ETIOLOGY, SURVIVAL AND CHEMICAL CONTROL OF BACTERIAL BLIGHT OF ANTHURIUM

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DEPARTMENT OF PLANT PATHOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
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D. I. (PGS)

ETIOLOGY, SURVIVAL AND CHEMICAL CONTROL OF BACTERIAL BLIGHT OF ANTHURIUM

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SUSHMA JOSEPH

Thesis submitted to the
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in partial fulfilment of the requirements
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Master of Science (AGRICULTURE)

in

PLANT PATHOLOGY

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CERTIFICATE

This is to certify that the thesis entitled "ETIOLOGY, SURVIVAL AND CHEMICAL CONTROL OF BACTERIAL BLIGHT OF ANTHURIUM" submitted by Miss. SUSHMA JOSEPH for the degree of MASTER OF SCIENCE (AGRICULTURE) in PLANT PATHOLOGY of the University of Agricultural Sciences, Bangalore, is a record of research work done by her during the period of her study in the University under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I. INTRODUCTION

Anthurium (Anthurium andreanum Linden) is an important cutflower crop that has recently come into economic prominence in Karnataka where floriculture has a great potential. Plants are in great demand among home gardeners and their cutflowers have a very good market within the state and abroad. World trade of anthurium is second to orchids among the tropical flowers and in Asia their popularity is increasing.

The genus Anthurium consist of more than 500 species and belong to family `Araceae'. Anthuriums naturally fall into two groups viz., foliage and flowering. Among the various species of anthurium, Anthurium andreanum Linden, or "Painters pallate" flower is the most important cutflower. It is a native of Columbia.

Anthurium andreanum was first brought to Hawaii from England in 1889 by Mr.S.M. Damon (Higaki and Watson, 1973). Anthurium planting materials mainly imported from the Netherlands are commercially grown in India. The Netherlands is still the world leader in Anthurium production and trade with about 30 million stems from 69 hectares grown under cover.

In India, anthuriums are grown in the regions which are endowed with a climate favourable to its growth viz., Assam,

Kerala and Karnataka. In Karnataka anthurium cultivation is expanding rapidly in Coorg and Bangalore areas where the climatic conditions are suitable for growth. There is a great potential in commercial cultivation of anthurium in India and also in particular Karnataka. However, one of the constraints in the expansion and successful cultivation of anthurium is the incidence of diseases. Among the diseases, bacterial blight is the most serious and devastating disease in the cutflower crop. Anthurium production in traditional producing countries have declined by 25 per cent since 1986, due to bacterial blight.

Under commercial cultivation conditions the disease is most destructive in late summers and during the monsoon season in nurseries where high humidity prevails and plants are overcrowded or where considerable overhead watering is practiced in anthuriums grown under controlled condition. As the cultivation of the cutflower crop has great potential and expanding rapidly, the incidence of disease is also increasing in recent years in commercial nurseries. Practically no information is available with regard to various aspect of disease both in Karnataka and elsewhere in India in order to formulate suitable strategy for the management of this disease. Hence investigations were undertaken with the following objectives.

1. Studies on the symptomatology
2. Etiology of the bacteria and proving of Koch's postulate
3. Studies on the host range of causal organism
4. Survival of the pathogen
5. Chemical control of the bacterial blight

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The cultivation of Anthuriums is limited by disease caused by Fungi, Bacteria, Viruses and Nematode. Among them bacterial blight caused by Xanthomonas campestris pv. dieffenbachiae (McCulloch and Pirone, 1939) Dye 1978b, is one of the most devastating disease noticed on Anthuriums grown in green houses.

Many bacterial disease have been so far recorded on Anthurium, from different parts of the world. Out of which, bacterial blight has been found to be causing considerable damage in the Anthurium growing areas. The estimated average annual loss due to Xanthomonas campestris pv. dieffenbachiae in the Anthurium crop in Hawaii during 1989 was $ 6387 per acre of which $ 2107 was labour cost the smaller the acreage of each farm greater cost per acre for control of blight, (Shehata et al., 1990). However in India, the disease has been largely noticed in varieties imported from abroad (Das et al., 1996). Since the disease is new in this country, there is practically no information available. The literature pertinent to the present study were reviewed and are presented in this chapter.

OCCURRENCE

The first report of a bacterial infection on a araceae host was recorded by Cook (1926) on Xanthosoma. Pirone

(1939) observed leaf spots on Diffenbachia caused by a bacteria. Later Muculloch and Pirone (1939) isolated the organism from the infected leaves and suggested a name for the pathogen as Bacterium dieffenbachiae.

Xanthomonas diffenbachiae was reported from Brazil on Anthurium by Robbs (1960). Xanthomonas diffenbachiae was reported on Aglaonema roblini from Florida by McFaddan (1962). A Xanthomonas sp. was also consistantly isolated from leaves of Philodendron oxycardium (McFadden, 1967). In 1969, Wehlburg, noticed a bacterium closely related to Xanthomonas vitians infecting Syngonium podophyllum.

Hayward (1972), from Hawaii, for the first time isolated Xanthomonas dieffenbachiae consistently from the leaves and spathe of infected Anthurium andreanum, about 90 per cent of the plants were reported to be affected, which in its severest form resulted in defoliation. Xanthomonas dieffenbachiae was also reported to incite leaf spot of Philodendron oxycardium in Florida (Knauss, 1972).

Guevara and Debrot (1984) recorded bacterial blight (X.campestris pv. dieffenbachiae) of Anthurium andreanum in Venezuala and noticed high incidence of the disease in the nurseries. Cooksey (1985) reported Xanthomonas campestris pv. dieffenbachiae on Anthurium from Southern California nurseries.

Bacterium isolated from Xanthosoma sagittifolium in Florida was conclusively proved to be caused by X.c pv. dieffenbachiae (Pohronezny et al., 1985). Dickey and Zumoff (1987) studied the bacterial blight of Syngonium caused by a pathovar of Xanthomonas campestris and they designated it as Xanthomonas campestris pv. syngonii. A similar report was also made by Chase et al. (1988) of a new disease of Syngonium "White Butterfly" caused by a pathovar of Xanthomonas campestris. Ko and Guo (1990) reported that Pythium, Trichoderma and Verticillium were associated with the necrotic rot of Anthurium blight caused by Xanthomonas campestris pv. dieffenbachiae.

In Tahiti, Anthurium blight (X.c pv.dieffenbachiae) was reported by Mu in 1990 and 60 per cent of the farms were reported to have infected plants. In Philippines, bacterial blight (X.c. pv. dieffenbachiae) was noticed to be a important disease on Anthurium (Natural, 1990). Young (1990a, b) reported X.c. pv dieffenbachiae on Anthuriums from Jamaica. The disease in some instances had been so severe it led to abandoning the crop on several farms. From Puerto Rico, Cortes - Monllor (1991) reported X.c. pv syngonii from lesions of Syngonium podophyllum. Chase (1992) reported X.c. pv. dieffenbachiae on Anthurium and other aroids.

In India, Anthurium blight was reported from Kerala on varieties imported from abroad. The bacterium isolated from

the infected parts had been identified as Xanthomonas sp. (Das et al., 1996). They also reported, death of 75 per cent plants in a period of 15 days.

Erwinia sp. on Aroids

Miller (1956, a) reported from Florida a bacterial leaf rot of Philodendron spp. caused by Erwinia sp. Later in 1957, Graham and Dowson reported bacteria causing leaf rot of Philodendron as Erwinia chrysanthemi or as f. sp. of Erwinia carotovora and Miller (1957) designated the strain as Erwinia chrysanthemi var. philodendri. McFadden (1958) observed a serious disease of Dieffenbachia picta and related varieties in Southern Florida and reported twelve strains of bacterium. McFadden (1960) named the new species of pathogen on Dieffenbachia as Erwinia dieffenbachiae.

Sauthoff and Bortels (1962) reported from West Germany, bacteriosis of Dieffenbachia which resembled Erwinia dieffenbachiae. Erwinia carotovora was recorded on dieffenbachia from Italy by Gullino (1966). Stolp and Sauthoff (1969) noticed Erwinia chrysanthemi on Dieffenbachia and other aroids in West Germany. Lai et al., (1978) reported E.chrysanthemi to cause bacterial blight of Syngonium from California. Five E.chrysanthemi isolates from diseased Diffenbachia maculata was reported from Belgium (Leyns et al., 1984).

Nemeth (1986) reported Erwinia chrysanthemi pv. dieffenbachiae causing stem rot of Dieffenbachia from Hungary. Chase (1992) reported softrot by E.carotovora subsp carotovora on Anthuriums and other ariods.

Pseudomonas sp. on Aroids

Pseudomonas chichorii was isolated from araceae hosts by Wehlburg et al. (1966). Bradbury (1986) reported Pseudomonas marginalis pv marginalis on Philodendron. Cuneiform blight on Xanthosoma brasiliense (Araceae) caused by Pseudomonas chichorii was reported by Romeiro et al. (1988) from Eastern Brazil. Pseudomonas spp. was also isolated from leaves and spathe of Anthuriums (Prior and Rott, 1989) in French West Indies.

Pseudomonas chichorii was reported by Chase (1992) on Anthurium and other aroids.

Pseudomonas solanacearum strain has also been reported on Anthuriums from Singapore (Yik et al., 1994). Scortichini (1994) reported leaf spot and blight of Dieffenbachia amoena caused by Pseudomonas marginalis pv. marginalis. Saddler et al. (1995) reported the presence of pseudomonad like bacteria pathogenic on Anthurium sp. Su and Lau (1995) noticed bacterial wilt of Anthurium from Taiwan and proved that it was race 1 and biovar 4 of Pseudomonas solanacearum.

SYMPTOMS

Bacterial blight by Xanthomonas campestris pv. diffenbachiae

Pirone, in 1939 was first to record bacterial leaf spot on Dieffenbachia. A detailed description of the disease was later made by McCulloch and Pirone (1939). They observed that, all parts of the leaf blade except the midrib are infectible. Petiole and stem were also not infected. Leaf spot were at first noticed to be tiny, translucent specks, which later enlarged. These spots were more or less circular to elongated and yellow or orange yellow. The extreme outer margin was seen to be irregular. They also recorded that when the lesions were numerous and conditions favourable for the parasite, they coalesced to form rather large areas, which ultimately led to death of the entire leaf. A considerable exudation, mostly of bacteria was recorded from the lower surface of the lesion.

On Aglaonema roebelini, a study by McFadden (1962) revealed, diffused, water soaked, firm spots 1.5 mm in dia surrounded by a chlorotic halo, on leaves infected by Xanthomonas dieffenbachiae. They also found out a second bacterium to frequently enter leaves infected by Xanthomonas pathogen. A careful study showed this pathogen was a soft rot organism similar to Erwinia aroideae. The interaction of both the pathogen resulted in a rapid collapse of the entire leaves and petioles into a soft slimy odoriferous mass.

McFadden (1963) noticed Xanthomonas (?dieffenbachia) caused spots which were water soaked, firm and irregular affected areas turn yellow, then become brown, brittle and torn on Syngonium podophyllum. and on Aglaonema caused water soaked brownish spots on the leaves.

McFadden (1967) revealed that a Xanthomonas infection on Philodendron oxycardium exhibited water soaked and brownish, narrow streaks along the margin of the leaf, often near the apex. Elongated water soaked areas extending from the leaf margin and radiating back to the mid vein was also evident. The stem andthe petiole showed no infection. The study further indicated hydathode to be the natural means for the bacterium to enter the leaves.

On Syngonium podophyllum, the les ions occurred mainly along the leaf margin, and at times formed elongated areas of disease tissue extending towards the midrib. Newly initiated lesion were dark green and water soaked, gradually turning yellow later brown and necrotic. Bacterial exudate was often noticed on leaveswhich later on dried to whitish flakes on the under surface of the leaf (Wehlburg, 1969).

In 1972, Hayward reported the occurrence of anthurium leaf blight on a single cultivar Kansako Red. It was noticed that the disease presented different symptoms on younger and older leaves, on the latter, angular pale brown necrotic

spots 1-3 mm in size were present which were surrounded by a marked yellow chlorotic halo. On the under surface dried bacterial exudate were present on or around the necrotic spots. Whereas on the younger leaves exudation scales were less obvious and the lesion were dark brown to black and more extensive. They were sometimes surrounded by a pale chlorotic margin. Lesions were variable in size, often angular and vein delimited or irregular and extending along the midrib for several centimeter. Blackened lesions on the younger leaves often extended from the midrib along and between the branch veins to fill intercostal areas; severely affected leaves were torn and distorted, similar symptoms were also observed on the spathe. No disease symptoms were observed on stem, petiole or on the spadix.

