CHARACTERIZATION AND MANAGEMENT OF BACTERIAL WILT OF CHILLIES CAUSED BY *Pseudomonas solanacearum*. E.F. Smith

By

JYOTHI. A. R.

THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Pathology
COLLEGE OF HORTICULTURE
Vellanikkara, Thrissur

1992

DECLARATION

I hereby declare that this thesis entitled "Characterization and management of bacterial wilt of chillies caused by Pseudomonas solanacearum E.F. Smith" 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 University or Society.

Vellanikkara,
12 - 8 - 1992

JYOTHI, A.R.

CERTIFICATE

Certified that this thesis entitled "Characterization and management of bacterial wilt of chillies caused by Pseudomonas solanacearum E.F. Smith" is a record of research work done independently by **Mr.Jyothi, A.R.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Dr.Koshy Abraham
Chairman
Advisory Committee
Associate Professor of
Plant Pathology

Vellanikkara,
12 - 8 - 1992

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr.Jyothi, A.R.**, a candidate for the degree of Master of Science in Agriculture with major in Plant Pathology, agree that the thesis entitled "Characterization and management of bacterial wilt of chillies caused by Pseudomonas solanacearum E.F. Smith" may be submitted by Mr.Jyothi, A.R. in partial fulfilment of the requirement for the degree.

Chairman — Dr.Koshy Abraham

Members — Prof.C.K. Ramakrishnan

Dr.Abi Cheeran

Dr.T.R. Gopalakrishnan

R. CHANDRA MOHANAN
External Examiner

ACKNOWLEDGEMENT

I express my deep sense of gratitude and indebtedness to Dr.Koshy Abraham, Associate Professor of Plant Pathology and Chairman of my Advisory Committee for his inspiring guidance, constructive criticisms, constant encouragement and advice, which I have received during the entire period of investigation and in the preparation of this manuscript.

I am really grateful to Prof.P.C.Jose, Professor and Head, Department of Plant Pathology (Retd.), Dr.Abi Cheeran, Associate Director of Research (Retd.), Kerala Agricultural University and Dr.T.R.Gopalakrishnan, Associate Professor, R.A.R.S. Ambalavayal, for having served as members of my Advisory Committee, and for their valuable suggestions and help rendered in the preparation and presentation of this thesis.

I am under obligation to Dr.C.K.Peethambaran, Associate Professor and Dr.James Mathew, Professor, Department of Plant Pathology for their expert advice, valuable suggestions and help rendered to me.

My sincere thanks are to Dr.T.K.Muralidharan, Principal Scientist and Officer in-charge, N.B.P.G.R. Regional Station, Thrissur, for permitting me to take observations on the chilli germplasm.

My abiding gratitude will remain with all the staff members and dearest students of the Department of Plant Pathology

for their sincere help, moral support and whole hearted co-operation throughout the study.

I shall be failing in my duty, if I do not mention the name of my class mate, Kalpana, for her full hearted co-operation, moral support and help rendered to me.

Let met place on record, my heartfelt thanks to Unnimon, Judy and all my friends each of who has contributed in some way or the other towards the completion of this work.

I am thankful to Sri.Joy for the neat typing of this thesis.

On a personel note, I wish to express and place on record my deep indebtedness and heartful gratitude to my father, mother, brother and all my family members for their moral support, constant prayers and sincere encouragement which helped me a lot for the completion of this thesis work.

Last, but not the least, I bow my head before God Almighty, whose blessings enabled me to complete this dream successfully.

JYOTHI, A.R.

Dedicated to
my loving parents

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

INTRODUCTION

Chilli (Capsicum spp.) is an indispensible spice cum vegetable crop of India, valued for its pungency and colour. It is a rich source of vitamins and minerals. The crop has originated in South America, and was brought to India during the 16th century. It has got a wide ecological adaptability and hence cultivated in many parts of the world. In India, chilli is cultivated in an area of 8.92 lakh ha with an annual production of 7.83 lakh tonnes. Andhra Pradesh, Maharashtra, Tamil Nadu, Karnataka, West Bengal, Gujarat, Bihar and Assam accounts for 96 per cent of total area under chilli in India. The cultivation of chilli in Kerala is limited to 638 ha with an annual production of 670 tonnes.

Heavy incidence of pests and diseases causes the major setbacks in the cultivation of chilli in Kerala. Among the diseases, bacterial wilt incited by Pseudomonas solanacearum (Smith) Smith is of prime importance (Plate 1). The disease manifests at all stages of crop growth with the maximum severity at the flowering stage. In chilli, this disease was first reported from U.S.A. as early as 1898 (Rolfs, 1898a, b, c) and its occurrence in India was recorded during 1969 from Madhya Pradesh. In India, a systematic investigation on the various aspects of bacterial wilt of chillies has not been carried out except for a few studies on its occurrence and management (ICAR, 1969; Rahim, 1972; George, 1973; Khan et al., 1979).

The causal agent of the disease P. solanacearum is a fastidious soil borne pathogen known for its endemic persistance in the soil. The disease occurs in diverse soil types of acidic and alkaline nature. The destructiveness of the disease is compounded by the wide host range of the causal organism. The disease affects more than 200 species of plants belonging to 33 families with the largest number of hosts in Solanaceae. In India, the economically important hosts include potato, tomato, brinjal, chillies, groundnut, ginger etc. There are also many possible interactions between strains of the pathogen, hosts and environment. Therefore, control of bacterial wilt is a challenge of considerable heirarchy and complexity.

Only very little information is available on the various aspects of the pathogen, sources of resistance against the disease, and disease management. Specific recommendations on the control of the disease are not available at present. In the light of the above facts, the present investigation was carried out with the following objectives:

1) Isolation of the pathogen from chilli and from other crops like brinjal, tomato and ginger.
2) Characterization of the pathogen.
3) Screening of chilli accessions/varieties for resistance against Pseudomonas solanacearum.
4) Management of the disease by conducting both in vitro and in vivo studies.

Plate 1. A bacterial wilt infected chilli plant

Review of Literature

REVIEW OF LITERATURE

The earliest report of the bacterial wilt was made by Burrill (1890) in connection with an unidentified bacterial disease of potato in U.S.A. But it was Smith (1896) who first described the bacterial wilt disease of many solanaceous crops and the causal organism as Pseudomonas solanacearum. The occurrence of bacterial wilt of chillies incited by P. solanacearum was first recorded from U.S.A. (Rolfs ,1898 a, b, c). Subsequently, the disease was reported from Philippines (Reinking, 1919 a, b); Java (Schwarz, 1926); Central America (Cook, 1931); Ceylon (Park, 1932); South America (Deslandes, 1944) and Thailand (Chandrasrikul and Wannapee, 1972).

In India, the incidence of bacterial wilt of chillies was reported from Madhyapradesh (I.C.A.R., 1969). Chattopadhyay and Mukherjee (1969) noted that chilli could be one of the hosts for their strains of P. solanacearum. From Karnataka the occurrence of bacterial wilt of chillies was reported by Khan et al. (1979). In Kerala, studies on certain aspects on the management of bacterial wilt of chillies and its pathogen were conducted by Rahim (1972), George (1973), and Devi (1978).

Earlier literature on loss assessment due to bacterial wilt of chillies, much of it of a fragmentary rather than systamatic nature, has been comprehensively reviewed by Kelman (1953). Agati (1949) estimated 10-40 per cent loss to chilli due to bacterial

wilt in Central Luzon. Zehr (1969) from Philippines reported a loss averaging 10 per cent on chillies. Khan et al. (1979) observed a yield loss of 20-22 per cent in chilli growing pockets of Bangalore and Kolar districts of Karnataka state.

2.1. The pathogen

The shape and size of the bacterium was first delineated by Smith (1896) as non spore forming, noncapsulate, gram negative small rods with polar flagella. Stanford and Wolf (1917) reported that the colonies of the bacterium on solid media were circular, glistening white slightly raised with smooth margin and appeared within 36-48 h.

Okabe (1937) had described four colony types, viz., F = wild types which are fluidal, irregular milky colony, readily isolated from the lesions; OP = opalescent, circular, homogenous;C = circular, light brownish, straite and SS = pale, fluorite green with cream coloured centre. The last three were isolated from advanced stage of the disease.

Kelman (1954) distinguished colony variants on Tetrazolium medium. These were the normal or wild type which were irregularly round, entire, white or white with light pink centre and the mutant or butyrous type which were round, translucent, smooth, deep red with a narrow light bluish border.

An association between levels of virulence and colony morphology of the pathogen on Triphenyl Tetrazolium Chloride (TZC) medium had been demonstrated (Okabe, 1949; Kelman, 1954; Okabe and Goto, 1954; Husain and Kelman, 1958). They observed that virulent wild type isolates formed irregularly round, fluidal, white colonies with light pink centres while avirulent mutants formed small butyrous colonies with distinct red centres.

Khan et al. (1979) reported that the chilli isolate produced convex, slimy, colonies with slight pinkish centre on TZC medium. On the same medium the colonies of tomato isolate were convex to flat, fluidal, slimy with pink centre, while the colonies of brinjal isolate were convex to flat fluidal, less slimy with pinkish centre. Mathew and Nayar (1983) stated that P. solanacearum isolated on TZC medium yielded circular, smooth and greyish white colonies with light pink centres. He et al. (1983) found that on TZC medium the virulent strains of the bacterium produced fluidal colonies with pink or light red centre after 48 h. Similar growth character of the bacterium on TZC medium were observed by other workers also (Swanepoel and Young, 1988; Prior and Steva, 1990).

Samuel (1980), while studying the growth of ginger isolate of P. solanacearum on different soild media observed maximum growth on Peptone Casamino Acid medium and Nutrient Agar and minimum growth on basal medium for Xanthamonads. Khan et al. (1979) studied and described the growth characters of the isolates of the

bacterial wilt pathogen from chilli, brinjal, potato and tomato on different media. Nayar (1982) evaluated growth of P. solanacearum on different solid media and found that bacterial wilt pathogen of brinjal produced excellent growth, slime and fluidity on Peptone Beef extract Agar.

Vaughan (1944) observed excellent growth of P. solanacearum in culture between pH 6 and 8.5. According to Kelman (1953) the optimum pH requirement of P. solanacearum was 6.6 to 6.7. Hingorani et al. (1956) recorded excellent growth of the bacterium between pH 6 and 8.5. Devi (1978) found that the isolate of P. solanacearum from different solanaceous crops favour a pH range of 5.5 to 7. Nayar (1982) noticed maximum growth of isolates of bacterial wilt pathogen of brinjal at pH 7.0 and no growth at pH 5 and 9.5.

Smith (1896) opined that a temperature range of 35 to 37°C was most favourable for growth of P. solanacearum in culture. Kelman (1953) stated that a relatively high temperature was required for the rapid growth of P. solanacearum. Devi (1978) found that the bacterial wilt pathogen from different host plants including chilli, brinjal and tomato preferred a temperature range of 30 and 35°C. Quimio and Tabei (1979) observed that, 61 isolates of the bacterium from five crops had varying temperature optima ranging from 31 to 36.5°C. Hayward (1979) reported that in Australia, race 1 isolates (Biovar III and IV) prefered a temperature of 37°C. Nayar

(1982) observed that all brinjal isolates of the pathogen recorded maximum growth at 35°C and that no growth occured at 10° and above 50°C. The isolates also caused blackening and rotting of the potato slices.

The absence of pigment production by P. solanacearum either on Yeast Glucose Chalk Agar or King's medium had been reported by many workers (Smith, 1914; Hayward, 1964; El-Helaly et al., 1969; Devi, 1978; Nayar, 1982; Swanepoel and Young, 1988). But, according to Krieg and Holt (1984) some strain produce a diffusible pigment in complex media, the pigment had not been chemically identified.

The aerobic nature of P. solanacearum was well established by many workers (Smith, 1914; Labrousse, 1932; Moraes, 1947). However, Honing (1912) showed that under some circumstances the organism developed to a limited degree when not in contact with air. Kelman and Jensen (1951) also opined that it could grow anerobically. Buchanan and Gibbons (1974) stated that strains of P. solanacearum could grow under anaerobic condition in media containing nitrate and an appropriate carbon source. While studying the utilization of carbon sources by isolates of P. solanacearum Devi (1978) noticed both aerobic and anaerobic growth.

Hayward (1964) studied the characteristics of P. solanacearum and reported that on tyrosine medium a diffusible brown pigment

was produced the intensity of which might vary between isolates. He further observed that none of the isolates produced a green fluorescent pigment on King's medium. Catalase and oxidase were produced by the organism and citrate but not melonate was utilized as sole source of carbon. Nitrate reduction and ammonia production were positive. It did not hydrolyse soluble starch or produce indole. An alkaline reaction was produced in litmus milk and growth occurred in 0.5 and 1 per cent sodium chloride broth. Growth of the bacterium occurred at 37°C but not at 40°C and no or slight gelatin liquefaction took place on prolonged incubation. Similar characters with slight variations were observed by many workers while studying the biochemical and physiological characters of strains of P. solanacearum from tomato, brinjal, chilli or ginger (Rath and Addy, 1977; Devi, 1978; He et al., 1983; Psallidas, 1985; Swanepoel and Young, 1988; Prior and Steva, 1990). However, an acidic reaction of the isolates of the pathogen in milk were observed by Samuel (1980) and Nayar (1982). They also observed positive urease activity and levan production.

The existence of variation among the isolates of P. solanacearum had been well demonstrated (Smith, 1896; Kelman, 1954; Okabe and Goto, 1961; Buddenhagen and Kelman, 1964; Rath and Addy, 1977; Addy et al., 1980).

Khan et al. (1979) compared the morphological, cultural and physiological characters of chilli isolate of P. solanacearum

with those isolates from egg plant, potato and tomato. Of the various carbon sources tested, glutamic acid served as an excellent source of carbon for chilli isolate. Ammonium oxalate as a nitrogen source, was utilized by brinjal isolate while, potassium and sodium nitrate were preferred by brinjal and tomato isolate but not by potato and chilli isolate. The isolates varied in their ability to withstand salt concentration and the brinjal isolate was relatively more tolerant. The isolates exhibited moderate to heavy slime production on Nutrient Agar slants. In nutrient broth, potato and brinjal isolates produced dark brown colour and chilli and tomato isolates produced light brown colour. On litmus milk only chilli isolate failed to produce any change in colour or coagulate casein. Chilli and tomato isolates produced dark brown melanin pigment whereas the other two isolates differed in this regard.

Starr and Weiss (1943) reported that P. solanacearum could utilize asparagine as a sole source of carbon and nitrogen. Palleroni and Duodoroff (1971) considered the inability to hydrolyse arginine as a negative nutritional character of P. solanacearum. Liberation of hydrogen sulphide and negative MR and VP tests by isolates of P. solanacearum was observed by many workers (Devi, 1978; He et al., 1983). Nayar (1982) noticed postive MR test and negative reaction for VP test and in the utilization of sodium citrate, with the isolates from brinjal.

A large number of carbon/organic compounds like glucose, ribose, fructose, sucrose, galactose, dextrose, lactose, maltose, mannose, xylose, trehalose, arabinose, cellobiose, mannitol, glycerol, dulcitol, sorbitol, inositol, dextrin, pectin and sodium acetate, were reported to be utilized by P. solanacearum with or without acid production (Dowson, 1957; Hayward, 1964; Devi, 1978; Samuel, 1980; Nayar, 1982; He et al., 1983; Psallidas, 1985; Lallmohamed et al., 1988; Swanepoel and Young, 1988; Prior and Steva, 1990).

Cross infectivity of isolates of P. solanacearum from different host plants were studied by many workers. Buddenhagen et al. (1962) have reported that P. solanacearum from many solanaceous plants like tobacco, tomato and brinjal were capable of cross infecting each other. Ishii and Hiryaki (1963) observed that ginger wilt pathogen was weakly virulent to tomato, chilli and eggplant. Quinon et al. (1964) showed that the Hawaiian ginger strain failed to bring about a wilt in tomato, tobacco and peanut, whereas the tomato isolate wilted tomato and peanut but not ginger and tobacco.

According to Lum (1973) the ginger isolate caused limited infection of tomato, tobacco and peanut whereas, tomato isolates caused typical wilting of tomato, tobacco, peanut as well as ginger. Devi (1978) observed that the chilli strain of P. solanacearum caused high degree of wilting in tomato and eggplant, and that

the brinjal and tomato isolates were capable of cross infecting each other. Samuel (1980) found that ginger isolate caused wilting in tomato, but tomato isolate failed to infect ginger. Ren and Fang (1981) reported that ginger strain is non pathogenic to tomato. Nayar (1982) showec that tomato and brinjal isolates were capable of cross infecting each other and that chilli and ginger isolate caused wilting of their respective hosts only. He et al. (1983) reported that ginger strain caused varying degree of wilting in tomato, eggplant and chilli and the chilli strain caused wilting in eggplant, tomato and chilli. One tomato strain and an eggplant strain caused wilting in tomato and eggplant and no wilting in chilli while, the other strain of tomato caused wilting in tomato, eggplant and chilli. Velupillai and Stall (1984) found that the strains of P. solanacearum from tomato, brinjal, potato and sunflower were all of race 1 and pathogenic to brinjal, chilli, potato and tomato. Some were pathogenic to sunflower and ginger but none affected groundnut. He (1985) observed that the ginger strain caused varying degree of wilting in tomato, eggplant, ginger and chilli. The chilli isolate however did not cause wilting on ginger, though highly virulent on tomato and eggplant. Tomato and eggplant isolates were capable of cross infecting each other, and these isolates caused no wilting on ginger. Prior and Steva (1990) showed that chilli isolate caused rapid wilting in tomato and eggplant. The tomato and eggplant isolates also caused wilting in chilli.

Several attempts have been made to group P. solanacearum isolate into biotypes, varieties or races on the basis of difference in physiological characteristics (Kelman, 1953; Harrison, 1961; Buddenhagen and Kelman, 1964; Hayward, 1964); pathogenecity (Kelman and Persoon, 1961; Buddenhagen et al., 1962); bacteriophage specificity (Hayward, 1964) and serological properties (Perez, 1962; Mortan et al., 1965).

Buddenhagen et al. (1962) differentiated strains of P. solanacearum into three races, race-1 affecting tobacco, tomato, many solanaceous and other weeds, and certain diploid bananas; race-2 affecting triploid bananas, heliconia or both; race-3 affecting potatoes and tomatoes, but highly virulent on other solanaceous crops. Later, two new races were proposed affecting ginger and mulberry from Philippines and China respectively (Buddenhagen, 1985). According to Persley et al. (1985) the bacterial wilt pathogen could be grouped into five races which differ in host ranges, geographic distribution and ability to survive under different environmental conditions,

1) Solanaceous strain (Race-1) : wide host range, distributed throughout the lowlands of tropics and subtropics;

2) Musaceous strain (Race-2) : restricted to Musa, and a few perennial hosts initially limited to American tropics, now spreading to Asia;

3) Potato strain (Race-3) : restricted to potato and a few alternative hosts in the tropics and subtropics;

4) Ginger strain (Race-4) : from the Philippines; and

5) Mulberry strain (Race-5) : from China

Hayward (1964) classified a collection of 185 isolates of P. solanacearum into 4 biotypes, based on the capacity to oxidise 3 disaccharides (lactose, maltose, cellobiose) and 3 hexose alcohols (mannitol, sorbitol, dulcitol); isolate of biotype-1 oxidized neither group; biotype-2 only disaccharides; biotype-3 both the groups and biotype-4 only hexose alcohols. Biotype-2 appeared to have a restricted host range and it was solely obtained from two host plants, potato and tomato whereas the other biotypes were obtained from many families in addition to Solanaceae.

It is well established that biovar III is the dominent strain of P. solanacearum affecting solanaceous crops and ginger (Hayward, 1964; Hayward et al., 1967; Tabei and Quimio, 1978; He et al., 1983; Prior and Steva, 1990). In Kerala, Devi (1978) compared twenty six different isolates of P. solanacearum from tomato, brinjal and chillies and grouped them into 12 pathogroups under race 1 and biotype III. Samuel (1980) and Nayar (1982) characterized isolates of bacterial wilt pathogen of ginger and brinjal respectively and reported that they belong to biotype III of P. solanacearum.

2.2. Screening for host resistance

Control of the bacterial wilt by exclusion of pathogen, eradication of the organism by soil treatments or prevention of infection

have proven to be impractical, ineffective or restricted in application. The most effective means of control for this organism is the development of resistant varieties (Kelman, 1953).

Empig et al. (1962) screened 11 varieties and 2 strains of pepper for bacterial wilt resistance and found that 'Pasites', 'All Big' and 'World Wonder' gave lowest disease index. Rahim and Samraj (1974) screened nine chilli varieties for resistance against P. solanacearum and found that the variety 'Khandari' was highly resistant, while 'Chinese giant' was highly susceptible. The varieties 'Pungent pride', 'Cherry red', 'Vattal', 'Dark purple' and 'Long red' were found to be moderately resistant.

Rathiah (1983) studied the reaction of Capsicum cultivar to fruit rot, bacterial wilt and Cercospora leaf spot of chilli and found that the variety 'Suryamukhi' was tolerent to all diseases and gave highest mean yield compared with 'Cluster'. G5 and G4 were most susceptible. Goth et al. (1983) reported that 'KAU Cluster' was resistant to four race 1 isolates and one race 3 isolate of P. solanacearum. Peter et al. (1984) evaluated four hot chillies, 'Pant C-1', 'KAU Cluster', 'White Khandari' and 'C[illegible]' along with US cultivars 'Yolo Wonder Improved', 'Hybrid pepper Bell Boy', 'Sweet Red Cherry Pickling', 'California Wonder', '672 Hungarian Wax' and 'Cabanelle 78 2860' for reaction to nine isolates of P. solanacearum (race 1 and race 3) and found that Pant C-1 was most resistant one.

Thomas (1985) observed that the line 'KAU Cluster' was resistant to bacterial wilt. Valdez (1985) had screened 21 accessions of pepper for resistance against bacterial wilt and found that only three varieties were resistant to both biovar III and IV. Girijadevi and Peter (1987) reported that 'KAU Cluster' was resistant to bacterial wilt during two seasons tested. They found that resistance to bacterial wilt is recessively inherited and that the F_1 hybrid Yolo Wonder Improved x KAU Cluster to be a promising one.

