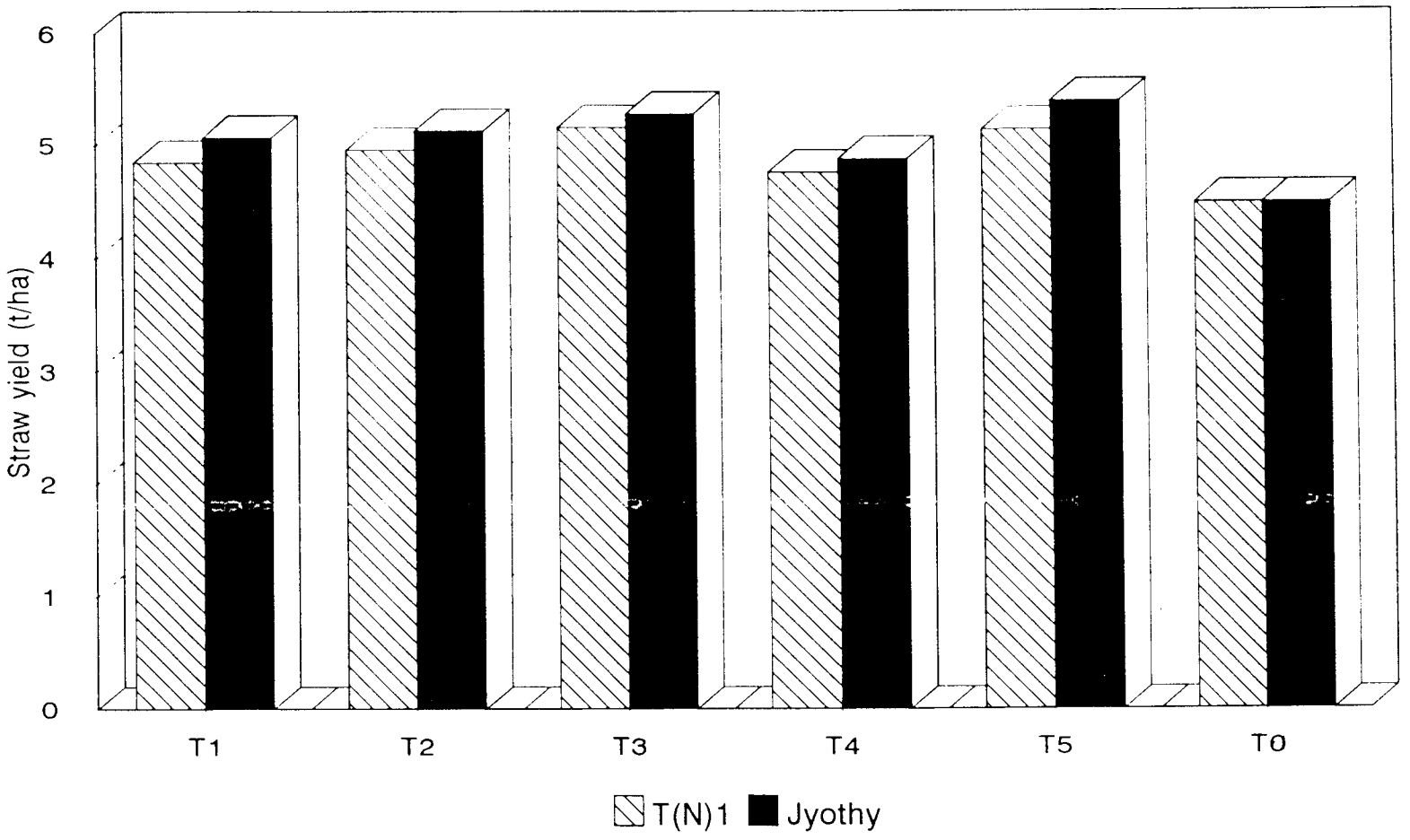
7.10 Effect of curative spraying on straw yield in T(N)1 and Jyothy

There were significant differences between treatments in straw yield in both T(N)1 and Jyothy affected with bacterial blight after curative spraying with different bactericidal agents. The straw yield of 5.21, 5.49 and 5.43 t/ha in T(N)1 and 5.15, 5.31 and 5.71 t/ha in Jyothy after spraying with streptomycin and oxytetracycline mixture of 250 and 500 ppm and cowdung extract were significantly higher than that of the respective control treatments (Table 34 and Fig. 25). The per cent increase in straw yield of 22.27 in TN(1) and 27.17 in Jyothy was maximum after spraying with a mixture of streptomycin and oxytetracycline of 500 ppm and cowdung extract respectively. A slight reduction in straw yield was also observed after spraying with Bactrinol-100 in both varieties of rice.

Table 33. Effect of prophylactic spraying on straw yield in T(N)1 and Jyothy - Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			Straw yield (t/ha)	% Increase over control	Straw yield (t/ha)	% Increase over control
1.	Streptocycline	500	4.85	8.02	5.07	12.92
2.	Streptomycin + oxytetracycline (1: 9)	250	4.96	10.47	5.13	14.25
3.	Streptomycin + oxytetracycline (1: 9)	500	5.16	14.92	5.28	17.59
4.	Bactrinol - 100	500	4.76	6.01	4.88	8.69
5.	Cowdung extract	20g/l	5.14	14.48	5.39	20.04
6.	Control	No spray	4.49		4.49	

C.D. for treatments 0.57.
(0.05 level)



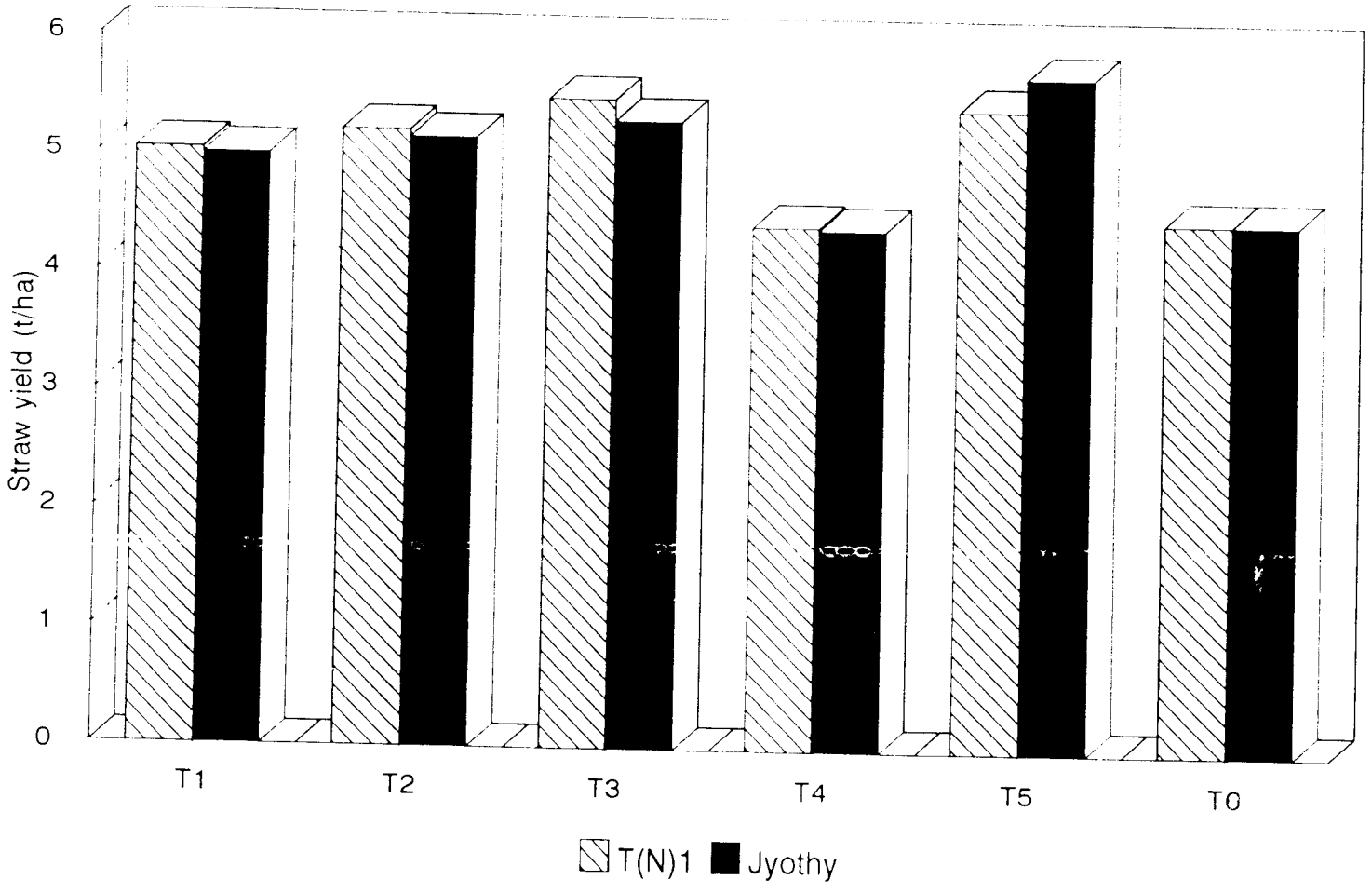
T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

Fig. 24. Effect of prophylactic spraying on straw yield in TN(1) and Jyothy

Table 34. Effect of curative spraying on straw yield in T(N)1 and Jyothy - Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			Straw yield (t/ha)	% Increase over control	Straw yield (t/ha)	% Increase over control
1.	Streptocycline	500	5.03	12.03	4.99	11.14
2.	Streptomycin + oxytetracycline (1: 9)	250	5.21	16.04	5.15	14.70
3.	Streptomycin + oxytetracycline (1: 9)	500	5.49	22.27	5.31	18.26
4.	Bactrinol - 100	500	4.43	-1.34	4.41	-1.78
5.	Cowdung extract	20g/l	5.43	20.94	5.71	27.17
6.	Control	No spray	4.49		4.49	

C.D for treatments 0.57.
(0.05 level)



T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

Fig. 25. Effect of curative sprayings on straw yield in TN(1) and Jyothy

7.11 Interaction between variety and method of spraying on straw yield in T(N)1 and Jyothy

The interactions between variety and method of spraying on straw yield in T(N)1 and Jyothy (Table 35) were not significant.

Table 35. Interaction between variety and method of spraying on straw yield in T(N) 1 and Jyothy.

Variety	Methods of spraying		Mean (Variety)
	Prophylactic	Curative	
T (N) 1	4.97	5.12	5.04
Jyothy	5.15	5.11	5.13
Mean (Method)	5.06	5.11	

C.D for Varieties (0.05 level) = 0.18
C.D for Methods (0.05 level) = 0.18
C.D for Variety x Method (0.05 level) = 0.26

7.12 Interaction between variety and treatment on straw yield in T(N)1 and Jyothy

The interactions between variety and treatment on straw yield in T(N)1 and Jyothy (Table 36) were also not significant. But there were significant differences between treatments. Maximum straw yield of 5.42 t/ ha was obtained after spraying with cowdung extract. The effect of spraying with 500 ppm streptomycin and oxytetracycline mixture was statistically on par with the above treatment.

Table 36. Interaction between variety and treatment on straw yield in T (N) 1 and Jyothy

Treatments	Concentration (ppm)	Varieties		Mean (Treatment)
		T(N)1	Jyothy	
Streptocycline	500	4.94	5.03	4.98
Streptomycin + oxytetracycline (1:9)	250	5.08	5.14	5.11
Streptomycin + oxytetracycline (1:9)	500	5.32	5.29	5.31
Bactrinol - 100	500	4.59	4.65	4.62
Cowdung extract	20g/1	5.04	5.55	5.42
Mean (Variety)		5.04	5.13	
C.D for Treatments (0.05 level)	0.29 .			

7.13 Effect of prophylactic spraying on thousand grain weight in T(N)1 and Jyothy

There was no significant difference in thousand grain weight in T(N)1 affected with bacterial blight after prophylactic spraying with different bactericidal agents (Table 37 and Fig. 26). But there was significant increase in thousand grain weight over control treatment in Jyothy. This was maximum after spraying with 20 g/l of cowdung extract with a net thousand grain weight of 25.92 g. The thousand grain weight of 25.69 and 25.23g , respectively, after spraying with the mixture of streptomycin and oxytetracycline at 500 and 250 ppm was also on par with this treatment. A slight reduction in thousand grain weight was observed by spraying Bactrinol-100 and streptocycline in T(N)1.