Guevara and Debrot (1984) reported the presence of necrotic spots with halo, mainly towards the margin of leaves and spathes on Anthurium andreanum. They indicated that the spread of infection was through the petioles, reaching the stem and rhizome and causing plant death. High relative humidity was recorded to favour disease incidence. Cooksey (1985) also attributed water soaked spot with chlorotic halo's to severely blighted leaves and spathes as symptoms caused by X.diffenbachiae.

In the fields, early symptom of bacterial leaf spot of Cocoyam were small, water soaked spots, usually more evident

on the abaxial surface as described by Pohronezny et al. (1985). They enlarged to produce necrotic spots as large as two centimeters in diameter surrounded by prominent chlorotic halo, some of which coalesced resulting in large dead areas. The infection, sometimes progressed into veins and proceeded basipetally, resulting in streaks of infected tissue. They suggested that the infections occurred through the hydathodes.

Zumoff and Dickey (1987) emphasised that, the pathogen X.c. pv. syngonii entered the cultivar 'White Butterfly' through the stomata. Sub-stomatal and intercellular spaces of the spongy mesophyll were colonized initially and caused no apparent effect on the surrounding cells even when initial water soaking was evident. As the water soaking progressed, disruption of mesophyll cells occurred, palisade and spongy parenchyma cells were surrounded by bacteria, followed by thinning and disruption of the cell wall. As infected leaves yellowed, dried, shrivelled the tissue were compressed and became completely indistinguishable. Chase (1988) recorded that optimum temperature for X.c. pv. dieffenbachiae is 22°C

Syngonium "White Butterfly" infected by X.campestris produced water soaking of interveinal tissue and was most prevalent during the early morning hours and frequently disappeared as the day progressed. This was noticed upto 10 days in the same portion of the leaf tissue before necrosi

developed. Lesion were nearly always confined within leaf veins (Chase et al., 1988).

Graser et al. (1990) made a study on various meteorological condition that favour infection of Anthurium by Xanthomonas campestris pv. dieffenbachiae. Pohronenzny et al. (1990), experimentally proved that intercoastal and marginal lesion on cocoyam leaves in Florida were both caused by X.c. pv. dieffenbachiae. They also concluded from the study that in nature, hy dathode infection occurred more frequently than stomatal infection. Sakai et al. (1990a) indicated that bacteria entered by hydathodes and later confined to xylem, whereas bacteria entering through the stomata were restricted from entering the xylem by a ring of sclerified ring.

Young (1990b) noticed systemic infection on Anthurium from Jamaica, Chase (1992) recorded local and systemic infection on Philodendron and Anthuriums.

Lipp et al. (1992) recorded that the symptoms caused by strains that infected Dieffenbachia, Anthurium and Syngonium appeared soon.

Lont, in 1994, noticed that X.c. pv. dieffenbachiae caused two kinds of infection. The first type started in the leaf and spatha. The second started in the stem and could spread quickly through the entire plant via the vascular

bundle system. Leaf infection usually started at the edges and bottom side of the leaf, which have the most stomata. During initial stage water soaked spot appeared on the bottom of the leaf. During later stage, brown spots formed on the edge of the leaf, surrounded by a rim of yellow leaf tissue, and led to the yellowing of the older leaves, revealing the systemic nature of infection.

Fukui et al. (1995a) in an attempt to monitor infection process by detecting light produced from a bioluminescent strain of X.c. pv. dieffenbachiae noticed that the relationship between symptom expression on infected leaves and extent of leaf infection (evaluated by bioluminescence emission) varied especially among susceptible cultivars. They concluded that this was because the infection progressed symptomlessly which created anillusion that the cultivar is highly resistant. Fukui et al. (1995b) also reported that severity of leaf infection was greater when plants were grown under a high temperature.

Local and systemic infection of Anthurium by Xanthomonas campestris pv. dieffenbachiae was reported by Kuehnle (1995) and later by Balakrishnan et al. (1996) from India.

Fukui (1996) recorded that X.c. pv. dieffenbachiae advanced very rapidly in some cultivars. He also noticed the

resistance ranking among tested cultivars for systemic infection did not always correspond to the ranking determined by comparing leaf area invaded by the pathogen. Some cultivars that were susceptible to leaf invasion were highly resistant to systemic infection and vice versa. Fukui et al. (1996) used bioluminoscent strains, a non-destructive method to quantify the severity of leaf infection enabling the evaluation of susceptibility and resistance to bacterial blight accurately.

From India, Das et al. (1996) reported the appearance of pale spots which develop into water soaked lesions. The lesions spread and coalesced to form chlorotic areas. Die back of leaves was also observed and within 2 to 3 days the entire leaves were shed.

Bacterial leaf rot or blight and soft rot caused by Erwinia spp.

Ciferri in 1927, observed that Bacillus carotovora and Bacillus aroides caused rotting of rhizomes of Xanthosoma sagittifolium. McFadden (1958) reported 12 isolates of a unidentified bacterium which caused symptoms like pale green and small leaves on Dieffenbachia . Bacterial stem rot of Diffenbachia was reported by Munnecke (1960) as the soft rot at soil level or associatedwith cutting wounds and plant collapsed in 2-3 weeks. Internally brown streaking spread inwardly and vertically.

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From West Germany, Sauthoff and Bortels (1962) observed leaf wilt and browning, foot rot and decay of vascular bundles in the stem of dieffenbachia caused by Erwinia dieffenbachiae. Knauss and Miller (1974) noticed Erwinia chrysanthemi from rotted roots, symptomless basal stem and petioles of 6-10 months of Philodendron selloum; from mature fruit of 4-5 yr. old seed producing plants and leaves of Philodendron selloum with bacterial blight.

Lai et al. (1978) reported bacterial blight of Syngonium caused by Erwinia chrysanthemi to manifest primarily as leaf spot. The initial stage of the disease is characterized by minute, necrotic, water soaked lesion approximately one mm in diameter. The initial spots were generally interveinal which became brown in colour, surrounded by a diffused yellowing. Under favourable conditions, the necrotic spots expanded rapidly into a large water soaked area, 1 to 2 cm in diameter, and as the spot enlarged, the distinct yellow border became diffused.

Nieves-Brun (1985) reported that foliar blight and soft rot of Dieffenbachia, caused by Erwinia chrysanthemi leading to foliage blight, leaf spotting, basal stem rot and root rot and the pathogen was present throughout the plant in the xylem and infection via roots was demonstrated. Initially confined to the xylem, later the pathogen spread intercellularly to the neighbouring parenchyma.

Bacterial disease on Aroids caused by Pseudomonas sp.

Bradbury (1986) reported Pseudomonas marginalis pv. marginalis on Philodendron selloum.

Romeiro et al. (1988) observed leaf blight starting from the edge of Xanthosoma brasilense leaves and resulting in complete leaf decay due to infection by Pseudomonas cichorii.

Prior and Rott (1989) described the symptoms of bacterial leaf spot caused by a species of Pseudomonas on Anthuriums, which was characterized as small angular greasy spot on the abaxial surface near veins, leaf margins and on spathes. Systemic or local infection usually resulted in death of the plant.

Pseudomonas solanacearum on Anthuriums first appeared as a yellowing of part of the outer leaf margin which gradually extended over the entire leaf area and then progressed to the inner leaves ultimately leading to wilting and death of the plant (Su and Lau, 1995).

Chase (1992) recorded the symptoms of Pseudomonas leaf spot and blight on Araceae caused by Pseudomonas cichorii. It was noted that lesions were initially water soaked and rapidly turned dark brown to black, often having concentric rings of light and dark tissue and sometimes surrounded by a bright yellow halo.

Scortichini (1994) reported that Pseudomonas marginalis pv. marginalis on Dieffenbachia caused small elongated, light brown lesions on the surface of the leaves and the leaves then turned completely brown and collapsed as the disease progressed.

MORPHOLOGY

Xanthomonas campestris pv. diffenbachiae

McCulloch and Pirone (1939) were first to describe the morphology of Bacterium dieffenbachiae causing leaf spot of Diffenbachia. They reported the bacteria as slender round-ended rods with a single polar flagellum which was 2 to 3 times the length of the rod. The majority of the rods were estimated to be of 0.3 to 0.4 µm by 1.0 to 1.5 µm. The bacteria were Gram-negative, but not acid fast. McFadden (1967) described the bacterium isolated from Philodendron oxycardium as motile, Gram-negative, monotrichous short rod. A similar description of morphology, of the bacterium isolated from Syngonium podophyllum was given by Wehlburg (1969).

Guevara and Debrot (1984) reported the morphology of Xanthomonas campestris pv. dieffenbachiae isolated from Anthurium andreanum as rod shaped bacteria of 1-2.4 µm x 0.04-0.6 µm, with a polar flagellum. Cooksey

(1985) also noticed morphology of Xanthomonas campestris pv. dieffenbachiae to be identical to the reports of the earlier scientists.

Dickey and Zumoff (1987) while describing X.campestris pv. syngonii (the name as proposed by them), noted that the organism were Gram negative, straight rod, non-sporing, motile with a single polar flagellum. White butterfly syngonium was also reported to be infected by a monotrichous bacteria (Chase, 1988).

Erwinia chrysanthemi

The colonies identified as E.chrysanthemi from Philodendron selloum by Knauss and Miller (1974) were white, and the bacteria were Gram negative with peritrichous flagella.

Lai et al. in 1978, reported the leaf rot causing organism on syngonium (Erwinia chrysanthemi) as Gram negative short rods (0.7 µm x 2 µm), grayish-white, motile with 5-12 peritrichous flagella.

Leyns et al. (1984) recorded the Erwinia chrysanthemi causing bacterial rot of Dieffenbachia maculata to be Gram negative, short rods of variable length.

Pseudomonas sp.

Prior and Rott (1989) reported that the Pseudomonas sp. which causes bacterial spot of Anthurium was motile Gram negative rod with a single polar flagellum.

Scortichini (1994) reported Gram negative pathogen causing leaf spot and blight to Dieffenbachia amoena which was identified as Pseudomonas marginalis pv. marginalis.

CULTURAL CHARACTERISTICS

Xanthomonas campestris pv. dieffenbachiae

McCulloch and Pirone (1939) noticed that Bacterium dieffenbachiae colony growth is slow at 23 to 25°C on beef peptone agar. Tiny white specks visible in 3 to 5 days slowly enlarged to become pale yellow, then Massicot yellow or Naples yellow. In 6 to 7 days well isolated colonies were 2 to 4 mm in diameter. They were circular, entire, flat, smooth, thin and translucent. Mottling was usually noticed in old culture. In crowded plates the surface colonies remained small, pale yellow, thin and transparent and submerged colonies were translucent, rather granular, spherical spindle-shaped or triangular.

Colonies on beef agar were developed as a smooth thin, transparent layer of growth. All agar cultures 3 or more weeks old were transparent. In beef agar stab there was

traces of growth on the upper 2 mm. Beef extract agar permitted slightly less growth, which was comparatively less yellow.

On all solid beef agar media the growth was soft, butyrous in texture but the 2 to 3 weeks old cultures were slightly viscid or slimy, old dry cultures had a slight iridescence with no fluorescence on any of the media.

Beef broth cultures at favourable temperatures had a thin, uniform clouding. Undisturbed cultures eventually had heavier clouding at the surface and irregular, patchy yellow rims, pellicles were also noticed occasionally. Tiny crystals were numerous in the rims and pellicle. Sediments were scanty to moderate, loose and flocculent, easily dissolved by shaking.

Beef agar or broth plus 0.2 per cent starch on one per cent dextrose is more favourable for the growth of this organism. On blood-serum slants growth was good. Potato dextrose agar with a pH value of 5.6 to 6.0 produced an abundant thick smooth and translucent growth whereas potato cylinders were not favourable for growth.

The optimum temperature for growth was recorded as 30 to 31°C. The minimum temperature for growth was about 5°C, the maximum between 37 to 38°C and the thermal death point was 48°C. No growth occurred when it was exposed to sunlight for

five minutes. Yellowish, mucoid growth of the bacterium was also reported by McFadden (1967) and Wehlburg (1969).

Hayward (1972) stated that a thin film of growth was evident in the pool of inoculum at 24 hr and discrete colonies were visible at 48 hr. Well separated colonies were 2 mm in diameter after 3 days at 30°C and upto 5 mm at 5 days and the colonies were yellow and showed viscid growth.

Pohronezny et al. (1985) reported that X.c. pv. dieffenbachiae colonies were yellow and mucoid on Sucrose nutrient agar and Yeast extract dextrose calcium carbonate agar. No fluorescent pigment was produced on King's medium B. Dickey and Zumoff (1987) described the colonies of strains of X.c. pv. dieffenbachiae from Syngonium as yellow, mucoid on nutrient agar with five per cent glucose. The pigmentation of these strains from syngonium was paler on nutrient agar with glucose, Nutrient Broth yeast extract agar and Potato dextrose agar media than the pigmentation of the other strains. Growth of the Syngonium strains was slower than that of the other strains. Colony size after three day at 27°C on NBY agar of Syngonium strains was less than one mm compared with 2-4.5 mm for other pathovar strains. On PDA medium after seven days less than one mm growth was recorded. Chase (1988) noticed the X.c. pv. dieffenbachiae grew from 18 to 34°C with the optimum at 22°C.