Jimenez et al. (1988) found that when 4 cultivars of sweet pepper were inoculated with P. solanacearum, 'Cholo' was most resistant compared with traditional cultivars, 'Agronomico 10' and 'Tacares PL'. '17245' was fairly resistant.

A study done at Vellanikkara revealed that Capsicum annum accessions CA 33 (KAU Cluster) and CA 219 were resistant to bacterial wilt disease (KAU, 1988). Gopalakrishnan and Thomas (1989) after conducting studies on resistance to bacterial wilt (P. solanacearum) and inheritance of clusterness in chilli reported that the accession, CA 33 which was further improved to the status of a variety 'Manjari' was resistant to bacterial wilt disease. Matos et al. (1990) evaluated fifty genotypes of Capsicum sp. and found that C. annum genotype NPH-143 (MC-4), NPH-144 (MC-5) and NPH-145 (MC-10) were highly resistant. A further 6 genotypes were rated as resistant and remainder as susceptible.

The weather and soil conditions influence the seasonal development and geographic distribution of plant disease. A high temperature of 28 to 36°C and high soil moisture favour rapid development of wilt diseases (Vaughan, 1944; Gallegely and Walker, 1949; Hingorani et al., 1956). Krausz and Thurston (1975) found that an elevated temperature of 32°C in environmental control chamber significantly increased severity of bacterial wilt in two tomato lines resistant to P. solanacearum. Studies by Mew and Ho (1977) on resistance of P. solanacearum in six cultivars of tomato as influenced by changes in soil temperature revealed that VC-48 maintained moderate resistance at 26, 30, 32°C. Hiryati et al. (1983) had observed that severity of diseases caused by P. solanacearum significantly increased with increased soil moisture from slightly above wilting point to slight below saturation point for each soil type tested. Akiew (1985) found that population of P. solanacearum decreased sharply with increase in temperature and with decrease in soil moisture. Ho (1988) reported that high rainfall especially towards middle end of growing season favoured high bacterial wilt disease incidence in tomato.

2.3 Management of the disease

2.3.1 In vitro sensitivity to chemicals

Attempts have been made by many scientists to test the in vitro sensitivity of P. solanacearum to plant protection chemicals. Moorgan and Goodman (1955) reported that low concentration of

Aureomycin and Terramycin effectively inhibited the pathogen. Hidaka and Murano (1956) found that Streptomycin at 0.3 µg per ml of water inhibited and 5 µg per ml killed the pathogen at once. Abo-El-Dahab (1957) observed that the different strains of P. solanacearum varied in response to chloramphenicol but were most tolerent to Neomycin. Foucart and Del-cambe (1960) tested various chemicals in in vitro and found that Actinomycin and Chloromycetin gave promising results in inhibiting the pathogen. Campacci et al. (1962) reported that among various chemicals tested the bacterium was most sensitive to Agristep, Streptomycin, Penicillin-G-potassic, Penicillin procain, Dihydro streptomycin sulphate and Erythromycin. Streptocycline was found to give good control of P. solanacearum in vitro (Chakravarti and Rangarajan, 1966). The inhibitory effects of Streptomycin and Streptocycline on Pseudomonas and Xanthomonas have been observed by many workers (Rangaswami, 1957; Desai et al., 1967; Dath and Devadath, 1969; Rangarajan and Chakravarti, 1969; Shivappashetty and Rangaswami, 1971). Several antibiotics like Ampicillin, Chloramphenicol, Kanamycin, Oxytetracylcine, Tetracycline, Penicillin-G, Streptomycin were reported to inhibit the pathogen (Goorani et al., 1978). Mondal and Mukherjee (1978) observed that Ampicillin, Streptomycin and Novobiocin at 500 ppm each were of promise against the pathogen in vitro. The in vitro effectiveness of Ambistryn-S and Agrimycin-100 against the ginger isolate of P. solanacearum was noticed by Samuel (1980). Nayar

(1982) found that Chloromycetin and Terramycin was most effective in inhibiting bacterial wilt pathogen of brinjal. He et al. (1983) reported that all the strains of P. solanacearum from China showed susceptibility to Streptomycin, but were resistant to Penicillin, Viomycin and Chloramphenicol. Farag et al. (1986) also observed that both virulent and avirulent forms of the pathogen were sensitive to Streptomycin and Dihydrostreptomycin. Gunawan (1989) found that optimum concentration for suppression of bacterial multiplication in vitro were 175 and 450 ppm of Streptomycin sulphate. Prior and Steva (1990) studied the sensitivity of some reference strains of P. solanacearum from French West Indies to selected antibiotics and found that chilli isolate showed varied sensitivity to Penicillin-G, Ampicillin, Erythromycin, Chloramphenicol and Rifampicin.

There are only few reports to show the in vitro sensitivity of P. solanacearum to fungicides. Goorani et al. (1978) reported that Nabam (Dithane A-40), Maneb (Dithane M-22). Dithane M-45 inhibited the pathogen. Leandro and Zak (1983) reported that Captan, Maneb, Mancozeb and Thiram at 1000 and 10000 ppm affected P. solanacearum in in vitro. The effectiveness of Bordeaux mixture, Copper oxychloride and Kocide in controlling bacterial blight of walnut was recorded by Severin and Kupferberg (1977). Grinepadeze et al. (1978) conducted in vitro trials with 21 fungicides against the bacterial disease of mulberry caused by P mori and reported that Chinosol, Zineb and Polychomphenthiuram showed high inhibitory activity.

2.3.2 Field management of the disease

Smith and Clayton (1943) found that increased levels of nitrogen reduced the incidence of wilt disease of tomato, potato, eggplant, chillies, castor, beans and petunia. The effect of antibiotics on the control of bacterial diseases of citrus, plum, pear, rice, beans, potatos, chillies, bhindi and tomato has been reported by early workers (Brown and Heep, 1946; Zaumeyer et al., 1953; Ark, 1955; Rangaswami et al., 1959; Desai et al., 1967). Rahim (1972) and George (1973) obtained excellent field control of bacterial wilt of chillies by spraying the foliage with Streptomycin and Streptocycline or by soil drenching with Cheshunt compound.

Dutta and Verma (1969) showed that seedling treatment with Streptocycline at one gram in 40 litres of water for 30 minutes was better than soil drenching or soil drenching and foliar spray combined.

Jayaprakash (1977) observed a reduction in percentage of wilted plants in pots amended with oil cakes, sawdust, cashew shell powder, coconut pith, oil palm seed waste and various crop residues. He found that a combination of soil amendment with organic material combined with chemical treatment as foliar spray of antibiotic was most effective method of control. Devi (1978) studied the effect of various treatments for control of bacterial wilt of tomato and found that soil amendments and antibiotic sprays had significant influence on incidence of disease. But none of the

treatments was found to be absolutely effective in checking the disease and the comparatively effective treatments was sawdust and urea plus Agrimycin-100 spray. Mishra (1980) evaluated a systemic fungicide Bavistin in controlling Hoogly wilt of Jute caused by a complex of Macrophomina phaseolina, P. solanacearum and Fusarium solani and reported that best control was given by 0.1% Bavistin. Kishun (1981) reported that soil application of bleaching powder is effective against bacterial wilt of tomato.

Sitaramaiah and Sinha (1983) evaluated five antibiotics in in vivo against bacterial wilt of brinjal and found that Penicillin and Agrimycin-100 were consistantly superior over other antibiotics against the pathogen. Foliar application of Agrimycin-100, Chloramphenicol and Streptomycin sulphate a day prior to bacterial inoculation were effective at high concentration, while Penicillin and Tetracycline did not inhibit the wilt bacterium at any of the concentrations tested. Murakoshi and Takahashi (1984) reported that 'Saroton G' (containing well rotten fowl dropping, zeolite and blended with useful gram negative facculatively anaerobic bacteria) was effective for control of disease in tomato when mixed in soil after fumigation. Clairon (1984) recommends liming with Calcium oxide @ 1 t/ha or Calcium carbonate @ 10 t/ha one month before urea application for reducing bacterial wilt of eggplant. Ojha et al. (1986) reported that complete control of bacterial wilt

of ginger was obtained by rhizome treatment with Emisan 6 + Plantomycin for 30 minutes followed by 3 sprayings. Bazzi and Calzolari (1986) found that industrial Bordeaux mixture and Copper oxychloride was more effective than Copper hydroxide and Kasugamycin for control of bacterial rot of lettuce caused by P. cichorii. Gunawan (1988) studied the effect of spraying intervals of Streptomycin sulphate/Oxytetracycline on bacterial wilt of tomato and found that spraying at four and seven days intervals gave highest control of P. solanacearum.

Ho (1988) reported that bleaching powder and Jeypine was most effective than other chemical tested in reducing the incidence of P. solanacearum in tomato. Kishun and Chand (1988) observed that application of bleaching powder @ 15 kg/ha was effective against bacterial wilt of tomato.

Materials and Methods

MATERIALS AND METHODS

3.1 Isolation of the pathogen

Chilli plants showing the initial symptoms of bacterial wilt disease were collected from different locations. The plants thus collected were subjected to ooze test and plant parts with profuse bacterial ooze were selected for isolation. They were cut into bits and surface sterilized with 0.1 per cent mercuric chloride solution for one minute and then washed in three changes of sterile distilled water. These bits were then placed on a sterilized glass slide in a drop of sterile distilled water and teased apart to obtain a bacterial suspension. The suspension was streaked on Triphenyl Tetrazolium Chloride Agar medium (TZC) to get well isolated colonies of the bacteria (Kelman, 1954).

Composition of Triphenyl Tetrazolium Chloride Agar (TZC) medium (Kelman, 1954)

Peptone	- 10.0 g
Casamino acid	- 1.0 g
Glucose	- 5.0 g
Agar agar	- 20.0 g
Distilled water	- 1000 ml
pH	- 6.8

The inoculated plates were incubated for 48 h at room temperature. Characteristic light pink centred slimy fluidal colonies were selected and were purified by repeated streaks on TZC medium. Altogether five chilli isolates of Pseudomonas solanacearum were selected. In addition to the chilli isolates, two isolates of P. solanacearum, each from brinjal and tomato and one from ginger were also used in this study The details of the isolates of the bacterium are furnished below.

Sl. No.	Isolates	Locality from which the diseased specimen was collected	Crop from which isolation was made	Year of isolation
1	2	3	4	5
1	C-1	Vegetable research plot, College of Horticulture, Vellanikkara	Chilli	1989
2	C-2	Vegetable plot, A.R.S., Mannuthy	Chilli	1989
3	C-3	Vegetable nursery, College of Horticulture, Vellanikkara	Chilli	1989
4	C-4	Instructional farm, College of Agriculture, Vellayani	Chilli	1989
5	C-5	Vegetable research plot, College of Horticulture, Vellanikkara	Chilli	1989
6	B-1	Vegetable plot, A.R.S., Mannuthy	Brinjal	1989
7	B-2	Vegetable research plot, College of Horticulture, Vellanikkara	Brinjal	1989
8	T-1	U.A.S., Bangalore	Tomato	1989
9	T-2	Vegetable research plot, College of Horticulture, Vellanikkara	Tomato	1989
10	G-1	Ginger experimental plot, R.A.R.S., Ambalavayal	Ginger	1989

3.1.2 Pathogenicity tests on the respective hosts

Pathogenicity of the different isolates of the bacterium on their respective hosts was proved by inoculating a thick suspension of 48 h old culture grown on Potato Dextrose Agar. The suspension of the isolates of the bacterium were prepared in sterile distilled water. Vigorously growing young respective host plants were inoculated by stem puncture method (Winstead and Kelman, 1952). The plants were inoculated by placing a drop of bacterial suspension on the leaf axil of the third expanded leaf below the stem tip and forcing a sharp needle into the vascular bundle. Cotton dipped in the bacterial suspension was placed on the injured portion. The inoculated plants were kept inside polythene cages for 48 h and watered regularly to maintain high humidity. The pathogen was re-isolated from the artificially inoculated host plants by the method already described. Morphological characters of the re-isolated colonies of the isolates were compared with that of the original isolates to ensure their identity. Stock cultures were maintained at room temperature as well as at 10°C by storing two or three loopful of the isolated bacteria in 5 ml of sterile distilled water in test tubes. Similarly, stock cultures were also maintained in Potato Dextrose Agar slants both at room temperature as well as in refrigerated condition. Cultures were tested periodically for virulence and purity by streaking on TZC medium.

3.2 Characterization of the pathogen

Characterization of the different isolates of the pathogen was done according to the methods recommended in the 'Mannual of Microbiological Methods', published by the Society of American Bacteriologists (1957) and 'Laboratory Methods in Microbiology' (Harrigan and Mc Cance, 1966).

3.2.1 Cultural characters

3.2.1.1 Morphology

The colony morphology of different isolates of the bacterium was studied from 24-48 h old culture of the bacterium grown on Peptone Casamino Acid medium. The gram reaction of the isolates of the bacterium was studied using Hucker's modified method of gram staining (Hucker and Conn, 1923).

3.2.1.2 Growth of the different isolates of the bacterium on TZC medium

The isolates were compared for their colony growth, colour, shape, type of margin, consistency, extent of growth, slime production and fluidity on TZC medium. A loopful of dilute suspension of the isolates of the bacterium prepared in sterile distilled water was streaked on the TZC medium in petridishes. Three replications were maintained and they were incubated at room temperature. Observations were taken after 24, 48, 72 and 96 h of incubation.

3.2.1.3 Growth of the bacterium (Isolate C-1) on different solid media

Nature of growth, colour, size, shape, type of margin, slime production and fluidity of the bacterial colonies of the chilli isolate C-1 were studied on six solid media. The solid media used and their compositions are as follows.

a) Peptone Casamino Acid medium

Peptone	- 10.0 g
Casamino acid	- 1.0 g
Glucose	- 5.0 g
Agar agar	- 20.0 g
Distilled water	- 1000 ml
pH	- 6.8

b) TZC medium (Kelman, 1954)

c) Potato Dextrose Agar medium

Potato	- 200.0 g
Dextrose	- 20.0 g
Agar agar	- 20.0 g
Distilled water	- 1000 ml
pH	- 6.8

d) Nutrient Agar medium

Peptone	- 10.0 g
Beef extract	- 5.0 g

Agar agar	- 20.0 g
Distilled water	- 1000 ml
pH	- 6.8

e) Peptone Beef extract medium

Peptone	- 10.0 g
Beef extract	- 5.0 g
Sucrose	- 50.0 g
Agar agar	- 20.0 g
Distilled water	- 1000 ml
pH	- 7.0

f) Yeast Glucose Chalk Agar

Yeast extract	- 10.0 g
Glucose	- 10.0 g
Chalk ($CaCO_3$)	- 20.0 g
Agar agar	- 20.0 g
Distilled water	- 1000 ml
pH	- 7.2

A loopful of the dilute suspension of the bacterial isolate was streaked on different media and incubated. Observations were taken after 24, 48, 72 and 96 h of incubation.

3.2.1.4 Growth of the isolates of the bacterium at different pH levels

Nutrient broth with varying pH viz., 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9 and 9.5 was used for the study. The isolates were

inoculated in the broths adjusted to above mentioned pH levels. The growth of each isolates was measured after 48 h using a Bausch and Lomb 'Spectronic 20' colorimeter adjusted to a wave length of 660 nm. Uninoculated broth served as control.

3.2.1.5 Growth of the isolates of the bacterium at different temperatures

Growth of the bacterial isolates was studied at varying temperatures of 10, 15, 20, 25, 30, 35, 40, 45, 50 and 55°C. A loopful each of the 24 h old bacterial culture was inoculated into the Nutrient broth and incubated at different temperatures mentioned above. The growth of each isolates was measured after 48 h using a Bausch and Lomb 'Spectronic 20' colorimeter adjusted to a wave length of 660 nm.

3.2.1.6 Potato soft rot test

Lelliott's method (Lelliott et al., 1966), was employed for the test. 7.8 mm thick slices of washed, peeled and alcohol flamed potato tubers were placed in sterile petri plates. The surface of slices were immediately covered with sterile distilled water, till the slices are half immersed. A loopful of 48 h old growth of the bacterial isolates was placed in a nitch made at centre of each slice. The slices were watched for rotting. Uninoculated slices served as control.

3.2.1.7 Pigment production

Production of water insoluble pigment by the different isolates was tested after incubation for 48 h on Yeast Glucose Chalk Agar medium.

The production of the water soluble pigment was studied on King's medium (King et al., 1954).

Composition of the medium

Peptone	- 20.0 g
Glycerine	- 10 ml
K_2HPO_4	- 1.5 g
$MgSO_4.7H_2O$	- 1.5 g
Agar agar	- 20.0 g
Distilled water	- 1000 ml
pH	- 7.2

The isolates were spot inoculated on the medium in petri plates, incubated for 48 h and examined for pigmentation around the colonies.

3.2.1.8 Oxygen requirements

Nutrient Dextrose Agar (containing 0.05 per cent Bromocresol purple) columns in test tubes were inoculated in duplicates by stabbing with different isolates of the bacterium using a straight inoculation needle. The agar surface of one set of the tubes was covered with sterile liquid paraffin to a depth of 1 cm. The tubes were incubated and observations were recorded.

3.2.2 Physiological characters

3.2.2.1 Starch hydrolysis

The ability of the isolates to hydrolyse starch was tested using starch medium containing 0.2 per cent soluble starch.

Composition of the medium

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

The isolates of the bacterium were spot inoculated on the medium poured in petri dishes. After four days of incubation, starch hydrolysis was tested by pouring Lugol's iodine solution on the agar surface and allowing to act for few minutes. A colourless or reddish brown zone around the bacterial growth in contrast to the blue background of the medium indicated positive test for starch hydrolysis.

3.2.2.2 Tyrosinase activity

Dye's medium (Dye, 1962) was employed for the test.

Composition of the medium

$NH_4H_2PO_4$	- 0.5 g
K_2HPO_4	- 0.5 g

$MgSO_4.7H_2O$	- 0.2 g
NaCl	- 5.0 g
Yeast extract	- 5.0 g
Tyrosine	- 0.5 g
Agar agar	- 20.0 g
Distilled water	- 1000 ml
pH	- 7.0

The medium was dispensed in test tubes, autoclaved and slants were prepared. The slants were then inoculated with different isolates of the bacterium and incubated for 48-72 h. Browning of the medium indicated tyrosinase activity.

3.2.2.3 Production of indole

Tryptophan broth was used for the test.

Composition of the medium

Casein digest or tryptophan	- 10.0 g
NaCl	- 5.0 g
Distilled water	- 1000 ml
pH	- 7.0

The medium was dispensed in tubes and autoclaved. Whatman No.1 filter paper strips (5 x 50mm) were soaked in warm saturated solution of oxalic acid and cooled. When the strips got covered with oxalic acid crystals, they were dried at room temperature and used without sterilization. The test cultures were inoculated in the broth and oxalic acid strips were inserted into the tubes

by the side of the plug and suspended over the broth. They were incubated and observed for 14 days. Change in colour of the oxalic acid crystals on test strips to pink or red indicated production of indole.

3.2.2.4 Production of hydrogen sulphide

The ability of different isolates to liberate hydrogen sulphide was tested using Peptone water medium containing one per cent Casamino acid. Five ml of the medium was dispensed in test tubes and autoclaved. Whatman No.1 filter paper, cut into strips of 5 x 50 mm size, were soaked in warm saturated solution of lead acetate, dried, autoclaved and again dried at 60°C. The tubes were inoculated with different isolates of the bacterium and the indicator strips were inserted aseptically between the plug and the tube, with the lower end of the strip just above the broth. The tubes were incubated at room temperature and observations were recorded at regular intervals for a period of 14 days. Blackening of the strips indicated liberation of hydrogen sulphide.

Composition of the medium

Peptone	- 10.0 g
NaCl	- 5.0 g
Casamino acid	- 10.0 g
Distilled water	- 1000 ml
pH	- 7.0

3.2.2.5 Nitrate reduction test

Nitrate broth medium was used for the test

Composition of the medium

KNO_3 (Nitrite free)	- 1.0 g
Peptone	- 10.0 g
Beef extract	- 5.0 g
Distilled water	- 1000 ml
pH	- 7.0

The medium was dispensed in tubes, autoclaved inoculated with different isolates of bacterium, incubated, and tested for the reduction of nitrate at regular intervals upto 15 days. The tests was performed by adding few drops of Griess Ilosvay's reagent consisting of sulphanilic acid (0.8 per cent in five molar acetic acid) and dimethyl-alpha-naphthyl amine (0.5 per cent in five molar acetic acid) to the nitrate broth culture. If no pink or red colour developed, it indicated that nitrate was present as such or reduced to ammonia and free nitrogen. Few zinc crystals were added to ensure whether the negative reaction was due to the reduction of nitrate beyond the nitrite level. If the broth became pink or red it indicated that the nitrate was present without reduction.

3.2.2.6 Action on milk

Action of the different isolates of the bacterium on milk was studied in bromocresol purple milk. A 1:3 dilution of skimmed

milk was prepared in water and bromocresol purple was added to give a final concentration of 0.002 per cent, when a light blue colour was obtained (Clark and Lubs, 1917). The milk medium was then dispensed in 5 ml aliquots in test tubes and sterilized by steaming for thirty minutes for three successive days. The medium was inoculated with 48 h old culture of the isolates of the pathogen, incubated and observations recorded at regular intervals for 30 days. The milk change from light blue to yellow colour in acidic reaction and to violet in alkaline reaction. Curdling was indicated by heterogenous clumps formed due to precipitation of casein, and peptonization was indicated by clearing of milk slowly.

3.2.2.7 Production of ammonia

Peptone water medium was used for this test.

Composition of the medium

Peptone	- 10.0 g
Distilled water	- 1000 ml
pH	- 7.0

The isolates of the bacterium were inoculated in water containing peptone and incubated for 48 h. The accumulation of ammonia was detected by using Nessler's reagent which gave a brown to yellow precipitate with ammonia.