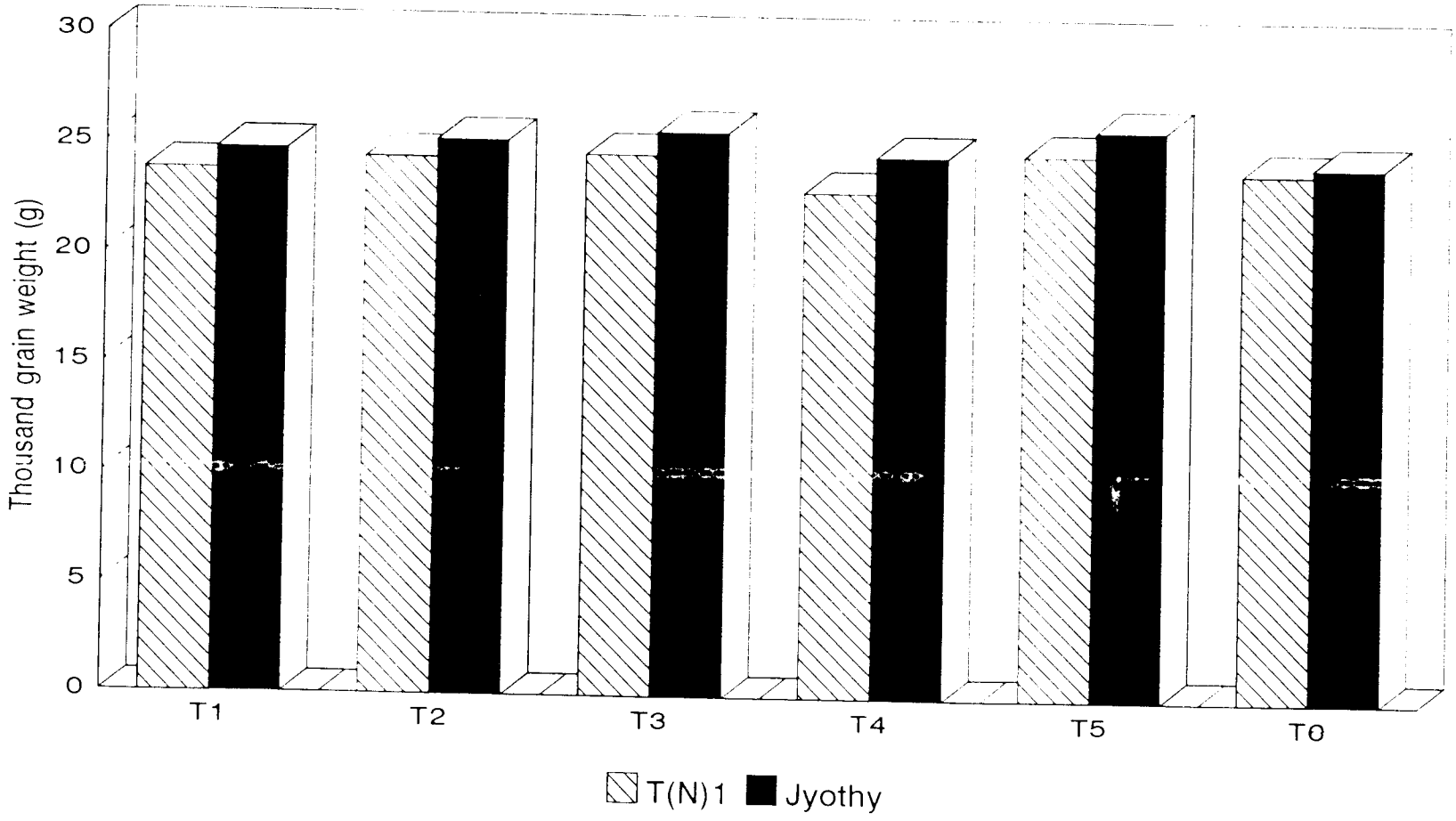
7.14 Effect of curative spraying on thousand grain weight in T(N)1 and Jyothy

There were significant differences between treatments in thousand grain weight in both T(N)1 and Jyothy affected with bacterial blight after curative spraying with different bactericidal agents. The thousand grain weight of 26.54 and 25.67 g in T(N)1 after spraying with cowdung extract (20g/l) and 500 ppm mixture of streptomycin and oxytetracycline and 26.37, 25.59 and 25.80 g in Jyothy after spraying with cowdung extract and 250 and 500 ppm of streptomycin and oxytetracycline mixture respectively was significantly higher than that of the respective control treatments (Table 38 and Fig. 27). A slight reduction in thousand grain weight was also recorded after spraying with Bactrinol-100 in T(N)1.

Table 37. Effect of prophylactic spraying on thousand grain weight in T(N)1 and Jyothy - Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			1000 grain weight (g)	% Increase over control	1000 grain weight (g)	% Increase over control
1.	Streptocycline	500	23.79	-1.00	24.74	1.60
2.	Streptomycin + oxytetracycline (1: 9)	250	24.42	1.62	25.23	3.61
3.	Streptomycin + oxytetracycline (1: 9)	500	24.63	2.50	25.69	5.50
4.	Bactrinol - 100	500	23.04	-4.12	24.67	1.31
5.	Cowdung extract	20g/l	24.79	3.16	25.92	6.45
6.	Control	No spray	24.03		24.35	

C.D for treatments 0.84.
(0.05 level)



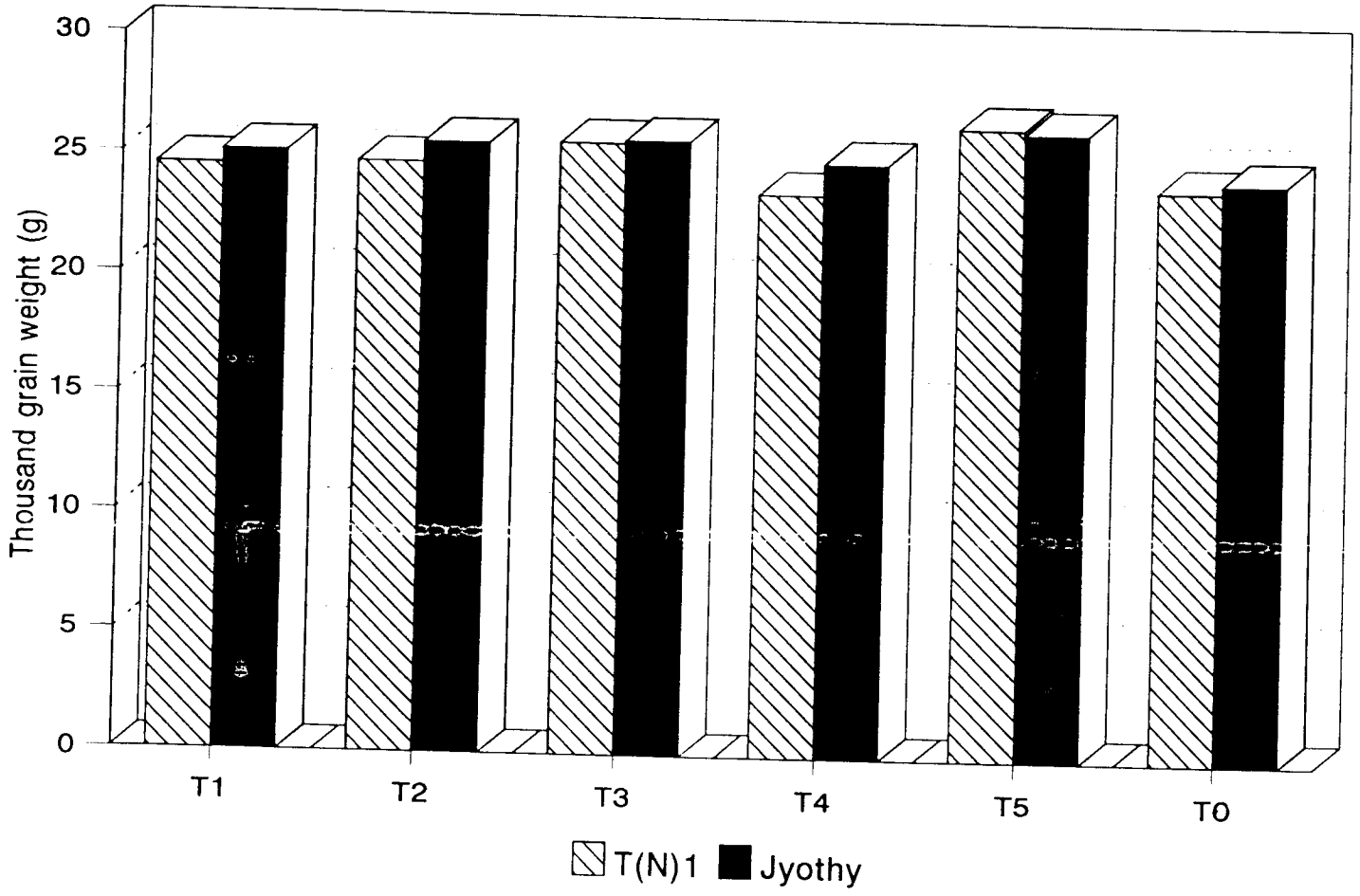
T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

Fig. 26. Effect of prophyiactic spraying on 1000 grain weight in TN(1) and Jyothy

Table 38. Effect of curative spraying on thousand grain weight in T(N)1 and Jyothy - Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			1000 grain weight (g)	% Increase over control	1000 grain weight (g)	% Increase over control
1.	Streptocycline	500	24.55	2.16	25.14	3.24
2.	Streptomycin + oxytetracycline (1: 9)	250	24.75	3.00	25.59	5.09
3.	Streptomycin + oxytetracycline (1: 9)	500	25.67	6.82	25.80	5.95
4.	Bactrinol - 100	500	23.65	-1.58	24.98	2.59
5.	Cowdung extract	20g/l	26.54	10.45	26.37	8.30
6.	Control	No spray	24.03		24.35	

C.D for treatments 0.84.
(0.05 level)



T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

Fig. 27. Effect of curative sprayings on 1000 grain weight in TN(1) and Jyothy

7.15 Interaction between variety and method of spraying on thousand grain weight in T(N)1 and Jyothy

The mean thousand grain weight was significantly high in Jyothy when compared to T(N)1. These were 25.41 and 24.58 g,respectively (Table 39). As regard to the two method of spraying,significant increase in thousand grain weight was obtained with curative spraying. The mean thousand grain weight of 25.30 g was significantly higher than that of prophylactic spraying. In the interaction between variety and method of spraying,significant increase in thousand grain weight was obtained only in T(N)1 after curative spraying. Here,the mean thousand grain weight of 25.03 g was significantly higher than that of prophylactic spraying.

Table 39. Interaction between the variety and method of spraying on thousand grain weight in T (N) 1 and Jyothy

Variety	Methods of spraying		Mean (Variety)
	Prophylactic	Curative	
T(N)1	24.13	25.03	24.58
Jyothy	25.24	25.57	25.41
Mean (Method)	24.69	25.30	

C.D for Varieties (at 0.05 level) = 0.27

C.D for Methods (at 0.05 level) = 0.27

C.D for Variety x Method (at 0.05 level) = 0.38.

7.16 Interaction between variety and treatment on thousand grain weight in T(N)1 and Jyothy

The mean thousand grain weight of 25.41 g was significantly high in Jyothy when compared to T(N)1. In both these varieties, the thousand grain weight was maximum after spraying with cowdung extract (Table 40). However, the interactions between variety and treatment were not significant.

Table 40. Interaction between variety and treatment on thousand grain weight in T(N)1 and Jyothy

Treatments	Concentration ppm	Variety		Mean (Treatment)
		T(N) 1	Jyothy	
Streptocycline	500	24.17	24.93	24.55
Streptomycin + oxytetracycline (1:9)	250	24.58	25.40	24.99
Streptomycin + oxytetracycline (1:9)	500	25.15	25.74	25.45
Bactrinol - 100	500	23.34	24.83	24.08
Cowdung extract	20g/l	25.66	26.14	25.90
Mean (Variety)		24.58	25.41	

C.D for Varieties (0.05 level) = 0.27

C.D for Treatments (0.05 level) = 0.42 .