Chase et al. (1988) consistently isolated pale yellow to cream coloured bacterium, which remained less than one mm in dia and frequently died unless transferred to fresh plates of Nutrient agar with five per cent sucrose from syngonium leaves "White Butterfly". No colonies of the suspected pathogen grew on any plates incubated at 30°C.

Erwinia chrysanthemi

Munnecke (1960), observed that E.chrysanthemi from Dieffenbachia showed abundant growth on YDC and sparse on beef peptone agar (BPA) and potato-dextrose agar. On YDCA the colonies appeared in 48 hrs and were well developed in three to five days at 20-25°C. Well isolated colonies were creamy-white raised with smooth margins, and 0.5-1.0 mm in diameter. The colonies remained discrete and did not spread over the surface of the medium. As the colonies aged, the surfaces were frequently beaded or wrinkled when viewed with a dissecting microscope. Small exudates of amber liquid appeared on the surface of the beaded colonies. The surface of the wrinkled colonies appeared shrivelled and somewhat dry. The colony character was not stable, since each type produced colonies of the other type when subcultured.

Lai et al. (1978) reported that E.chrysanthemi from Syngonium podophyllum produced grayish-white butyrous colonies on nutrient agar and gray colonies under anaerobic conditions.

Pseudomonas sp. on Aroids

Prior and Rott in 1989, observed that the colonies of Pseudomonas sp. on Anthurium were circular, raised with an entire margin and creamy white on King's A or King's B and Yeast dextrose agar medium. No fluorescent pigment was produced on King's A or King's B. But, P.marginalis pv. marginalis on Dieffenbachia was seen to produce fluorescent pigment on King's B under UV rays (Scortichini, 1994).

PHYSIOLOGICAL AND BIOCHEMICAL PROPERTIES

McCulloch and Pirone (1939) reported that Bacterium dieffenbachiae produced hydrogen sulphide and ammonia at a moderate degree. Nitrate was not reduced. Starch was moderately hydrolyzed and milk was slowly peptonised. The bacterium fermented and exhibited acid reaction on dextrose, saccharose, galactose and levulose within 8 to 10 days, however on lactose, glycerol maltose and mannitol the reaction was very less. The optimum pH required was 6.4 to 6.8. And the organism was proved to be aerobic.

Mc Fadden (1962) conducted biochemical, cultural, morphological and cross-inoculation tests on the bacteria isolated from Aglaonema sorbitini and the pathogen was found to be indistinguishable from X.diffenbachiae. Mc Fadden (1967) performed test on the bacterium isolated from Philodendron oxycardium and proved it to be X.dieffenbachiae

which produced acid from sucrose, glucose, lactose, xylose. galactose, maltose, arabinose, fructose, glycerol and mannitol. Hydrolysis of starch and liquification of gelatin was noticed, but failed to reduce nitrate. The Xanthomonas from Syngonium podophyllum failed to produce acid from raffinose (Wehlburg, 1969).

From Anthurium andraeanum, Hayward (1972) reported that X.c. pv. dieffenbachiae were aerobic and catalase positive and produced acid oxidatively from arabinose, cellobiose, fructose, galactose, glucose, glycerol, lactose, maltose, mannose, mannitol, raffinose, sucrose and trehalose and produced no acid from dulcitol, erythritol, inositol, rhamnose, salicin and sorbitol. Starch, aesculin Tween 80 and gelatin were actively hydrolysed. A pronounced soft rot was produced in potato slices in 2-8 days. Pectolytic enzyme as produced with one per cent pectic acid, one per cent pectin or one per cent sodium polypectate citrate, malonate and acetate were utilized as sole source of carbon and adipate and tartrate were not utilized. No nitrate reduction was seen.

Cooksey (1985) recorded that X.c. pv. dieffenbachiae was positive for catalase; protein digestion, hydrolysis of starch, gelatin and asculin, lipolysis of Tween 80 and acid from glucose, mannose and arabinose. Finding were negative for oxidase, urease, growth at 36°C, indole production and nitrate reduction.

Pohronezny et al. (1985) observed that X.c. pv. dieffenbachiae from Cocoyam, were catalase positive, produced hydrogen sulfide from peptone, liquefied gelatin, hydrolyzed aesculin and grew at 35°C. The isolates were oxidase negative and did not ferment glucose, indole was not produced and urease activity was not detected and reduction of nitrate was not observed. Asparagine was not utilized as a sole source of carbon and nitrogen. Most isolates produced acid from glucose, arabinose, cellobiose, fructose, galactose, lactose, maltose, mannose, raffinose, sucrose and trehalose, but failed to produce acid from glycerol, mannitol, dulcitol, erythritol, inositol, insulin, rhamnose, salicin or sorbitol.

Bonner et al. (1987) reported that about 35 per cent of 435 pathogenic strains of X.c. pv. dieffenbachiae tested failed to utilize starch.

The Xanthomonas sp. from Syngonium exhibited production of hydrogen sulphide from peptone, hydrolysis of asculin, acid from L(+) arabinose, D(+) galactose and utilization of acetate, citrate, malate, propionate and succinate. But negative results were observed for Voges-Proskauer test, indole production, urease activity, arginine dihydrolase, lysine and ornithine decarboxylase, acid from α-methyl-D-glucoside and utilization of tartrate (Dickey and Zumoff, 1987).

Alvarez et al. (1990) reported that the blight pathogen (X.c. pv. dieffenbachiae) can grow on glutamic acid as the sole carbon and nitrogen source and growth is optimum at pH 6 and inhibited at highly acidic condition.

Pohronezny et al. (1990) saw that the strains of X.c. pv. dieffenbachiae from Cocoyam were catalase positive and oxidase negative, hydrolyze gelatin, aesculin and starch and negative for nitrate reduction. Asparagine was not utilized as a sole source of carbon and nitrogen. Proteolysis occurred in litmus milk. Acid was produced from D(+) galactose, D-glucose, maltose, D-mannose and sucrose, acid was not produced from dulcitol, erythritol, inositol and mannitol.

Chase et al. (1992) noticed strains of X.c. pv. dieffenbachiae from Colocasia, Diffenbachia and Philodendron were highly pectolytic whereas those from Xanthosoma and syngonium were not. He also reported that majority of the strains could be identified to their host of origin based on pattern of carbon utilization, but strains from Anthurium and Dieffenbachia were apparently more diverse in their carbon source utilization several hydroxy acids and 15 : 0 iso and 15 : 0 anteiso compounds have also been identified as criteria for discriminating pathovars of X.campestris. In their work they concluded that based on the various physiological, pathological and fatty acid the difference

between the proposed X.c. pv. syngonii and X.c. pv. dieffenbachiae was not significant.

Lee et al. (1992) while studying quinate or shikimate utilization in Xanthomonas campestris observed that X.c. pv. dieffenbachiae cannot utilize them as a sole carbon source, even caffeic gallic and protoctechnic acid were not utilized.

Lipp et al. (1992) in their study observed that 62 per cent Anthurium strain did not hydrolyse starch as compared to seven per cent of strains from other hosts.

Wells et al. (1993) in a study of cellular fatty acid composition of nine pathovars of X.campestris classified or ranked X.c. pv. dieffenbachiae as a group by itself.

Erwinia chrysanthemi

Garibaldi and Bateman (1971) recorded the Erwinia chrysanthemi from Philodendron produced four polygalacturonic acid transeliminase. The molecular weight of pectic enzymes isolated ranged from 30.00 to 36.00 and the isoelectric point from pH 4.6 to 9.4 and exhibited a Ca^{++} requirement and optimum pH of 8.2 and 9.8. Electrolyte loss, maceration and death of potato tissue were induced by 5 of the purified enzymes. Garibaldi and Bateman (1973) noticed that strains of E.chrysanthemi from Philodendron sp. and Dieffenbachia sp. produced polygalacturonic acid, lyase, cellulase and proteolase.

Pupillo et al. (1976) made a study of the exocellular pectate layer produced by three E.chrysanthemi strains. in polypectate broth and on in infiltrated Dieffenbachia and recorded the production 4 isozymes (1 alkaline, 2 central and 1 acid).

Lai et al. (1978) reported that E.chrysanthemi from syngonium reduces nitrate, produce hydrogen sulphide from cysteine and catalase, but failed to produce oxidase or hydrolyze starch. The bacterium liquefied gelatin and produced pectinase on pectate gels, rotted fresh potato, utilized malonate and tartarate produced no gas from lactose, produced indole and phosphatase and was resistant to 50 µg/ml erythromycin.

Leyns et al. in 1984, reported that the isolates of Erwinia chrysanthemi from Dieffenbachiae maculata had catalase but no oxidase activity. The strains were facultative anaerobes and produced acid from D-arabinose, L arabinose, D-cellobiose, D-fructose, D-galactose, D-glucose, mannitol, D-mannose, L-rhamnose, D-ribose, salicin, sucrose, D-xylose and L-xylose. No acid was produced from adoxitol, dulcitol, glycerol, lactose, maltose, D-melezitose and α-methyl glucoside. Asculin was hydrolysed. Indole and acetoin were produced. Nitrate was reduced. There was no urease, ornithine decarboxylase, lysine decarboxylase or arginine dihydrolase activity. Citrate was used as the sole carbon source.

Pseudomonas sp. on Aroids

Prior and Rott in 1989 reported the Pseudomonas sp. isolated from Anthurium are strict aerobes and gave positive results for catalase; use of arginine and asparagine as sole source of carbon and nitrogen; hydrogen sulphide production; urease activity; cellulose hydrolysis and produced acid from galactose, arabinose and glycerol, but failed to show indole production, levan production, aesculin production, acetoin production and production of acid from inositol, sorbitol, mannose, sucrose, cellobiose and rhamnose.

Scortichini (1994) recorded that Pseudomonas marginalis pv. marginalis produced levan, 2 ketogluconate and produced acid from glycerol, L-arabinose, ribose, D-xylose galactose, D-glucose, D-fructose, D-mannose, rhamnose, mannitol, α-methyl D-glucoside. N-acetyl glucoseamine, arbutin, asculin, salicin, cellobiose, maltose, melibiose, sucrose-trehalose, D-raffinose, B-gentilnose, D-xylose.

The bacterium also showed presence of oxidase, nitrate reduction, rotting potato, arginine dihydrolase, gelatin liquif tion, catalase, lipolysis of Tween 80 and growth at 39°C. The isolate failed to utilize, erythritol, D-arabinose, L-xylose, adonitol, sorbitol, α-methyl D-mannoside, amygdalin, lactose, insulin, melizitose, starch,

glycogen, xylitol, D-turamose,. D-tagatose, D-fucose, L-fucose, D-arabitol, gluconate and 5-ketoglutconate.

HYPERSENSITIVITY REACTION

Isolates from Syngonium of Erwinia chrysanthemi elicited a strong hypersensitive reaction on tobacco leaves (Lai et al., 1978).

Pohronezny et al. (1985) used isolates of X.c. pv. dieffenbachiae to elicite hypersensitivity in White Burley tobacco. Chase et al. in 1988, noticed that most strains of X.c. pv. dieffenbachiae produce hypersensitive reaction on Bonny Best tomato, Hick's tobacco and Early Calwonder Pepper.

Prior and Rott (1989) noted that all isolates of Pseudomonas sp. from anthurium elicited hypersensitivity in Xanthi and Samsun N.N. tobacco, Caladium bicolor and Xanthosoma sagittifolium.

Pohronezny et al. (1990) recorded that all strains of X.c. pv. dieffenbachiae induced hypersensitivity in tobacco. Chase et al. (1992) recorded a positive reaction for hypersensitivity on tobacco, tomato and pepper.

Scortichini (1994) failed to notice hypersensitive reaction on tobacco by Pseudomonas marginalis pv. marginalis isolated from Diffenbachia amoena.

PATHOGENICITY

Xanthomonas campestris pv. dieffenbachiae

Pirone (1939) noticed typical symptoms in one to two weeks by atomizing a suspension of the bacterium on the lower leaf surface of Dieffenbachia . The same organism was also reisolated repeatedly from the leaves. McCulloch and Pirone (1939) proved the pathogenicity of Bacterium dieffenbachiae. Infection was secured on Dieffenbachia plant in 15 to 18 days in the green house and outdoors. With a warm, moist atmosphere, the lesions were visible in seven to eight days as tiny, translucent specks which continued to develop and produce the visual disease symptoms.

McFadden (1967) observed symptoms develop following artificial inoculation on Philodendron after 5-10 days of incubation, when bacterium was added to the guttation droplet.