3.2.2.8 Gelatin liquefaction

Gelatin 0.4 per cent was added to Nutrient Agar and sterilized by autoclaving. The isolates of the bacterium were spot inoculated in the medium in petri dishes and incubated. After 48-72 h, the agar surface was flooded with 0.2 per cent mercuric chloride solution in dilute hydrochloric acid (20 per cent) and allowed to act for few minutes, to precipitate the gelatin in the medium (Smith et al., 1946). A clear zone surrounding the bacterial growth indicated positive gelatin utilization.

3.2.2.9 Catalase test

To detect the production of catalase by the bacterium, a loopful of 24 h old culture of different isolates was smeared on the glass slide and covered with few drops of 20 volume hydrogen peroxide. Production of gas bubbles was an indication of catalase positive reaction.

3.2.2.10 Arginine hydrolase test

Thornley's medium was used for the study (Thornley, 1960). Composition of the medium

Peptone	- 1.0 g
K_2HPO_4	- 0.3 g
NaCl	- 5.0 g
Agar agar	- 3.0 g
Phenol red	- 0.01 g

L arginine monochloride	- 10.0 g
Distilled water	- 1000 ml
pH	- 7.2

Five ml aliquots, each of the semi solid medium was dispensed in test tubes, autoclaved, cooled and stab inoculated with test isolates. The surface of the medium was sealed with sterile liquid paraffin to a depth of 1 cm. The tubes were incubated and observations recorded for seven days at regular intervals. A change in the colour of the medium to red indicated arginine hydrolase activity.

3.2.2.11 Urease test

Christensen's Urea Agar (Christensen, 1946) was employed for this test.

Composition of the medium

Peptone	- 1.0 g
NaCl	- 5.0 g
KH_2PO_4	- 2.0 g
Glucose	- 1.0 g
Phenol red (0.2%)	- 6.0 ml
Agar agar	- 20.0 g
Distilled water	- 1000 ml
pH	- 6.8

Ninety ml aliquotes of the medium was dispensed in 250 ml flasks and autoclaved. To each flask 10 ml of 20 per cent urea solution (sterilized by filteration) was added and dispensed in sterilized test tubes in 5 ml quantities and slants were prepared. The slants were inoculated with different isolates of the bacterium and observations recorded for 15 days at regular intervals. Urease production was indicated by the change in colour of the medium from yellow to pink or red.

3.2.2.12 MR and VP tests

Methyl red broth was used for both the tests.

Composition of the medium

Proteose peptone	- 5.0 g
Glucose	- 5.0 g
K_2HPO_4	- 5.0 g
Distilled water	- 1000 ml
pH	- 7.0

Five ml quantities of the medium were dispensed in tubes and sterilized by steaming for 30 minutes for three successive days. Two sets of tubes were inoculated with 48 h old cultures of the isolates for MR and VP test respectively. The tubes were incubated for seven days. For MR test, few drops of 0.02 per cent Methyl red in 50 per cent alcohol was added to culture tubes. A distinct red colour indicated positive Methyl red reaction.

For VP test, 0.6 ml of alpha naphthol solution (5 per cent in 95 per cent alcohol) and 0.2 ml of 40 per cent aqueous solution of KOH were added to 1 ml of the culture. The mixture was shaken for few minutes and allowed to stand for 2 h. A crimson or ruby colour indicated positive VP test.

3.2.2.13 Utilization of asparagine as sole source of carbon and nitrogen

The test was performed using Dye's medium (Dye, 1966).

Composition of the medium

Solution 1 : K_2HPO_4 - 8.0 g; KH_2PO_4 - 2.0 g
Distilled water - 100 ml

Solution 2 : $MgSO_4.7H_2O$ - 2.0 g; $FeSO_4$ - 0.5 g
NaCl - 1.0 g; $MnSO_4$ - 0.02 g;
H_2SO_4 - 1 drop; Distilled water - 100 ml

Solution 3 : Na_2MoO_4 - 0.02 g
Distilled water - 100 ml

Solution 4 : $CuSO_4$ saturated solution in distilled water

Ten ml of each solution was mixed in the order of 3, 4, 2 and 1, filtered, and then added to 960 ml of distilled water. The medium was dispensed in 5 ml quantities in tubes and autoclaved. The different isolates of the bacterium were inoculated into the tubes, incubated and examined for growth. Growth of the bacterium in the medium indicated the utilization of asparagine.

3.2.2.14 Production of levan

Peptone Beef extract medium containing 5 per cent sucrose was used for the test.

Composition of the medium

Peptone	- 10.0 g
Beef extract	- 5.0 g
Sucrose	- 50.0 g
Agar agar	- 20.0 g
Distilled water	- 1000 ml

pH - 7.0

Dilute suspension of the bacterial isolates were streaked over the medium in petri dishes and incubated for 48 h. Presence of large, white, domed and mucoid colonies on medium characterized the production of leven.

3.2.2.15 Utilization of organic acids

Hayward's semisolid medium (Hayward, 1964) was used for the test.

Composition of the medium

Peptone	- 1.0 g
$NH_4H_2PO_4$	- 1.0 g
KCl	- 0.2 g
$MgSO_4.7H_2O$	- 0.2 g

Bromothymol blue	- 0.03 g
Agar agar	- 3.0 g
Distilled water	- 1000 ml
pH	- 7.2

Sodium salts of three organic acids viz., sodium citrate, sodium acetate and sodium benzoate were added to the medium to obtain a concentration of one per cent. The medium was autoclaved and dispensed in test tubes. A loopful of each bacterial isolate was inoculated into the medium and observations were recorded at regular intervals for a period of one month.

3.2.2.16 Utilization of carbon compounds

Twelve carbon compounds viz., glucose, fructose, dextrose, ribose, galactose, maltose, sucrose, lactose, cellulose, mannitol, glycerol and dulcitol were tested individually for the utilization by the isolates of the bacterium. Hayward's semisolid medium was used as the basal medium. An aliquot of 90 ml of each of the basal medium was dispensed in 250 ml conical flask and autoclaved. 10 per cent solution of the carbon compounds were prepared in distilled water and steam sterilized. 1 ml each of the sterilized solution was added to 90 ml aliquots of the melted medium and dispensed in sterilized test tubes to a depth of 4 cm. The medium was inoculated with different isolates. In one set of tubes containing the carbon compounds, the agar surface was covered with sterile

liquid paraffin to a depth of 1 cm. The inoculated tubes were incubated and observations recorded at regular intervals upto a period of one month. Change in colour of the medium to yellow indicated positive utilization of the carbon compounds with acid production.

3.2.2.17 Cross inoculation studies

For cross inoculation studies, bacterial ooze was collected from chilli, brinjal, tomato and ginger in sterile distilled water. The bacterial ooze collected from all these plants were cross inoculated on all the plants using the method suggested by Winstead and Kelman (1952). The identity of the bacterial pathogen from the ooze collected from different host plants was confirmed by streaking the ooze on TZC medium.

3.3 Screening of chilli accessions/varieties against bacterial wilt disease

Twenty nine accessions/varieties of chillies obtained from the Department of Olericulture, College of Horticulture were evaluated for their relative resistance/tolerence to bacterial wilt. The experiment was conducted during August-October 1990 in a wilt sick field. The experiment was laid out in Randomized Block Design with 3 replications. The following accessions/varieties were used for the experiment.

Sl. No.	Accession No.	Accession/variety	Place of collection
1	CA 375	NBPGR 469	NBPGR, Vellanikkara
2	CA 217	Local	College of Horticulture, Vellanikkara
3	CA 452	Jwalasakhi	College of Agriculture, Vellayani
4	CA 515	Phule 7	Mahatma Phule Krishi Viswa Vidyalaya
5	CA 222	Green Chuna	Mannuthy, Thrissur
6	CA 417	NBPGR-319	NBPGR, Vellanikkara
7	CA 205	Local	Puthur, Thrissur
8	CA 379	NBPGR-186	NBPGR, Vellanikkara
9	CA 53	Pant C-1	GBPUAT, Pant Nagar
10	CA 337	Punjab lal	P.A.U., Ludhiana
11	CA 418	NBPGR-322	NBPGR, Vellanikkara
12	CA 451	Jwalamukhi	College of Agriculture, Vellayani
13	CA 192	Jawahar-218	College of Horticulture, Vellanikkara
14	CA 3	White Khandari	Mannuthy, Thrissur
15	CA 389	NBPGR-215	NBPGR, Vellanikkara
16	CA 449	NBPGR-157-C-3-15	NBPGR, Vellanikkara
17	CA 209	Local	Puthur, Thrissur
18	CA 356	NBPGR-130-A leniar	NBPGR, Vellanikkara
19	CA 213	Local	Puthur, Thrissur
20	CA 207	Local	Puthur, Thrissur
21	CA 33	Manjari/KAU Cluster	College of Horticulture, Vellanikkara
22	CA 225	Local	Edappally, Cochin
23	CA 409	NBPGR-289	NBPGR, Vellanikkara
24	CA 372	NBPGR-419	NBPGR, Vellanikkara

Sl. No.	Accession No.	Accession/variety	Place of collection
25	CA 367	NBPGR-36-A-Conical	NBPGR, Vellanikkara
26	CA 388	Local	College of Horticulture, Vellanikkara
27	CA 408	NBPGR-288	NBPGR, Vellanikkara
28	CA 345	Local	College of Horticulture, Vellanikkara
29	CA 160	Local	Edappally, Cochin

Thirty days old chilli seedlings were transplanted in the main field. Before transplanting the field was prepared by incorporating cowdung at the rate of 20-25 t/ha. The seedlings were planted on ridges with a spacing of 45 x 45 cm. The fertilizers were given as per the Package of Practice recommendation (Kerala Agricultural University, 1989).

Wilt incidence was recorded at weekly intervals starting from two weeks after transplanting for a period of eleven weeks and the final wilt percentage of each accession/variety was calculated. The wilted plants were subjected to ooze test to confirm the association of the pathogen with the wilt. The severity of wilt incidence were scored according to Mew and Ho (1976).

R - Resistant - below 20 per cent plants wilted

MR - Moderately resistant - more than 20 - below 40 per cent plants wilted

MS - Moderately susceptible - more than 40 - below 60 per cent plants wilted

S - Susceptible - more than 60 per cent plants wilted

Meteriological data viz., maximum and minimum atmospheric temperature, soil temperatures at 7 AM and 2 PM, atmospheric humidity, rainfall, number of rainy days, and soil moisture were recorded during the experimental period. A correlation coefficient was worked out between the meteriological data and the wilt incidence for each accession/variety.

3.4 Preliminary evaluation of chilli accessions of NBPGR - Regional Station, Vellanikkara for host resistance against bacterial wilt disease

A total of 721 chilli accessions maintained at the National Bureau of Plant Genetic Resource, Regional Station, Vellanikkara were evaluated for their resistance/tolerence reaction to bacterial wilt incidence. The evaluation was conducted during September-January 1990-91. Observations on the wilt incidence were recorded at weekly intervals after 45 days of transplanting.

3.5 Management of the disease

3.5.1 In vitro evaluation of plant protection chemicals against P. solanacearum

In vitro efficacy of common antibiotics and fungicides in inhibiting the growth of the bacterium was tested by the standard filter paper disc method. The details of the antibiotics and fungicides used and their concentration are given below.

Chemicals	Active ingredient	Concentrations
Streptocyline	Streptomycin sulphate 90% and Tetracycline hydrochloride 10%	250, 500, 750, 1000 ppm
Terramycin	Oxy tetracycline hydrochloride	250, 500, 750, 1000 ppm
Tetracycline	Tetracycline hydrochloride	250, 500, 750, 1000 ppm
Chloromycetin	Chloramphenicol	250, 500, 750, 1000 ppm
Ambistryn-S	Streptomycin sulphate	250, 500, 750, 1000 ppm
Dithane-M-45	Co-ordination product of Zinc ion + Maneb	1000, 2000, 3000, 4000 ppm
Thiride	Tetramethyl Thiuram disulphide	1000, 2000, 3000, 4000 ppm
Foltaf 80 WP	Cis-N-[(1,1,2,2-tetrachloro-ethyl) thio]-4 cyclohexene 1,2, dicarboximide	1000, 2000, 3000, 4000 ppm
Blue copper - 50WP	Copper oxychloride	1000, 2000, 3000, 4000 ppm
Bordeaux mixture	Copper sulphate + lime	0.5, 1, 1.5 and 2%

The isolate C-1 was used for the study. The differenct concentrations of the chemicals were prepared in sterile distilled water. Sterile filter paper discs of 10 mm diameter were dipped in the solution and placed over Peptone Beef extract Agar medium seeded with 48 h old cultures of the bacterium. Sterile filter paper discs dipped in sterile water served as control. The plates were incubated at room temperatures and observations were recorded after 48 h.

3.5.2 Field experiment on the management of bacterial wilt of chillies

A field experiment was conducted during March-June 1991, in a wilt sick field of College of Horticulture, Vellanikkara to find out a management practice to reduce the severity of the disease. The experiment was laid out in Split Plot Design with 5 major and 5 minor treatments. The details of the experiment are given below.

Design	- Split Plot
Variety	- Pant C-1
Main plot	- 5
Sub plot	- 5
Replications	- 3
Spacing	- 45 x 45 cm

Main plot treatments - 5

1) Dried and powdered cowdung
    a) 50 g/plant one month after transplanting
    b) 50g/plant at the time of flowering
2) Lime
    a) 25 g/plant one month after transplanting
    b) 25 g/plant at the time of flowering
3) Neem cake
    a) 25 g/plant one month after transplanting
    b) 25 g/plant at the time of flowering
4) Burning of soil-just before transplanting
5) Control

Sub plot treatments - 5

1) Antibiotic
(Streptocycline - 1000 ppm)

   a) Drenching one month after transplanting

2) Antibiotic
(Streptocycline - 1000 ppm)

   a) Drenching one month after transplanting
   b) Drenching at the time of flowering

3) Fungicide
(Bordeaux mixture - 1%)

   a) Drenching one month after transplanting

4) Fungicide
(Bordeaux mixture - 1%)

   a) Drenching one month after transplanting
   b) Drenching at the time of flowering

5) Control

These treatments were given over and above the Package of Practice Recommendations (Kerala Agricultural University, 1989). Wilt incidence was recorded at weekly intervals for 12 weeks.

3.6 Statistical analysis

Data relating to different experiments were analysed statistically following the method of Snedecor and Cochran (1967). F test was carried out by analysis of variance method and significant results were compared by working out the critical differences.

Results

RESULTS

4.1 The pathogen

The bacterial wilt pathogen was isolated from newly wilted chilli plants on Triphenyl Tetrazolium Chloride Agar medium (TZC). Five different isolates of the bacterium from chillies were brought into pure culture. Similarly, two isolates of the pathogen each from brinjal and tomato, and one isolate from ginger were also isolated. Koch's postulates were proved with all the isolates.

4.2 Characterization of the pathogen

4.2.1 Cultural characters

4.2.1.1 Morphology

All the bacterial isolates from the different host plants were gram negative short rods. On TZC medium all the isolates produced circular, smooth, greyish white, fluidal and slimy colonies with light pink centre after 24-48 h of incubation (Plate 2).

4.2.1.2. Growth of the different isolates of the bacterium on TZC medium

All the isolates of the bacterium gave rise to circular, smooth, convex, greyish white, fluidal and slimy colonies with a light pink centre within a period of 24 h on TZC medium. Among the different isolates, the maximum colony diameter (7.2 mm) at the end of 96 h was observed for the isolate C-1. Almost a similar growth was noticed with the isolate T-2. The isolates C-2, B-1

Plate 2. Typical colonies of P. solanacearum on TZC medium

and T-1 exhibited a growth of 4 mm after 96 h, while all the other isolates recorded a growth ranging from 3 to 3.2 mm. Maximum slime production and fluidity were noticed in the case of isolate C-1. The slime production and fluidity were good for isolates C-2, B-1, T-1 and T-2 and moderate for the other isolates (Table 1).

4.2.1.3 Growth of the bacterium (Isolate C-1) on different solid media

The growth of chilli isolate C-1 on six different solid media was compared and the results are presented in Table 2. Among the six different solid media tried, the maximum growth (8 mm) was noticed in Peptone Beef extract Agar after 96 h. This medium also gave excellent fluidity and slime production. Peptone Casamino acid Agar and Potato Dextrose Agar supported a growth of 7.5 mm after 96 h, and slime production and fluidity in these media were good. Eventhough, there was slight reduction of growth at the end of 96 h in Triphenyl Tetrazolium Chloride Agar medium compared to Peptone Beef extract Agar, Peptone Casamino acid Agar and Potato Dextrose Agar, this media supported excellent slime production and fluidity of the bacterium. Growth, slime production and fluidity of the bacterium in Nutrient Agar and Yeast Glucose Chalk Agar were moderate.

4.2.1.4 Growth of the isolates of the bacterium at different pH levels

Growth of the ten isolates of the pathogen in Nutrient broth

Table 1. Growth characters of different isolates of the bacterium on TZC medium

Isolate	Nature and colour of colony	Growth, Slime, Fluidity		Average diameter of 10 isolated colonies in mm after			
				24 h	48 h	72 h	96 h
C-1	Circular, smooth, convex, greyish white with light pink centre	Gr	++++	2.0	3.0	5.5	7.2
		Sl	++++				
		Fl	++++				
C-2	,,	Gr	+++	1.5	2.5	3.5	4.0
		Sl	+++				
		Fl	+++				
C-3	,,	Gr	+++	1.0	2.0	2.2	3.2
		Sl	++				
		Fl	++				
C-4	,,	Gr	++	1.5	2.0	2.5	3.0
		Sl	++				
		Fl	++				
C-5	,,	Gr	++	1.5	2.5	3.0	3.0
		Sl	++				
		Fl	++				
B-1	,,	Gr	+++	1.0	2.2	3.5	4.0
		Sl	+++				
		Fl	+++				
B-2	,,	Gr	+++	1.5	2.5	3.2	3.2
		Sl	++				
		Fl	++				
T-1	,,	Gr	+++	2.0	3.0	3.6	4.0
		Sl	+++				
		Fl	+++				
T-2	,,	Gr	++++	2.5	3.5	4.4	7.0
		Sl	+++				
		Fl	+++				
G-1	,,	Gr	++	1.5	2.5	3.0	3.0
		Sl	++				
		Fl	++				

++++ Excellent
+++ Good
++ Moderate

Gr - Growth
Sl - Slime
Fl - Fluidity

Table 2. Growth characters of the bacterial isolate C-1 on different solid media

Media	Nature and colour of colony	Growth Slime Fluidity	Average diameter of 10 isolated colonies in mm after			
			24 h	48 h	72 h	96 h
Peptone Casamino acid Agar	Circular, smooth, greyish white, convex with entire margin	Gr ++++ Sl +++ Fl +++	2.8	5.7	7.3	7.5
Triphenyl Tetrazolium Chloride Agar	Circular, smooth, greyish white with light pink centre, convex, with entire margin	Gr ++++ Sl ++++ Fl ++++	2.0	3.0	5.5	7.2
Potato Dextrose Agar	Circular, smooth, creamy white, convex with entire margin	Gr ++++ Sl +++ Fl +++	2.5	4.4	7.0	7.5
Nutrient Agar	Circular, smooth, greyish white, convex with entire margin	Gr ++ Sl ++ Fl ++	2.5	2.8	3.8	4.8
Peptone Beef extract Agar	Circular, smooth, creamy white, convex with entire margin	Gr ++++ Sl ++++ Fl ++++	3.5	5.5	7.5	8.0
Yeast Glucose Chalk Agar	Circular, smooth, creamy white, convex with entire margin	Gr ++ Sl ++ Fl ++	2.5	3.5	3.8	5.5

++++ Excellent
+++ Good
++ Moderate

Gr - Growth
Sl - Slime
Fl - Fluidity

adjusted to different pH levels was recorded by measuring the optical density of the broth in comparison with uninoculated control after 48 h. The results of the study are presented in Table 3.

Among the different pH levels tested, the maximum growth of the isolates was observed between pH 6.5 and 7.5. Though, all the isolates of the pathogen except isolate C-2 recorded maximum growth at pH 7, the best pH for the isolate C-2 was found to be 6.5. At all other pH levels viz., 5.5, 6, 8, 8.5 and 9 the growth was meagre. All the isolates failed to grow at pH 5 and 9.5.

4.2.1.5 Growth of the different isolates of the bacterium at different temperatures

Growth of the ten isolates of the bacterium at various temperatures was studied and results are presented in Table 4. The maximum growth of the isolates C-1, B-1 and T-1 was recorded at 30°C, while that for other isolates was 35°C. None of the isolates grew at temperature of 55°C. At 25 and 40°C also moderately good growth was recorded for all the isolates. Above 45 and below 15°C growth of the bacterial isolates was negligible.

4.2.1.6 Potato soft rot test

The potato soft rot test for all the isolates was conducted as described in Materials and Methods. Inoculation of the different

Table 3. Growth of the isolates of the bacterium at different pH levels

pH	O.D. values of the isolates									
	C-1	C-2	C-3	C-4	C-5	B-1	B-2	T-1	T-2	G-1
5.0	0	0	0	0	0	0	0	0	0	0
5.5	0.11	0.12	0.14	0.20	0.25	0.17	0.24	0.16	0.17	0.09
6.0	0.38	0.23	0.27	0.35	0.25	0.25	0.38	0.45	0.45	0.13
6.5	0.77	0.71	0.55	0.54	0.56	0.34	0.65	0.71	0.80	0.48
7.0	0.81	0.66	0.71	0.68	0.67	0.56	0.80	0.78	0.87	0.74
7.5	0.74	0.45	0.60	0.56	0.57	0.43	0.61	0.60	0.78	0.39
8.0	0.34	0.23	0.32	0.33	0.31	0.18	0.32	0.25	0.30	0.11
8.5	0.12	0.10	0.14	0.11	0.05	0.10	0.18	0.05	0.23	0.10
9.0	0.09	0.02	0.07	0.03	0.01	0.03	0.04	0.01	0.09	0.04
9.5	0	0	0	0	0	0	0	0	0	0

Table 4. Growth of the isolates of the bacterium at different temperatures

Temperature (°C)	O.D. value of the isolate									
	C-1	C-2	C-3	C-4	C-5	B-1	B-2	T-1	T-2	G-1
10	0.05	0.02	0.16	0.05	0.01	0.16	0.13	0.05	0.19	0.05
15	0.24	0.16	0.23	0.16	0.16	0.27	0.22	0.15	0.21	0.18
20	0.51	0.29	0.41	0.22	0.28	0.37	0.29	0.30	0.38	0.21
25	0.57	0.47	0.46	0.40	0.30	0.50	0.36	0.58	0.41	0.31
30	0.77	0.59	0.64	0.69	0.53	0.77	0.60	0.68	0.52	0.51
35	0.76	0.64	0.73	0.76	0.70	0.70	0.63	0.62	0.64	0.58
40	0.36	0.51	0.60	0.53	0.58	0.24	0.41	0.49	0.53	0.41
45	0.22	0.23	0.19	0.23	0.30	0.14	0.18	0.13	0.22	0.19
50	0.03	0.05	0.02	0.01	0.02	0.02	0.04	0.02	0.01	0.03
55	0	0	0	0	0	0	0	0	0	0

isolates of the pathogen caused blackening and rotting of the potato slices within 48 h.