7.17 Effect of prophylactic spraying on chaff per cent in T(N)1 and Jyothy

There were significant differences in chaff per cent in both T(N)1 and Jyothy affected with bacterial blight after prophylactic spraying with different bactericidal agents (Table 41 and Fig. 28). The reduction in chaff per cent was significant in all the treatments when compared to control treatment both in T(N)1 and Jyothy. The reduction was maximum after spraying with cowdung extract in T(N)1 (94.78%) and after spraying with 500 ppm streptomycin and oxytetracycline mixture in Jyothy (87.91%). The extent of reduction after spraying with 250 ppm of streptomycin and oxytetracycline mixture was also on par with the above treatments.

7.18 Effect of curative spraying on chaff per cent in T(N)1 and Jyothy

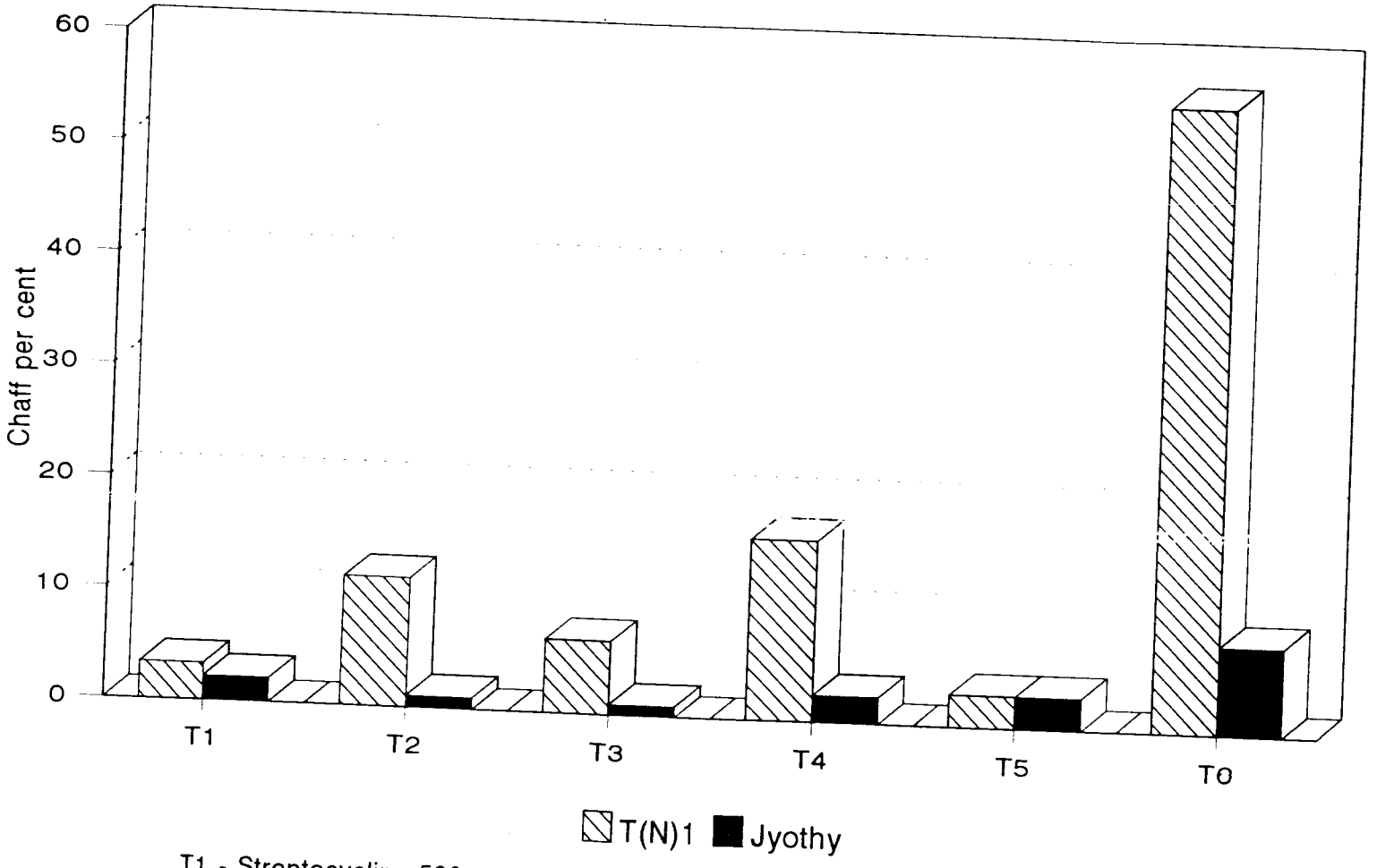
There were significant differences in chaff per cent in both T(N)1 and Jyothy affected with bacterial blight after curative spraying with different bactericidal agents. (Table 42 and Fig. 29). The reduction in chaff per cent was significant in all the treatments when compared to control both in T(N)1 and Jyothy. The reduction was maximum after spraying with cowdung extract. The per cent reduction in chaff over control treatment was 95.99 and 94.35 in T(N)1 and Jyothy, respectively. In Jyothy, the extent of reduction after spraying with 250 and 500 ppm of streptomycin and oxytetracycline mixture was statistically on par with the above treatment.

Table 41. Effect of prophylactic spraying on chaff per cent in T(N)1 and Jyothy - Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			Chaff per cent	% Reduction over control	Chaff per cent	% Reduction over control
1.	Streptocycline	500	3.31 (21.37)*	94.10	2.18 (8.36)	72.68
2.	Streptomycin + oxytetracycline (1:9)	250	11.60 (19.91)	79.32	1.05 (5.80)	86.84
3.	Streptomycin + oxytetracycline (1:9)	500	6.60 (15.96)	88.23	0.96 (5.55)	87.97
4.	Bactrinol - 100	500	16.29 (23.81)	70.95	2.42 (8.87)	69.67
5.	Cowdung extract	20g/l	2.93 (9.83)	94.78	2.93 (4.61)	63.28
6.	Control	No spray	56.08 (48.54)		7.98 (16.3)	

C.D. for treatments (0.05 levels) = 2.46

* Figures in parentheses are transformed percentages in degrees.



T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

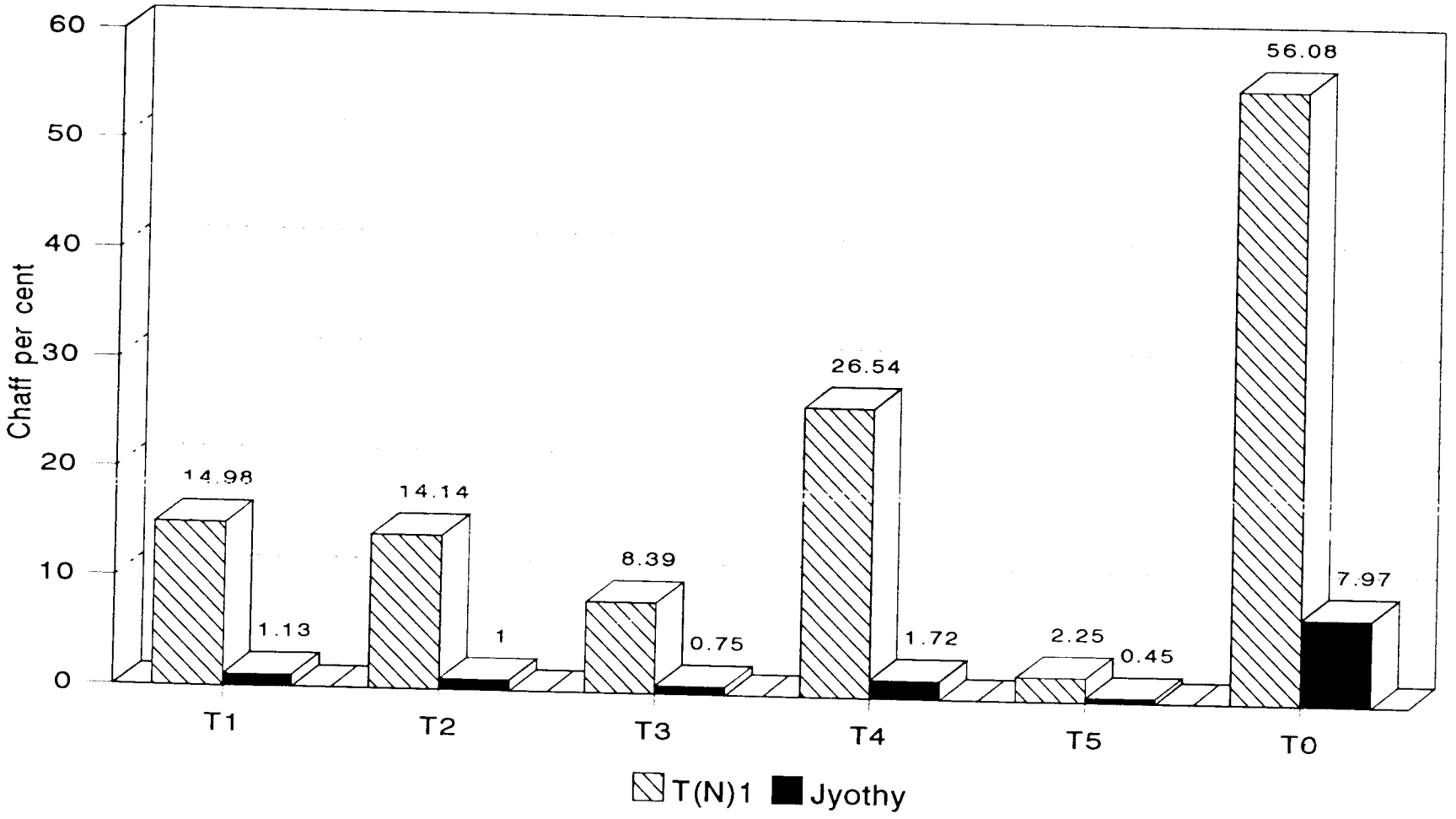
Fig. 28. Effect of prophylactic spraying on Chaff per cent in TN(1) and Jyothy

Table 42. Effect of curative spraying on chaff per cent in T(N)1 and Jyothy - Pooled data for additional crop of 1992 and 1993

Sl. No.	Treatments	Concentration (ppm)	T(N)1		Jyothy	
			Chaff per cent	% Reduction over control	Chaff per cent	% Reduction over control
1.	Streptocycline	500	14.98 (31.21)*	73.29	1.13 (6.1)	85.82
2.	Streptomycin + oxytetracycline (1: 9)	250	14.14 (25.94)	74.79	1.0 (5.73)	87.45
3.	Streptomycin + oxytetracycline (1: 9)	500	8.39 (23.55)	85.04	0.75 (4.93)	90.59
4.	Bactrinol - 100	500	26.54 (31.01)	52.67	1.72 (7.53)	78.42
5.	Cowdung extract	20g/l	2.25 (8.42)	95.99	0.45 (3.87)	94.35
6.	Control	No spray	56.08 (48.54)		7.97 (16.3)	

C.D. for the treatments (0.05 level) = 2.46

* Figures in parenthesis are transformed percentages in degrees



T1 - Streptocycline 500 ppm T2 - Streptomycin + oxytetracycline (1:9) 250 ppm
T3 - Streptomycin + oxytetracycline (1:9) 500 ppm T4 - Bactrinol-100 500 ppm
T5 - Cowdung extract 20g/l T0 - Control

Fig. 29. Effect of curative sprayings on Chaff per cent in TN(1) and Jyothy

7.19 Interaction between variety and method of spraying on chaff per cent in T(N)1 and Jyothy

The chaff per cent in Jyothy was significantly lower than that of T(N)1. They were 6.13 and 21.10 per cent respectively (Table 43). As regard to the two methods of spraying, there was significant reduction in chaff per cent by prophylactic spraying. In the interaction between variety and method of spraying, significant reduction in chaff per cent was recorded in T(N)1 by prophylactic spraying while in Jyothy, no significant difference was obtained between the two methods spraying.

Table 43. Interaction between variety and method of spraying on chaff per cent in T(N)1 and Jyothy

Variety	Methods of spraying		Mean (Variety)
	Prophylactic	Curative	
T(N)1	18.18	24.03	21.10
Jyothy	6.63	5.63	6.13
Mean (Method)	12.40	14.83	

C.D for Varieties (0.05 level) = 0.78

C.D for Methods (0.05 level) = 0.78

C.D for Variety x Method (0.05 level) = 1.10

7.20 Interaction between variety and treatment on chaff per cent in T(N)1 and Jyothy

The chaff per cent in Jyothy was significantly lower than that of T(N)1. In both these varieties, the reduction in chaff per cent was maximum after spraying with cowdung extract (20 g/l) (Table 44). The chaff per cent recorded in these varieties was 9.12 per cent and 4.23 per cent in T(N)1 and Jyothi respectively. Effect of spraying with 250 and 500 ppm streptomycin and oxytetracycline mixture in Jyothy was also statistically on par with the above treatment.