On Syngonium podophyllum, Wehlburg (1969) demonstrated pathogenicity by wound inoculation causing typical lesion in one to ten days.

Hayward (1972) inoculated the culture to Anthurium andraeanum which resulted in lesion development from the wounds leading to water soaked areas after 7-14 day or within 3-4 weeks and X.dieffenbachiae was reisolated from the lesions.

Pathogenicity of X.c. pv. dieffenbachiae on Anthurium andraeanum was again confirmed by Guevara and Debrot (1984) and Cooksey (1985) on flowers of anthurium in 1-14 days by infection on spray inoculation.

The isolates of X.c. pv. dieffenbachiae from cocoyam was reported to induce symptom when artificial inoculated on Cocoyam within 3-4 days (Pohronezny et al., 1985).

Dickey and Zumoff (1987) petiole inoculated Xanthomonas campestris strains from Syngonium into the same host and noticed dark water soaked areas predominantly along the veins toward the wing of the lamina until it reached the margin. As the water soaking continued to spread, older affected tissues became light brown, dark brown, necrotic and eventually dry and papery. Then a yellow border was developed around the necrotic and subsequently led to shrivelling of the entire leaf.

In a similar experiment conducted by Chase et al. (1988) with X.campestris pathovar causing "White Butterfly" of Syngonium, symptom appeared as water soaking on syngonium within about 10 days of inoculation.

Norman and Alvarez (1989) recorded water soaked lesions on dieffenbachia leaves after 10 days in the glass house even at levels of 10^{-5} dilution.

Pohronezny et al. (1990) in their pathogenicity study on X.c. pv. dieffenbachiae infecting Cocoyam, recorded more marginal lesions when inoculated early in the morning when leaves were guttating and the number of intercoastal lesions was higher in plants inoculated in the afternoon than those inoculated in the early morning.

Erwinia sp. from Aroids

Ciferri (1927) proved pathogenicity of the Bacillus carotovora isolated from Xanthosoma sagittifolium. Munneke (1960) fulfilled the Koch's postulate of E.chrysanthemi on Dieffenbachia . First symptoms appeared 1-3 weeks after inoculation and death occurred in 2-6 weeks. Disease progression was fast in summer and slowest in winter. Knauss and Miller (1974) noticed that E.chrysanthemi could be artificially inoculated by soil infestation and root-dip of Philodendron selloum. Haygood and Strider (1979) reported that wounding enhanced infection by artificial inoculation with consistent results obtained at 22-28°C with inoculum concentration of 5×10^7 and 2×10^8 CFU/ml.

Lai et al. (1978) could produce characteristic leaf rot symptoms within two weeks after inoculation into intact leaves of Dieffenbachia. Reisolation from infected leaf tissue yielded the same organism as that isolated from the original affected leaves.

Dickey (1981) recorded that E.chrysanthemi from Dieffenbachia caused positive reaction on Dieffenbachia amoena and Dieffenbachia maculata.

Leyn et.al(1984) observed disease symptom developed within 5 days of inoculation, starting with a slightly depressed water soaked region at the inoculation site of E.chrysanthemi on Dieffenbachia. This region enlarged quickly. The epidermis of the stem ruptured, exposing brown slimy rotten tissue. In some cases the stem rotted completely and collapsed.

Pseudomonas sp. on Aracea

Prior and Rott (1989) while working with Pseudomonas sp. of Anthuriums, noticed symptom identical to those observed under natural condition, on spray inoculated and soil inoculated anthuriums. Symptom developed within 5-6 days and 3 weeks when spray inoculated and soil inoculated respectively.

Pathogenicity of strains of Pseudomonas marginalis pv. marginalis of Dieffenbachia was tested by Scortichini (1994). Symptoms started appearing after 7 days. Tissues became water soaked at first, the lesions enlarged and turned light brown subsequently. Within one month all the inoculated leaves were blighted and no stem rotting was observed.

Xanthomonas campestris pv. dieffenbachiae

McCulloch and Pirone (1939) inoculated Drac ena fragrans plants with the Dieffenbachia leaf-spot bacterium (Bacterium dieffenbachiae) which resulted in lesions on the leaf. McFadden (1962), tested X.diffenbachiae from its natural host Aglaonema robelinii on various aroids, of which only Dieffenbachia sp. proved susceptible. Wehlburg (1969) recorded that all isolates of Xanthomonas sp. from Syngonium were mildly pathogenic on Iceburg lettuce.

Hayward in 1972, reported that Xanthomonas dieffenbachiae from Anthurium, was pathogenic on Philodendron oxycardium and Dieffenbachia picta. On Philodendron water soaked lesions 2-5 mm in size developed around the site within 7-14 days.

Inoculations on Dieffenbachia the initial symptoms were similar but at later stages produced elongated areas of coalesced infection. From both the hosts the organism reisolated from the infected part. Cooksey (1985), also reported that X.c. pv. dieffenbachiae from anthurium, produced symptoms on Dieffenbachia maculata, Xanthomonas campestris pv. dieffenbachiae from cocoyam produced water soaked spots on abaxial leaf surface of Dieffenbachia within 7-8 days (Pohronezny et al., 1985).

Dickey and Zumoff (1987), tried to inoculate Xanthomonas sp. from Syngonium on Dieffenbachia maculata, D.amoena, Philodendron selloum, P.panduriforme and Geranium, but failed to detect any kind of symptom on the above hosts. A similar observation was recorded by Chase et al. (1988), where the host range was tested on ten members of Araceae family, with the same result.

Graham et al. (1990) reported that X.c. pv. dieffenbachiae elicited symptoms on citrus. In an host range study by Chase et al. (1992) strains of Xanthomonas campestris from Syngonium podophyllum, Dieffenbachia moculata, Anthurium sp., Aglaonema commutlatum were inoculated to all the four host mentioned above. The symptoms that developed on each host plant were the same regardless of the origin of the strain used to inoculate the plants except on Syngonium. The first type of symptom was similar to those described for other aroids generally occurred when plants were inoculated with strains from host other than Syngonium cultivar White Butterfly. The second symptom type is characterized by severe water soaking and necrosis. Symptom severity was affected by both the strain origin and the host plant. In general, Syngonium developed most severe symptom, Anthurium and Dieffenbachia also developed moderate symptom. Both Aglaonema and Philodendron were apparently resistant.

Lipp et al. (1992) reported that many strains from hosts other than Anthurium were pathogenic only on Dieffenbachia and their host of origin. The majority of the Anthurium strains were more virulent and infected a broader range of host than those from other aroids, and strain isolated from Syngonium (designated as X.c. pv. syngonii) caused symptoms on Dieffenbachia .

Erwinia species infecting Areaceae

Bacillus carotovora isolated from Xanthosoma saggittifolium showed infection on Colocasia antiquorum, Alocasia macrovrhiza, Calacium schombungii, Zantedeschia aethiopica, Iris hyacinth, gladiolus and carrot (Ciferri, 1927). Munnecke (1960) in an attempt to study E.chrysanthemum infecting Dieffenbachia inoculated it on many host, but got positive results only on Philodendron hastorum. Even carnation str. of Eriwinia chrysanthemi showed pathogenicity on Philodendron but the vice-versa was not observed (Nelson and Dickey, 1967). Mazzucchi and Alberghina (1972) recorded positive reaction on Dieffenbachia picta when infiltrated with E.carotovora var. chrysanthemi Banana and maize isolates of Erwinia chrysanthemi was seen to be pathogenic on Dieffenbachiae (Rivera et al., 1980). Dickey (1981) recorded that strains of Erwinia carotovora sp. carotovora from caladium and banana were pathogenic on Syngonium podophyllum. And Syngonium strains and caladium

strains of E.carotovora ssp. carotovora also showed positive reaction on Philodendron panduriforme and P.selloum.

Host range of Pseudomonas spp. on Areaceae

Chase (1992) reported that, Pseudomonas chichorii isolated from diseased leaf of Scindapsus was also pathogenic on Araceae hosts.

Prior and Rott (1989) infiltrated Pseudomonas sp. pathogenic on Anthurium sp. into leaves of Dieffenbachia sequina water soaked lesions appeared within 24 hr and progressed out of infiltrated areas in 48 h after inoculation.

In an host range study by Chase (1992) noticed that hosts of P.chichorii includes Aglaonema spp., Anthurium spp., Caladium spp., Diefenbachia spp., Monstera spp., Philodendron spp., Spathiphyllum spp. and Syngonium podophyllum.

Scortichini (1994) recorded that P.marginalis pv. marginalis isolated from Dieffenbachia amoena also infected Lactuca sativa. The symptoms appeared in 6-7 days after inoculation as water soaked tissue noticed on the lamination of the leaf which later turned black and were surrounded by a light chlorotic halo.

SELECTIVE AND SEMI-SELECTIVE MEDIA

Pohronezny et al. (1985) made a study of growth and colony characteristics on Miller Schroth agar (MS), Kings medium B, SX agar and Crystal violet pectate medium without crystal violet (CVP). Colonies were non-fluorescent on Kings medium B and no isolate grew on MS agar and a strain showed hydrolysis of starch on SX agar. Some isolates also degraded pectate on modified CVP medium.

Chase et al. (1988) studied different media for the bacteria strains isolated from syngonium causing 'White Butterfly' and X.c. pv. dieffenbachiae. The strains from Syngonium failed to grown on CVP, SX and Nutrient agar and growth was noticed on Wilbrink's Agar (WA) and Nutrient agar amended with 0.5% sucrose (NAS), whereas some strains of X.c. pv. dieffenbachiae showed growth on CVP and SX and all of them showed growth on SX.

Norman and Alvarez (1989) in an attempt to grow X.c. pv. dieffenbachiae which do not grow on starch - based selective media, used cellobiose - starch (CS) and esculin-trehalose (ET) medium. On CS medium 92 per cent produced colonies of atleast 5-7 mm in diameter and the rest required 4 to 6 days to reach the size and on ET medium all strains of X.c. pv. dieffenbachiae produced light brown to dark brown zones 5 mm or more in diameter within 48 hrs. Most of the non-xanthomonads failed to grow on CS and ET and the

Triphenyl-tetrazolium chloride (TZC) gave a added benefit of distinguishing xanthomonads by the differential production of red pigment in colonies. Among the xanthomonads, none, except X.albilineans, X.c..oryzae and X.manihotis could grow on ET and CS media respectively.

Prior and Rott (1989) noticed that some isolates of Pseudomonas sp. causing leaf spot of Anthurium produced a brown diffusible pigment when grown at 38 ± 2°C on solid Kelman's medium without TZC and amended with 1 g/l yeast extract (KY medium).

Pohronezny et al. (1990) used starch methionine agar for isolation. Chase et al. (1992) in a study of various strains of X.c. pv. dieffenbachiae from different hosts on four starch based media; cellobiose starch (CS) basal starch cycloheximide agar (BSCAA), SX medium and nutrient starch cycloheximide agar (NSCAA). For most strains CS medium supported the best growth and SX the least growth.

Lipp et al. (1992) purified strains of X.c. pv. dieffenbachiae on Cellobiose - starch (CS) and Field house - Sasser medium. Norman and Alvarez, in 1994a used modified ET containing 200 ppm of cycloheximide for purification.

SURVIVAL

McCulloch and Pirone (1939) recorded that the culture of Bacterium dieffenbachiae remained alive for atleast four

months at room temperature with reduced vigour. At 4°C it remained alive for six months with their original vigour.

Tanabe et al. (1990) reported that X.c. pv. dieffenbachiae the agent of Anthurium blight survived for several month in culture of MS Anthurium medium.

Norman and Alvarez (1994a) observed that X.c. pv. dieffenbachiae survived for more than one year on or within stage II shoots without producing symptoms and was successively transferred three times, as latently infected shoots were multiplied. X.c. pv. dieffenbachiae could not grow and survive for beyond two weeks in Murashige and Skoog medium lacking plant material.

Erwinia chrysanthemi

Haygood et al. (1982) used rifampicin resistant strain to study the survival of Erwinia chrysanthemi isolated from Philodendron selloum. An enrichment technique was used to enable isolation of bacterium from detached, artificially infected leaves, 11-13 months after they had been placed either on glass house bench upon and buried in potting media or in a lab. The pathogen was detected from potting media, with or without presence of living roots upto 12 months. The pathogens also survived for 5-6 months in association with the leaves of 23 host and non-host glass house ornamentals

and was recovered after 13 months from artificially infested seed stored at 5°C.