4.2.1.7 Pigment production

All the isolates failed to produce water insoluble and water soluble pigment in Yeast Glucose Chalk Agar and King's medium respectively.

4.2.1.8 Oxygen requirements

All the isolates grew and changed the colour of Nutrient Dextrose Agar medium from purple to yellow at a slow and fast rate in tubes with and without paraffin respectively indicating that the isolates could grow both aerobically and anaerobically.

4.2.2 Physiological characters

4.2.2.1 Starch hydrolysis

None of the isolates had the ability to hydrolyse starch as indicated by the absence of a colourless zone around the bacterial growth in contrast to the blue background of the medium.

4.2.2.2 Tyrosinase activity

All the isolates developed only a slight brown colouration in the medium which indicated that they possessed only a low tyrosinase activity.

4.2.2.3 Production of indole

The oxalic acid crystals on the test strips did not turn pink or red. This showed that none of the isolates produced indole.

4.2.2.4 Production of hydrogen sulphide

Liberation of hydrogen sulphide by all the isolates of the bacterium was observed. However, the isolates C-4 and B-2 liberated less hydrogen sulphide as evidenced by mild blackening of the lead acetate strips.

4.2.2.5 Nitrate reduction test

Different isolates produced a red colouration in the nitrate broth upon addition of Griess Ilosvay's reagent showing that they were capable of reducing nitrate to nitrite.

4.2.2.6 Action on milk

All the isolates turned colour of the milk from light blue to yellow indicating an acidic reaction. They also curdled the milk.

4.2.2.7 Production of ammonia

The bacterial isolates produced a precipitate upon the addition of Nessler's reagent to Peptone water medium. This indicated that they were capable of producing ammonia.

4.2.2.8 Gelatin liquefaction

The bacterial isolates showed no indication of utilizing gelatin as no clear zone was seen surrounding the bacterial growth.

4.2.2.9 Catalase test

Catalase positive reaction was shown by the different isolates of the bacterium with slight variation in their intensity.

4.2.2.10 Arginine hydrolase test

None of the isolates turned Thornley's semisolid Arginine medium to red indicating their inability to hydrolyse arginine.

4.2.2.11 Urease test

The isolates showed positive urease activity as indicated by the colour change of Christensen's Urea Agar from yellow to red.

4.2.2.12 MR and VP tests

Positive reaction for MR test was noticed with all the isolates as evidenced by the presence of distinct red colour in culture tube when few drops of 0.02 per cent Methyl red in fifty per cent alcohol was added.

The isolates failed to produce crimson colour upon addition of 0.6 ml of alpha-naphthol solution (5 per cent in 95 per cent

alcohol) and 0.2 ml of 40 per cent aqueous solution of KOH, which indicated that they were VP negative.

4.2.2.13 Utilization of asparagine as sole source of carbon and nitrogen

The medium containing 0.2 per cent asparagine supported growth of all the isolates which indicated that they could utilize asparagine as sole source of carbon and nitrogen.

4.2.2.14 Production of levan

Large, white, domed and mucoid colonies were produced by all the isolates on Peptone Beef extract medium containing 5 per cent sucrose.

4.2.2.15 Utilization of organic acids

Of the three sodium salts of organic acids tested all the isolates utilized sodium acetate and sodium benzonate, while they failed to utilise sodium citrate as a source of carbon.

4.2.2.16 Utilization of carbon compounds

Of the twelve carbon compounds tested, all isolates of the bacterium produced acid in glucose, ribose, fructose, sucrose, lactose, dextrose, mannitol, glycerol, maltose, galactose and dulcitol as indicated by change of colour of the medium. Cellulose was not utilized by any of the isolates.

Table 5. Comparison of the cultural and physiological characters of the different bacterial isolates

Sl. No.	Characters studied	Isolates									
		C-1	C-2	C-3	C-4	C-5	B-1	B-2	T-1	T-2	G-1
1	Gram reaction	-	-	-	-	-	-	-	-	-	-
2	Potato soft rot test	+	+	+	+	+	+	+	+	+	+
3	Pigment production										
	a) Water soluble	-	-	-	-	-	-	-	-	-	-
	b) Water insoluble	-	-	-	-	-	-	-	-	-	-
4	Oxygen requirement										
	a) aerobic	+	+	+	+	+	+	+	+	+	+
	b) anerobic	+*	+*	+*	+*	+*	+*	+*	+*	+*	+*
5	Starch hydrolysis	-	-	-	-	-	-	-	-	-	-
6	Tyrosinase activity	+	+	+	+	+	+	+	+	+	+
7	Production of indole	-	-	-	-	-	-	-	-	-	-
8	Production of H_2S	+	+	+	+*	+	+	+*	+	+	+
9	Reduction of nitrate	+	+	+	+	+	+	+	+	+	+
10	Action on milk	A	A	A	A	A	A	A	A	A	A
11	Production of ammonia	+	+	+	+	+	+	+	+	+	+
12	Gelatin liquefaction	-	-	-	-	-	-	-	-	-	-
13	Celatase test	+	+	+	+	+	+	+	+	+	+
14	Arginine hydrolase activity	-	-	-	-	-	-	-	-	-	-
15	Urease test	+	+	+	+	+	+	+	+	+	+
16	MR test	+	+	+	+	+	+	+	+	+	+
17	VP test	-	-	-	-	-	-	-	-	-	-

Contd.

Table 5. Continued

Sl. No.	Characters studied	Isolates									
		C-1	C-2	C-3	C-4	C-5	B-1	B-2	T-1	T-2	G-1
18	Utilization of asparagine as sole source of carbon and nitrogen	+	+	+	+	+	+	+	+	+	+
19	Production of Levan	+	+	+	+	+	+	+	+	+	+
20	Utilization of organic acids										
	a) Sodium acetate	+	+	+	+	+	+	+	+	+	+
	b) Sodium citrate	-	-	-	-	-	-	-	-	-	-
	c) Sodium benzoate	+	+	+	+	+	+	+	+	+	+
21	Utilization of carbon compounds										
	a) Glucose	+	+	+	+	+	+	+	+	+	+
	b) Ribose	+	+	+	+	+	+	+	+	+	+
	c) Frutose	+	+	+	+	+	+	+	+	+	+
	d) Sucrose	+	+	+	+	+	+	+	+	+	+
	e) Lactose	+	+	+	+	+	+	+	+	+	+
	f) Dextrose	+	+	+	+	+	+	+	+	+	+
	g) Mannitol	+	+	+	+	+	+	+	+	+	+
	h) Glycerol	+	+	+	+	+	+	+	+	+	+
	i) Maltose	+	+	+	+	+	+	+	+	+	+
	j) Galactose	+	+	+	+	+	+	+	+	+	+
	k) Dulcitol	+	+	+	+	+	+	+	+	+	+
	l) Cellulose	-	-	-	-	-	-	-	-	-	-

-	=	Negative reation
A	=	Acidic reaction
+*	=	Slow positive reaction
+	=	Positive reaction

4.2.2.17 Cross inoculation studies

Cross inoculation studies were carried out as described in the Materials and Methods and the results are presented in the Table 6. The isolates of the bacterium from chilli, tomato, brinjal and ginger produced high wilt incidence on their respective hosts after five days. The chilli isolate caused wilting of brinjal, tomato and ginger plants after 5-6 days. The brinjal isolate caused high wilt incidence on chilli after five days of inoculation and a low wilt incidence on tomato. However, it did not produce any symptoms on ginger. After five days of inoculation tomato isolate produced high wilt incidence on chilli but a low incidence in brinjal. The tomato isolate also did not show any symptoms on ginger. The ginger isolate caused high incidence of wilt in chilli after ten days of inoculation, while it did not produce any symptoms on brinjal and tomato.

4.3 Screening of chilli accessions/varieties against bacterial wilt disease

Twenty nine accessions/varieties of chilli obtained from the Department of Olericulture, College of Horticulture were evaluated for their resistance/tolerance to bacterial wilt. The results of the study showed that none of the accessions/varieties were immune to the disease (Table 7, Fig. 1). But the variety Manjari (KAU Cluster/CA 33) was found to be resistant as it showed less than 20 per cent of wilt incidence. This was followed by accessions

Table 6. Cross inoculation with the bacterial isolates from different hosts

Isolate	Relative virulence on different hosts			
	Chilli	Brinjal	Tomato	Ginger
Chilli	H	H	H	H
Brinjal	H	H	L	O
Tomato	H	L	H	O
Ginger	H	O	O	H

H = High (65-100% wilt incidence)
M = Medium (40-65% wilt incidence)
L = Low (Below 40% wilt incidence)
O = Nil
[Winstead and Kelman, 1952]

CA 205 and CA 207 which recorded less than 40 per cent wilt incidence.

Statistical analysis of the data on percentage of wilt incidence revealed significant difference among the different chilli accessions varieties. The variety 'Manjari' recorded only 18 per cent wilt incidence. However, it was statistically on par with accessions CA 205, CA 207, CA 213 and CA 367. The accessions CA 205 and CA 207 had only less than 40 per cent wilt incidence, but it was on par with CA 213, CA 367, CA 375, CA 389, CA 418, CA 337, CA 356, CA 345 and CA 209, with a wilt incidence of less than 60 per cent. All other accessions/varieties had a wilt incidence of more than 60 per cent. The accessions CA 451, CA 449, CA 388, CA 53 and CA 160 recorded a wilt incidence of above 90 per cent. According to the scale of Mew and Ho (1976) the chilli accessions/ varieties screened in the present study could be grouped as below.

Resistant	: CA 33 (Manjari)
Moderately resistant	: CA 205, CA 207
Moderately susceptible	: CA 213, CA 367, CA 375, CA 389, CA 418, CA 337, CA 356, CA 345 and CA 209
Susceptible	: CA 379, CA 515, CA 192, CA 225, CA 408, CA 3, CA 409, CA 417, CA 222, CA 452, CA 372, CA 217, CA 451, CA 449, CA 388, CA 53 and CA 160

Table 7. Screening of chilli accessions/varieties against bacterial wilt disease

Sl. No.	Accessions/ varieties	Wilt incidence (%)	Reaction	Sl. No.	Accessions/ varieties	Wilt incidence (%)	Reaction
1	CA 375	49.63	MS	16	CA 449	95.23	S
2	CA 217	87.93	S	17	CA 209	58.06	MS
3	CA 452	83.33	S	18	CA 356	53.33	MS
4	CA 515	63.87	S	19	CA 213	41.43	MS
5	CA 222	77.20	S	20	CA 207	39.27	MR
6	CA 417	76.66	S	21	CA 33 (Manjari/ KAU Cluster)	18.00	R
7	CA 205	33.07	MR	22	CA 225	65.53	S
8	CA 379	60.63	S	23	CA 409	75.30	S
9	CA 53 (Pant C-1)	96.67	S	24	CA 372	84.10	S
10	CA 337	51.67	MS	25	CA 367	43.47	MS
11	CA 418	50.73	MS	26	CA 388	96.27	S
12	CA 451	91.67	S	27	CA 408	66.67	S
13	CA 192	65.26	S	28	CA 345	53.70	MS
14	CA 3 (White Khandhari)	70.33	S	29	CA 160	96.67	S
15	CA 389	50.03	MS				

CD (0.05) = 26.85.

R = Resistant - < 20% wilt

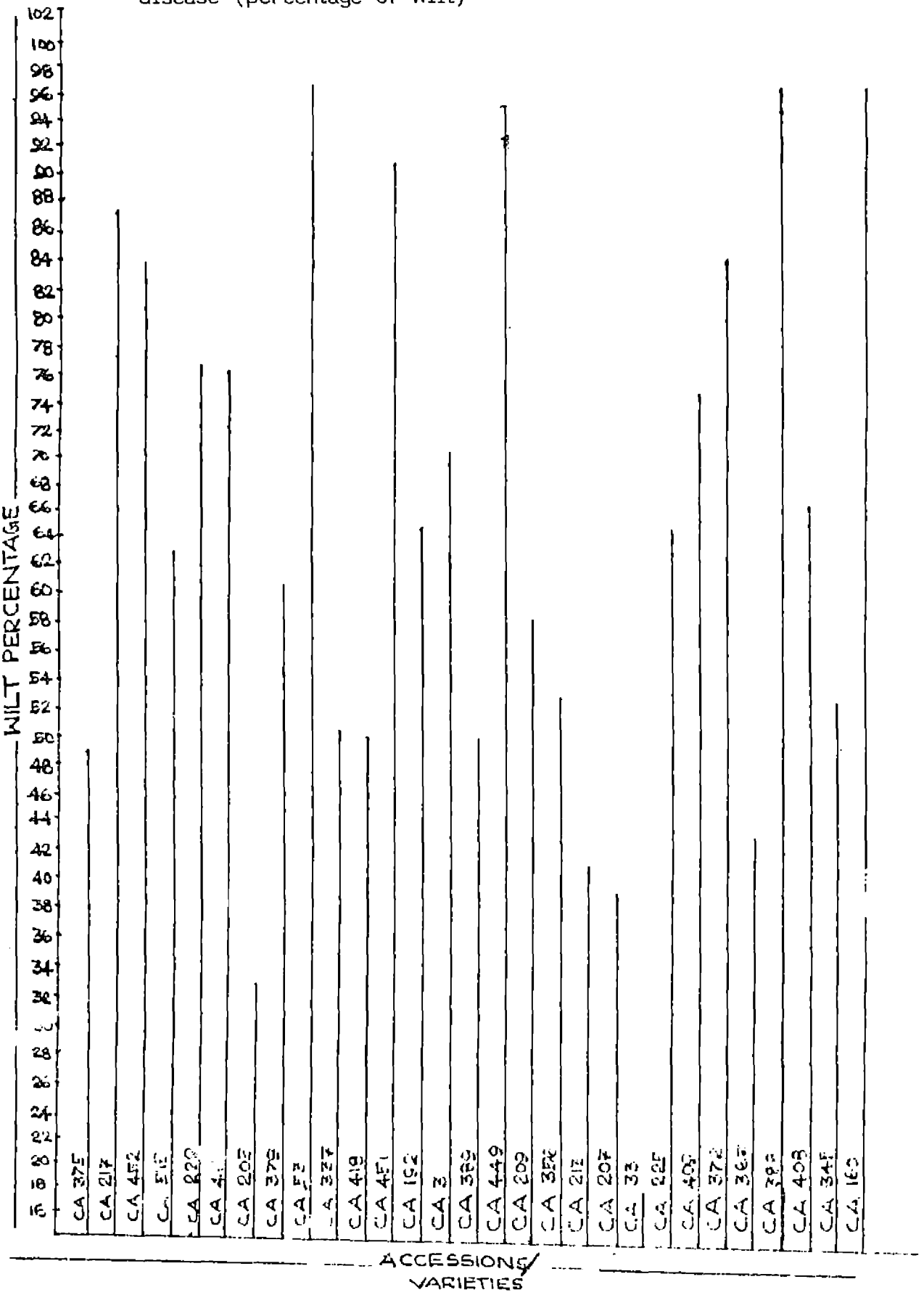
MR = Moderately resistant - > 20 < 40% wilt

MS = Moderately susceptible - > 40 < 60% wilt

S = Susceptible - > 60% wilt

[Mew and Ho, 1976]

Fig. 1. Screening of chilli accessions/varieties against bacterial wilt disease (percentage of wilt)



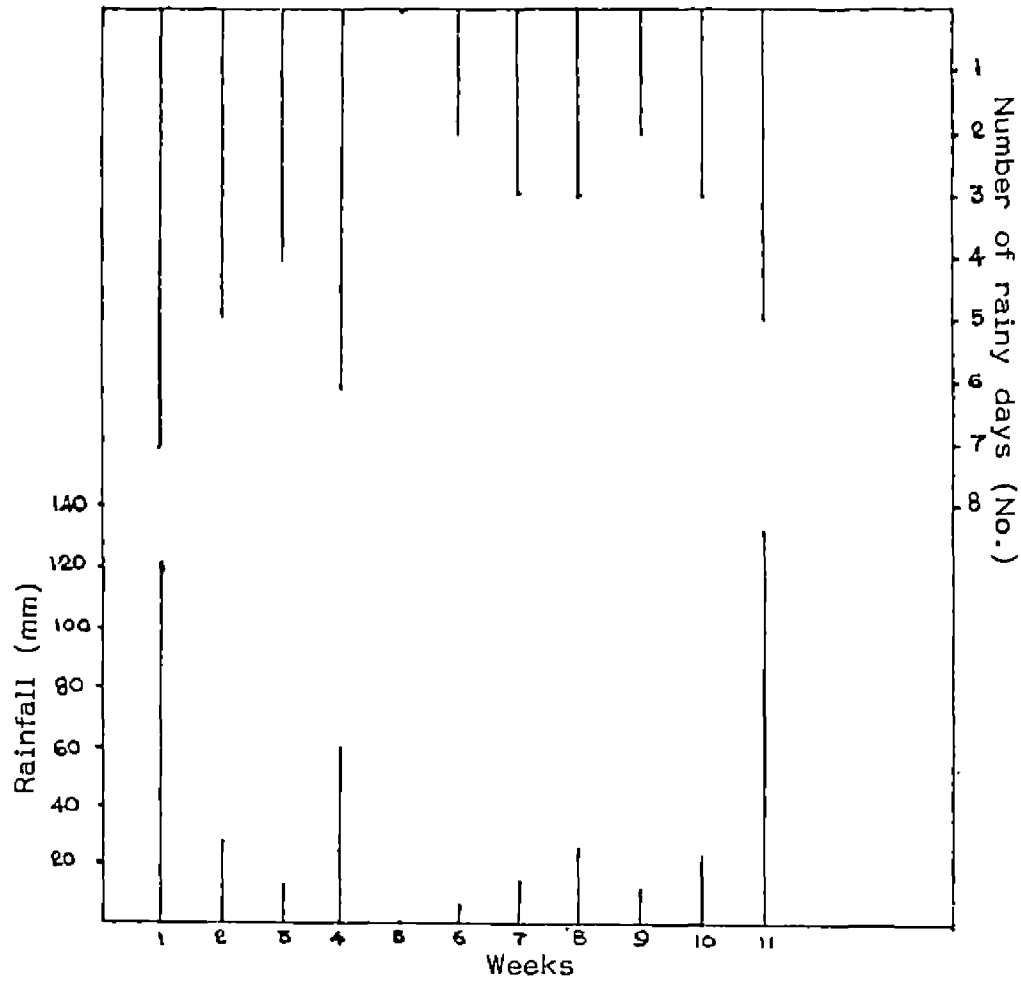
In order to correlate the incidence of the disease of different accessions/varieties of chillies with meteorological factors, observations on the maximum and minimum atmospheric temperature, maximum and minimum soil temperature, atmospheric humidity, rainfall, number of rainy days and soil moisture were recorded and its weekly averages are given in Fig. 2, Appendix 1.

Correlation coefficient was worked out between various environmental factors and wilt percentage of different accessions/ varieties of chillies. It was noticed that there was no significant correlation between wilt incidence and the various environmental factors for all the accessions/varieties except accession CA 408 (Appendix II). A positive correlation between wilt incidence and soil moisture was obtained with the accession CA 408, while a negative correlation was noticed between wilt incidence and minimum atmospheric temperature and minimum soil temperature (7 AM).

4.4 Preliminary evaluation of Chilli accessions of NBPGR Regional Station, Vellanikkara for host resistance against bacterial wilt disease

The resistance/tolerence reaction of chilli accessions maintained by NBPGR regional station was recorded. The results clearly indicated a high extent of variation among the chilli accessions to bacterial wilt infection under natural condition (Appendix III).

Fig. 2. Weather conditions during the crop growth period



Out of a total of 721 accessions 54 accessions did not show any incidence of wilt. 67 accessions showed below 20 per cent wilt and 109 accessions recorded a wilt percentage between 21 and 40 per cent. Between 41 to 60 per cent wilt incidence was recorded by 127 accessions and above 60 per cent wilt incidence was shown by 364 accessions.

4.5 Management of the disease

4.5.1 *In vitro* evaluation of plant protection chemicals against *P. solanacearum*

This study was aimed to assess the efficacy of antiobiotics and fungicides in inhibiting the growth of the bacterial wilt pathogen, *P. solanacearum*.