8. ECONOMIC BENEFIT OF CONTROLLING BACTERIAL BLIGHT OF RICE UNDER FIELD CONDITIONS

The relative economic benefit of prophylactic and curative sprayings on the control of bacterial blight of rice were also studied (Table 45) based on the data available from the field experiment at Mathurpadam Nedumudi, Kuttanad.

If suitable control measures are taken in time, there can be a net return of Rs. 2.49 and Rs. 2.94 per rupee invested after prophylactic or curative spraying respectively with 20g/l of cowdung extract in the variety Jyothy. The net return per rupee invested in curative spraying with streptocycline was Rs. 2.24. The net return per rupee invested was low in all other prophylactic and curative treatments when compared to the net return from control plants.

Table 44. Interaction between variety and treatment on chaff per cent in T(N)1 Jyothy

Treatments	Concentration (ppm)	Varieties		Mean (Treatment)
		T(N)1	Jyothy	
Streptocycline	500	26.29	7.23	16.76
Streptomycin + oxytetracycline (1:9)	250	22.92	5.77	14.34
Streptomycin + oxytetracyclinee (1:9)	500	19.75	5.24	12.49
Bactrinol - 100	500	27.41	8.20	17.80
Cowdung Extract	20g/l	9.12	4.23	6.68
Mean (Variety)		21.10	6.13	

C.D for Varieties (0.05 level) = 0.78

C.D for treatments (0.05 level) = 1.23

C.D for Variety x Treatment (0.05 level) = 1.74.

Table 45. Economic benefits of controlling bacterial blight of rice

Sl. No.	Treatment	Concentration (ppm)	Net return per rupee invested (Rs.)			
			Jyothy		T(N)1	
			Prophylactic spraying	Curative spraying	Prophylactic spraying	Curative spraying
1.	Streptocycline	500	2.06	2.24	1.84	1.93
2.	Streptomycin + oxytetracycline (1: 9)	250	1.78	1.95	1.59	1.66
3.	Streptomycin + oxytetracycline (1: 9)	500	1.43	1.78	1.28	1.37
4.	Bactrinol - 100	500	1.66	1.74	1.61	1.63
5.	Cowdung extract	20g/l	2.49	2.94	2.25	2.29
6.	Control		2.14	2.14	2.10	2.10

In rice variety T(N)1,the net return per rupee invested from plants sprayed with 20g/l of cowdung extract by prophylactic and curative methods respectively was Rs. 2.25 and Rs. 2.29. In all other treatments,the net return per rupee invested was low when compared to the net return from control plants.

DISCUSSION

DISCUSSION

Bacterial blight is one of the most important diseases of rice in South East Asia. In India, the occurrence of this disease has been reported from Andhra Pradesh, Bihar, Gujarath, Haryana, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Orissa, Punjab, Tamil Nadu, Uttar Pradesh and West Bengal (Reddy, 1983 and Durgapal, 1985). Interestingly, in Kerala, the disease is of significance only in Kuttanad particularly during the additional crop season (June-July to September-October).

In the present investigation, the main objective was to find out the reasons for recurrence of bacterial blight disease in Kuttanad mainly during the additional crop season. The importance of existing agronomic practices including selection of rice varieties for cultivation, survival of the pathogen in infected plant material, self sown rice and weeds of the region and the influence of weather was studied in detail for this purpose.

An extensive survey was conducted initially in Kuttanad Taluk covering 115 farmers in 12 Krishibhavans such as Champakulam, Edathua, Kavalam, Kainakary, Muttar, Nedumudi, Pulinkunnu, Ramankari, Thakazhi, Veliyanadu, Neelamperoor and Thalavadi during June 1992 to March 1994.

The information collected included percentage incidence of bacterial blight along with disease score in various locations surveyed, varieties cultivated by farmers during punja and additional crop seasons, nature and distribution of weeds and self sown rice, if any, in and around rice fields and aquatic waste lands and weather data for the survey period of 1992 to 1994. The survey showed that there was considerable variation in the incidence of bacterial blight in Kuttanad. The disease was maximum in Ramankari and Nedumudi Krishibhavan areas while it was minimum in Kavalam, Kainakary and Muttar areas (Table 1, 2 and 3 and fig. 1, 4 and 5). Some of the locations did not have any disease incidence under these conditions. Besides, the rice varieties cultivated by the farmers were also found to influence the recurrence of bacterial blight in the region. Most of the farmers (50%) cultivated the highly bacterial blight susceptible variety, Red Triveni, during the additional crop seasons of 1992 and 1993 followed by the variety Jyothy. The other varieties cultivated in the region included Asha, Bhadra, Cul. 1280, Jaya, Pavizham and Sindhuram. During the punja season of 1992-94 also, most of the farmers cultivated Red Triveni followed by Jyothy (Table 4, 5, 6 and 7).

It was clear from the survey that Red Triveni and Jyothy were the most popular rice varieties cultivated by the farmers in Kuttanad. They were growing these varieties because of their quality and consumer preference in the state for red grain rice. Therefore, the bacterial blight susceptible nature of these varieties did not prevent the farmers from cultivating them. Further, the incidence of bacterial blight in these varieties was insignificant during the main cropping season of punja (Table 5 and 7). The local availability of

sufficient seed material may also be another reason influencing the continuous cultivation of these varieties in the region. Hence, the only solution to reduce or eliminate the incidence of bacterial blight from Kuttanad is to introduce new disease resistant red grain varieties for large scale cultivation in the region.

The casual organism of bacterial blight was isolated from Nedumudi from the rice variety Red Triveni and identified as *Xanthomonas campestris* pv. *oryzae*. The name of the pathogen has changed to *Xanthomonas oryzae* pv. *oryzae* according to the current nomenclature described by Young *et al.* (1992). It could reproduce the disease upon artificial inoculation in T(N)1, the highly susceptible check variety commonly used for testing the virulence of *Xanthomonas oryzae* pv. *oryzae*. This isolate was capable of both gelatin liquefaction and starch hydrolysis. These observations were not in agreement with that reported earlier by Ishiyama (1922). However, subsequently, Reddy (1966) and Chakravarthi and Rangarajan (1967) reported that most of the isolates of this pathogen from India had the ability of gelatin liquefaction and starch hydrolysis. The optimum temperature for the growth of the present isolate was also slightly higher than 30°C.

Detailed investigations were carried out to understand the mode of survival of the pathogen during and in between the two major cropping seasons in Kuttanad. In the first part of this study, the extent of survival of *Xanthomonas oryzae* pv. *oryzae* in different naturally infected materials such as seed, straw, stubbles, soil and water was studied. In the second part, role of some of the commonly occurring weeds and self sown rice in and around

rice fields and aquatic waste lands of Kuttanad as a perennial source of the pathogen was investigated. The practice of off season cultivation existing in the region and the influence of weather on the occurrence of bacterial blight disease during the punja and additional crop seasons were closely monitored in the third part of this investigation. Many workers have studied earlier the extent of survival of *Xanthomonas oryzae* pv. *oryzae* in infected seed, straw and stubbles and reported different periods of survival of the pathogen. Chattopadhyay and Mukherjee (1971) reported that in naturally infected seed, *Xanthomonas oryzae* pv. *oryzae* survived for 30 to 160 days after harvest depending on the variety. Murthy and Devadath (1984) reported that the pathogen survived in seeds for 170-180 days in 54% of seeds in July-November season and in 45% of the seeds during *rabi* season. Singh and Rao (1977) demonstrated the presence of *Xanthomonas oryzae* pv. *oryzae* in and on seeds for a period upto 11 months after harvest. Raj and Pal (1988) reported that infected leaves seemed to provide the primary inoculum for the next crop since the pathogen remained viable in leaves, irrespective of the storage conditions over nine months. Trimurthy *et al.* (1982) reported that the pathogen survived in diseased stubble on the soil surface for 190 days and in stubbles burried in soil for 110 days. They suggested that in double cropped areas infected stubbles were source of inoculum for the next crop. This sort of variation in the survival period of the pathogen may be due to lack of uniformity in disease intensity at different locations, varieties cultivated and also due to differences in the time interval after harvest for the collection of samples and the method adopted for subsequent storage of such samples. But what is important is to find out the extent of survival of the pathogen in

different infected materials of plant origin and its significance with regard to the existing cultivation practices adopted by farmers in a region. It was found during this investigation that the pathogen could survive for a maximum period of 42 days in seed, 105 days in straw and 56 days in stubbles when stored at room temperature (Table 10, 11, and 12 and Fig. 11, 12 and 13).

Interestingly, when the infected stubbles were left in the open field itself, the extent of survival of the pathogen was greatly reduced to a maximum period of 28 days (Table 13 and fig. 14). This could be due to the detrimental effect of relatively high temperature and U.V. irradiation occurring under field conditions. At the same time, the pathogen could survive only for 14 days under flooded condition in the field due to anaerobic conditions in the soil (Table 13 and Fig. 14).

As mentioned earlier, it was important to find out whether this type of survival in different infected plant materials had got any role in the recurrence of bacterial blight in Kuttanad. This could become critical, if infected seed materials were used for raising the next crop especially in an area with an immediate past history of bacterial blight disease incidence. It was observed during the survey that many farmers here were indeed in the habit of using seeds from a previous crop without knowing whether such seeds were actually infected with the pathogen or not. If such seeds were used before the end of the observed period of viability of the pathogen in the seed material, it could serve as a potential source of inoculum for a subsequent crop susceptible to

bacterial blight disease. Singh *et al.* (1980a) observed that the bacterium could survive for about 10 months at room temperature and the seeds retained enough infection to cause an epidemic under favourable conditions. The results of the present study also revealed the possibility of seed transmission of the disease. In a continuous cropping pattern of Kuttanad ,the interval between two successive seasons was only around 30 days, infected seed could serve as a ready source of primary inoculum for the recurrence of bacterial blight in the region.

In the present study, the pathogen was found to survive in infected straw for about 105 days. Here also, the infected leaves/straw seemed to provide the primary inoculum for the next crop under conditions described above. This study was in agreement with that reported by Raj and Pal (1988). Chattopadhyay and Mukherjee (1975) reported that the residue from harvested crops provided the inoculum for the subsequent crop, particularly when two crops were raised in a year. Results of the present study also were in agreement with this work.

As regard to the second important factor, whether the farmers were raising the next crop in an infected field immediately after the harvest of a previous crop, it was found that due to various reasons in Kuttanad ,there was a sort of continuity in cultivation between two cropping seasons. As a result, very often the fields were not fully cleared of infected straw and stubbles, there by providing another source of inoculum for infection to a subsequent crop that is susceptible to bacterial blight disease.

Hence, by taking into consideration the fact that the pathogen could survive for a maximum period of 28 days under open field conditions, it is essential to keep the field after harvest either exposed to sunlight or under flood fallowing for a minimum period of at least one month to ensure the complete destruction of the pathogen.

The survival of *Xanthomonas oryzae* pv. *oryzae* in infected soil and water was also studied. However, the results were negative in the sense that no pathogen could be isolated from infected soil and water either by direct plating technique or by artificial inoculation on a susceptible variety of rice (Table 14). This result was in contrast to some of the earlier reports which indicated the presence of pathogen and its phage in irrigation water (Murthy and Devadath (1982a). Murthy and Devadath (1982) reported that the survival in soil was also influenced by the type of soil. In acid sulfate and saline soils, the pathogen survived for less than 10 days. The pathogen survived better in alluvial soils than in black calcareous and laterite soils. But the results of the present study are in conformity with the finding of Singh (1971) who reported that the pathogen did not survive in unsterilzed soil for a week and at pH levels below seven the period of survival was further deteriorated.

Another study carried out during the present investigation was on the nature of weed population in and around the infected fields of Kuttanad during the two major cropping seasons. It was observed that grasses, sedges, broad leaf weeds and ferns were present in the area surveyed in Kuttanad (Table 15).