SEROLOGY

Xanthomonas campestris pv. dieffenbachiae

Bonner et al. (1987) used eight monoclonal antibodies (Mabs) to characterise 365 strains of Xanthomonas campestris pv. dieffenbachiae using ELISA. Strains were isolated from 12 genera of aroids collected from five Hawaiian Islands, Florida and California. Approximately 97 per cent of the total X.c. pv. dieffenbachiae strains and 99 per cent of 190 Anthurium strains reacted with one or more Mabs. Thirteen distinct group were identified, 44 per cent of the anthurium strains is from 6 groups, 3 of which were exclusively Anthurium strains. Group 9 has predominantly Colocasia esculenta, other group contained strains from variety of aroids. One Mab 97-2-1-1 reacted with 98 per cent of 124 non-starch hydrolysis X.c. pv. dieffenbachiae strain but none of the hydrolysis strains. They concluded that Mabs could be useful for identifying and differentiating strains of X.c. pv. dieffenbachiae and could be valuable in epidemiological studies.

Lazo and Gabriel in 1987 detected indigenous, cryptic plasmid in all strains of Xanthomonas campestris pv. dieffenbachiae.

Lazo et al. (1987) reported the use of Restriction Fragment-Length Polymorphism to study X.c. pv. dieffenbachiae. The DNA of various strains of Xanthomonas campestris were digested with restriction endoneuclease EcoRI and a random cosmid DNA clone XCT1 was used as probe. And they concluded that strains from Philodendron sp. and Dieffenbachia sp. both correspond to that of X.campestris pv. dieffenbachiae.

Norman and Alvarez (1989) used Xanthomonas specific monoclonal antibodies XI and XII in a ELISA to confirm identity of presumed colonies of Xanthomonas campestris pv. dieffenbachiae.

Alvarez et al. (1990) reported 12 serological group and 6 of which are principally on Anthuriums. Lippet al. (1992) used six monoclonal antibodies to group 323 strains of Xanthomonas campestris pv. dieffenbachiae isolated from 12 genera of aroids and collected from five Hawaiian islands, Florida, California and Australia. Nine per cent of these strains did not react with any of the six Mabs. Of the remaining 91 per cent, 12 major serogroups were identified, 95 per cent of the Anthurium strains formed seven group four of which contained exclusively Anthurium strains. Thirty six of 43 strains from Syngonium reacted with the Mabs. Further they observed that X.c. pv. syngonii strains were serologically closely related to strains from Anthurium

whereas the second from Syngonium was identical to X.c. pv. dieffenbachiae isolated from Aglaonema, Philodendron, Dieffenbachia and Colocasia, so they concluded that both the strains from Syngonium should be included in X.c. pv. dieffenbachiae.

Hernandez and Trujillo (1993) obtained the antisera of X.campestris isolated from Xanthosoma sagittifoliumand reported that it reacted only with its homologous antisera. Berthier et al. (1993) noticed a high degree of variability of DNA finger print with X.campestris pv. dieffenbachiae.

Norman and Alvarez (1994b) developed a miniplate enrichment/ELISA system for rapid detection and identification of Xanthomonas campestris pv. dieffenbachiae causal agent of Anthurium blight. The identity of Xanthomonas campestris pv. dieffenbachiae was confirmed by ELISA using an X.c. pv. dieffenbachiae specific monoclonal antibody (X cd 108). Sensitivity and specificity of the miniplate enrichment/ELISA were determined using 10 µl subsamples containing end point dilutions of X.c. pv. dieffenbachiae on mixed suspensions containing various ratios of competitive bacteria to X.c. pv. dieffenbachiae. The miniplate enrichment ELISA system was sufficiently sensitive to detect one or more colony forming unit per well. Monoclonal antibody Xcd 108 reacted with all strains of X.c. pv. dieffenbachiae pathogenic to Anthurium but not with most

non-pathogenic strains isolated from anthriums. The predictive value of test results for the miniplate enrichment/ELISA system when compared with standard isolation procedure was 97.9 per cent, this system was useful for detection of epiphytic population of X.c. pv. dieffenbachiae on leaf surfaces.

Berthier et al. (1994) isolated a new insertion sequence from X.c. pv. dieffenbachiae. Sequence analysis showed that this element is 1,158 bp long and has 15-bp inverted repeat ends containing two mismatches. Comparison of this sequence with sequence in data bases revealed significant homology with Escherichia coli IS5, IS1051, which detected multiple restriction fragment length polymorphisms which was used as a probe to characterise strains from the pathovar dieffenbachiae.

Norman and Alvarez (1996) demonstrated the use of serological methods for epidemiological studies.

Pseudomonas sp. on Araceae

Prior and Rott (1989) recorded that all isolates of anthurium pathogen (Pseudomonas sp.) reacted positively when stained by indirect fluorescent antibody technique.

Scortichini (1994) reported that identification of P.marginalis pv. marginalis on Dieffenbachia was facilitated

by performing unidimensional SDS-PAGE of bacterial whole cell proteins. The protein profile of the isolates under study were visually compared with those of P.marginalis pv. marginalis isolated from Chichorium intibus and Lactuca sativa, P.cichorii from L.sativa and capsicum and Eriwinia chrysanthemi pv. dieffenbachiae with Pseudomonas marginalis pv. marginalis from Dieffenbachia. Qualitative and quantitative difference in protein composition was noticed with P.chichorii and Erwinia chrysanthemi pv. dieffenbachiae.

CONTROL MEASURES

Cultural practices

Xanthomonas campestris pv. dieffenbachiae

Pirone (1939) recommended the removal of heavily spotted plants, wider spacing and the avoidance of over head watering to control leaf spot of diffenbachia. McCulloch and Pirone (1939) recommended the separation of infected plants from the healthy plants and lowering of temperature since high temperature encouraged the growth of the bacteria (Bacterium dieffenbachiae). Chase (1987) reported a fall in leaf area infected by X.campestris as the osmocote rate was increased.

Dickey and Zumoff (1987) suggested removal of infected leaves at the junction of the petiole and stem as soon as

symptom occurred and avoidance of overcrowding and overhead watering of stock plants. Similar suggestion was given by Chase (1988) to control X.campestris from Syngonium.

Chase (1989) recorded percentage of blighted leaf area of Syngonium decreased linearly as the rate of complete fertilize (liquid 20 : 20 : 20) or slow release (19 : 6 : 12) increased. Increase rates of either nitrogen or potassium were equally effective in reducing symptom expression. Severity of blight on Syngonium White Butterfly can be minimized with moderate increase in application rates of complete fertilizers, nitrogen or potassium.

Graser et al. (1990) recorded various meteorological conditions to determine the condition under which blight infection of Anthurium is favoured. Furutani et al. (1990) made a preliminary research on techniques to reduce pH of guttated xylem sap of Anthurium plant; on amino acids and reducing sugars in the sap and on the acid neutralizing capacity of the leaf surface in relation to possible means of controlling blight of Anthuriums. Higaki et al. (1990) noticed the incidence of bacterial blight to decrease with increasing nitrogenous fertilizer upto 400 lb N/acre per year. No difference in disease incidence was noticed with use of organic and inorganic type of media and/or fertilizer and various combination of both.

Miller (1990) stated that most effective control of X.campestris of Syngonium is by rigourous hygine and adequate fertilizer application. Mu (1990) suggested the use of tissue cultured healthy plants for propagation. Poole and Chase recommended against application of excess fertilizer to help prevent bacterial blight(1990).Sakai (1990) reported that the levels of amino compounds in the fluid from plants of Anthurium andraenum increased with increasing amount of ammonium fertilizer and was greater than when the plants were given nitrate fertilizers. So it was suggested that lowering the level of amino compounds in guttation fluid by use of nitrate fertilizer may reduce the level of blight infection of undamaged plants in the nursery. Sakai et al. (1990b) also observed that use of new growth media does not reduce blight.

Chase (1992) stated that nutritional control of disease was possible. Plants receiving fertilizer at rates greater than the recommended rate are less susceptible to the pathogen. In plants receiving a slow-release fertilizer (Osmocote 19-6-12) at rates upto 18.4 g per 10 cm pot, disease severity decreased linearly in Anthurium and syngonium compared to plants receiving lower levels of fertilizers.

Norman and Alvarez in 1994a suggested that latently infected Anthurium as the source for outbreak of blight.

Haygood et al. (1982a,b) reported that high N levels reduced disease severity of Phillodendron selloum and disease severity showed a weak trend of increase with increase K levels.

Leyns et al. (1984) noticed that temperature of 29°C and extended period of moisture on leaf surface and wounding was required for infection on Dieffenbachia . Cortes-Monllor (1986) reported that spread was rapid in rainy periods and advised the removal of crop residue from field to reduce bacterial spot of Xanthosoma sagittifolium. Nemeth (1986) recommended quarantine measure to prevent spread and introduction.

Psedomonas sp. on Araceae

Chase (1992) recommended high fertilizer levels to reduce susceptibility to P.cichorii without reducing plant growth or quality of many aroids.

Chemical control

Xanthomonas campestris pv. dieffenbachiae

Robbs in 1960, reported the weekly application of Streptomycin at 200 ppm to control Anthurium blight. Knauss (1971) noticed that application of 200 to 400 ppm Streptomycin was ineffective to control X.dieffenbachiae of

Philodendron oxycardium due to the development of resistance to streptomycin.

Hayward (1972) recorded the X.dieffenbachiae from Anthurium was sensitive to neomycin sulfate 30 µg; tetracyclin hydrochloride 30 µg, novobiotin 30 µg, chlortetracyclin 30 µg, erythromycin 15 µg, streptomycin 10 µg, polymyxin B, 300 IU and chloromycetin 5 and 30 µg.

Knauss (1972) recommended Streptomycin sprays 100-400 ppm at 4-7 days interval to control X.c. pv. dieffenbachiae of Phillodendron selloum.

Knauss et al. (1972) stated that effective control of X.c. pv. dieffenbachiae on Phillodendron oxycardium would be given by Kocide 101 at 1, 15 and 2 lb in combination with Dithane M-45 at 1.5 lb in 100 gal water. Good control was obtained when this was applied in alternate week with agristep (200 ppm). Guevara and Debrot (1984) noticed in vitro inhibition of the pathogen isolated from Anthurium at Streptomycin 500 ppm and Trimiltox Forte.

Higaki et al. (1990) noticed application of pesticides including a miticide, fungicide [Dithane M-45 (Mancozeb)] and herbicide increased susceptibility. Nishijima (1990) recorded that biocide agribom killed X.c. pv. dieffenbachiae in 2 min when used at 2 ppm but on anthurium it caused chlorosis at 100 ppm. The bacterium was also killed,

Kuehnle et al. (1995) attempted to transfer the apparent systemic resistance from Anthurium antioquiense Engler to the Anthurium andreanum F_1 hybrids, which showed high degree of resistance to the bacteria. They released two cultivar with improved resistance `Kalapana' and `Tropic Ice' but later succumbed to blight, so they conducted research to introduce three various antibacteria genes and synthetic derivative from Hyalophora cecropia and bacteriophage for bacterial resistance and some regenerated anthuriums showed delayed symptom development.

Balakrishnan et al. (1996) recommended use of planting materials free from disease; increased activity of beneficial microorganism in soil through the use of organic manures, strict sanitation and tools washed in alcohol or other antiseptic solution after use on diseased plants.

Erwinia sp. on Araceae

Sauthoff and Bortels (1962) suggested the control of Erwinia dieffenbachiae of Dieffenbachia by soil steaming, tool disinfection and removal of infected cutting. Other plants which may act as a reservoir of Erwinia chrysanthemi should be considered in nursery planting design to reduce infection on syngonium (Knauss and Wel burg, 1970). Knaus and Miller (1974) recommended the control of E.chrysanthemi of Phidodendron selloum by using disease free seeds.

in vitro by exposure to oxytetracyclin 32 ppm for 16 days and *in vivo* by drenching infected plants with oxytetracyclin at 1000 or 1500 ppm 3 or 4 times at weekly intervals.

Chase (1992) recommended the weekly spray with an antibiotic (Oxytetracycline at 1-1.5 lb per acre or streptomycin sulphate at 1-2 lb per acre) for 6-8 weeks only in Anthuriums and chemical control of Xanthomonas leaf spot of Philodendron was recommended to be cupric hydroxide and mancozeb.

Chase (1993) in a study of efficacy of fosetyl-Al for control of *X.c.* pv. *dieffenbachiae* concluded that the chemical does not give consistent or reliable control.

Balakrishnan *et al*. (1996) suggested spraying of plant thoroughly with Streptomycin sulphate or oxytetracyclin (200 mg/L of water) on a weekly schedule for 6 to 8 weeks.

Erwinia sp. on Araceae

Miller (1956b) reported that the antibiotics were more effective to control bacterial disease of foliage when applied prior to infection. Agrimycin (5% streptomycin-1 1.5% terramycin) at 200 ppm applied 48hrs before infection completely prevented symptom development so does Streptomycin nitrate 20 per cent. On naturally infected plant agrimycin at 200 ppm repeated at 4 day interval gave the most effective

control but when applied as soil drench the antibiotic failed to prevent or arrest infection.