A. Antibiotics

The effect of Chloromycetin, Streptocycline, Terramycin, Tetracycline and Ambistryn-S at 250, 500, 750 and 1000 ppm in inhibiting the growth of *P. solanacearum* was studied by standard filter paper disc method. The results are presented in the Table 8 and Fig.3. From the data, it is evident that all the five antibiotics had varying inhibitory effects on the growth of the bacterium. Among the different antibiotics maximum inhibition of the bacterium was noticed with Chloromycetin. However, this was on par with Streptocycline and these two antibiotics were statistically superior to other antibiotics tested. The inhibitory effect of Terramycin was

Table 8. *In vitro* sensitivity of *P. solanacearum* to antibiotics

Sl. No.	Antibiotics	Inhibition zone in mm				Mean
		250 ppm	500 ppm	750 ppm	1000 ppm	
1	Streptocycline	21.67	25.00	34.33	38.87	29.91
2	Terramycin	24.67	26.67	30.33	31.33	28.25
3	Tetracycline	21.67	25.00	27.33	32.00	26.50
4	Chloromycetin	26.00	30.67	32.00	33.67	30.58
5	Ambistryn-S	16.67	21.33	27.67	32.00	24.42

CD (0.05) for comparison between antibiotics = 1.387
CD (0.05) for comparison between combination = 2.775

superior to Tetracycline which in turn was superior to Ambistryn-S. With all the antibiotics, higher concentrations resulted in better inhibition. Streptocycline at 1000 ppm gave maximum inhibition and was significantly superior to all the other antibiotics. Eventhough Streptocycline at 750 ppm was significantly better than its lower concentrations it was on par with 1000 ppm of Ambistryn-S, Tetracycline and Chloromycetin. Terramycin, Tetracycline, Ambistryn-S and Chloromycetin all at 1000 ppm were on par with Chloromycetin 750 ppm in inhibiting the growth of the pathogen. The minimum inhibition on the growth of the bacterium was noticed with 250 ppm of Ambistryn-S and it was significantly inferior to all the other antibiotics.

B. Fungicides

Thiride, Blue Copper, Foltaf and Dithane M-45 each at 1000, 2000, 3000 and 4000 ppm and Bordeaux mixture at 0.5, 1, 1.5 and 2 per cent concentration were tested for their inhibitory effect on the growth of the bacterium. The results are presented in Table 9 and Fig. 3. Foltaf and Dithane M-45 failed to inhibit the bacterial growth. Among the three fungicides (Thiride, Blue Copper and Bordeaux mixture) which were inhibitory to the bacterium, Bordeaux mixture recorded the maximum inhibition and it was on par with Thiride and they were significantly superior than Blue Copper. In general, the inhibition of bacterium was directly proportional to the concentration. Bordeaux mixture 1 per cent was

Table 9. *In vitro* sensitivity of *P. solanacearum* to fungicides

Sl. No.	Fungicides	Inhibition zone in mm				Mean
		1000 ppm	2000 ppm	3000 ppm	4000 ppm	
1	Thiride	18.33	20.33	21.67	21.00	20.3
2	Blue copper	10.00	14.67	17.00	21.00	15.67
3	Foltaf	0	0	0	0	0
4	Dithane M-45	0	0	0	0	0
		0.5%	1.0%	1.5%	2.0%	
5	Bordeaux mixture	22.33	24.00	22.66	14.33	20.83

CD (0.05) for comparison between fungicide = 1.01
CD (0.05) for comparison of combination = 2.02

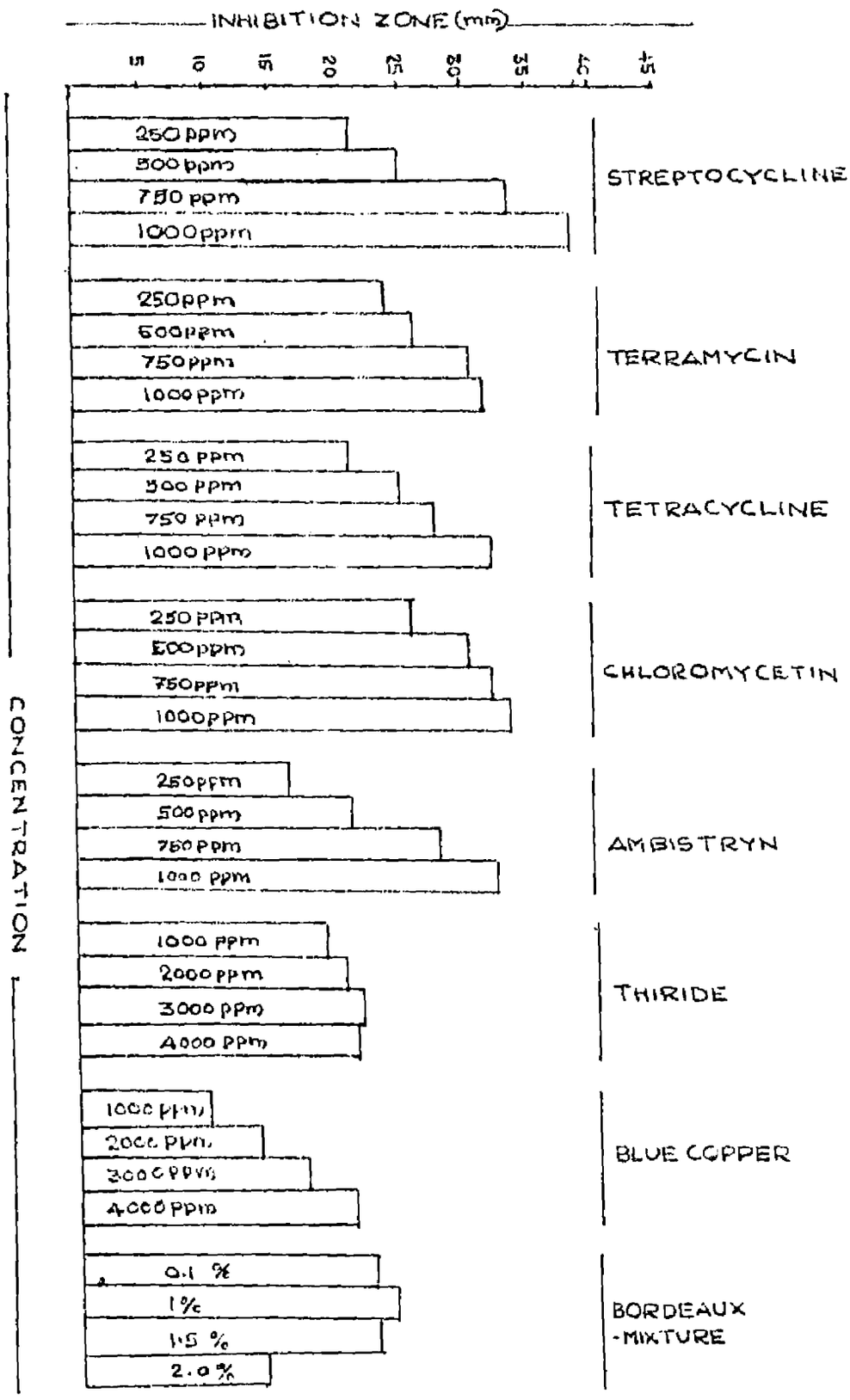


Fig. 3. In vitro evaluation of chemicals against Pseudomonas solanacearum

on par with 0.5 and 1.5 per cent concentration. However, they were significantly superior to its higher concentration of 2 per cent. Bordeaux mixture 1 per cent was also superior to various concentration of the other fungicides tested. Thiride at 3000 ppm and 4000 ppm were found to be on par with Blue copper at 4000 ppm and Bordeaux mixture at 0.5 and 1.5 per cent. There was also no significant difference between Blue copper 2000 ppm and Bordeaux mixture 2 per cent. Blue copper at 1000 ppm recorded the least inhibitory effect to the bacterium.

4.5.2. Field experiment on the management of bacterial wilt of chillies

A field experiment was conducted with five main plot treatments and five sub plot treatments in a wilt sick field for the management of the bacterial wilt of chilli. The results are presented in the Table 10. Analysis of the data on the percentage wilt incidence did not show any significant difference among the main plot and sub plot treatments. However, it was evident from the data that the major treatments showed a tendency in reducing the disease incidence. Among the major treatments, plants receiving cowdung recorded minimum percentage of wilt incidence, followed by the treatment where soil was burnt before planting. Maximum disease incidence was noticed in control plots. Among the sub plot treatments, plants which received two application of Streptocycline

Table 10. Field experiment on the management of bacterial wilt of chillies (percentage of wilt incidence)

Minor treatments	Major treatments					Mean
	M_1	M_2	M_3	M_4	M_5	
S_1	49.86	61.02	62.07	55.40	81.27	61.92
S_2	67.75	52.23	58.33	51.26	43.93	54.70
S_3	54.04	64.18	49.50	63.87	66.94	59.70
S_4	49.72	72.90	61.77	76.88	67.94	65.85
S_5	55.47	71.37	76.49	45.88	75.75	64.99
Mean	55.37	64.34	61.63	58.66	67.16	

CD (0.05) for major treatments - NS
CD (0.05) for minor treatment - NS
NS - Not significant, M - Major treatments, S - Minor treatments

Major treatment

M_1 Cowdung dried and powdered (50 g/plant 1 month after transplanting and at the time of flowering
M_2 Lime (25 g/plant 1 month after transplanting and at the time of flowering)
M_3 Neemcake (25 g/plant 1 month after transplanting and at the time of flowering)
M_4 Burning of soil
M_5 Control

Minor treatment

S_1 Antibiotic - Drenching one month after transplanting
S_2 Antibiotic - Drenching 1 month after transplanting and at the time of flowering
S_3 Fungicide - Drenching one month after transplanting
S_4 Fungicide - Drenching 1 month after transplanting and at the time of flowering
S_5 Control

[S_1, S_2 - streptocycline - 1000 ppm; S_3, S_4 - Bordeaux mixture 1% - selected on the basis of *in vitro* studies]

recorded the minimum wilt incidence followed by the plot receiving one application of Bordeaux mixture. The interaction effect between the major and minor treatments were also not significant.

Discussion

DISCUSSION

Bacterial wilt incited by Pseudomonas solanacearum (Smith) Smith is one of the wide spread and severe diseases of chilli. This disease causes much damage to many crops of economic importance in the tropical and subtropical regions of the world. In India, the various aspects of bacterial wilt disease of chillies have not been investigated in a systematic manner except a few studies on its occurrence and management (I.C.A.R., 1969; Rahim, 1972; George, 1973; Khan et al., 1979). In view of the serious nature of the disease, the present investigation was undertaken to characterize the pathogen, to screen different chilli accessions/ varie for finding out source of resistance, and to evolve a suitable management practice for the disease.

The bacterial wilt pathogen P. solanacearum was isolated from newly wilted chilli plants and its pathogenicity established. Ten isolates of the pathogen, five from chillies, two each from tomato and brinjal, and one from ginger, were used for the present study.

The different isolates of the pathogen were gram negative short rods as delineated by Smith (1896). On Triphenyl Tetrazolium Chloride Agar medium (TZC) all the ten isolates of the pathogen gave rise to circular, smooth, convex, greyish white, fluidal and slimy colonies with a light pink centre. Similar growth chara-

cters of different isolates of P. solanacearum from various host plants on TZC medium has been documented by several workers (Kelman, 1954; Khan et al., 1979; He et al., 1983; Mathew and Nayar, 1983). Among the ten isolates of the bacterium, the isolate C-1 from Vellanikkara showed the maximum growth on TZC medium. Growth of this isolate on different solid media showed some variations. Of the six solid media tried, excellent growth, slime production and fluidity were observed in Peptone Beef extract Agar, thus indicating that this media could be well utilized for the mass multiplication and for other routine laboratory studies. This finding is in agreement with the earlier work of Nayar (1982).

All the bacterial isolates recorded maximum growth between a pH range of 6.5-7.5, the optimal being 7.0. The exception being the isolate C-2 which had maximum growth at pH 6.5. None of the isolates grew at pH 5 or 9.5. The optimal pH for the growth of P. solanacearum was reported to be between 6.6 to 6.7 (Kelman, 1953). Hingorani et al. (1956) recorded excellent growth of bacterium between pH 6 and 8.5. However, Nayar (1982) did not observe any growth of the bacterial wilt pathogen from brinjal at pH 5 and 9.5.

The different isolates of the pathogen were mesophilic in nature with a maximum growth between 30 and 35°C. The isolates C-1, B-1 and T-1 showed maximum growth at 30°C while for others, the optimum temperature was 35°C. None of the isolates grew at

55°C. Smith (1896) reported that a temperature of 35-37°C was most favourable for the growth of P. solanacearum in culture. Devi (1978) noticed good growth of P. solanacearum from chilli, tomato and brinjal between 30 and 35°C. According to Kelman (1953) a relatively high temperature is a requisite for the rapid multiplication of P. solanacearum in culture.

Inoculation of the different isolates of the bacterium caused blackening and rotting of the potato slices. A similar observation was also recorded by Nayar (1982). The bacterial isolates used in the present study failed to produce any pigments on Yeast Glucose Chalk Agar or on King's medium as reported by Smith (1914), Hayward (1964), El-Helaly et al. (1969), Devi (1978) and Nayar (1982). The different isolates preferred aerobic condition for good growth while only meagre growth was noticed under anaerobic condition. The aerobic nature of P. solanacearum was established by Smith (1914). However, there were reports that the organism can develop to a limited degree when it is not in contact with air (Honing, 1912; Kelman and Jenson, 1951; Devi, 1978).

The bacterial wilt pathogen isolated from different host plants were similar to each other in terms of the biochemical and physiological properties. All the isolates tested did not produce indole or hydrolyse starch though all of them showed positive reaction for nitrate reductase and catalase activity. Devi (1978), He et al. (1983), Prior and Steva (1990) have reported

similar characters for isolates of P. solanacearum from various host plants including chilli. The isolates produced small amounts of brown diffusible pigment on tyrosine medium, and formed ammonia. All the above reactions are typical characteristics of P. solanacearum (Hayward, 1964). Working with isolates of P. solanacearum from chilli, tomato and eggplant, Devi (1978) and He et al. (1983) observed liberation of hydrogen sulphide. Similar results were obtained in the present investigation also.

An acidic reaction was exhibited by all the isolates of the pathogen in milk which was in accordance with the findings of Samuel (1980) and Nayar (1982). However, variation in reaction either acidic or alkaline in milk was noticed for different isolates of P. solanacearum by Rath and Addy (1977) and Devi (1978).

With respect to gelatin liquefaction none of the isolates were found to liquefy gelatin. Very slow or no liquefaction of gelatin by P. solanacearum was reported by Hayward (1964). Starr and Weiss (1943) considered the ability of utilization of asparagine as sole source of carbon and nitrogen as a character of P. solanacearum. In the present study, the isolates utilized asparagine as sole source of carbon and nitrogen. Positive urease activity and levan production observed in the present study were in accordance with that of Samuel (1980) and Nayar (1982). All the isolates showed positive MR and negative VP test as observed by Nayar (1982). Among the sodium salts of organic acids tested for utilization,

it was found that acetate and benzoate were utilized while citrate was not utilized by the isolates. He et al. (1983) observed acetate utilization by chilli, tomato, eggplant and ginger strain of P. solanacearum while the inability of P. solanacearum to utilize citrate was documented by Nayar (1982).

The isolate used in the study were not capable of hydrolysing arginine which was considered as one of the negative nutritional character of P. solanacearum by Palleroni and Duodoroff (1971). A variety of carbon compounds viz., glucose, ribose, fructose, sucrose, lactose, dextrose, mannitol, glycerol, maltose, galactose and dulcitol were utilized by the isolates studied. However, cellulose was not utilized by the isolates. The results are in accordance with the findings of Devi (1978), Samuel (1980) and Nayar (1982). Thus, the bacterial isolates from different host plants were basically similar to each other in terms of the biochemical and physiological properties and most of these were in accordance with those described by Hayward (1964) for P. solanacearum. However, slight variation in respect to certain biochemical and physiological characters were observed with the isolates used in the present study with those reported by Hayward (1964). Variations among isolates of P. solanacearum were reported by many workers (Buddenhagen and Kelman, 1964; Rath and Addy, 1977).

Cross inoculation studies showed variation in the different isolates as regards to its ability to infect the different host plants.

The cross inoculation of chilli isolates caused typical wilt symptoms on tomato, brinjal and ginger plants. Conversely the isolates from tomato, brinjal and ginger on inoculation to chilli caused rapid and typical wilting. It was noticed that the tomato and brinjal isolates were capable of cross infecting each other. Interestingly it was found that tomato and brinjal isolates did not cause any wilting on ginger and the ginger isolates did not take up infection on tomato and brinjal. The ability of chilli strains of P. solanacearum in causing high degree of wilting in tomato and eggplant have been reported (Devi, 1978; He et al., 1983; He, 1985; Prior and Steva, 1990). Further, Velupillai and Stall (1984) and Prior and Steva (1990) had found that the strains from tomato and eggplant affect chilli. The cross infectivity of brinjal and tomato with varying intensities have been well documented by Devi (1978), Nayar (1982) and He (1985). The inability of tomato or brinjal isolate to cause typical wilting on ginger have been observed by many workers (Quinon et al., 1964; Samuel, 1980; He, 1985). Quinon et al. (1964) and Ren and Fang (1981) reported that ginger strain failed to bring about wilt on tomato and Nayar (1982) had observed that ginger strain did not cause any wilt on tomato and eggplant. The ability of ginger strain to cause wilting on chilli at various intensities was documented by works of Ishii and Hirayaki (1963), He et al. (1983) and He (1985). The effect of chilli isolate of the pathogen causing wilt on ginger has not been

previously reported. However, Lum (1973) and Vellupillai and Stall (1984) observed that tomato isolates of the bacterium caused wilting on ginger.

Based on the present studies on the morphological, cultural, biochemical, physiological properties and on the pathogenicity tests, the pathogen causing bacterial wilt of chillies could be identified as P. solanacearum (Smith) Smith. Further, on the basis of the above characteristics and the host range the isolates from chilli, tomato and brinjal could be classified as the race 1 of P. solanacearum (Buddenhagen et al., 1962). However, ginger isolate can be put into race 4 as it behaved differentially in host reaction (Persley et al., 1985).

Hayward (1964) differentiated strains of P. solanacearum into four biotypes according to their ability to oxidize three disaccharides (lactose, maltose and cellobiose) and three hexose alcohols (mannitol, sorbitol and dulcitol). The isolates used in the present study utilized disaccharides (lactose, maltose) and hexose alcohols (mannitol, dulcitol) thus it could be possible to group them as biovar III of P. solanacearum (Hayward, 1964). The existence of biovar III of the pathogen in Kerala has been previously established by many workers (Devi, 1978; Samuel, 1980 and Nayar, 1982).

The most effective way of controlling bacterial diseases is the use of resistant varieties, supplimented with proper cultural practices and chemical application. An attempt was thus made to screen available chilli accessions/varieties of College of Horticulture for host resistance against P. solanacearum. Of the 29 accessions/ varieties of chillies screened none of them was found to be immune to the disease. However, the result of the study revealed significant difference among the accessions/varieties in the percentage of wilt incidence. The minimum percentage of wilt incidence was noticed in the variety Manjari (CA 33/KAU Cluster) followed by accessions CA 205 and CA 207. According to the score suggested by Mew and Ho (1976), the variety Manjari (CA 33/KAU Cluster) could be considered as resistant to the disease. The accessions CA 205 and CA 207 recorded wilt percentage between 20 to 40 per cent and could be grouped as moderately resistant. Between 40 and 60 per cent wilt incidence was noticed by the accessions CA 213, CA 367, CA 375, CA 389, CA 418, CA 337, CA 356, CA 345, CA 209, thus coming under the group moderately susceptible. All other accessions /varieties were susceptible to the disease recording more than 60 per cent wilt incidence. The resistant reaction of Manjari (CA 33/KAU Cluster) to bacterial wilt was reported by many workers (Goth et al., 1983; Thomas, 1985 and Gopalakrishnan and Thomas, 1989). However, some early reports suggested the resistant reaction of CA 3 (White Khandhari) and CA 53 (Pant C-1) to bacterial wilt disease (Rahim and Samraj, 1974; Peter et al.,

1984). However, in the present study these varieties were found to be susceptible to the disease. The resistant or moderately resistant reaction exhibited by the accessions/varieties might be due to their biochemical make up which restrict wilt development. The susceptible reaction shown by earlier identified resistant varieties like Pant C-1 and White Khandhari might be due to break-down of resistance mechanism because of climatic factors or change in virulence of the pathogen.

Atmospheric factors play an important role in the development of plant disease. These factors may either favour the rapid multiplication/survival of the pathogen or it may make the plant vulnerable to infection. In the present investigation an attempt was made to study the role of environmental factors in the development of wilt incidence in chilli accessions/varieties. It was noticed that there was no significant correlation between wilt incidence and environmental factors for all the accessions, except CA 408. A positive correlation between wilt incidence and soil moisture was obtained with the accession CA 408. Role of high soil moisture in increasing the severity of bacterial wilt by P. solanacearum was established by earlier workers (Gallegely and Walker, 1949; Hingorani et al., 1956; Hiryati et al., 1983).

Screening of large number of lines/types of a crop with considerable genetic diversity is a method for locating resistant lines/types against disease which could be further utilized for the

development of resistant varieties with desirable characters. With this idea, a large number of accessions of chilli maintained at Regional Station of National Bureau of Plant Genetic Resources, Vellanikkara, were screened for host resistance against bacterial wilt under field conditions during September-January 1990-91. The study revealed that, out of the 721 accessions of chilli, 54 accessions did not show any incidence of bacterial wilt, while the others showed varying degree of disease incidence. Thus, the study indicated that the 54 apparently resistant accessions could be utilized for locating sources of resistance against the disease.

In order to find out a suitable chemical for reducing the severity of the disease, an *in vitro* study was conducted using five antibiotics and five fungicides. Of the five antibiotics tested, Chloromycetin and Streptocycline exhibited maximum inhibition of the bacterium and they were significantly superior to other antibiotics. Ambistryin recorded the minimum inhibition. Streptocycline at 1000 ppm concentration showed maximum inhibition of the bacterium. Among the fungicides tested, Bordeaux mixture exhibited maximum inhibition. Foltaf and Dithane M-45 failed to inhibit the growth of bacterium. Bordeaux mixture at one per cent gave the maximum inhibition of the bacterium.