Although most of the weeds were common for both the seasons, weeds like *Echinochloa colona* and *Eleocharis plantaginea* were present in large numbers only during additional crop season while weeds like *Tragus* sp. *Schenoplectus* sp. and *Marselia quadrifoliata* were more prominent during punja season. All these weeds were screened for natural incidence of bacterial blight symptom. Only two weeds namely *Oryza sativa* var. *fatua* (varinellu) and *Paspalum conjugatum* showed symptoms similar to bacterial blight infection in rice (Table 16, Plate V and VI). The symptoms on 'varinellu' were similar to that of rice. It started as yellowing from the tip of leaves and progressed downwards. These lesions later changed to straw colour. The symptoms were usually observed at the panicle initiation stage and were quite conspicuous on the boot leaf extending to the panicle base. But in *Paspalum conjugatum*, the initial symptoms appeared as yellowing of leaves and as the disease progressed infected leaves turned black in colour and dried. The symptoms first appeared on lower leaves which spread later to upper leaves. These weeds could serve as a source of inoculum depending on its location in and around the mainfield, its population density and also based on the fact whether they were already infected with bacterial blight before the main crop. It was found during this investigation that among the above two weeds which showed bacterial blight symptoms, 'varinellu' was rather more critical for the incidence of bacterial blight in Kuttanad. This was because, this particular weed was seen along with rice crop in the main field with almost identical morphological characters. Further, because of the early seed shedding habit of the weed, the seeds produced by it would fall on the ground and remain there viable till the next cropping season. Since the seed borne nature of

Xanthomonas oryzae pv *oryzae* is rather well understood now at least in the case of rice, 'varinellu' seeds in a field could also serve as a potential source of inoculum for bacterial blight disease in an ensuing rice crop because of the its systemic nature. However, the seed borne nature of the pathogen could not be studied because of the difficulty in collecting sufficient number of seeds from the puddled paddy field. Hence, it is essential to remove this weed completely during early stages of its growth itself. This will ensure elimination of bacterial blight infected varinellu from rice fields. The importance of weeds in perpetuation of bacterial blight pathogen had been reported earlier also. Duan *et al* (1979) observed that the pathogen of bacterial blight could survive in the roots of *Paspalum distichum*, *Cyanadon dactylon* and rice. These infected weeds from rice fields induced leaf blight in healthy rice seedlings when planted together in pots eventhough no symptoms were present in the above ground parts. Li *et al.* (1985) reported that infected *Paspalum distichum* and *Cyanadon dactylon* could induce infection on rice plants. Valluvaparidasan and Mariappan (1989) confirmed the susceptibility of *Cyperus rotundus* and *Pennisetum scrobiculatum* to bacterial blight pathogen. They also identified *Echinochloa crusgalli*, *Brachiaria mutica* and *Panicum maximum* as alternate hosts of bacterial blight pathogen. Brar and Thind (1994) observed that *Echinochloa colonum* acted as a host to *Xanthomonas oryzae* pv. *oryzae*. However, Rakesh Mehra and Thind (1994) reported that *Cyperus difformis*, *C. iria*, *C. rotundus*, *Digitaria ciliaris* and *Echinochloa colonum* commonly seen in and around bacterial blight infected rice fields did not develop disease symptoms either naturally or artificially.

The observation on self sown rice showed that they mainly originated as part of various harvesting operations besides seed dispersal by birds, rodents and ants. It was found that self sown rice could be seen in Kuttanad during both the cropping as well as non cropping seasons (Table 17, 18, 19 and 20; Plate VII). They were particularly dominant in the months of March, April, May, June, July, August and December. The presence of self sown rice in the months of July, August and December corresponded with maximum tillering and panicle initiation stages of rice in the field. Therefore, the presence of bacterial blight infected self sown rice,particularly in the months of July, August and December could be critical for the spread of this disease in Kuttanad. As regard to the occurrence of self sown rice during other months, these plants could serve as an alternate host for the survival of the pathogen. Such plants could also become a focal point of infection for bacterial blight disease during the next cropping season. Similar observations were also made by Murthy and Devadath (1981) and Durgapal (1985).

Another factor which was found to influence the incidence of bacterial blight disease in Kuttanad was the practice of off season cultivation of rice in one location or another. This often happened due to delayed monsoon, flooding and even due to non availability of sufficient labour for various operations from land preparation to harvesting. The net result was the presence of rice crop near to an already identified endemic location for bacterial blight disease. This became a serious problem if the rice variety cultivated happened to be a bacterial blight susceptible variety like Red Triveni or Jyothy. The only solution for this is to avoid as far as possible off season cultivation of

rice at least in areas where the incidence of bacterial blight disease is periodically reported.

Many earlier workers have also stressed the importance of weather conditions on the increase of bacterial blight disease of rice in a particular location. Goto *et al.* (1955) reported that a combination of rainy weather, stormy winds and temperature of 22-26°C favoured an outbreak of bacterial blight disease. Sulaiman and Ahamed (1965) reported that the critical condition for the disease was found in the month of July when the maximum tempeature was 29°C, minimum temperature 24°C, rainfall 1394.6 mm and relative humudity 91 per cent. Reddy and Pillai (1974) have also reported that a well distributed rainfall and relative humudity of 90 per cent and above, for 15 h per day favoured the outbreaks of bacterial blight disease. Further, Mohiuddin *et al.* (1977a) concluded from seven years observations that more than 27 rainy days during August, September and December (total rainfall 200 mm) contributed to a greater incidence of the disease. In the present investigation, the disease incidence was high only during the additional crop season. The average maximum and minimum temperature, relative humidity, total rain fall and wind velocity for the two additional crop seasons were 30.4°C, 23.9°C, 88.2%, 504.45 mm and 3.2 km/h, respectively. For the two punja seasons, these were 32.6°C, 23.2°C, 82.0%, 68 mm and 2.7 km/h, respectively (Table 21 and 22, Figs. 15, 16 and 17). From this data, it was evident that the weather conditions were quite different during the two seasons and that a favourable climatic condition existed mainly during the additional crop season in Kuttanad for bacterial blight incidence. Analysis of weather

factors during the different cropping seasons revealed that the maximum temperature, high rainfall and wind velocity were the important factors influencing the occurrence of bacterial blight disease. In Kuttanad a similar study had been conducted earlier by Sreelatha (1985). Thus by taking these parameters into consideration, it was quite obvious why there is bacterial blight disease incidence in Kuttanad mainly during the additional crop season and not during punja season, even though all the other factors favouring an outbreak of the disease are present during both the cropping seasons. These included the possible use of bacterial blight infected seed material for cultivation, presence of infected straw and stubbles in the field due to incomplete removal or destruction and the presence of infected weeds like *Oryza sativa* var. *fatua* and *Paspalam conjugatum* and self sown rice in and around rice fields. Hence, there appears to be some sort of natural check for the expression of virulence by the pathogen during the punja season especially due to unfavourable weather conditions. This could be the reason why there is only a mild incidence of bacterial blight disease during punja season in Kuttanad.

In the last part of this investigation, the control of bacterial blight disease under field conditions was studied using antibiotics, Bactrinol-100 and cowdung extract with an objective to find out whether there was any need for the control of this disease and if so which of the bactericidal agent was more suitable for this purpose as this disease was found to occur only during the panicle initiation stage in Kuttanad without affecting much the net grain yield. If the disease was to occur at an earlier stage of plant growth, proper

control measures would have been necessary to save the crop. Hence, this fact was also taken into consideration while evaluating different bactericidal agents for the control of bacterial blight disease under field conditions. In the first part of this study, different antibiotics such as penicillin, streptomycin, oxytetracycline, chloramphenicol, streptocycline, an organic synthetic compound Bactrinol-100 and fresh cowdung extract were evaluated for any inhibitory effect on *Xanthomonas oryzae* pv. *oryzae* under *in vitro* conditions. Except penicillin, all other antibiotics inhibited growth of the pathogen. The zone of growth inhibition increased with an increase in the concentration of various antibiotics tested. The maximum growth inhibition of 3.16 was obtained with oxytetracycline followed by chloramphenicol (Table 23 and Fig. 18). The inhibitory effect of different antibiotics like chloramphenicol (Wakimoto and Mukoo, 1963), streptocycline, (Desai *et al.*, 1967), tetracycline (Balaraman and Soumini Rajagopalan, 1978) on the growth of *Xanthomonas oryzae* pv. *oryzae* had been reported earlier also.

Since, oxytetracycline was found to be the most effective in inhibiting growth of the pathogen, possibility of using a higher level of this antibiotic in a combination with streptomycin in the present ratio of 9:1 to 1:9 was also tried. It was observed that with an increase in the proportion of oxytetracycline in the above mixture there was significant increase in the level of growth inhibition (Table 24, Fig. 19 and Plate VIII). This line of work was initiated to explore the possibility of improving the efficacy of some

In all, five treatments were selected for field evaluation trial. These included streptocycline at 500 ppm, streptomycin + oxytretracycline (1:9) at 250 ppm and 500 ppm, Bactrinol-100 at 500 ppm and cowdung extract at 20 g/l. The two rice varieties used for this experiment were Jyothy and T(N)1. Two different spraying methods, prophylactic and curative were also evaluated under field conditions. The prophylactic sprayings were given at 25 and 40 DAS in T(N)1 and 30 and 45 DAS in Jyothy while the curative sprayings were given only after the incidence of bacterial blight disease at 55 and 70 DAS in T(N)1 and at 60 and 75 DAS in Jyothy. The main objective of prophylactic spraying was to find out whether, by giving one or two such protective sprayings to a bacterial blight susceptible variety of rice being cultivated in a known endemic area for this disease, it was possible to reduce the severity of leaf blight infection.

The important observations taken for both the experiments were on per cent disease index, grain and straw yield, 1000 grain weight and percentage of chaff content. The pooled data for these parameters were presented in Tables 25 to 44 and Figs.20 to 29.

The reduction in disease index after spraying with cowdung extract was 34.42 and 34.13 per cent by prophylactic spraying in T(N)1 and Jyothy (Table 25 and Fig. 20) and 44.21 and 36.44 per cent respectively in these varieties by curative spraying (Table 26 and Fig. 21). The efficacy of Bactrinol-100 was below than that of streptocycline in both T(N)1 and Jyothy with per cent reduction of 1.54 and 9.42 by prophylactic spraying and 13.76

and 12.65 respectively after curative spraying. In streptocycline sprayed plants, the extent of disease reduction was 12.71 and 15.03 per cent by prophylactic spraying and 16.54 and 20.27 per cent by curative spraying in T(N)1 and Jyothy respectively. These results indicated that cowdung extract at the rate of 20g/l could be effectively used for the control of bacterial blight disease as a substitute for costly phytoantibiotic preparations. Mary *et al.* (1986) observed that a foliar spray of cowdung extract (20g/l) controlled bacterial blight equivalent to that given by penicillin (100 ppm), paushamycin (250 ppm) and streptomycin (100 ppm). Sreekumar and Nair (1990) reported that the extent of disease control achieved by spraying cowdung extract was found to be better than some of the chemical treatments like terramycin 100 ppm, streptocycline at 100, 250 or 500 ppm and Bactrinol-100 at 250 and 500 ppm.

The grain yield obtained also confirmed the relative efficacy of cowdung extract in controlling bacterial blight disease over other treatments. In comparison with streptocycline and Bactrinol-100, the grain yield obtained by spraying with cowdung extract was maximum in both the types of spraying schedule in T(N)1 and Jyothy. The actual grain yield obtained was 5.14 and 5.58 t/ha by prophylactic spraying (Table 29 and Fig. 22) and 5.12 and 6.43 t/ha by curative sprayings in T(N)1 and Jyothy respectively (Table 30 and Fig. 23). These represented an actual yield increase of 6.20 and 12.96 per cent by prophylactic spraying and 5.79 and 30.16 per cent by curative spraying in comparison to the control treatment which yielded only 4.84 and 4.94 t/ha in T(N)1 and Jyothy respectively. The corresponding grain yield

in plants sprayed with streptocycline by prophylactic method was 4.85 and 5.30 t/ha and 4.99 and 5.74 t/ha by curative spraying.

In many earlier reports, substantial yield losses due to bacterial blight had been reported. Rao and Kauffman (1977) observed a potential grain loss of 56 per cent from Andra Pradesh in highly susceptible Karuna variety, 10 per cent in moderately susceptible IR8 and insignificant loss in relatively resistant IR22 variety during the monsoon season under field condition. Raina *et al.* (1981) reported an yield loss of 60 to 70 per cent in T(N)1 in Punjab. However, in the present study, the yield loss due to bacterial blight was not significant probably due to the fact that in Kuttanad this disease occured only during the panicle initiation stage. Since, the over all growth of the plants was not much affected, there was also less loss in grain yield due to bacterial blight infection in Kuttanad.