Against, E.chrysanthemi on Philodendronsp. antibiotics agrimycin 100, Streptomycin nitrate and Streptomycin sulfate were most effective (Miller, 1957). During the winter month dipping Philodendron plants, before packing in unventilated containers, in solutions of agrimycin, panodrench, actidione on thylate greatly reduced bacterial soft rot (Miller, 1958).

Munnecke (1960) reported a partial control of E.chrysanthemi of Dieffenbachia by dipping cutting in agrimycin 100. Miller and McFadden (1961) controlled E.chrysanthemion Philodendron sp. by agrimycin applied at 4 days interval which reduced number of infected leaves from 128 to 7.

Vantomme et al. (1984) suggested pre-treatment of the mother plant of Dieffenbachia followed by dipping of cutting overnight and 5 subsequent weekly foliar spray with ammonium salt CGA 78039 for control of E.chrysanthemi.

Pseudomonas sp. of Araceae

P.cichori infection on various Araceae host can be controlled with preventive application of Streptomycin sulphate (200 pppm).

Biological control

X.campestris pv. diffenbachiae

Webb et al. (1987) tested various sugars and acids and indicated that butyric acid was most effective in preventing growth of X.c. pv. dieffenbachiae whereas Xanthan gum enhanced the pathogenic population.

Fernandez et al. (1990) presented the results of field trials with 4 selected antagonist of X.c. pv. dieffenbachiae but none of the treatments gave low disease incidence.

Higaki et al. (1990) revealed that application of non-pathogenic bacteria had no effect on blight incidence.

Norman and Alvarez (1994a) reported enhancement of bacterial growth in presence of coconut water.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

3.1 STUDY OF SYMPTOMS

The leaf blight of Anthurium was noticed in KGS Nurseries and Farms, Chamrajpet, Bangalore; Krishnendra nurseries, Bangalore and many other commercial farms in and around Bangalore especially during warm, humid weather conditions.

The leaf infection started at the edge of the leaf. At the initial stages, water soaked lesions appeared which later, turned brown as the infected tissues got killed and became surrounded by a rim of yellow leaf tissue.

The spots appeared more or less circular to elongated and when the lesions were numerous on a leaf, the lesions coalesced to form rather large areas which ultimately led to death of the entire leaf. Severely infected leaves were torn and distorted.

The veins and veinlets also got infected and the infection moved to the petiole and finally to the stem, which became brown and resulted in rotting of the main stem. The leaves became yellow and defoliated. The spathe and the spadix showed necrotic spots which frequently coalesced and led to partial or full browning. The plant completely dried within a couple of weeks of symptom appearance.

The Anthurium leaves showing the above symptoms were collected from KSG Farm and Krishnendra Nurseries, situated around Bangalore for the isolation of the causal agent.

The association of the bacteria with the disease symptoms was detected by the Ooze tests as observed under the microscope under high power objective (40x).

3.2 ISOLATION OF THE CAUSAL ORGANISM FROM THE BACTERIAL BLIGHT AFFECTED ANTHURIUM PLANTS

Infected leaves collected from both the farms were cut aseptically into small bits along with the healthy tissues and the infected bits were surface sterilized in one percent sodium hypochlorite solution for one minute. Washed in three series of sterile water to remove traces of sodium hypochlorite. The diseased tissues pieces were then suspended in a test tube containing 3 ml sterilized water till the water became turbid due to oozing of bacterial cells from cut ends. The bacterial suspension was serially diluted in 9 ml sterile distilled water. Then one ml of the diluted bacterial suspension was poured into sterilized petriplates and luke warm nutrient agar medium was then poured into the plates. The plates were rotated in clockwise and anticlockwise direction to see that the bacterial suspension is distributed uniformly so as to obtain well separated bacterial colonies. The inoculated plates were incubated at

28°C for 72 hrs. Observation were made for development of bacterial colonies if any.

At the end of incubation period well separated yellow glistening convex, small, mucoid colonies, developed on the medium. Repeated isolations made from the diseased anthurium leaves consistently yielded yellow, round, convex small and glistening colonies.

3.3 PURIFICATION AND MAINTENANCE

The suspected bacterial colonies isolated from the disease plants collected from the two farms were picked up and purified by streaking the culture on to the surface of yeast extract dextrose calcium carbonate agar (YDCA Schaad and Stall, 1988) contained in a sterilized petriplates. The inoculated plates were incubated at 28°C for 72 hrs and the observations were made for the development of well separated typical yellow coloured bacterial colonies. The purified bacterial cultures were streaked on to the nutrient agar slants and stored at 5°C in a refrigerator for further use as stock cultures. The culture isolated from KSG Farm, Chamrajpet and Krishnendra nurseries, Devanahalli were designated as A and B isolates, respectively.

3.4 IDENTIFICATION OF THE BACTERIUM

The identification of the bacterium isolated from diseased anthurium leaves was done by conducting

morphological, physiological, biochemical and pathogenicity studies.

3.4.1 Morphological characteristics

The morphological characteristics such as cell shape, Gram reaction, capsule and spore staining characters were studied for isolates A and B as described by (Bradbury, 1970 and Schaad and Stall, 1988).

3.4.2 Physiological and biochemical characters

The physiological and biochemical characters of both the isolates of the bacteria were studied for hydrolysis of starch, gelatin liquification, indole production, hydrogen sulphide production, urease reaction, acid from different sugars and asculin hydrolysis. The tests were conducted as per the methods described by Bradbury (1970) and Schaad and Stall (1988).

3.4.3 Differentiation of the species Xanthomonas

For the purpose of differentiating the species of Xanthomonas colonies of bacterial isolates, isolated from diseased anthurium leaves were subjected to the following diagnostic tests as suggested by Schaad and Stall (1988).

1. **Growth on Yeast extract dextrose calcium carbonate agar:** The bacterial suspensions of isolate A and B were made in sterile water by adding a loopful of 48 hrs cultures into

10 ml of sterile water. Then one ml of the suspension was poured into sterilized petriplates and then lukewarm YDCA was poured into the plates. The plates were rotated in clockwise and anticlockwise direction to get a uniform distribution of the bacteria in the medium. The inoculated plates were then incubated at 28°C for 48 hrs. Observations were made for development of bacterial colonies.

2. **Growth at 35°C** : The two isolates, viz., A and B were streaked on nutrient agar slants and placed at 35°C for 5 days. The observations were made for development of bacterial colonies after five days.

3. **Protein digestion** : Reconstituted powdered skim milk was sterilized and mixed with sterile melted yeast extract nutrient agar to obtain a ten per cent weight/volume concentration and poured over the surface of a thin layer of nutrient agar in petriplates. The plates were then dried. The two isolates `A and B' of the bacteria were spot inoculated. Observations were recorded for a clear zone around the colonies after three, five and seven days.

4. **Hydrolysis** of asculin : Asculin broth was prepared using yeast salt broth, ferric ammonium citrate 0.5 per cent (w/v) and asculin 0.1 per cent (w/v), the pH was adjusted to 6.8. The two isolates viz., `A and B' were inoculated into the broth and incubated upto 28 days. The observation was

recorded for development of a dark brown colour in the asculin broth.

5. **Gelatin liquifaction** : Freshly prepared and autoclaved nutrient agar supplemented with 0.4 per cent gelatin was poured into petriplates. The medium after solidification was spot inoculated with the two isolates on the surface of the medium. The inoculated plates were incubated at 27°C for three days. After three days, the surface of the medium was flooded with acid mercuric chloride solution. A clear zone around the colonies were used as a indication for gelatin hydrolysis.

6. **Urease production** : A modified yeast salt broth (Yeast extract reduced to 0.1% w/v with cresol red 0.0016% w/v added) was prepared and autoclaved. A ten per cent filter sterilized urea solution was added to get a two per cent concentration, the medium was then dispersed into sterile test tubes and loopful of the bacterial cultures were added separately. An increase in alkalinity was indicated by a magenta red colour (pH 9.0) as the evidence of urease activity.

7. **Acid from arabinose, glucose and mannose** : Arabinose, glucose and mannose broth were prepared with bromothymol blue indicator and poured into test tubes with a inverted duram's tube. The broth was then autoclaved and inoculated with

24 hr cultures of isolate A and B. Observation were taken after 48 hr for a change in colour from green to yellow indicating the production of acid from the sugars.

3.5 PATHOGENICITY TEST

The pathogenicity test was carried out to prove the Koch's postulates in order to know whether the bacteria isolated from the diseased anthurium leaves is pathogenic or not, under artificial conditions.

3.5.1 Hypersensitive reaction on tobacco

The two isolates of the bacteria were multiplied in nutrient broth medium. A loopful of bacterial culture was inoculated to nutrient broth contained in Erleyenmayer's flask separately. The inoculated flasks were incubated for 48 hr at 28°C.

The bacterial cultures were centrifuged at 15000 rpm in high speed refrigerated centrifuge (Remi-Model) for 10 min. The supernatent was discarded and the pellets of the two isolates were collected separately and suspended in sterile distilled water and the concentration of the cell suspension was adjusted to 2 x 10^7 cfu/ml in spectrophotometer (20D Milton and Roy, USA) at wave length of 480 nm. The bacterial suspensions were injected into intracellular spaces of intact tobacco leaves viz., (Nicotiana tobaccum var. Samsum,

Nicotiana glutinosa) using hypodermic needle. The injected plants were kept in glasshouse at 25°C. Leaves inoculated with sterilized distilled water served as control. The inoculated leaves were observed for the development of confluent necrotic lesions during next 48 hrs.

3.5.2 Pathogenicity of the bacterial isolates to anthurium plants

Anthurium plants var. Andes Lipstick were raised in pots containing sterilized sand : soil : pebble mixture (1 : 1 : 1) by planting healthy plants. The plants were supplied with plant nutrient solution (Hogland, 1920) so as to supply the necessary nutrients required for the plant growth. Plants were watered daily once.

The two isolates of the bacteria were multiplied separately in nutrient broth taken in Eryleynmayers flask by inoculating a loopful of 48 hrs old bacterial cultures separately. The inoculated flasks were incubated for three days at 28°C.

The anthurium plants kept for 48 hrs, in humid tents made of plastic sheets, with a humidity of about 80 per cent were taken. The bacterial suspension of both the isolates in which the cell suspension was adjusted to 7×10^7 cfu/ml was sprayed on to the plants separately with the help of an automizer. The sprayed plants were again kept in humid tent

for the next 48 hrs. Thereafter the plants were taken out from the humid tent and kept in the environment controlled glass house. The plants similarly sprayed with sterile water served as control. Observations were recorded for the development of symptoms on the leaves once in five days. Later, when the plants started expressing characteristic symptoms the bacteria was reisolated as explained in 3.1 and compared with the original culture of X.c. pv. dieffenbachiae by studying the staining, colony character and biochemical characteristics.

3.6 Survey for the incidence of Bacterial blight of Anthuriums (*Xanthomonas campestris* pv. *dieffenbachiae*)

A survey was conducted on the incidence of bacterial blight in commercial horticultural nurseries in Karnataka during November 1995 to January 1997 to record the percentage incidence of Bacterial blight of Anthurium caused by X. c. pv dieffenbachiae and imported from different countries on different varieties.

The farms were visited twice at six monthly interval and observations were made for the incidence of disease. Observations were recorded by selecting fifty plants in random at each spot and 50 to 250 Anthurium plants were examined depending on the availability of varieties and size of the farm.

3.7 Host range of X. c. pv. dieffenbachiae causing bacterial blight of Anthurium

The ability of the pathogen to infect different ornamental plants belonging to family araceae was tested by inoculating the pathogen to the plants under artificial conditions. Ten foliage plants comprising of aroids were selected for the purpose of inoculation as indicated in the Table 1.

The plants were raised in the pots containing sterilized soil and were supplied with Ho glands plant nutrient solution (Ho gland, 1920) to provide the nutrient necessary for plant growth. The two isolates viz., `A and B' were multiplied by inoculating a loopful of culture into Erleyenmayer's flask separately and incubated at 28°C for 48 hrs. The cells were harvested by spinning at 33500 g for 15 minutes in high speed refrigerated centrifuge. The pellets were collected and suspended in sterile distilled water. The concentration of the bacterial cells was adjusted to 5 x 10^6 cfu/ml of water in spectrophotometer at 480 nm. Plants raised in pots containing sterilized soil were preincubated at high relative humidity for 48 hrs by keeping the potted plants in the humid tent made of polythene sheet. The plants were injured slightly with insect pin and the bacterial suspension of the two isolates were sprayed on the surface of injured leaves with low speed automizer. After inoculation

Table 1. Plants used for host range studies of *Xanthomonas campestris* pv.*dieffenbachiae*.