The inhibitory effect of Streptocycline, Streptomycin, Chloromycetin, Terramycin, Tetracycline, Streptomycin sulphate,

Ambistryn, Erythromycin, Dihydrostreptomycin, Actinomycin, Agrimycin, Aureomycin in inhibiting the growth P. solanacearum was reported by several workers (Moorgan and Goodman, 1955; Foucart and Delcambe, 1960; Campacci et al., 1962; Chakravarti and Rangarajan, 1966; Desai et al., 1967; Goorani et al., 1978; Samuel, 1980; Nayar, 1982; Farag et al., 1986; Prior and Steva, 1990). The in vitro efficacy of Thiram, Dithane M-45, Dithane M-22 and Captan in inhibiting the growth of P. solanacearum was reported by Leandro and Zak (1983). But in the present study Dithane M-45 did not show any inhibitory effect on the bacterium.

A field experiment on the management of bacterial wilt of chillies was conducted in a wilt sick field. Results of the experiment showed that none of the treatments gave an absolute control of the disease. Analysis of the data revealed no significant differences among main and sub plot treatments. However, certain major and minor treatments showed a tendency to reduce disease incidence. Plants receiving cowdung as a major treatment recorded the minimum percentage of wilt incidence followed by treatments where soil was burned before planting. Among sub plot treatments, plants receiving two applications of Streptocycline recorded minimum wilt incidence followed by those receiving one application of Bordeaux mixture.

Usefullness of foliar application of Streptomycin or Streptocycline or soil drenching of Cheshunt compound in reducing the

bacterial wilt incidence of chillies was reported by Rahim (1972) and George (1973). A perusal of literature revealed no report on the effectiveness of application of soil amendments and plant protection chemicals on the absolute control of bacterial wilt of chillies caused by P. solanacearum. However, there are reports on the control of bacterial wilt of other crops with soil amendments and plant protection chemicals. Jayaprakash (1977) observed the effectiveness of soil amendments and chemical treatments on the control of bacterial wilt of tomato. But Devi (1978) opined that application of soil amendments and antibiotics caused only limited control of bacterial wilt of tomato. In the present investigations though there were no significant reduction in the wilt incidence in plants receiving major and minor treatments some of them showed a tendency to reduce the severity of disease. Kelman (1953) after reviewing the work on P. solanacearum has concluded that though certain fertilizers and organic materials may influence disease severity, they did not achieve the necessary degree of control. In general, control of bacterial diseases of plants by soil amendments and chemicals is found to be less successful and the bacterial wilt of chilli is no exception to this.

Summary

SUMMARY

Bacterial wilt caused by Pseudomonas solanacearum (Smith) Smith is one of the most severe diseases of chillies. Thus, the present investigation was undertaken to characterize the pathogen, to screen different chilli accessions/varieties for finding out a source of resistance and to evolve a suitable management practice for the disease.

The bacterial wilt pathogen was isolated from infected chilli plants and its pathogenicity established. Ten isolates of the pathogen, viz., five from chillies, two each from tomato and brinjal and one from ginger were used for the present study.

All the bacterial isolates produced circular, smooth, greyish white, fluidal and slimy colonies with light pink centre in TZC medium. In this medium, the isolate C-1 from chilli produced the maximum growth, slime and fluidity. Growth of this isolate on different solid media was studied and it was found that maximum growth, slime production and fluidity was on Peptone Beef extract Agar.

The different bacterial isolates recorded maximum growth between a pH range of 6.5 - 7.5. Among the different temperatures tested, the isolates C-1, B-1 and T-1 showed maximum growth at 30°C while for the others the optimum temperature was 35°C.

The bacterial wilt pathogen isolated from different host plants were similar to each other in terms of the biochemical and physiological properties. The isolates did not produce any water soluble or water insoluble pigments. All the isolates grew aerobically though anaerobic growth was observed at a slow rate. The isolates did not hydrolyse starch or produce indole and showed a low tyrosinase activity. All of them utilized asparagine as sole source of carbon and nitrogen and produced levan, ammonia and hydrogen sulphide. The isolates showed positive results for nitrate reduction, catalase, urease and MR tests, but gave negative reaction for VP test. They were unable to hydrolyse arginine or liquify gelatin and exhibited an acidic reaction in milk. The bacterial isolates utilized sodium acetate and sodium benzoate and not sodium citrate. All the carbon sources studied viz., glucose, ribose, fructose, sucrose, lactose, dextrose, mannitol glycerol, maltose, galactose and dulcitol, except cellulose were utilized by the isolates of the bacterium.

Cross inoculation studies using the isolates from chilli, tomato, brinjal and ginger were conducted. The chilli isolate caused wilting of brinjal, tomato and ginger. Conversely the isolates from tomato, brinjal and ginger on inoculation to chilli caused typical wilting. The brinjal and tomato isolates were cross infectable. The isolates from brinjal and tomato did not cause any wilting on ginger and the ginger isolates did not take up infection on

tomato and brinjal. On the basis of above studies, the isolates of the bacterium were identified as Pseudomonas solanacearum (Smith) Smith. Further, according to Hayward's classification the isolates used in the study belong to biovar III of P. solanacearum.

Twenty nine accessions/varieties of chilli were screened for host resistance against P. solanacearum. Results revealed that the variety 'Manjari' (K.A.U. Cluster/CA 33) was resistant to bacterial wilt, while accessions CA 205 and CA 207 were moderately resistant. All the others were susceptible or moderately susceptible. No significant correlation between environmental factors and wilt incidence was noticed for all accessions/varieties except CA 408, for which a positive correlation was noticed between soil moisture and wilt incidence. 721 accessions of chilli maintained at Regional Station of National Bureau of Plant Genetic Resources, Vellanikkara were evaluated for resistance reaction against bacterial wilt. Results revealed that 54 accessions did not show any incidence of bacterial wilt.

An in vitro study was conducted to find out the inhibitory effect of antibiotics and fungicides to P. solanacearum. Of the five antibiotics tested Chloromycetin and Streptocycline exhibited the maximum inhibition of the bacterium and they were significantly superior to Tetracycline, Terramycin and Ambistryn-S. Among the different concentrations of antibiotics, Streptocycline at 1000 ppm

concentration exerted the maximum inhibition of the bacterium. Among the fungicides viz., Bordeaux mixture, Blue copper, Thiride Diithane M-45 and Foltaf, Bordeaux mixture exerted the maximum inhibition of the bacterium. Foltaf and Dithane M-45 failed to inhibit the growth of bacterium. Bordeaux mixture at one per cent concentration showed the maximum inhibition.

A field experiment on the management of bacterial wilt of chillies was conducted with five major treatments and five minor treatments. Results revealed no significant difference between main and sub plot treatments in reducing the disease incidence. However, plants receiving cowdung as a major treatment recorded comparitively less percentage of wilt incidence. Among the minor treatments, plants receiving two application of Streptocycline-1000 ppm also showed a tendency to reduce the wilt incidence.

References

REFERENCES

*Abo-El-Dahab, M.K. 1957. Effects of certain antibiotics on representative phytopathogenic bacteria with special reference to Pseudomonas solanacearum. Diss. Abstr. 17:2391-2392.

Addy, S.K., Das, G.C., Thakuria, D. and Rath, P.K. 1980. Studies on wilt of tomato. J. Res. Assam Agric. Univ. 1:62-67.

*Agati, J.A. 1949. Brown rot of solanaceous plants. Plant Industry Digest. 12:31-34.

Akiew, E.B. 1985. Influence of soil moisture and temperature on the persistance of Pseudomonas solanacearum. In: Bacterial wilt disease in Asia and the South Pacific. (Ed.) Persley, G.J. ACIAR. Proc.No.13: 77-78.

Ark, P.A. 1955. Use of streptomycin pyrophyllite dust against pear blight and walnut blight. Plant Dis. Reptr. 39:926-928.

*Bazzi, C. and Calzolari, A. 1986. Chemical control of bacterial rot (Pseudomonas cichorii) of lettuce. Preliminary evaluation of some treatments. Informatore Fitopatologica 36:30-32.

*Brown, J.G. and Heep, D.M. 1946. Effect of streptomycin on budwood infected with Phytomonas pruni. Science. 104:208.

Buchanan, R.E. and Gibbons, N.E. 1974. Bergey's Manual of Determinative Bacteriology. 8th ed. The Williams and Wilkins Company, Baltimore: pp.232-233.

Buddenhagen, I. and Kelman, A. 1964. Biological and physiological aspects of bacterial wilt caused by Pseudomonas solanacearum. Ann. Rev. Phytopath. 2:203-230.

Buddenhagen, I., Sequeira, L. and Kelman, A. 1962. Designation of races in Pseudomonas solanacearum. Phytopathology. 52:726.

Buddenhagen, I.W. 1985. Bacterial wilt revisited. In: Bacterial wilt disease in Asia and the South Pacific. (Ed.) Persley, G.J. ACIAR Proc.No.13:126-143.

*Burrill, T.J. 1890. Preliminary notes upon the rotting of potatoes. Proc. 11th Ann. Meet. Soc. Prom. Agr. Sci. 8:21-22.

*Campacci, C.A., Pacheco, C.D.N. and De Fazia, G.M. 1962. Tests in vitro with antibiotics for inhibition of Pseudomonas solanacearum. Arg. Inst. Biol. Sao Paulo. 29:117-131.

Chakravarti, B.P. and Rangarajan, M. 1966. Streptocycline, an effective antibiotic against bacterial plant pathogen. Hind. Antibiot. Bull. 8:209-211.

*Chandrasrikul, A. and Wannapee, L. 1972. Diseases of chilli and their control. Science. 26:43-55.

Chattopadhyay, S.B. and Mukherjee, K. 1969. Bacterial wilt of potato in West Bengal. Bull. Bot. Soc. Beng. 23:11-15.

Christensen, W.B. 1946. Urea deposition as a measure of differentiating Proteus and Paracolon cultures from each other and from Salmonella and Shigella types. J. Bacteriol. 52:461.

*Clairon, M. 1984. Possibility of reducing bacterial wilt (Pseudomonas solanacearum) in egg plant (Solanum melongena) by modifying nitrogen fertilization. Bulletin Agronomique Antilles Guyano No.3:4-5.

Clark, W.M. and Lubs, M.A. 1917. A substitute for litmus for use in milk cultures. J. Agric. Res. **10**:105-111.

*Cook, M.T. 1931. Annual report of the division of botany and plant pathology. Porto Rico Insular Expt. Sta. Ann. Rpt. for 1929-30: 93-109.

Dath, A.P. and Devadath, S. 1969. In vitro effects of antibiotics against Xanthomonas translucens f sp oryzicola. Indian Phytopath. **22**:386-389.

Desai, S.G., Patil, M.K. and Desai, M.V. 1967. In vitro activity of streptocycline against bacterial plant pathogens. Indian Phytopath. **20**:296-300.

Deslandes,A.J.1944.Observacoes fitopathologicos na Amazonia: Min. da Agr. Bol. Fitossan. (Rio-de-Jan) **1**:197-242 (Abs: Rev. Appl. Mycol. 1947. **26**:333-334.

Devi, R. 1978. Bacterial wilt of tomato in Kerala. Host range and survival of the pathogen and control. Ph.D. Thesis, Kerala Agricultural University, Trichur.

Dowson, W.J. 1957. Plant Diseases due to Bacteria. Cambridge University Press, London: pp.232.

Dutta, A.K. and Verma, S.S.P. 1969. Control of bacterial wilt of egg plant with streptocycline. Hind. Antibiot. Bull. **11**:260-261.

*Dye, D.W. 1962. The inadequacy of the usual determinative tests for the identification of Xanthomonas spp. N. Z. J. Sci. 55:393-416.

*Dye, D.W. 1966. Cultural and biochemical reactions of additional Xanthomonas spp. N. Z. J. Sci. 9:913-919.

*El-Helaly, A.F., Abo-El-Dahab, M.K. and El-Goorani, M.A. 1969. Chromogenesis in cultures of Pseudomonas solanacearum. J. Phytopath. 1:1-11.

*Empig, L.T., Calub, A.G., Katigbak, M.M. and Deanon, J.R. 1962. Screening tomato, eggplant and pepper varieties and strains for bacterial wilt (Pseudomonas solanacearum E.F.Smith) resistance. Philipp. Agric. 46:303-314.

*Farag, N.S., Fawzi, F.G., El-Said, S.I.A. and Mikhal, M.S. 1986. Streptomycin in relation to potato brown rot control. Acta phytopathologica et Entomologica Hungarica. 21:115-122.

*Foucart, G. and Del-cambe, L. 1960. A search of chemotherapeutic agents against bacterial wilt of potato. Parasitica. 16: 126-139.

Gallegely, M.E. and Walker, J.C. 1949. Relation of environmental factors to bacterial wilt of tomatoes. Phytopathology. 39: 936-946.

George, V.C. 1973. Effect of interplanting cowpea (Vigna sinensis) and the application of streptomycin and other chemicals on the wilt disease of chillies (Capsicum spp) caused by Pseudomonas solanacearum and on the rhizosphere microflora. M.Sc.(Ag.) Thesis. University of Kerala.

Girijadevi, T. and Peter, K.V. 1987. Field resistance of Capsicum hybrid Yolowonder improved x KAU cluster to bacterial wilt. Agric. Res. J. Kerala. **25**:293-294.

*Goorani, M.A., Abo-El-Dahab, M.K. and Wagih, E.E. 1978. Tests in vitro and in pots with certain chemicals for inhibition of Pseudomonas solanacearum. Zentralbl. Bacteriol. Parasitenkd. Infektionskr. Hyg. **133**:235-239.

Gopalakrishnan, T.R. and Thomas, P. 1989. Clusterness and bacterial wilt resistance in chilli (Capsicum annum L.). Proceedings of the First Kerala Science Congress, February, 1989, Cochin: 1-7.

Goth, R.W., Peter, K.V. and Webb, R.E. 1983. Bacterial wilt (Pseudomonas solanacearum) resistance in pepper and eggplant lines. Phytopathology. **73**:808.

*Grinepadeze, M.S.H., Khurtsia, B.N., Khutsishvili, N.A. and Tukhareli, A.R. 1978. Comparitive toxicity of new fungicides towards the casual agent of bacterial disease of mulberry [Pseudomonas mori (Boyer and Lambert) Stevans]. Soobshcheniya Akademii Nank Gruzinskoi SSR. **92**:713-716.

*Gunawan, O.S. 1988. The effect of spraying intervals of Streptomycin sulphate/Oxytetracycline 15/1.5 WP on bacterial wilt of tomato, Pseudomonas solanacearum. Buletin Penilitian Hortikultura, **16**:114-116.

*Gunawan, O.S. 1989. The effect of concentration of streptomycin sulphate antibiotic on multiplication of Pseudomonas solanacearum E.F.Smith. Buletin Penilitian Hortikultura. **17**:110-111.

Harrigan, W.F. and Mc Cance, M.E. 1966. Laboratory Methods in Microbiology. Academic press, London and New York: pp.343.

*Harrison, D.E. 1961. Bacterial wilt of Potatoes. Field symptoms of the disease and studies on the causal organism, Pseudomonas solanacearum var. asiaticum. Aust. J. Agric. Res. **12**:854-871.

Hayward, A.C. 1964. Characteristics of Pseudomonas solanacearum. J. Appl. Bacteriol. **27**:265-277.

*Hayward, A.C. 1979. Systematics of Pseudomonas solanacearum In: Proceedings II Regional symposium on potato production. South east Asia and the Pacific, 5-16 February, 1978, Los Banos, Laguna, Philippines: 35-69.

*Hayward, A.C., Moffett, M.L. and Pegg. K.G. 1967. Bacterial wilt of ginger in Queensland. Queensland J. Agric. and Animal Sci. **24**:1-5.

He, L.Y. 1985. Bacterial wilt in the People's Republic of China. In: Bacterial wilt disease in Asia and the South Pacific, (Ed.) Persley, G.J. ACIAR, Proc.No.13:126-143.

He, L.Y., Sequeira, L. and Kelman, A. 1983. Characteristics of strains of Pseudomonas solanacearum from China. Plant Disease. **67**:1357-1361.

*Hidaka, Z. and Murano, H. 1956. Studies on the Streptomycin for plants I. Behaviour of Pseudomonas solanacearum and Pseudomonas tebaci treated with streptomycin in vitro and surface absorption of streptomycin in the plant. Ann. Phytopath. Soc. Japan. **20**:143-147.

Hingorani, M.K., Mehta, P.P. and Singh, N.J. 1956. Bacterial brown rot of potatoes in India. Indian Phytopath. **9**:67-71.

*Hiryati, A., Maene, L.M.J. and Hamid, N. 1983. The effects of soil types and moisture levels of bacterial wilt disease of groundnut (Arachis hypogea). Pertanika. **6**:26-31.

*Ho, B.L. 1988. Bacterial wilt control in tomato using house hold disinfectants. MARDI Research Journal. **16**:73-76.

*Honing, J.A. 1912. Beschrijving van de Deli-stammen van (Bacillus solanacearum Smith), de oorzaak der slijmziekte. Deli Proefsta. te Medan, Meded. **6**:219-250.

*Hucker, G.J. and Conn, H.J. 1923. Methods of gram staining. N. Y. State Agr. Expt. Sta. Tech. Bull: pp.129.

Husain, A. and Kelman, A. 1958. Relation of slime production to mechanism of wilting and pathogenicity of Pseudomonas solanacearum. Phytopathology. **48**:155-165.

Indian Council of Agricultural Research. 1969. Annual report of the Indian Council of Agricultural Research for the year, 1969.

Ishii, M. and Hiryaki, M. 1963. Ginger wilt caused by Pseudomonas solanacearum (E.F. Smith). Plant Dis. Reptr. **47**:710-713.

Jayaprakash, M.G. 1977. Studies on the control of bacterial wilt of tomato with reference to organic soil amendments and chemicals. M.Sc.(Ag.) Thesis. Kerala Agricultural University, Trichur.

*Jimenez, J.M., Bustamante, E., Bermudez, Weind Gamboo, A. 1988. Response of four cultivars of sweet pepper to bacterial wilt in Coasta Rica. Manejo Integrado de Plagas. 7:19-28.

Kelman, A. 1953. The bacterial wilt caused by Pseudomonas solanacearum. N. C. Agr. Expt. Sta. Tech. Bull. 99:pp.194.

Kelman, A. 1954. The relationship of pathogenicity of Pseudomonas solanacearum, to colony appearance on a tetrazolium medium. Phytopathology. 44:693-695.

Kelman, A. and Jensen, J.H. 1951. Maintaining virulence in isolates of Pseudomonas solanacearum. Phytopathology. 41:185-187.

Kelman, A. and Persoon, L.H. 1961. Strains of Pseudomonas solanacearum, differing in pathogenicity to tobacco and peanut. Phytopathology. 51:158-161.

Kerala Agricultural University. 1988. Annual Progress Report 1987-'88 on I.C.A.R. adhoc scheme on breeding for resistance to bacterial wilt in chillies and brinjal.

Kerala Agricultural University. 1989. Package of Practices Recommendations, Directorate of Extension, Kerala Agricultural University, Trichur, Kerala: p.253.

Khan, A.N.A., Shetty, K.S. and Patil, R.B. 1979. Occurrence of bacterial wilt of chilli in Karnataka and its relationship to the wilts of other solanaceous crops. Indian Phytopath. 32:507-512.

*King, E.O., Ward, M.K. and Raney, D.E. 1954. Two simple media for the demonstration of pyocyanin and fluorescin. J. lab. Clin. Med. 44:301-307.

Kishun, R. 1981. Effects of antibiotics and fungicides on bacterial wilt of tomato. Proc. Fifth Int. Conf. Plant Path. Bact. Cal.:575-579.

Kishun, R. and Chand, R. 1988. Effect of bleaching powder on Pseudomonas solanacearum and other soil microflora. J. Soil Biol. Ecol. **8**:90-94.

Krausz, J.P. and Thurston, H.D. 1975. Breakdown of resistance to Pseudomonas solanacearum in tomato. Phytopathology **65**:1272-1274.

Krieg, N.R. and Holt, J.G. 1984. Bergey's Manual of Systematic Bacteriology. Williams and Wilkins, Baltimore, U.S.A.: pp.177-178.

*Labrousse, F. 1932. Essais sur la technique bacteriologique en pathologie vegetale (2° partie). Le "fil", fletrissement bacterien de la tomate. Ann. des. Epiphyt. **18**:317-339.

Lallmohomed, G.M., Rakotobe-Rabehevitra and Rakotondramanana 1988. Biovars and races of Pseudomonas solanacearum in Madagascar - a preliminary study. Plant Prot. Bull. **36**: 54-59.

*Leandro, M.G. and Zak, L.F. 1983. Effect of various pesticides against Pseudomonas solanacearum in potato. Agrociencia. Mexico. No.51:93-100.

*Lelliott, R.A., Eve Billing and Hayward, A.C. 1966. A determinative scheme for the fluorescent plant pathogenic Pseudomonads. J. Appl. Bacteriol. **29**:470-489.

*Lum, K.Y. 1973. Cross inoculation studies of Pseudomonas solanacearum from ginger. MARDI Research Bulletin. **1**:15-21.

Mathew, J. and Nayar, K. 1983. Bacterial wilt of brinjal incited by Pseudomonas solanacearum var. asiaticum in Kerala. Indian Phytopath. **36**:400.

*Matos, F.S.A., Lopes, C.A. and Takatsu, A. 1990. Identification of sources of resistance to Pseudomonas solanacearum in Capsicum sp. Horticultura Brasileira. **8**:22-23.

Mew, T.W. and Ho, W.C. 1976. Varietal resistance to bacterial wilt in tomato. Plant Dis. Reptr. **60**:264-268.

Mew, T.W. and Ho, W.C. 1977. Effect of soil temperatures on resistance of tomato cultivars to bacterial wilt. Phytopathology. **67**:907-911.

Mishra, C.B.P. 1980. Evaluation of a systemic fungicide (Bavistin) in controlling Hooghly wilt of Jute. Pesticides. **14**:22-23.

Mondal, R. and Mukherjee, N. 1978. Sensitivity of plant bacteria to some antibiotics, antibacterials and other drugs. Zertischrift fur Pflanzenkrankheitan and Pflanzenschutz. **85**:607-616.

Moorgan, B.S. and Goodman, R.N. 1955. In vitro sensitivity of plant bacterial pathogens to antibiotics and antibacterial substances. Plant Dis. Reptr. **39**:487-490.