The straw yield from diseased plants increased significantly in treated plots in relation to the control treatment. The straw yield after spraying with cowdung extract was 5.14 and 5.39 t/ha by prophylactic spraying and 5.43 and 5.71 t/ha by curative spraying in T(N)1 and Jyothy respectively (Table 33 and 34 Fig. 24 and 25). The corresponding straw yield from streptocycline treated plots was 4.85 and 5.07 t/ha by prophylactic spraying and 5.03 and 4.99 t/ha by curative spraying. In Bactrinol-100 treated plots by prophylactic spraying the increase in straw yield was 6.01 and 8.69 per cent in comparison with control. Natarajan and Lalithakumari (1989) have reported a similar increase in straw yield from bacterial blight affected rice plants after taking

appropriate control measures. Similarly,Sreekumar and Nair (1990) also got maximum increase in straw yield from bacterial blight affected plants after spraying cowdung extract (100g/l).

There was significant increase in thousand grain weight and reduction in chaff per cent over control treatment in both T(N)1 and Jyothy after prophylactic and curative sprayings (Tables 37, 38, 41 and 42; Fig. 26 to 29). These were maximum in plants sprayed with cowdung extract. In streptocycline and Bactrinol-100 sprayed plots, there was slight reduction in 1000 grain weight due to prophylactic spraying in T(N)1 while by curative spraying such reduction was observed only in Bactrinol-100 treated plots (Tables 37, 38 and Fig. 26 and 27). In Jyothy, increase in 1000 grain weight was recorded by streptocycline and Bactrinol-100 treated plots in both the methods of spraying. The per cent reduction in chaff content over control was 94.78, 94.10 and 70.95 by prophylactic spraying with cowdung extract, streptocycline and Bactrinol-100 in T(N)1 and 63.28, 72.68 and 69.67 respectively by the same treatments in Jyothy (Table 41 and Fig. 28). By curative spraying, the per cent reduction in T(N)1 by these treatments was in the order of 95.99, 73.29 and 52.67 and 94.35, 85.82 and 78.42 per cent respectively in Jyothy (Table 42 and Fig. 29). Sreekumar and Nair (1990) had reported earlier that in plants sprayed with cowdung extract, the thousand grain weight was greatly increased. The use of different concentrations of cowdung extract 20, 50 and 100g/l, also resulted in an increase in thousand grain weight from diseased Jyothy and C-153 rice varieties. There was also reduction in the number of chaffy grains formed after spraying with different concentrations of cowdung extract.

It was concluded from these observations that there is a need for the control of bacterial blight disease in Kuttanad. But it was found that two prophylatic spraying with selected bactericidal agents neither resulted in any significant reduction in disease index nor increase in yield as compared to curative spraying (Table 27 and 31). This could be due to the fact that in Kuttanad, bacterial blight disease usually occured only around the panicle initiation stage or even later and since the prophylactic sprayings were given much earlier to the actual incidence of this disease, it was probably not much effective for disease control. Such a prophylactic spraying schedule would have been effective, had there been an incidence of bacterial blight disease at an early stage of plant growth. Therefore, a need based curative spraying schedule would be most effective for the control of bacterial blight disease in Kuttanad. Further, the efficacy could be increased by choosing the right type of bactericidal agent for the control of this disease. This was because during the present investigation it was found that spraying with cowdung extract at the rate of 20g/l was most effective unlike streptocycline and Bactrinol-100 in reducing the per cent disease index and in increasing significantly the grain and straw yields.

On working out the economic benefit of controlling bacterial blight disease, it was observed that the net return for each rupee invested can be greatly increased by spraying infected plants with cowdung extract at the rate 20g/l. The returns from plants sprayed with all other bactericidal agents tried during this investigation, was low when compared to the unsprayed control treatment. Thus it will be economically advantageous to use cowdung extract to control bacterial blight of rice.

The important findings of the present investigation were as follows:

1. In Kuttanad, bacterial blight disease of rice was found to occur with varying intensity at different locations. While the incidence of this disease was severe in areas like Ramankari and Nedumudi, it was minimum in locations such as Kavalam, Kainakary and Muttar. In two of the locations namely Neelamperoor and Thalavadi there was no incidence of bacterial blight disease during 1992 to 1994.

2. Most of the farmers were found to cultivate bacterial blight susceptible varieties such as Red Triveni and Jyothy. Hence, the incidence of this disease in the region could be reduced by introducing new bacterial blight resistant red grain varieties of rice acceptable both to farmers as well as to the consumers in the state.

3. Off season cultivation of rice was found to be quite prevalent in the region due to climatic factors and non-availability of suitable labour for various agricultural operations. Consequently a continuation in the cropping season was observed eventhough there were only two cropping seasons, punja and additional in Kuttanad. This was found responsible to some extent for the use of infected seed material for cultivation and the survival of bacterial blight pathogen in the region. The problem can be solved by introducing the concept of group farming in the region so that at least one or two months of fallowing will be available between the two cropping season. This will ensure the complete destruction of bacterial

7. Since weather factors were found to greatly influence the severity of bacterial blight disease in Kuttanad, the need for raising an additional crop of rice especially in areas endemic for bacterial blight is to be seriously reconsidered. The farmers may be encouraged to practice pisciculture during this period to compensate for any economic loss for not raising an additional crop of rice. This will greatly help to prevent the survival of bacterial blight pathogen leading to gradual elimination of the disease from the region.

SUMMARY

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Bacterial blight caused by *Xanthomonas oryzae* pv. *oryzae* is one of the most important diseasesof rice in South East Asia. In Kerala, this disease is prevalent in Palakkad and Kuttanad regions comprising Alleppey, Pathanamthitta and Kottayam districts. In Kuttanad, eventhough this disease occur both during Punja (November-December to February-March) and additional crop (June-July to September-October), it becomes severe only during the additional crop season. Therefore, the present investigation was taken up to understand the factors responsible for the recurrence of this disease in a severe form only during this season. The mode of survival of the pathogen during and in between the two major cropping seasons of the region was also studied. An extensive survey was also conducted among 115 farmers in 12 Krishibhavans of Kuttanad Taluk for this purpose to collect specific information on existing cultural practices, crop varieties, nature and distribution of weed flora and self sown rice in and around rice fields and on weather data from June 1992 to March 1994. The pathogen isolated from an infected rice field at Nedumudi was subjected to *in vitro* antibiotic assay. Since oxytetracycline was found to be the most effective in inhibiting the growth of the pathogen, the possibility of using a higher level of this antibiotic in a mixture of streptomycin and oxytetracycline in the present ratio of 9:1 to 1:9 was also assessed. As last part of this investigation, the efficacy of two

different methods of spraying,prophylactic and curative using selected antibiotics, Bactrinol-100 and cowdung extract on the control of bacterial blight disease was tested under field conditionsat Nedumudi in Kuttanad.

The survey showed that there was considerable variation in the incidence of bacterial blight. Among the 12 Krishibhavans of Kuttanad taluk, viz., Champakulam, Edathua, Kavalam, Kainakary, Muttar, Nedumudi, Pulinkunnu, Ramankari, Thakazhi, Veliyanadu, Neelamperoor and Thalavadi, surveyed, the disease was maximum in Ramankari and Nedumudi Krishibhavan areas and minimum Kavalam, Kainakary and Muttar areas. Neelamperoor and Thalavadi areas did not have any disease incidence during the period of survey. Further, between the two major cropping seasons, the disease incidence was more during the additional crop season than during the punja season. During the additional crop season of 1992 and 1993, 50 per cent of the farmers cultivated the highly susceptible variety Red Triveni, followed by Jyothy (25.47%). The other varieties cultivated were Asha, Cul. 1280, Jaya, Pavizham, Sindhuram etc. (24.53%). During the punja season of 1992-93, 47.66% cultivated Red Triveni followed by Jyothy (34.58%) and other varieties like Asha, Cherupavizham, Cul. 1280, Sindhuram, Pavizham etc. (17.76%). During the additional crop season of 1993 also, 46.4% cultivated Red Triveni followed by Jyothy (24.1%), Parijatha (14.3%) and other varieties like IR100, Jaya, Pavizham, Sindhuram etc. (15.2%) and in punja 1993-94, nearly 34.66% cultivated Red Triveni, 31.68% White Triveni, 24.75% Jyothy and 8.91% other varieties. Red Triveni was found as highly susceptible to bacterial blight disease.

The isolate of the pathogen *Xanthomonas oryzae* pv. *oryzae* from the rice variety Red Triveni from Nedumudi, Kuttanad was an aerobic, gram -ve, rod shaped bacterium producing light yellow, circular, slimy and raised colonies on PSA medium. Acid production without gas formation was observed in the utilization of sugars, urease activity was negative, capable of both gelatin liquefaction and starch hydrolysis. It produced an alkaline reaction in milk without coagulation and peptonization and hydrogen sulphide from peptone water. The optimum temperature for the growth of the pathogen was slightly higher than 30°C.

The pathogen *Xanthomonas oryzae* pv. *oryzae* was found to survive for a maximum period of 42 days in infected seed, 105 days in infected straw, 56 days in infected stubbles at room temperature, 24 days in infected stubbles under dry land condition and 14 days under wet land conditions. The pathogen did not survive in soil and water.

Grasses, sedges, broad leaf weeds and ferns were present in the area surveyed in Kuttanad taluk. Weeds like *Cyanadon dactylon*, *Echinochloa stagnina*, *E. crusgalli*, *Oryza rufipogon*, *Oryza sativa* var. *fatua*, *Panicum repens*, *Paspalum conjugatum*, *Cyperus distance*, *Fimbristylis dichotoma*, *Ludwigia parviflora* and *Salvinia molesta* were dominant during both the cropping seasons. However, weeds like *Echinochloa colona* and *Eleocharis plantaginea* were present in large numbers only during additional crop season and weeds like *Tragus* sp., *Schenoplectus* sp. and *Marselia quadrifoliata* were more prominent during punja season. Weeds like *Salvinia molesta*,

Monochoria vaginalis, *Nymphaea nouchali* and *Paspalum* sp. were mostly seen in aquatic waste lands along with other weeds like *Isachne dispa*, *Cyperus distance* and *Eichornia crassipes*. Weeds such as *Oryza sativa* var. *fatua* ('*varinellu*') and *Paspalum conjugatum* showed symptoms similar to bacterial blight infection in rice. The symptoms on *Oryza sativa* var. *fatua* were similar to that of rice. The symptoms started as yellowing from the tip of leaves and progressed downwards. These lesions later changed to straw yellow colour. The symptoms were usually observed at the panicle initiation stage and quite conspicuous on the boot leaf extending to the panicle base. But in *Paspalum conjugatum*, the initial symptoms appeared as yellowing of leaves and as the disease progressed, the infected leaves turned black and dried. The symptoms first appeared on lower leaves which spread later to upper leaves. Between the two positive weeds, the occurrence of '*varinellu*' was rather critical for the occurrence of bacterial blight in Kuttanad since this weed was seen along with the rice crop in the main field with almost identical morphological characters. Because of the early seed shedding habit of this weed, the seeds produced by it fall on the ground and remain there viable till the next cropping season. The presence of infected '*varinellu*' seeds in a field could serve as a potential source of inoculum for bacterial blight disease in an ensuing rice crop. The observations on the self sown rice plants showed that infected self sown rice could be seen in Kuttanad during the cropping as well as non cropping seasons. They were particularly prominent in the months of March, April, May, June, July, August and December. The presence of infected self sown rice plants in the months of July, August and December corresponded with maximum tillering and panicle initiation stages of rice in the main field.

Occurrence of self sown rice plants during off season could serve as alternate host for survival of pathogen. Due to certain specific reasons particularly as a result of delayed monsoon, flooding and even due to non-availability of sufficient labour, the cultivation practices were often found to extend beyond the normal seasons in Kuttanad with the net result that the chances of survival of bacterial blight pathogen *Xanthomonas oryzae* pv. *oryzae* on the rice crop was considerably enhanced. This could also contribute for the endemic nature of bacterial blight disease in the region.

The varying weather conditions of additional and punja crop seasons also played an important role for the severity of bacterial blight disease in Kuttanad. The average maximum and minimum temperatures, relative humidity, total rainfall and wind velocity for the additional crop seasons of 1992 and 1993 were 30.4°C, 23.9°C, 88.2%, 504.45 mm and 3.2 Km/h respectively and during *punja* seasons of 1992-93 and 1993-94 were 32.6°C, 23.2°C, 82.0%, 68 mm and 2.7 Km/h respectively. It was found that the disease incidence was more during the additional crop season than during the punja season.