Sl. No.	Common name	Scientific name
1.	Aglaonema	*Aglaonema* sp.Schott
2.	Alocasia	*Alocasia indica* - *metallica*
3.	Anthurium	*Anthurium magnificum* Linden
4.	Anthurium	*Anthurium andreanum* Linden
5.	Dieffenbachia	*Dieffenbachia picta* (Lodd.) Schott
6.	Money plant	*Scindapsus aureus* Engler
7.	Monstera	*Monstera deliciosa* Liebm.
8.	Philodendron	*Philodendron* sp.
9.	Rhodospatha	*Rhodospatha hastata* L.
10.	Syngonium	*Syngonium podophyllum* Schott
11.	Syngonium	*Syngonium auritum* (L.) Schott

the plants were kept in high humidity in the plastic tent for 48 hrs in the glasshouse. The plants injured but sprayed with sterile water served as control.

3.8 The efficiency of semi-selective and selective media in supporting the growth Xanthomonas campestris pv. dieffenbachiae

Four semi selective and selective media developed earlier by various workers for the X. c. pv. dieffenbachiae were tested in the present experiment to evaluate these media for their efficacy and efficiency in supporting the growth of bacterium which was identified to be X.c. pv. dieffenbachiae, so that the medium which is found highly efficient could be used for growth and other ecological studies. The media tested were Tween medium (Guire et al., 1986), SX agar (Schaad and White, 1974), BSCAA medium (Randhawa and Schaad, 1984) and CS medium (Norman and Alvarez, 1989).

The nutrient agar medium was used as a standard check for the purpose of comparing the growth of the bacteria.

The following is the composition of the various semi-selective and selective media used in the investigation.

(i) **Tween medium**

Peptone	...	10.00 g/l
Potassium bromide	...	10.00 g/l
Calcium chloride	...	250.00 mg

Tween - 20	...	10.00 ml
Cephalaxin	...	25.00 mg
5-Flurouracil (Sigma)	...	6.00 mg
Tobramycin (Sigma)	...	0.40 mg
Cycloheximide	...	75.00 mg
Agar	...	18.00
Water	...	1000 ml

(ii) CS medium

Cellobiose	...	5.00 g/l
Potato starch	...	10.0 g
$MgSO_4 7H_2O$	...	0.10 g/l
K_2HPO_4	...	0.80 g/l
KH_2PO_4	...	0.80 g/l
Agar	...	18.0 g
Cycloheximide	...	150.0 mg
Cephalexin	...	50.0 mg
Trimethoprim	...	30.0 mg
Pyridoxine	...	1.0 mg
Methyl green (1% aqueous solution)	...	1.5 ml
D-methionine	...	3.0 mg
Triphenyl tetrazolium chloride	...	0.001%
Water	...	1000.0 ml

(iii) SX agar

Starch	...	10.00 g/l
Beef extract	...	1.00 g/l

Ammonium chloride	...	1.00 g/l
Dipotassium hydrogen phosphate	...	5.00 g/l
Methyl violet 2B	...	1.00 ml*
Methyl green	...	2.00 ml*
Cycloheximide	...	250.00 mg***
Agar	...	18.00
Water	...	1000.00 ml

Note : * : 1% solution in 20% ethanol
** : 1% aqueous solution
*** : Add 5.0 g to 10.0 ml methanol, bring to 100 ml with water

(iv) **BSCAA medium**

Starch (soluble-potato)	...	10.00 g/l
Glycine	...	0.20 g/l
Dipotassium hydrogen phosphate	...	1.00 g/l
Potassium dihydrogen phosphate	...	1.00 g/l
Magnesium sulphate	...	0.20 g/l
Methyl green (1% in water)	...	0.20 g/l
Agar	...	18.00 g/l
Water	...	1000.00 g/l
Cycloheximide (5.0 g to 10.0 ml methanol and bring to 100 ml adding water)	....	5.00 g/l

The media were sterilized by autoclaving for 15 minutes at 121°C at 15 lb pressure. All the antibiotics were filter sterilized through 0.2 µm millipore filter and added to

cooled (50°C) media after autoclaving. The media were poured into sterilized Petri dishes and dried for 2 days at room temperature to eliminate surface moisture before use.

A loopful of 48 hr old cultures of the two isolates was added to 10 ml sterile water blank and one ml of this suspension was further serially diluted using 9 ml sterile water and 100 µl of 10^{-5} and 10^{-6}, dilutions were spread on the medium in each plate using a sterilized spreader under aseptic conditions. The inoculated plates were incubated at 28°C for 48 hrs. Observations were recorded for number of colonies developed and the characters of colonies on each medium.

3.9 Survival of the X. c. pv dieffenbachiae causing bacterial blight

Crop residue provides a means by which plant pathogenic bacteria survive in the soil. The present investigation was undertaken to know the length of survival of the bacterium.

The polyethene bags measuring 15 x 20 cm were filled with mixture of sand and alfisol. Anthurium leaves severely affected by bacterial blight caused by X. c. pv dieffenbachiae were collected from commercial horticultural nursery near Devahanalli, Bangalore district during the monsoon season 1996. The disease was diagonised by the ooze test as caused by a bacterium. Further the identity of the

bacterium was confirmed by isolating on Tween medium and cellobiose starch medium on which the bacterium produced small yellow, convex colony and reddish round to irregular colony respectively.

The diseased leaves were cut into small bits and used in the following treatments.

Treatment 1 : Diseased leaf bits (10 g) were placed on the surface of soil taken in polythene bags.

Treatment 2 : Diseased leaf bits (10 g) were mixed thoroughly with the soil taken in the polyethene bags

Treatment 3 : Diseased leaf bits (10 g) were burried 9 cm deep in the soil taken in the polyethene bags

Treatment 4 : A 48 hrs culture grown in nutrient broth was uniformly mixed with soil taken in the polyethene bags

All the bags were kept in the glasshouse. The soil moisture in the bags was maintained at 50 per cent water holding capacity by careful watering. At regular interval of 7 days one gram of sample was drawn from each bag at three spots. The samples were assayed for the recovery of bacteria from soil by following the dilution plating at each time using Tween medium. Three replications were maintained for each treatment.

3.10 MANAGEMENT OF BACTERIAL BLIGHT OF ANTHURIUM CAUSED BY *Xanthomonas campestris* pv. *dieffenbachiae*

3.10.1 *In vitro* evaluation of antibacterial chemicals on the growth of *Xanthomonas campestris* pv. *dieffenbachiae*

Seven antibacterial chemicals viz., Streptomycin sulphate, Paushamycin (Streptomycin sulphate 9% w/w + Tetracyclin hydrochloride 1% w/w), Streptocycline (Streptomycin sulphate 90% w/w + Tetracycline hydrochloride 10% w/w), Bacterimycin (Dibromodinitro propane mono-tri-diol), Coptox 50 WP (Copper oxychloride), Emisan-6 (Methoxy ethyl mercuric chloride) and Bavistan (Carbendazin 50 WP) at concentrations mentioned in Table 2 were evaluated to test their efficacy in inhibiting the growth of *X.c.*pv. *dieffenbachiae* by inhibition zone assay method under *in vitro* conditions.

The two isolates A and B were multiplied by inoculating the culture in nutrient broth taken in Erleyenmayer's flask. The inoculated flasks were incubated at 28°C for 48 hrs. The bacterial culture was seeded to nutrient agar. The seeded medium was poured into sterilized petriplates and allowed to solidify.

The chemical, solution were prepared at different concentrations as given in the Table 2. The filter paper discs measuring 0.5 mm in dia were soaked in the solutions

Table 2. Antibacterial chemicals used at different concentrations to study their effect on the growth of Xanthomonas campestris pv. dieffenbachiae.

Sl. No.	Antibiotic/Bactericide	Concentration (ppm)
1.	Streptocycline (Streptomycin sulphate 90% w/w + Tetracycline hydrochloride 10% w/w)	300 400 500
2.	Steptomycin sulphate	300 400 500
3.	Paushamycin (Streptomycin sulphate 9% w/w + Tetracycline hydrochloride 1% w/w)	300 400 500
4.	Bacterimycin (Dibromodinitro propane mono-tri-diol)	300 400 500
5.	Coptox 50 WP (Copper oxychloride)	2000 3000
6.	Emisan-6 (Methoxy ethyl mercuric chloride)	1000 2000
7.	Bavistan (Carbendazin 50 WP)	300 400 500

for 10 minutes and transferred onto the seeded medium. The inoculated plates were incubated in the refrigerator at 5°C for 4 hrs to allow the diffusion of chemical into the medium. The plates were incubated at 28°C for 3 days and observed for the production of inhibition zone around the filter paper discs.

3.10.2 *In vivo* evaluation of antibacterial chemicals on the development of root-rot due to *Xanthomonas campestris* pv. *dieffenbachiae*

Streptocycline, Copper oxychloride and Emisan-6 at the concentration of 500 ppm, 3000 ppm and 2000 ppm respectively were evaluated for their efficacy in controlling the root-rot caused by *X.c.*pv. *dieffenbachiae* infected plants. The experiment was carried out in MRS UAS, GKVK, Bangalore.

Anthurium plants whose roots were affected by root-rot due to *X.c.* pv. *dieffenbachiae* were treated with chemical solutions prepared at different concentrations. The roots were dipped in the solutions for an hour and the plants were planted in pots containing sterilized soil. Twenty plants were treated with each chemical. Nutrient solution (Hogland, 1920) was provided so as to supply the nutrients necessary for growth. The observation on the percentage recovery of plants were recorded after 30 days of planting.

3.10.3 Effect of antibiotics and copper oxychloride on the development of bacterial blight of Anthurium

A trial in the field in the commercial horticultural farm was taken up to find out the effect of streptocyline at 500 ppm, streptomycin sulphate (500 ppm), paushamycin (500 ppm) and copper oxychloride at 0.2 per cent on the development of bacterial blight of Anthurium.

A plot of anthurium affected with bacterial blight was selected. Streptocycline (500 ppm), streptomycin sulphate (500 ppm), paushamycin (500 ppm) and copper oxychloride at 0.2 per cent were sprayed thrice at 15 days interval. Ten plants were selected in each row for each chemical. Observation were recorded for the disease incidence and severity of the disease 3-4 days after the spray.

3.10.4 Effect of plant extracts on the growth of *X.c.* pv. *dieffenbachiae* *in vitro*

The efficiency of plant extracts viz., *Adathoda zeylenica* L., Ocimum (*Ocimum sanctum* L.), Citronella (*Cymbopogan winterianus* Jowitt.), Neem (*Azadirachta indica*) and Garlic (*Allium sativa*) were tested for their inhibitory effect on the growth of *Xanthomonas campestris* by inhibition zone assay method.

A heavy suspension of *X.c.* pv. *dieffenbachiae* (7×10^8 cfu/ml) was mixed with molten (50°C) nutrient agar contained

in an Erlenmayer's flask so as to get a thick growth of the bacteria on the medium. The seeded medium was poured into sterilized petriplates and allowed to solidify. The sterilized filter paper disc (Whatman No. 44) measuring 8 mm diameter were soaked in plant extracts and placed on the surface of the seeded nutrient agar medium in the petri dishes. The inoculated plates were incubated first at 5°C for 4 hrs so as to allow the diffusion of the extract into the medium. The plates were then incubated at 30°C for 48 hrs.

Observations were recorded for the production of zone of inhibition around the filter paper disc, against X.c. pv. dieffenbachiae by measuring the diameter of the inhibition zone.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

4.1 STUDY OF SYMPTOMS

The leaf infection initially appeared as small scattered angular water-soaked lesions on the edge of the leaf. The infected tissues got killed very soon and the spots turned brown, surrounded by a rim of yellow leaf tissue (Plate 1). Several spots appeared on the margins of leaves, as the disease advanced, the spots increased in size and coalesced giving a blighted appearance (Plate 2, 3 and 4). The veins and veinlets were infected and became brown and necrotic and the infection spread to the petiole. Thus the entire leaf gets blighted and were shed.

Brown necrotic spots were also noticed to appear on the spathe and spadix of infected anthurium plants (Plate 5). The petioles of the discoloured leaf and spadix showed browning and broke off readily from the stem.

The plants with leaf petiole and spathe infection resulted in the infection of the stem. The infected stem showed browning, then blackening and rotting, finally the infection moved to the roots and caused rotting with brown discolouration (Plate 6 and 7).

In a systemically infected plant all the leaves showed yellowing and ultimately resulted in the death of the plant (Plate 8).

Plate 1. Anthurium leaves showing necrotic lesions at the margin, surrounded by a yellow halo, due to the infection of X.c. pv. dieffenbachiae.

Plate 2. Anthurium leaves showing blight symptoms caused by X.c. pv. dieffenbachiae.

Plate 3. Necrotic spots on the margin of anthurium leaves due to the infection of X.c. pv. dieffenbachiae.

Plate 4. Extensive blighting of anthurium leaves due to X.c. pv. dieffenbachiae.