*Moraes, A. de M. 1947. Uma bacteriose vascular da batateira (Bacterium solanacearum, E.F. Smith). Agron. Lusit [Portugal] **9**:277-328.

Morton, D.J., Dukes, P.D. and Jenkins, S.F. 1965. Serological identification of Pseudomonas solanacearum in four solanaceous hosts. Phytopathology. **55**:1191-1193.

*Murakoshi, S. and Takahashi, M. 1984. Trials of some control of tomato, bacterial wilt caused by Pseudomonas solanacearum. Bull. Kanagawa Hort. Expt. Sta. No.31:50-56.

Nayar, K. 1982. Etiology, survival and control of bacterial wilt of brinjal caused by Pseudomonas solanacearum. E.F.Smith. M.Sc.(Ag.) Thesis, Kerala Agricultural University, Trichur.

Ojha, K.L., Yadav, B.P. and Bhagat, A.P. 1986. Chemical control of bacterial wilt of ginger. Indian Phytopath. **39**:600-601.

*Okabe, N. 1937. Studies on the variation of Bacterium solanacearum. Ann. Phytopath. Soc. Japan. **7**:95-104.

*Okabe, N. 1949. Studies on Bacterium solanacearum with special reference to the pathogenicity of colony variants. Res. Bull. Shizuoka. Agr. Coll. **1**:41-59.

*Okabe, N. and Goto, M. 1954. Studies on Bacterium solanacearum VI. A comparative study of the colony types. Organism, F and OP. Shizuoka Univ. Fac. Agric. Rep. **4**:41-60.

*Okabe, N. and Goto, M. 1961. Studies on Pseudomonas solanacearum XI. Pathotypes in Japan. Shizuoka Uni. Fac. Agric. Rep. **11**:25-42.

Palleroni, N.J. and Duodoroff. 1971. Phenotypic characterization and de-oxyribonucleic acid homologies of Pseudomonas solanacearum. J. Bacteriol. **107**:690-696.

*Park, M. 1932. Report of mycological division. Ceylon Admn. Rpts., Rpt. Dir. Agr. for 1931: 103-111.

*Perez, J.E. 1962. The use of Fuller's formamide method in the serological identification of Pseudomonas solanacearum. J. Agr. Univ. Peurto Rico. **46**:144-153.

Persley, G.J., Batugal, P., Gapasin, D. and Vander Zaag. 1985. Summary of Discussion and Recommendations. In: Bacterial wilt disease in Asia and the South Pacific. (Ed.) Persley, G.J., ACIAR, Proc.No.13:7-9.

Peter, K.V., Goth, R.W. and Webb, R.E. 1984. Indian hot peppers as sources of resistance to bacterial wilt, Phytophthora root rot and root knot nematode. Hort. Science. **19**:277-278.

Prior, P. and Steva, H. 1990. Characteristics of strains of Pseudomonas solanacearum from the French West Indies. Plant Disease. **74**:13-17.

*Psallidas, P.G. 1985. Bacterial wilt of tomato and eggplant caused by Pseudomonas solanacearum in Greece (Abstract) 3rd National Phytopathological Conference, Hellenic Phytopathological Society, October 16-18, 1985, Greece.

*Quimio, A.J. and Tabei, H. 1979. Temperature relation of Philippine solanaceous isolates of Pseudomonas solanacearum. Philipp. Phytopath. **15**:69-75.

Quinon, V.L., Aragaki, H. and Ishii, M. 1964. Pathogenicity and serological relationship of three strains of Pseudomonas solanacearum in Hawaii. Phytopathology. **54**:1096-1099.

Rahim, M.A. 1972. Studies of bacterial wilt of chillies with special reference to varietal resistance, control and changes that are brought about in rhizosphere microflora. M.Sc.(Ag.) Thesis. University of Kerala.

Rahim, M.A. and Samraj, J. 1974. Comparitive resistance of certain varieties of chillies to the bacterial wilt caused by Pseudomonas solanacearum, E.F.Smith. Agric. Res. J. Kerala. **12**:105.

Rangarajan, M. and Chakravarti, B.P. 1969. Efficacy of antibiotics and fungicides against corn stalk rot bacteria. Hind. Antibiotics Bull. **11**:177-179.

Rangaswami, G. 1957. Effect of some antibiotics on Xanthomonas malvacearum, and on the microflora of seed cotton. Indian Phytopath. **10**:8-10.

Rangaswami, G., Rao, R.R. and Lakshmanan, A.R. 1959. Studies on the control of citrus canker with streptomycin. Phytopathology. **49**:224-226.

Rath .iah, Y. 1983. Yield and reaction to fruit rot, bacterial wilt, and Cercospora leaf spot of chilli cultivars. J. Res. Assam Agric. Univ. **4**:31-33.

Rath, P.K. and Addy, S.K. 1977. Variation in Pseudomonas solanacearum, causing bacterial wilt of tomato. Indian Phytopath. **30**:502-505.

*Reinking, O.A. 1919a. Host index of disease of economic plants in the Philippines. Philipp. Agric. **8**:38-54.

Reinking, O.A. 1919b. Philippine plant diseases. Phytopathology. 9:114-140.

*Ren, H. and Fang, C. 1981. Identification of causal organism of the bacterial wilt of ginger. Acta Phytopathologica Sinica 11:51-56.

*Rolfs, P.H. 1898a. Diseases of the tomato. Fla. Agr. Expt. Sta. Bull. 47:128-136.

*Rolfs, P.H. 1898b. Bacterial tomato blight (Bacillus solanacearum Smith). Report of the biologist and horticulturist. Fla. Agr. Expt. Sta. Ann. Rept. for 1898:30-31.

*Rolfs, P.H. 1898c. Bacterial tomato blight (Bacillus solanacearum, Smith). Injurious insects and diseases of the year. Fla. State. Hort. Soc. Rpt. Proc. Ann. Meeting. 11:90-93.

Samuel, M. 1980. Etiology of the bacterial wilt of ginger incited by Pseudomonas solanacearum E.F.Smith and its control. M.Sc.(Ag.) Thesis, Kerala Agricultural University, Trichur.

*Schwarz, M.B., 1926. De invloed van de voorvrucht op het optreden van slijmziekte (Bacterium solanacearum) in Arachis hypogea en eenige andere gewassen. Inst. v. Plantenziekten, Meded. 71:37.

*Severin, V. and Kupferberg, S. 1977. Studies on the bacterial blight of walnut caused by Xanthomonas juglandis. Analele Institulus de Cercetari Pentru Protectia Plantelor. 12:73-81.

Shivappashetty, K.S. and Rangaswami, G. 1971. In vitro and in vivo activities of streptocycline on bacterial blight of rice caused by Xanthomonas oryzae. Indian Phytopath. **24**: 145-152.

Sitaramaiah, K. and Sinha, S.K. 1983. Relative efficacy of some selected antibiotics on bacterial wilt (P. solanacearum biotype 3) of brinjal. Indian J. Mycol. Pl. Pathol. **13**: 277-281.

*Smith, E.F. 1896. A bacterial disease of the tomato, eggplant and Irish potato (Bacillus solanacearum nov sp). U. S. Dept. Agric. Div. Veg. Phys. Path. Bull. **12**:1-28.

*Smith, E.F. 1914. Bacteria in relation to plant diseases. Carnegie Inst. Wash. **3**:309.

*Smith, N.R., Gordan, R.E. and Clark, F.E. 1946. Aerobic mesophilic spore forming bacteria. U. S. Dept. Agr. Misc. Publ: 559.

Smith, T.E. and Clayton, E.E. 1943. Control of granville wilt (Bacterium solanacearum) of tobacco and other plants by application of urea to soil. Phytopathology. **33**:11-12.

Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods VI Ed. Oxford and IBH Publishing Co., Calcutta, India.

Society of American Bacteriologists. 1957. Manual of Microbiological methods. Mc Graw Hill Book Co. Inc., New York, U.S.A.

Stanford, E.F. and Wolf, F.A. 1917. Studies on Bacterium solanacearum. Phytopathology. **7**:155-165.

Starr, M.P. and Weiss, J.E. 1943. Growth of Phytopathogenic bacteria in a synthetic asparagine medium. Phytopathology. **33**:313-318.

Swanepoel, A.E. and Young, B.W. 1988. Characteristics of South African Strains of Pseudomonas solanacearum. Plant Disease. **72**:403-405.

Tabei, H. and Quimio, A.J. 1978. Strain differentiation of Pseudomonas solanacearum affecting solanaceous crops in Philippines, JARQ **12**:238-240.

Thomas, P. 1985. Transfer of clusterness to bell pepper (Capsicum annum L. var. grossum Sendt). M.Sc.(Ag.) Thesis, Kerala Agricultural University, Trichur.

Thornley, M. 1960. The differentiation of Pseudomonas solanacearum from other gram negative bacteria on the basis of arginine metabolism. J. Appl. Bacteriol. **23**:37.

Valdez, R.B. 1985 Bacterial wilt in the Philippines. In: Bacterial wilt disease in Asia and the South Pacific. (Ed.) Persley, G.J., ACIAR, Proc. No.13:49-56.

Vaughan, E.K. 1944. Bacterial wilt of tomato caused by Phytomonas solanacearum. Phytopathology. **34**:443-458.

*Velupillai, M. and Stall, R.E. 1984. Variation among strains of Pseudomonas solanacearum from Florida. Proc. Florida State Hort. Soc. **97**:209-213.

Winstead, N.N. and Kelman, A. 1952. Evaluation of resistance in tomato to Pseudomonas solanacearum. Phytopathology. **42**: 628-634.

Zaumeyer, W.J., Thomas, H.R., Mitchell, T.W. and Fisher, H.H. 1953. Field control of halo blight of leaves with Streptomycin. Phytopathology. **43**:407.

*Zehr, E.I. 1969. Studies of the distribution and economic importance of Pseudomonas solanacearum E.F. Smith in certain crops in the Philippines. The Philippine Agriculturist. **53**:210-213.

* Originals not seen

Appendices

Appendix-I. Observations on the weather parameters during the period of growth of chilli accessions/varieties

Period* (week)	Max. temp. (°C)	Min. temp. (°C)	Soil temp. at 7 AM (°C)	Soil temp. at 2 PM (°C)	At humidity (%)	Rainfall (mm)	No. of rainy days	Soil moisture (%)
1	28.5	23.3	25.4	27.9	83.5	121.6	7	15.6
2	29.7	23.1	26.1	30.1	79.5	28.3	5	15.0
3	30.6	23.6	26.9	30.7	78.0	14.7	4	5.5
4	30.0	23.1	26.8	30.2	84.0	60.9	6	8.3
5	30.9	24.0	27.5	31.1	77.5	0	0	6.9
6	31.0	23.4	27.6	31.0	77.5	6.9	2	7.0
7	31.1	23.1	26.9	31.5	79.0	16.9	3	8.3
8	30.6	22.5	26.6	31.7	81.5	26.9	3	8.2
9	32.4	23.7	27.5	34.4	77.5	14.4	2	8.7
10	33.5	23.2	27.3	33.5	75.0	22.3	3	9.6
11	31.8	23.3	26.6	31.4	85.0	133.9	5	10.6

*Starting from second week of August to last week of October

Appendix-II. Correlation coefficients between meteorological factors and wilt incidence of different chilli accessions/varieties

Meteorological factors	Correlation coefficients of the accessions/varieties								
	CA 418	CA 451	CA 192	CA 3	CA 389	CA 449	CA 209	CA 356	CA 213
Max. temp.	-0.5653	-0.5622	-0.2946	-0.3334	-0.5146	-0.1823	-0.3157	-0.3677	-0.4571
Min. temp.	-0.3115	0.0909	0.1919	0.4885	-0.3349	-0.4681	-0.4648	0.2142	0.2097
Soil temp. (M) (7 AM)	-0.2543	-0.5837	0.0244	0.0508	-0.4089	-0.0346	-0.1823	-0.2230	-0.4459
Soil temp. (N) (2 PM)	-0.3451	-0.5555	-0.3433	-0.2739	-0.4263	-0.0996	-0.2037	-0.2414	-0.5079
At humidity	0.0478	0.0396	-0.0960	-0.0611	0.2629	-0.0607	0.0029	0.0748	0.0952
Rainfall	-0.2392	0.1157	-0.1995	-0.1401	0.0437	-0.2890	-0.2958	0.0466	0.2311
No. of rainy days	0.0307	0.4787	-0.0234	-0.0654	0.1563	-0.1883	0.0847	-0.1688	0.4136
Soil moisture	-0.0830	0.3783	-0.3464	-0.2595	-0.0790	-0.1762	-0.2529	0.0772	0.0821

Contd.

Appendix-II. Continued

Meteorological factors	Correlation coefficients of the accessions/varieties									
	CA 207	CA 33	CA 225	CA 409	CA 372	CA 367	CA 388	CA 408	CA 345	CA 160
Max. temp.	-0.5187	-0.1668	-0.2557	-0.4850	0.0497	-0.1852	-0.1473	-0.5619	-0.2453	-0.2633
Min. temp.	-0.0947	-0.2313	0.1388	-0.2839	0.0714	-0.0249	-0.0515	-0.6215*	-0.0906	-0.1868
Soil temp. (7 AM)	-0.4512	-0.1288	-0.0766	-0.2442	0.3823	-0.1653	0.0647	-0.7057*	-0.2815	-0.2663
Soil temp. (2 PM)	-0.0793	-0.1179	-0.1017	-0.4773	0.2113	-0.2004	-0.1372	-0.4210	-0.2656	-0.2577
At humidity	0.2557	0.0237	-0.1069	-0.0358	-0.3007	0.0070	-0.1350	0.2456	0.0387	0.0929
Rainfall	0.2586	-0.1152	-0.2798	-0.0786	-0.5747	-0.0134	-0.3202	0.1069	0.0469	0.0076
No.of rainy days	0.0874	-0.1529	-0.0035	-0.1615	-0.4024	-0.0307	-0.1017	0.3429	0.1647	0.2062
Soil moisture	0.3702	-0.0422	-0.3462	0.0187	-0.5223	0.0703	-0.1772	0.6215*	0.0653	0.0924

Contd.

*Significant at 0.05% level

Appendix-II. Continued

Meteorological factors	Correlation coefficients of the accessions/varieties									
	CA 375	CA 217	CA 452	CA 515	CA 222	CA 417	CA 205	CA 379	CA 53	CA 337
Max. temp.	0.0010	-0.2220	-0.4750	-0.2917	-0.3387	-0.1572	-0.1258	-0.5723	-0.3104	-0.3398
Min. temp.	-0.3321	0.0836	-0.5468	0.0749	0.1027	0.0989	-0.3241	-0.5150	0.4344	-0.0226
Soil temp. (7 AM)	0.0612	-0.1263	-0.3677	-0.0791	-0.0276	0.2326	-0.1207	-0.4705	0.2361	0.0442
Soil temp. (2 PM)	0.0874	0.0620	-0.3167	-0.3266	-0.2110	-0.2082	0.1037	-0.4393	-0.3619	-0.2444
At humidity	-0.0566	-0.1094	0.3089	-0.2273	-0.2594	-0.1549	-0.0797	0.2915	-0.2815	-0.1842
Rainfall	-0.2890	-0.2728	-0.0328	-0.2471	-0.3057	-0.2858	-0.3008	-0.0395	-0.4105	-0.4023
No.of rainy days	-0.3125	0.0154	-0.0276	0.0672	-0.0958	-0.2143	-0.0320	0.2556	-0.3656	-0.4083
Soil moisture	-0.2382	-0.0372	0.1095	-0.1536	0.1117	-0.3422	-0.1578	0.0605	-0.3357	-0.0588

Appendix III. Reaction of chilli accessions of NBPGR Regional

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
1.	6-1	7	85.7	S	31	518-3	7	71.4	S
2.	6-2	7	28.6	MR	32	518-4	7	0	R
3.	36	7	100.0	S	33	518-5	7	28.6	MR
4.	52	5	60.0	MS	34	530-1	7	0	R
5.	129-1	2	100.0	S	35	539-1	7	42.9	MS
6.	129-2	7	42.8	MS	36	539-2	7	100.0	S
7.	159-0	7	71.4	S	37	539-3	9	11.1	R
8.	236-0	4	25.0	MR	38	539-4	6	50.0	MS
9.	263	7	28.6	MR	39	597-1	7	42.9	MS
10.	271	4	100.0	S	40	634-1	7	42.9	MS
11.	347	6	33.3	MR	41	634-2	7	28.6	MR
12.	375-1	7	14.3	R	42	634-3	7	57.1	MS
13.	443_1	3	100.0	S	43	634-4	7	14.3	R
14.	443-2	3	33.3	MR	44	634-5	7	0	R
15.	443-3	4	50.0	MS	45	634_6	7	28.6	MR
16.	453	7	42.9	MS	46	634-7	7	0	R
17.	454	7	42.9	MS	47	634-8	10	10.0	R
18.	480-1	7	42.9	MS	48	534-9	7	28.6	MR
19.	480-2	6	0	R	49	634-10	7	28.6	MR
20.	480-3	7	14.3	R	50	656	7	14.3	R
21.	483-1	7	0	R	51	793-1	7	28.6	MR
22	483-2	7	57.1	MS	52	793-2	4	50.0	MS
23	483-3	7	14.3	R	53	793-3	4	28.6	MR
24	486	7	28.6	MR	54	795-1	7	100.0	S
25	490-1	6	16.6	R	55	795-2	7	85.8	S
26	490-2	6	0	R	56	796	7	57.1	MS
27	491-1	7	71.4	S	57	797-1	7	14.3	R
28	491-2	7	71.4	S	58	797-2	7	0	R
29	518-1	7	57.1	MS	59	797-3	5	0	R
30	518-2	7	71.4	S	60	797-4	6	16.7	R

Station, Vellanikkara to bacterial wilt

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
61	797-5	7	0	R	91	873-1	7	85.7	S
62	803-1	7	42.9	MS	92	873-2	7	85.7	S
63	803-2	7	28.6	MR	93	873-3	9	25	MR
64	811-1	7	14.3	R	94	953-1	8	100.0	S
65	811-2	7	28.6	MR	95	953-2	6	33.3	MR
66	811-3	7	71.4	S	96	953-3	6	100.0	S
67	811-4	2	0	R	97	956-1	7	42.9	MS
68	811-5	7	28.6	MR	98	956-2	7	42.9	MS
69	836-1	7	0	R	99	956-3	7	42.9	MS
70	841-1	7	42.9	MS	100	956-4	7	14.3	R
71	841_2	3	33.3	MR	101	956-5	7	57.1	MS
72	841-3	10	70.0	S	102	956-6	7	57.1	MS
73	846-1	7	71.4	S	103	957-1	7	28.6	MR
74	846_2	7	57.1	MS	104	957-2	9	77.8	S
75	846-3	7	42.9	MS	105	960-1	9	33.3	MS
76	846-4	7	71.4	S	106	960-2	7	100.0	S
77	847-1	7	14.3	R	107	960-3	7	28.6	MR
78	847-2	7	28.6	MR	108	961-1	7	28.6	MR
79	847-3	7	57.1	MS	109	961-2	7	57.1	MS
80	849-1	7	85.0	S	110	963-1	7	71.4	S
81	851-1	7	14.3	R	111	963-2	7	71.4	S
82	851-2	7	14.2	R	112	963-3	7	85.7	S
83	852-1	9	44.4	MS	113	963-4	7	42.9	MS
84	865-1	7	0	R	114	963-5	3	100.0	S
85	865-2	7	14.3	R	115	963-6	4	100.0	S
86	868-1	7	28.6	MR	116	993-1	8	37.6	MR
87	868-2	7	14.3	R	117	993-2	4	75	S
88	868-3	7	85.7	S	118	993-3	7	71.4	S
89	868-4	7	57.1	MS	119	993-4	7	71.4	S
90	868-5	7	28.6	MR	120	1020-1	7	100.0	S

(Contd.....

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
121	1020-2	7	42.9	MS	151	1105-1	8	62.5	S
122	1021-1	7	71.4	S	152	1106-1	7	42.9	MS
123	1021-2	7	57.1	MS	153	1106-2	7	28.6	MR
124	1022-1	7	42.9	MS	154	1106-3	7	28.6	MR
125	1022-2	7	57.1	MS	155	1107	7	71.4	S
126	1022-3	7	28.6	MR	156	1108-1	7	28.6	MR
127	1027-1	7	57.1	MS	157	1108-2	7	0	R
128	1027-2	7	100.0	S	158	1110-1	7	28.6	MR
129	1029	7	71.4	S	159	1110-2	7	0	R
130	1032-1	7	0	R	160	1110-3	7	100.0	S
131	1032-2	7	71.4	S	161	1110-4	8	12.5	R
132	1032-3	6	100.0	S	162	1112-1	8	75.0	S
133	1034-1	7	57.1	MS	163	1112-2	7	42.9	MS
134	1037-1	7	100.0	S	164	1112-3	7	42.9	MS
135	1037-2	7	28.6	MR	165	1112-4	7	28.6	MR
136	1037-3	7	14.3	R	166	1113	2	100.0	S
137	1051-1	7	71.4	S	167	1116-1	7	100.0	S
138	1051-2	11	100.0	S	168	1117-1	7	28.6	MR
139	1091	6	66.7	S	169	1117-2	7	71.4	S
140	1095-1	7	14.3	R	170	1117-3	7	71.4	S
141	1095-2	7	57.1	MS	171	1121	7	71.4	S
142	1096-1	1	100.0	S	172	1122	7	71.4	S
143	1096-2	7	100.0	S	173	1123	6	100.0	S
144	1097-1	7	71.4	S	174	1124	3	0	R
145	1097-2	7	71.4	S	175	1127-1	3	66.7	S
146	1097-3	7	100.0	S	176	1127-2	4	25.0	MR
147	1097-4	7	14.3	R	177	1127-3	6	33.3	MR
148	1097-5	7	100.0	S	178	1129	7	14.3	R
149	1101-1	7	57.1	MS	179	1130	7	42.9	MS
150	1101-2	6	16.7	R	180	1132	7	57.1	MS

....)