Eventhough all the factors favouring an outbreak of bacterial blight disease such as the possible use of infected seed material for cultivation, presence of infected straw and stubbles in the field due to incomplete removal and destruction and the presence of infected weeds like *Oryza sativa* var. *fatua* and *Paspalum conjugatum* and self sown rice in and around the rice fields were present during both the cropping seasons, there appears to be some sort of natural check for the expression of virulence by the pathogen during the

punja season mainly due to unfavourable weather conditions. This could be the reason for low incidence of bacterial blight disease during the punja season in Kuttanad and in the same locality a severe disease incidence during the additional crop season.

The pathogen *Xanthomonas oryzae* pv. *oryzae* was tested for sensitivity to antibiotics, Bactrinol-100 and fresh cowdung extract under *in vitro* conditions. Except for penicillin, all other antibiotics inhibited growth of the bacterium. The zone of growth inhibition increased with an increase in the concentration of antibiotics tested. The maximum growth inhibition of 3.16 cm was obtained with oxytetracycline followed by chloramphenicol (2.92 cm) which was statistically on par with oxytetracycline. The effect of streptocycline, the commercially produced phytoantibiotic and streptomycin on par with chloramphenicol. However, the extent of growth inhibition obtained with Bactrinol-100 was not significant. The different concentrations of cowdung extract did not inhibit the growth of the pathogen *in vitro*.

The effect of increasing concentration of oxytetracycline in combination with streptomycin on growth of *Xanthomonas oryzae* pv. *oryzae* was studied with 100, 250 and 500 ppm concentrations. It was found that the growth inhibition increased not only with the concentration of antibiotic from 100 to 500 ppm but also with increasing concentration of oxytetracycline. The mean zone of growth inhibition obtained with higher proportion of oxytetracycline in the mixture when compared with normal proportion of 9:1 was significantly high. The maximum zone of growth inhibition of 3.43 cm

was obtained with 1:9 proportion of streptomycin and oxytetracycline. Two levels of the same, 250 and 500 ppm were selected for further field evaluation trials.

In all, five treatments were selected for field evaluation trial. This included streptocycline at 500 ppm, streptomycin + oxytetracycline (1:9) at 250 ppm and 500 ppm, Bactrinol - 100 at 500 ppm and cowdung extract at 20g/l. The two rice varieties used in this experiment were T(N)1 and Jyothy. Two different spraying methods, prophylactic and curative were also evaluated under field conditions. The prophylactic sprayings were given at 25 and 40 DAS in T(N)1 and 30 and 45 DAS in Jyothy, while the curative sprayings were given only after the incidence of bacterial blight disease at 55 and 70 DAS in T(N)1 and 60 and 75 DAS in Jyothy. The main objective of prophylactic spraying was to find out whether by giving one or two such protective sprayings to a bacterial blight susceptible variety of rice being cultivated in a known endemic area for this disease, it was possible to reduce the severity of leaf blight infection.

The important observations taken for both the experiments were on per cent disease index, grain and straw yield, thousand grain weight and percentage of chaff content. There was significant reduction in per cent disease index after spraying with various bactericidal agents except Bactrinol - 100. The reduction in disease index, 34.42 and 34.13 per cent by prophylactic spraying in T(N)1 and Jyothy and 44.21 and 36.44 per cent respectively by curative sprayings was maximum after spraying with cowdung extract at

the rate of 20g/l. The extent of reduction with 500 ppm streptomycin and oxytetracycline mixture in Jyothy after prophylactic and curative sprayings was also on par with cowdung extract spraying. The mean disease index was significantly low in Jyothy (38.06%) when compared to the highly susceptible variety T(N)1 (48.32%). As regard to the two methods of spraying, significant reduction in per cent disease index was obtained with curative spraying rather than prophylactic.

No significant differences were observed between treatments in grain yield in both T(N)1 and Jyothy after prophylactic spraying. However, in Jyothy the increase in grain yield was significant in all the treatments except Bactrinol-100 by curative spraying. The yield increase of 6.20 and 12.96 per cent was maximum after prophylactic spraying in T(N)1 and Jyothy respectively with 20g/l of cowdung extract. This corresponded to a net yield of 5.14 and 5.58 t/ha respectively. The maximum per cent increase in yield over control in Jyothy was 31.78 after curative spraying with 500 ppm streptomycin and oxytetracycline mixture. The mean grain yield was significantly higher in Jyothy when compared to T(N)1. As regard to the two method of sprayings, significant increase in grain yield was obtained after curative spraying. The yield losses due to bacterial blight were not significant probably due to the fact that in Kuttanad this disease occured only during the panicle initiation stage.

Significant differences between treatments in straw yield in both T(N)1 and Jyothy affected with bacterial blight were observed after prophylactic

curative spraying with different bactericidal agents. Both in prophylactic spraying and curative spraying, the per cent increase in straw yield was maximum after spraying with a mixture of streptomycin and oxytetracycline at 500 ppm in T(N)1 and in Jyothy after spraying with cowdung extract at the rate of 20g/l.

The mean thousand grain weight was significantly high in Jyothy when compared to T(N)1 after prophylactic and curative method of sprayings with different bactericidal agents. These were 25.41 g and 24.58 g respectively. As regard to two method of spraying, significant increase in thousand grain weight was obtained after curative spraying. In both T(N)1 and Jyothy, the thousand grain weight was maximum after spraying with cowdung extract 20 g/l.

The chaff per cent in Jyothy was significantly lower than that of T(N)1 after prophylactic and curative method of spraying with different bactericidal agents. In T(N)1 significant reduction in chaff per cent was recorded by prophylactic method of spraying while in Jyothy no significant difference was obtained by the two methods of spraying. In both these varieties, the reduction in chaff per cent was maximum by spraying with cowdung extract 20g/l.

It was concluded from these observations that there is a need for the control of bacterial blight disease in Kuttanad. But it was found that two prophylactic sprayings with selected bactericidal agents neither resulted in any

significant reduction in disease index nor increase in yield as compared to curative sprayings. This could be due to the fact that in Kuttanad, bacterial blight disease usually occured only around the panicle initiation stage or even later and since the prophylactic sprayings were given much earlier to the actual incidence of this disease, it was not much effective for disease control. Therefore, a need based curative spraying schedule would be most effective for the control of bacterial blight disease in Kuttanad. Since it was found from the present investigation that spraying with cowdung extract at the rate of 20g/l was most effective unlike spraying with streptocycline and Bactrinol - 100 in reducing the per cent disease index and increasing significantly the grain and straw yield, the efficacy could be increased by choosing cowdung extract at the rate of 20g/l for the control of this disease.

On working out the economic benefit of controlling bacterial blight disease, it was observed that the net return for each rupee invested can be greatly increased by spraying infected plants with cowdung extract at the rate of 20g/l. The return from plants sprayed with all other bactericidal agents tried during this investigation was low when compared to the unsprayed control treatment. Thus it will be economically advantageous to use cowdung extract to control bacterial blight of rice.

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* Originals not seen

APPENDICES

APPENDIX - I

Krishibhavan – Nedumudi

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Red Triveni 1285	7 7	50 45	Red Triveni Asha	7 3	20 10	Parijatha IR100 Jyothy	7 7 7	60 25 40	Red Triveni	5	30
2.	Red Triveni Asha	7 7	70 20	Asha Red Triveni	3 5	10 20	Red Triveni Jyothy	7 3	60 30	Red Triveni	5	30
3.	Jyothy	5	60	Red Triveni	7	30	Red Triveni	7	60	White Triveni	5	25
4.	Jyothy	3	5	Jyothy	5	20	Jyothy	5	40	Jyothy	3	20
5.	Red Triveni	7	60	Red Triveni	7	30	Red Triveni	5	30	Red Triveni	5	30
6.	Red Triveni	7	70	Red Triveni Pavizham	5 1	30 5	Red Triveni	5	35	Red Triveni Pavizham	5 3	30 20
7.	Jyothy	7	50	Jyothy Pavizham	7 1	30 5	Jyothy	5	65	Pavizham	3	20
8.	Jyothy	3	10	Bhadra	1	20	Parijatha IR100	7 7	60 25	Bhadra	1	10
9.	Red Triveni	7	50	Jyothy	3	10	Parijatha	7	60	Jyothy	1	10
10.	Red Triveni	7	60	Red Triveni	7	20	Red Triveni Jyothy	7 3	50 20	White Triveni	1	5

APPENDIX - II

Krishibhavan – Pulinkunnu

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Red Triveni	5	25	Red Triveni	3	10	Jyothy	3	20	White Triveni	3	10
2.	Red Triveni	5	45	Jyothy	3	20	Red Triveni	5	40	White Triveni	3	20
3.	Jyothy	1	1	Jyothy	3	5	Parijatha	7	50	White Triveni	5	30
4.	Jyothy	5	30	Jyothy	1	5	Parijatha	7	50	White Triveni	1	10
5.	Jyothy	3	5	Jyothy	0	0	Parijatha	7	50	Red Triveni	5	30
6.	Red Triveni	5	20	Jyothy	0	0	Red Triveni	5	20	White Triveni	5	15
7.	Red Thriveni	7	50	Red Thriveni	3	10	Parijatha	7	50	White Triveni	1	10
8.	Jyothy	3	5	Jyothy	0	0	Jyothy	3	5	Jyothy	0	0
9.	Red Triveni	7	60	Jyothy	1	5	Red Triveni	5	20	Jyothy	0	0
10.	Red Triveni	5	50	Jyothy	1	5	Parijatha	7	45	Red Triveni	5	30

APPENDIX - III

Krishibhavan – Kavalam

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Jyothy	1	20	Jyothy	1	5	Jyothy IR100	3 3	20 15	White Triveni	1	5
2.	Jyothy	1	25	Jyothy	1	10	IR100	3	20	White Triveni	1	5
3.	Jyothy	1	20	Jyothy	1	5	IR100	3	20	White Triveni	1	5
4.	Red Triveni	3	35	Red Triveni	3	5	Red Triveni	5	30	Red Triveni	3	5
5.	Red Triveni	3	30	Red Triveni	3	5	Red Triveni	5	30	Red Triveni	3	5
6.	Red Triveni	3	30	Red Triveni	3	10	Red Triveni	5	30	White Triveni	1	5
7.	Sindhuram	1	10	Sindhuram Red Triveni	1 3	10 5	Jyothy	3	20	White Triveni	1	5
8.	Red Triveni	3	35	Red Triveni	3	5	Red Triveni	3	30	Red Triveni	3	5
9.	Red Triveni	3	30	Red Triveni	3	5	Red Triveni	5	30	Red Triveni	3	10
10.	Sindhuram	1	20	Jyothy	1	5	Jyothy	3	20	White Triveni	1	10

APPENDIX - IV

Krishibhavan – Kainakary

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Red Triveni	5	25	Red Triveni	1	1	Jyothy Red Triveni	3 5	20 20	White Triveni	1	5
2.	Jyothy	5	25	Jyothy	0	0	Jyothy Red Triveni	3 5	30 30	Red Triveni	1	3
3.	Jyothy Red Triveni	1 5	1 25	Jyothy Red Triveni	0 1	0 2	Jyothy Red Triveni	3 5	20 30	Jyothy	0	0
4.	Red Triveni	3	10	Red Triveni	1	3	Red Triveni	7	45	White Triveni	1	3
5.	Red Triveni	3	10	Red Triveni	1	2	Jyothy Red Triveni	3 7	10 40	Jyothy	0	0
6.	Red Triveni	3	10	Red Triveni	1	5	Red Triveni	5	60	Red Triveni	1	5
7.	Red Triveni	5	20	Red Triveni	1	3	Red Triveni	5	40	Red Triveni	1	3
8.	Red Triveni	5	25	Red Triveni	1	2	Red Triveni	5	50	Red Triveni	1	3
9.	Red Triveni	5	20	Red Triveni	1	2	Red Triveni	5	40	Red Triveni	1	3
10.	Red Triveni	5	20	Red Triveni	1	2	Red Triveni	5	50	Jyothy White Triveni	0 1	0 3