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
181	1134-1	7	42.9	MS	211	3935	4	100.0	S
182	1134-2	7	42.9	MS	212	1402	7	71.4	S
183	1135_1	7	71.4	S	213	1403-1	4	25.0	MR
184	1135-2	7	85.7	S	214	1403-2	3	0	R
185	1135-3	7	42.9	MS	215	1404	1	100.0	S
186	1135-4	7	57.1	MS	216	1405	1	100.0	S
187	1139-1	5	60.0	MS	217	1406	4	0	R
188	1140	7	57.1	MS	218	1407	7	85.7	S
189	1148-1	7	100.0	S	219	1410	1	0	R
190	1148-2	7	71.4	S	220	1411	1	100.0	S
191	1148-3	7	85.7	S	221	1412	3	33.3	MR
192	1163-1	7	28.6	MR	222	1414	7	71.4	S
193	1334	7	71.4	S	223	1415	7	28.6	MR
194	1342	3	100.0	S	224	1417	7	42.9	MS
195	1345-1	7	71.4	S	225	1418	1	100.0	S
196	1346-1	7	71.4	S	226	1419	7	42.9	MS
197	1346-2	2	0	R	227	1423	2	50.0	MS
198	1347-1	8	87.5	S	228	1424	7	28.6	MR
199	1349-1	9	77.8	S	229	1425	3	66.7	S
200	1353	2	100.0	S	230	1426	6	100.0	S
201	1357-1	7	85.7	S	231	1427	5	20.0	R
202	1358	7	28.6	MR	232	1428	2	100.0	S
203	1364	3	0	R	233	1429	7	85.7	S
204	1374	7	57.1	MS	234	1430	7	71.4	S
205	1383	7	14.3	R	235	1432	7	42.9	MS
206	1384	7	14.3	R	236	1433	7	100.0	S
207	1387	7	100.0	S	237	1435	7	71.4	S
208	1389	7	85.7	S	238	1436	4	50.0	MS
209	1400-1	7	28.6	MR	239	1437	7	42.9	MS
210	1400-2	7	28.6	MR	240	1438	7	85.7	S

(Contd...

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
241	1439	7	100.0	S	271	1473	7	14.3	R
242	1440	8	12.5	R	272	1474	7	71.4	S
243	1441	9	22.2	MR	273	1475	7	28.6	MR
244	1442	7	57.1	MS	274	1476	3	33.3	MR
245	1443	1	100.0	S	275	1477	7	14.3	R
246	1444	7	28.6	MR	276	1478	7	42.9	MS
247	1445	7	42.9	MS	277	1479	3	66.7	S
248	1446	7	42.9	MS	278	1480	7	85.7	S
249	1447	7	14.3	R	279	1481	7	57.1	MS
250	1448	7	71.4	S	280	1482	4	0	R
251	1449	7	85.7	S	281	1483	6	0	R
252	1450	7	100.0	S	282	1485	6	50.0	MS
253	1451	2	100.0	S	283	1488	7	42.9	MS
254	1452	7	14.3	R	284	1490	7	28.6	MR
255	1453	6	83.3	S	285	1491	7	28.6	MR
256	1454	6	83.3	S	286	1492	7	0	R
257	1456	7	28.6	MR	287	1493	7	0	R
258	1457	7	100.0	S	288	1494	7	71.4	S
259	1458	7	57.1	MS	289	1495	7	14.3	R
260	1461	2	0	R	290	1496	4	0	R
261	1462	2	0	R	291	1497	7	42.9	MS
262	1463	7	0	R	292	1498	7	0	R
263	1464	7	42.9	MS	293	1499	6	50.0	MS
264	1466	7	57.1	MS	294	1500	6	66.7	S
265	1467	7	0	R	295	1501	7	0	R
266	1468	7	0	R	296	1502	5	100.0	S
267	1469	6	100.0	S	297	1503	2	50.0	MS
268	1470	6	0	R	298	1505	4	50.0	MS
269	1471	6	16.7	R	299	1506	7	71.4	S
270	1472	7	14.3	R	300	1507	4	50.0	MS

.....)

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
301	1508	1	100.0	S	331	1541	6	33.3	MR
302	1510	1	100.0	S	332	1542	7	100.0	S
303	1511	7	100.0	S	333	1543	9	100.0	S
304	1512	7	100.0	S	334	1544	7	100.0	S
305	1513	2	100.0	S	335	1545	7	71.4	S
306	1514	7	85.7	S	336	1546	7	42.9	MS
307	1516	9	55.6	MS	337	1547	7	100.0	S
308	1517	9	33.3	MR	338	1548	7	57.1	MS
309	1519	4	25.0	MR	339	1551	1	100.0	S
310	1521	7	28.6	MR	340	1552	7	100.0	S
311	1522	7	28.6	MR	341	1553	7	100.0	S
312	1523	7	28.6	MR	342	1554	7	85.7	S
313	1524	6	16.7	R	343	1556	5	60.0	MS
314	1525	7	14.3	R	344	1557	7	100.0	S
315	1526	7	14.3	R	345	1558	6	100.0	S
316	1527	5	40.0	MR	346	1559	3	100.0	S
317	1528	5	0	R	347	1560	7	100.0	S
318	1529	7	0	R	348	1561	7	42.9	MS
319	1530	7	0	R	349	1562	1	100.0	S
320	1531	7	71.4	S	350	1563	5	40.0	MR
321	1532	7	28.6	MR	351	1564	7	71.4	S
322	1533	7	100.0	S	352	1565	7	100.0	S
323	1534	1	100.0	S	353	1566	7	100.0	S
324	1535	7	42.0	MS	354	1567	7	85.7	S
325	1536	7	100.0	S	355	1568	7	100.0	S
326	1537	7	100.0	S	356	1569	3	33.3	MR
327	1538	7	71.4	S	357	1570	7	100.0	S
328	1539_1	7	100.0	S	358	1571	5	60.0	MS
329	1539_2	7	100.0	S	359	1572	8	75.0	S
330	1540	7	100.0	S	360	1573	7	100.0	S

(Contd.....

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
361	1574	7	85.7	S	391	1608	7	100.0	S
362	1575	7	57.1	MS	392	1609	7	85.7	S
363	1576	2	100.0	S	393	1610	7	71.2	S
364	1577	6	100.0	S	394	1611	7	100.0	S
365	1578	5	100.0	S	395	1612	7	100.0	S
366	1579	7	71.4	S	396	1613	10	100.0	S
367	1580	7	100.0	S	397	1614	3	100.0	S
368	1582	7	100.0	S	398	1615	7	57.1	MS
369	1583	7	100.0	S	399	1616	4	75.0	S
370	1584	7	100.0	S	400	1617	7	100.0	S
371	1585	7	85.7	S	401	1618	5	80.0	S
372	1586	3	100.0	S	402	1619	7	100.0	S
373	1587	7	100.0	S	403	1620	4	100.0	S
374	1588	7	100.0	S	404	1621	7	100.0	S
375	1589	2	100.0	S	405	1622	7	28.5	MR
376	1590	7	85.7	S	406	1623	7	85.7	S
377	1592	4	75.0	S	407	1624	7	85.7	S
378	1593	7	100.0	S	408	1625	7	71.4	S
379	1594	7	100.0	S	409	1626	6	100.0	S
380	1595	7	100.0	S	410	1627	7	57.1	MS
381	1596	7	100.0	S	411	1628	6	100.0	S
382	1597	7	100.0	S	412	1629	7	71.4	S
383	1598	8	100.0	S	413	1630	3	100.0	S
384	1599	9	77.8	S	414	1631	7	85.7	S
385	1601	7	100.0	S	415	1632	6	100.0	S
386	1603	7	71.8	S	416	1633	3	100.0	S
387	1604	5	100.0	S	417	1634	7	71.4	S
388	1605	7	100.0	S	418	1635	7	100.0	S
389	1606	1	100.0	S	419	1636	7	28.6	MR
390	1607	7	100.0	S	420	1637	6	56.7	MS

...)

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
421	1638	9	100.0	S	451	1670	5	40.0	MR
422	1639	3	100.0	S	452	1671	5	100.0	S
423	1640	5	100.0	S	453	1672	5	100.0	S
424	1641	5	100.0	S	454	1673	7	57.1	MS
425	1643	5	100.0	S	455	1674	5	20.0	R
426	1644	3	100.0	S	456	1675	5	80.0	S
427	1645	5	100.0	S	457	1676	5	80.0	S
428	1646	5	100.0	S	458	1677	5	100.0	S
429	1647	3	100.0	S	459	1678	5	40.0	MR
430	1648	5	100.0	S	460	1679	5	100.0	S
431	1649	5	100.0	S	461	1680	5	60.0	MS
432	1650	5	100.0	S	462	1682	5	100.0	S
433	1651	5	100.0	S	463	1683	5	100.0	S
434	1652	5	60.0	MS	464	1684	5	60.0	MS
435	1653	5	60.0	MS	465	1685	5	100.0	S
436	1654	5	100.0	S	466	1686	5	100.0	S
437	1655	5	100.0	S	467	1687	5	100.0	S
438	1656	6	100.0	S	468	1688	5	60.0	MS
439	1657	5	100.0	S	469	1689	8	50.0	MS
440	1659	5	60.0	MS	470	1690	5	80.0	S
441	1660	5	100.0	S	471	1691	5	80.0	S
442	1661	5	40.0	MR	472	1692	5	100.0	S
443	1662	5	40.0	MR	473	1693	5	100.0	S
444	1663	5	100.0	S	474	1694	5	80.0	S
445	1664	3	100.0	S	475	1695	5	100.0	S
446	1665	2	100.0	S	476	1696	5	80.0	S
447	1666	5	100.0	S	477	1697	5	40.0	MR
448	1667	5	100.0	S	478	1698	5	100.0	S
449	1668	5	100.0	S	479	1699	5	100.0	S
450	1669	5	80.0	S	480	1700	5	100.0	S

(Contd.

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
481	1701	5	100.0	S	511	1735	5	80.0	S
482	1702	5	100.0	S	512	1736	5	100.0	S
483	1703	5	100.0	S	513	1737	5	100.0	S
484	1704	5	100.0	S	514	1738	5	60.0	MS
485	1705	2	100.0	S	515	1739	5	100.0	S
486	1706	5	60.0	MS	516	1740	8	100.0	S
487	1707	4	75.0	S	517	1741	5	100.0	S
488	1708	5	60.0	MS	518	1742	5	80.0	S
489	1709	5	100.0	S	519	1743	5	40.0	MR
490	1710	5	100.0	S	520	1744	5	100.0	S
491	1711	5	100.0	S	521	1745	5	100.0	S
492	1712	5	100.0	S	522	1746	5	80.0	S
493	1713	5	100.0	S	523	1747	5	100.0	S
494	1715	5	100.0	S	524	1748	5	100.0	S
495	1716	5	100.0	S	525	1749	2	100.0	S
496	1717	5	40.0	MR	526	1751	5	80.0	S
497	1718	5	100.0	S	527	1752	5	80.0	S
498	1719	5	80.0	S	528	1753	5	100.0	S
499	1720	5	40.0	MR	529	1754	5	60.0	MS
500	1721	5	60.0	MS	530	1755	5	100.0	S
501	1722	3	100.0	S	531	1756	2	100.0	S
502	1723	5	100.0	S	532	1757	2	100.0	S
503	1724	5	100.0	S	533	1758	5	100.0	S
504	1725	5	100.0	S	534	1759	5	100.0	S
505	1726	5	60.0	MS	535	1760	5	60.0	MS
506	1727	5	60.0	MS	536	1761	5	100.0	S
507	1728	5	100.0	S	537	1762	5	40.0	MR
508	1729	5	100.0	S	538	1763	5	60.0	MS
509	1730	5	100.0	S	539	1764	5	60.0	MS
600	1731	5	100.0	S	540	1765	5	80.0	S

.....)

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
541	1766	5	100.0	S	571	847-5	5	20.0	R
542	1768	5	0	R	572	851-3	5	40.0	MR
543	1769	5	80.0	S	573	852-2	5	80.0	S
544	1770	5	80.0	S	574	865-3	5	20.0	R
545	1771	5	100.0	S	575	868-6	5	40.0	MR
546	1772	5	60.0	MS	576	868-7	1	0	R
547	1773	8	100.0	S	577	873-4	5	60.0	MS
548	304-1	5	40.0	MR	578	956-7	5	40.0	MR
549	304-2	5	20.0	R	579	956-8	5	80.0	S
550	375-2	2	100.0	S	580	956-9	6	50.0	MS
551	518-6	4	25.0	MR	581	956-10	5	100.0	S
552	518-7	2	50.0	MS	582	956-11	5	20.0	R
553	539-5	5	0	R	583	956-12	5	60.0	MS
554	597-2	5	40.0	MR	584	957-3	5	80.0	S
555	625-1	5	20.0	R	585	957-4	5	60.0	MS
556	634-11	5	20.0	R	586	960-4	5	40.0	MR
557	634-12	5	60.0	MS	587	963-7	5	60.0	MS
558	634-13	5	0	R	588	993-5	5	0	R
559	634-14	5	0	R	589	993-6	5	60.0	MS
560	634-15	5	20.0	R	590	1020-3	5	40.0	MR
561	795-3	5	20.0	R	591	1022-4	5	20.0	R
562	803-3	5	40.0	MR	592	1022-5	5	100.0	S
563	803-4	5	0	R	593	1022-6	5	100.0	S
564	811-6	3	33.3	MR	594	1027-3	5	80.0	S
565	811-7	5	60.0	MS	595	1027-4	8	100.0	S
566	836-2	5	100.0	S	596	1032-4	5	40.0	MR
567	841-4	5	0	R	597	1037-4	5	100.0	S
568	846-5	5	80.0	S	598	1037-5	5	100.0	S
569	846-6	5	20.0	R	599	1051-3	5	100.0	S
570	847-4	5	40.0	MR	600	1095-3	5	100.0	S

(Contd.....)

Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.	Sl. No.	Accession number of NBPGR	No. of plants observed	Wilt incidence (%)	Wilt incidence Reaction.
601	1095-4	5	100.0	S	632	634-11	5	20.0	R	662	157-2	5	60.0	MS	692	963-10	5	20.0	R
602	1097-6	5	80.0	S	633	634-12	5	60.0	MS	663	158-1	5	20.0	R	693	1020-4	5	40.0	MR
603	1097-7	4	100.0	S	634	634-13	5	20.0	R	664	159-2	5	100.0	S	694	1022-7	5	100.0	S
604	1097-8	5	80.0	S	635	634-14	5	80.0	S	665	5[illegible]-2	5	100.0	S	695	1022-8	5	80.0	S
605	1097-9	5	100.0	S	636	956-7	5	100.0	S	666	59[illegible]-3	5	80.0	S	696	1051-4	4	25.0	MR
606	1105-2	5	100.0	S	637	956-8	5	80.0	S	667	625-2	5	20.0	R	697	1097-10	5	60.0	MS
607	1106-4	5	100.0	S	638	956-9	5	80.0	S	668	634-16	5	60.0	MS	698	1105-3	5	100.0	S
608	1106-5	1	100.0	S	639	956-10	5	40.0	MR	669	634-17	5	20.0	R	699	1106-5	5	80.0	S
609	1108-3	5	60.0	MS	640	956-11	5	80.0	S	670	803-5	8	12.5	R	700	1106-6	5	40.0	MR
610	1112_5	5	60.0	MS	641	956-12	5	100.0	S	671	811-8	5	40.0	MR	701	1112-7	5	40.0	MR
611	1112-6	5	100.0	S	642	956-13	5	20.0	R	672	811-9	5	80.0	S	702	1116-3	5	0	R
612	1116-2	7	100.0	S	643	956-14	5	20.0	R	673	841-5	5	40.0	MR	703	1127-5	5	100.0	S
613	1117-4	5	40.0	MR	644	956-15	7	28.6	MR	674	841-6	5	80.0	S	704	1134-4	5	80.0	S
614	1117-5	5	0	R	645	956-16	5	40.0	MR	675	846-7	5	20.0	R	705	1345-3	5	60.0	MS
615	1127-4	5	60.0	MS	646	956-17	5	20.0	R	676	846-8	5	60.0	MS	706	1347-3	5	60.0	MS
616	1134-3	3	66.66	S	647	956-78	5	20.0	R	677	846-9	5	40.0	MR	707	1349-2	5	20.0	R
617	1135-5	1	0	R	648	956-19	5	40.0	MR	678	849-2	5	60.0	MS	708	1357-2	5	20.0	R
618	1135_6	2	100.0	S	649	956-20	5	40.0	MR	679	868-8	5	60.0	MS	709	1400-4	4	100.0	S
619	1135_7	5	80.0	S	650	956-21	5	40.0	MR	680	956-13	5	80.0	S	710	834.0	5	80.0	S
620	1341-2	5	60.0	MS	651	956-22	1	100.0	S	681	956-14	7	57.1	MS	711	811-10	5	100.0	S
621	1347-2	5	20.0	R	652	963-7	5	40.0	MR	682	956-15	6	66.7	S	712	847-6	5	40.0	MR
622	1400-3	5	40.0	MR	653	963-8	5	20.0	R	683	956-16	1	0	R	713	847-7	5	80.0	S
623	304-1	5	80.0	S	654	963-9	5	40.0	MR	684	956-17	5	80.0	S	714	956-20	5	80.0	S
624	304-2	5	60.0	MS	655	963-10	5	100.0	S	685	956-18	5	100.0	S	715	957-21	5	80.0	S
625	304-3	5	40.0	MR	656	1022-4	2	100.0	S	686	956-19	5	60.0	MS	716	961-3	5	40.0	MR
626	304-4	5	0	R	657	1134-3	5	100.0	S	687	957-5	5	0	R	717	1027-5	5	60.0	MS
627	518-6	5	0	R	658	1154-1	5	80.0	S	688	957-6	5	20.0	R	718	1034-2	5	60.0	MS
628	518-7	5	80.0	S	659	1154-2	5	40.0	MR	689	957-7	5	40.0	MR	719	1095-5	5	60.0	MS
629	518-8	4	100.0	S	660	129-3	1	100.0	S	690	963-8	5	0	R	720	1106-7	5	20.0	R
630	518-9	5	40.0	MR	661	157-1	5	100.0	S	691	963-9	5	40.0	MR	721	1139-2	10	10.0	R
631	539-5	5	80.0	S															

R = Resistant – < 20% Wilt
MR = Moderately resistant – >20 < 40 % Wilt
MS = Moderately susceptible – >40 < 60% Wilt
S = Susceptible – >60% Wilt

[Mew and Ho, 1976]

Appendix-IV. Analysis of variance for wilt percentage of the different chilli accessions/ varieties

Source	Sum of squares	df	Mean square	F ratio
Treatment	37012.562	28	1321.877	3.438*
Block	1325.919	2	662.959	1.724
Error	21532.001	56	384.500	
Total	59870.482	86		

* Significant at 0.05 level

Appendix-V. Analysis of variance for *in vitro* sensitivity of *P. solanacearum* to antibiotics

Source	df	SS	MS	F
Treatments	19	1638.40	86.232	30.43**
Between antibiotics	4	305.74	76.435	27.008**
Within antibiotics	15	1332.66	88.844	33.393**
Error	40	113.33	2.83	
Total	59	1751.73		

** Significance at 0.05 and 0.01 level

Appendix-VI. Analysis of variance for *in vitro* sensitivity of *P. solanacearum* to fungicides

Source	df	SS	MS	F
Treatments	11	577.22	52.475	36.349**
Between fungicides	2	194.89	97.44	67.48**
Within fungicides	9	382.33	42.48	29.41**
Error	24	34.66	1.44	
Total	35	611.88		

** Significant at 0.05 and 0.01 level

Appendix-VII. Analysis of variance for percentage of wilt on the field experiment on the management of bacterial wilt of chilli

Source	df	SS	MS	F
Total	74	39442.75	533.01	-
Main plot	4	2676.88	669.22	1.153^{NS}
Block	2	362.11	181.055	-
Error (a)	8	4642.97	580.37	-
Sub plot	4	2599.01	649.75	1.2116^{NS}
Interaction	16	7511.51	481.97	0.8987^{NS}
Error (b)	40	21450.27	536.26	-

NS - Not significant

CHARACTERIZATION AND MANAGEMENT OF BACTERIAL WILT OF CHILLIES CAUSED BY *Pseudomonas solanacearum*. E.F. Smith

By

JYOTHI. A. R.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Pathology
COLLEGE OF HORTICULTURE
Vellanikkara, Thrissur

1992

ABSTRACT

Bacterial wilt is one of the most serious disease of chillies in Kerala. The pathogen was isolated from infected chilli plants and its pathogenicity established. Ten isolates of the pathogen viz., five from chillies, two each from tomato and brinjal and one from ginger were used in the study and they were characterized and identified as biovar III of Pseudomonas solanacearum (Smith) Smith based on the morphological, cultural, biochemical and physiological characters, coupled with its pathogenicity.

Twentynine accessions/varieties of chillies were screened for host resistance against bacterial wilt and the study revealed that the variety 'Manjari' (KAU Cluster/CA 33) was resistant to the disease. The accessions CA 205 and CA 207 exhibited moderately resistant reaction. There was no significant correlation between environmental factors and wilt incidence of all the accessions/varieties except CA 408, for which a positive correlation was noticed between soil moisture and wilt incidence.

721 accessions of chilli maintained at Regional Station of National Bureau of Plant Genetic Resources, Vellanikkara were evaluated for resistance to bacterial wilt. The results indicated that fiftyfour accessions, did not exhibit any incidence of the disease.

In vitro inhibitory effect of antibiotics and fungicides to *P. solanacearum* was tested. Chloromycetin and Streptocycline exhibited the maximum inhibition of the bacterium and they were superior to Terramycin, Tetracycline and Ambistryn-S. Of the different fungicides, Bordeaux mixture exerted the maximum inhibition of the bacterium, followed by Thiride and Blue copper. Dithane M-45 and Foltaf were not inhibitory to the bacterium.

Field experiment on the management of bacterial wilt of chillies revealed no significant difference between main and sub-plot treatments in reducing the disease incidence. However, plants receiving cowdung as a major treatment, and two application of streptocycline-1000 ppm as minor treatment showed a tendency to reduce the wilt incidence.