APPENDIX - V

Krishibhavan – Champakulam

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Jyothy	3	50	Jyothi	3	5	Jyothy	3	20	White Triveni	0	0
2.	Jyothy	3	50	Jyothy	1	5	Red Triveni	7	30	White Triveni	0	0
3.	Red Triveni	5	60	Red Triveni	5	5	Red Triveni	7	30	Red Triveni	3	5
4.	Jyothy	3	25	Jyothy	3	5	Red Triveni	5	30	Red Triveni	3	5
5.	Jyothy	3	20	Jyothy	3	5	Asha	5	30	Jyothy	1	5
6.	Red Triveni	5	50	Red Triveni	5	10	Pavizham	5	30	Jyothy	1	5
7.	Red Triveni	5	60	Red Triveni	5	10	Jyothy	3	20	Jyothy	0	0
8.	Pavizham	5	50	Pavizham	3	5	Red Triveni	5	30	White Triveni	0	0
9.	Pavizham	5	40	Pavizham	0	0	Red Triveni	5	30	White Triveni	0	0
10.	Asha	5	30	Jyothy	1	2	Jyothy	0	0	Jyothy	0	0

APPENDIX - VI

Krishibhavan – Ramankari

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Red Triveni	5	30	Jyothi Red Triveni	5 5	30 30	Red Triveni Parijatha	5 7	50 60	Jyothy Red Triveni	5 5	30 30
2.	Red Triveni	5	40	Jyothy	5	30	Red Triveni Sindhuram	7 7	50 50	Jyothy	3	30
3.	Red Triveni	7	40	Red Triveni Sindhuram	7 5	20 20	Red Triveni Parijatha	7 7	50 50	Red Triveni Sindhuram	7 5	20 20
4.	Jyothy	7	30	Jyothy	7	30	Red Triveni IR100	7 7	30 40	Jyothy	7	30
5.	Red Triveni	7	30	Red Triveni Sindhuram	3 5	20 20	Red Triveni Sindhuram	7 5	40 20	Red Triveni	3	20
6.	Red Triveni Sindhuram	7 3	30 10	Red Triveni	3	10	Red Triveni	7	40	Red Triveni	3	10
7.	Red Triveni	5	20	Sindhuram	3	10	Red Triveni	7	40	Sindhuram	3	10
8.	Jyothy	5	40	Red Triveni	3	20	Red Triveni Parijatha	5 7	40 50	Red Triveni	3	20
9.	Red Triveni	7	40	Red Triveni Jyothy	5 3	25 10	Red Triveni Parijatha	7 7	50 50	Red Triveni Jyothy	5 3	25 10
10.	Red Triveni	7	50	Jyothy	3	20	Red Triveni Sindhuram	7 7	40 50	Jyothy	3	20

APPENDIX - VII

Krishibhavan – Edathua

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Cul 8759 Jyothy	5 5	40 20	Red Triveni	3	20	Red Triveni	7	50	Red Triveni	3	20
2.	Red Triveni Cul 1280 Cherupavizham Cul 153 (Kunjipappan)	5 5 5 5	30 30 30 30	Jyothy Cul 1280	5 1	20 5	Red Triveni	7	40	Jyothy	3	20
3.	Jyothy	5	40	Jyothy Cherupavizham	3 3	20 20	Jyothy	3	40	Cherupavizham	3	20
4.	Red Triveni	5	40	Red Triveni	3	20	Red Triveni	5	50	Red Triveni	3	20
5.	Red Triveni	5	40	Red Triveni	3	20	Red Triveni	7	50	White Triveni	3	15
6.	Red Triveni Cul 1280	5 3	40 20	Red Triveni	3	10	Jyothy	3	20	White Triveni	3	15
7.	Red Triveni	7	40	Red Triveni	5	20	Jyothy	5	20	Red Triveni	3	20
8.	Pavizham Jaya	3 5	10 20	Red Triveni	5	20	Pavizham	5	20	Red Triveni	3	20
9.	Pavizham Jaya	3 5	10 20	Red Triveni	5	20	Jaya	5	40	White Triveni	3	15
10.	Unidentified	3	50	Unidentified	3	20	Unidentified	3	50	Red Triveni	3	20

APPENDIX - VIII

Krishibhavan – Veliyanadu

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Red Triveni	5	25	Red Triveni	3	10	Parijatha	5	40	Jyothy	1	10
2.	Jyothy	5	30	Jyothy	1	10	Red Triveni	5	50	Jyothy	1	10
3.	Red Triveni	7	20	Red Triveni	3	20	IR100	7	60	Red Triveni	3	10
4.	Red Triveni	7	50	Jyothy	1	10	Parijatha	5	30	Red Triveni	3	20
5.	Jyothy	3	20	Red Triveni	3	20	Jyothy	3	30	Jyothy	5	25
6.	Jyothy	5	10	Red Triveni	3	30	Jyothy	3	25	Red Triveni	5	30
7.	Red Triveni	5	30	Red Triveni	3	30	Parijatha	5	40	Jyothy	3	10
8.	Jyothy	5	20	Jyothy	1	5	Parijatha	5	45	White Trrveni	5	30
9.	Red Triveni	3	30	Jyothy	1	7	Red Triveni	5	50	Pavizham	3	30
10.	Red Triveni	3	20	Red Triveni	3	20	Red Triveni	5	50	Bhadra	1	10

APPENDIX - IX

Krishibhavan – Muttar

Locations	Seasons surveyed										
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Cul 1285	5	30	Jyothi	0	0	Red Triveni	7	40	Red Triveni	3	20
2.	Red Triveni	5	40	Red Triveni	3	10	Red Triveni	7	40	Jyothy	0	0
3.	Jyothy	5	30	Jyothy	0	0	Jyothy	3	10	Jyothy	0	0
4.	Red Triveni	5	40	Red Triveni	3	10	Red Triveni	7	40	Jyothy	0	0
5.	1280	3	20	Chempavizham	0	0	Chempavizha	3	20	White Triveni	1	10
6.	Red Triveni	5	35	Red Triveni	3	10	Red Triveni	7	40	White Triveni	1	10
7.	Pavizham	5	20	Pavizham	1	5	Red Triveni	7	40	White Triveni	1	10
8.	Jaya	1	5	Jaya	1	5	Jaya	5	40	Red Triveni	3	20
9.	Jyothy	1	5	Jyothy	0	0	Jyothy	3	10	Red Triveni	3	20
10.	Pavizham	5	20	Pavizham	1	5	Jyothy	1	10	White Triveni	1	10

APPENDIX - X

Krishibhavan – Thakazhi

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	1280	5	10	Red Triveni	1	5	Red Triveni	7	50	Red Triveni	3	20
2.	Red Triveni	5	20	Jyothy	0	0	Jyothy	3	30	White Triveni	3	30
3.	Jaya	3	5	1280	3	5	Pavizham	5	20	White Triveni	3	10
4.	Red Triveni	5	20	Red Triveni	3	5	Red Triveni	5	40	White Triveni	3	10
5.	153 (Kunjipappan)	5	30	Red Triveni	3	5	Jyothy	3	40	Jyothy	1	10

X

APPENDIX - XI

Krishibhavan – Thalavadi

Locations	Seasons surveyed											
	Additional 92			Punja 92-93			Additional 93			Punja 93-94		
	Variety	BB disease		Variety	BB disease		Variety	BB disease		Variety	BB disease	
		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)		Score	Incidence (%)
1.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil
2.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil
3.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil
4.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil
5.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil
6.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil
7.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil
8.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil
9.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil
10.	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil	Jyothy	Nil	Nil

SURVIVAL OF *Xanthomonas campestris* pv. *oryzae* AND ITS CONTROL IN KUTTANAD

By

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ABSTRACT OF A THESIS
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ABSTRACT

The present investigation was taken up to understand the factors responsible for the recurrence of bacterial blight disease in a severe form only during the additional crop season in Kuttanad. The mode of survival of the pathogen during and in between the two major cropping seasons of Kuttanad region were also studied in detail. An extensive survey was also conducted among 115 farmers in 12 Krishibhavans of Kuttanad taluk for this purpose to collect specific informations on existing cultural practices, crop variety, nature and distribution of weed flora and self sown rice plants in and around rice fields and on weather data from June 1992 to March 1994. The efficacy of two different methods of spraying, prophylactic and curative using streptocycline, mixture of streptomycin and oxytetracycline in the proportion 1:9, Bactrinol-100 and cowdung extract on the control of bacterial blight disease was tested under field condition at Nedumudi in Kuttanad.

The survey showed that there was considerable variation in the incidence of bacterial blight in Kuttanad taluk. Among the 12 Krishibhavan areas the disease incidence was maximum in Ramankari and Nedumudi and minimum in Kavalam, Kainakary and Muttar. In Neelamperoor and Thalavadi areas there was no incidence of this disease during the period of survey. Between the two major cropping seasons the disease incidence was more during the additional crop season than during Punja season. Red Triveni and Jyothy

were the most popular varieties cultivated in the area and more than 50% of the farmers cultivate Red Triveni. It was observed that the variety Red Triveni as highly susceptible to bacterial blight disease.

The isolate of the pathogen *Xanthomonas oryzae* pv. *oryzae* from the rice variety Red Triveni was capable of both gelatin liquefaction and starch hydrolysis.

The pathogen *X. oryzae* pv. *oryzae* was found to survive for a maximum period of 42 days in infected seed, 105 days in infected straw, 56 days in infected stubbles at room temperature, 24 days in infected stubbles under dry land condition and 14 days under wet land condition. The pathogen did not survive in soil and water. Weeds like *Oryza sativa* var. *fatua* and *Paspalum conjugatum* served as alternate host for the pathogen.

Bacterial blight infected self sown rice plants could be seen in Kuttanad during the cropping and non cropping seasons. Due to certain specific reasons, the cultivation practices were often found to extend beyond the normal cropping seasons in the region resulting in the chances of survival of bacterial blight pathogen in the host plant itself. The specific weather conditions during the additional crop season played an important role for the severity of bacterial blight disease in this season in Kuttanad.

The pathogen *X. oryzae* pv. *oryzae* was tested for sensitivity to antibiotics, Bactrinol-100 and cowdung extract under *in vitro* conditions. The maximum growth inhibition was obtained with oxytetracycline followed by chloramphenicol which was statistically on par with oxytetracycline.

The effect of increasing concentrations of oxytetracycline in combination with streptomycin on growth of *X. oryzae* pv. *oryzae* was studied with 100, 250 and 500 ppm concentrations. The growth inhibition increased not only with the concentration of antibiotic from 100 to 500 ppm but also with increasing concentration of oxytetracycline. The maximum zone of growth inhibition was obtained with 1:9 proportion of streptomycin and oxytetracycline.

The five treatments selected for field evaluation trial included streptocycline at 500 ppm, streptomycin + oxytetracycline (1:9) at 250 ppm and 500 ppm, Bactrinol-100 at 500 ppm and fresh cowdung extract at 20g/l. Two different spraying methods, prophylactic and curative were evaluated in two rice varieties, T(N)1 and Jyothy.

The reduction in disease index by prophylactic and curative sprayings was maximum after spraying with cowdung extract 20g/l. As regards to two methods of spraying, significant reduction in per cent disease index was obtained with curative spraying.

The maximum per cent increase in grain yield over control was obtained after curative spraying with 500 ppm streptomycin and oxytetracycline mixture in Jyothy followed by cowdung extract 20 g/l. In T(N)1 and Jyothy both by prophylactic and curative spraying, the thousand grain weight was maximum with cowdung extract 20 g/l. As regards to two methods of spraying, significant increase in grain yield and thousand grain weight was obtained after curative spraying. In T(N)1, both by prophylactic

and curative spraying the per cent increase in straw yield was maximum with a mixture of streptomycin and oxytetracycline at 500 ppm and in Jyothy with cowdung extract 20g/l. In T(N)1 significant reduction in chaff per cent was recorded by prophylactic spraying while in Jyothy no significant difference was obtained by the two methods of spraying. In both these varieties the reduction in chaff per cent was maximum by spraying with cowdung extract (20g/l).

It was observed that two prophylactic spraying with selected bactericidal agents, neither resulted in any significant reduction in disease index nor increase in yield as compared to curative spraying. This could be due to the fact that in Kuttanad bacterial blight disease usually occurred only around the panicle initiation stage or even later. Therefore a need based curative spraying schedule would be most effective for the control of bacterial blight disease in Kuttanad.

On working out the economic benefits of controlling bacterial blight it was observed that there will be economic return only from spraying infected plants of both T(N)1 and Jyothy with cowdung extract 20g/l. The return from plants sprayed with all other treatments in the investigation was low when compared to unsprayed control plants. Thus it will be economically advantageous to use cowdung extract to control bacterial blight of rice.