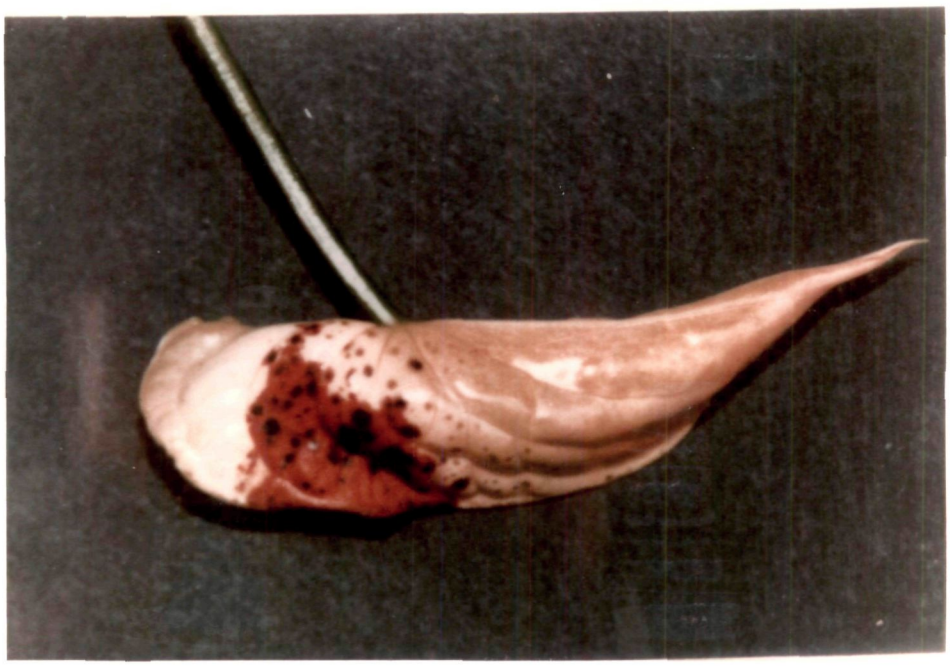

Plate 5. Spathe of anthurium showing necrotic reddish lesion due to X.c. pv. dieffenbachiae infection.

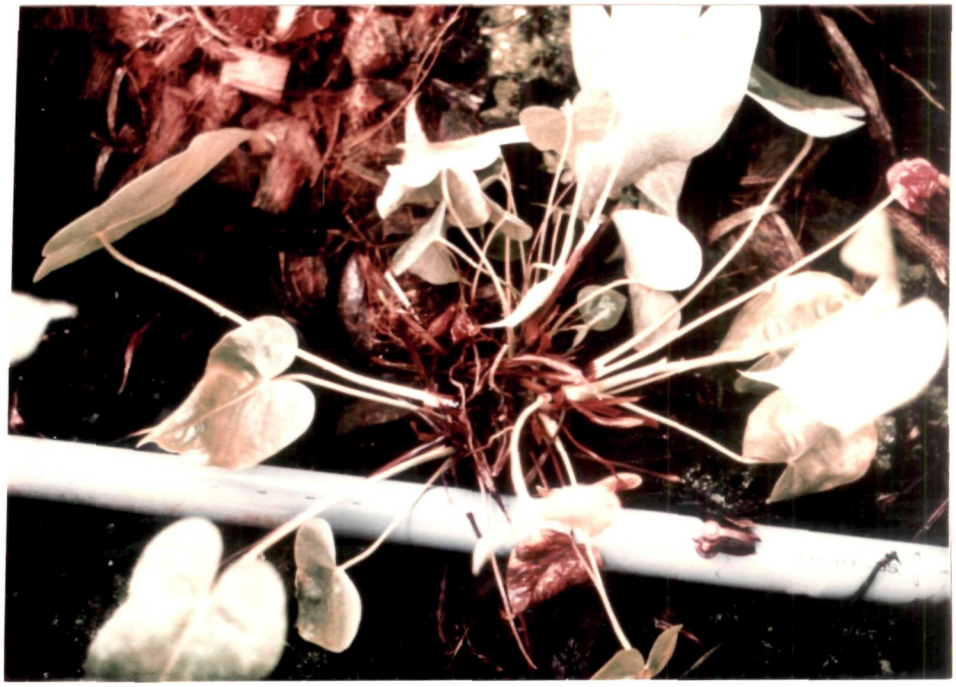

Plate 6. Anthurium stem exhibiting browning and rotting symptoms caused by X.c. pv. dieffenbachiae.

Plate 7. Anthurium stem and roots showing browning and rotting due to X.c. pv. dieffenbachiae infection.

Plate 8. Anthurium plant showing yellowing of leaves due to the systemic infection of X.c. pv.dieffenbachiae.

4.2 ISOLATION OF THE CAUSAL ORGANISM FROM THE DISEASED LEAVES

Tentative diagnosis of the cause of the disease was made by ooze test. The ooze test was conducted by cutting a small bit of the leaf tissue from the infected leaves and suspending it in a drop of sterile water taken on a microscope glass slide and observing under low power objective of the microscope. Within few minutes the bacterial ooze started jetting out from the cut ends of the infected tissue, thus revealing the association of bacteria with the disease.

Isolation were made from the anthurium leaves showing the symptoms as described under 4.1.1. Repeated isolations made on nutrient agar medium yielded yellow, mucoid, glistening, slimy, convex round colonies (Plate 9).

Well separated out colonies were purified on YDCA medium and used for further studies. The colonies on YDCA medium were deep yellow, highly viscous, irregular to round and slimy (Plate 10). The bacterial colonies isolated from KSG farm and Krishnendra Nurseries were designated as A and B respectively.

4.3 IDENTIFICATION OF THE BACTERIUM

The results of the various morphological and biochemical tests are given in Table 3. The bacterial cells

D.I.(HS)

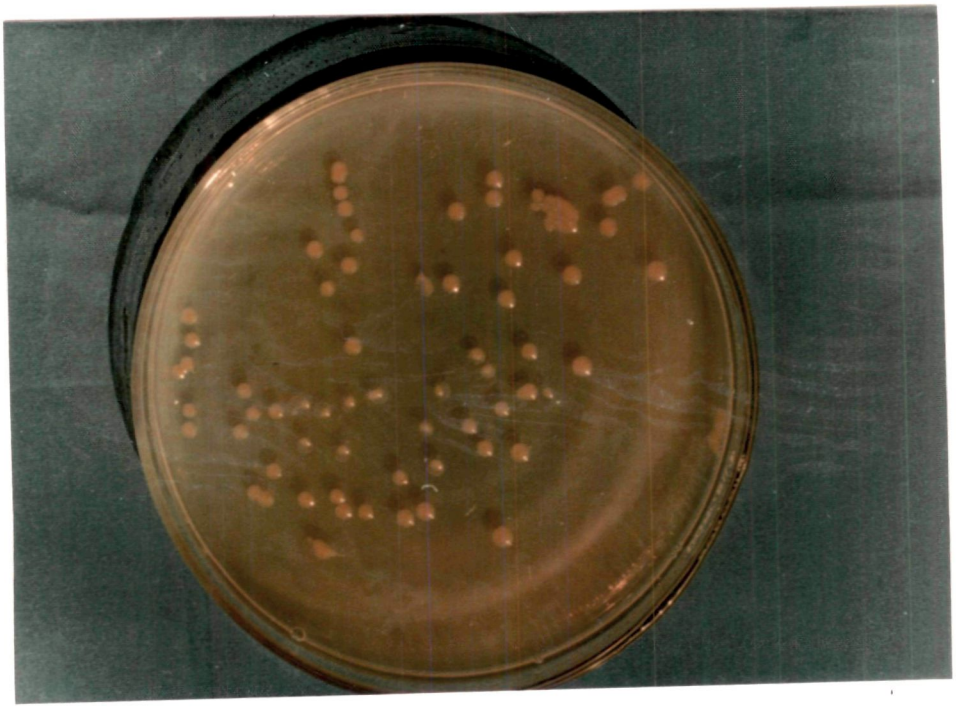

Plate 9. Typical yellow coloured colonies of X.c. pv. dieffenbachiae on nutrient agar isolated from anthurium leaves with blight symptoms.

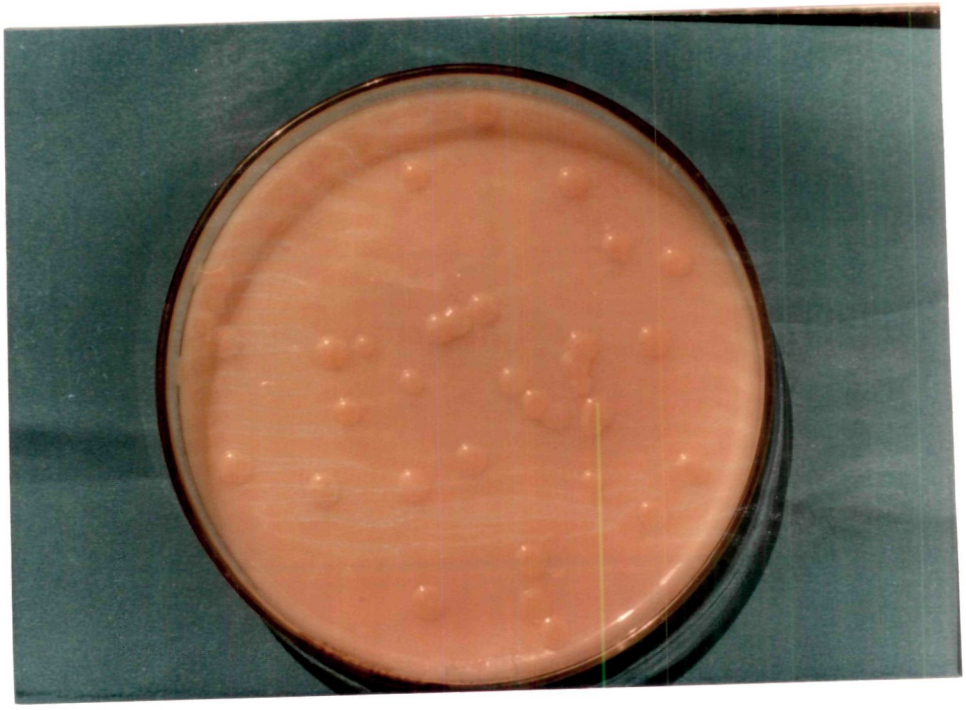

Plate 10. Mucoid yellow colonies of X.c.pv.dieffenbachiae.

of two isolates were found to be rod shaped, occurred singly, Gram negative, monotrichous flagellated non-capsulated, negative to spore and acid fast staining. On the basis of cultural, morphological and staining characteristics the yellow coloured colonies isolated on nutrient agar were tentatively identified to be Xanthomonas. The two isolates; A and B on yeast extract calcium carbonate agar were mucoid, shining deep yellow and both the isolates made good growth at 35°C.

The two isolates liquified gelatin, hydrolysed asculin, digested protein and no urease production was detected. Further both the isolates utilized arabinose, glucose, mannose as source of carbon and produced acid as evidenced by the change in colour of the solution from green to yellow colour. Thus indicating that the two isolates A and B were Xanthomonas campestris.

The two isolates produced hydrogen sulphide from peptone and failed to produce indole from tryptone. Isolate B showed mild hydrolysis of starch, whereas isolates A failed to hydrolyse starch. Acids were produced in the following sugars, fructose, maltose, lactose, cellobiose sucrose and trehalose and not from manitol and glycerol.

Table 3. Characteristics of the bacterium causing leaf blight of Anthurium (*Xanthomonas campestris* pv. *dieffenbachiae*).

Characteristics	Isolate A	Isolate B
I. Cultural characteristics		
1. On nutrient agar	Round, shining yellow colonies	Round, shining yellow colonies
2. On yeast extract dextrose calcium carbonate agar	Slimy viscous irregular to round deep yellow colonies	Slimy viscous irregular to round deep yellow colonies
II. Morphology		
1. Shape	Small rods	Small rods
2. Occurrence	In singles	In singles
III. Staining		
1. Gram reaction	-ve	-ve
2. Capsule reaction	+ve	+ve
3. Spore staining	-ve	-ve
4. Flagella staining	Monotrichous	Monotrichous
IV. Biochemical characteristics		
1. Starch hydrolysis	-ve	Mild
2. Hydrogen sulphide production	+ve	+ve
3. Indole production	-ve	-ve
4. Reduction of NO_3 to NO_2	-ve	-ve
5. Acids from		
(a) Fructose	+ve	+ve
(b) Maltose	+ve	+ve
(c) Lactose	+ve	+ve
(d) Cellulose	+ve	+ve
(e) Sucrose	+ve	+ve
(f) Trehalose	+ve	+ve
(g) Manitol	-ve	-ve
(h) Glycerol	-ve	-ve

Table 4. Diagnostic tests for differentiating the species of Xanthomonas.

Sl. No.	Tests	Reactions	
		Isolate A	Isolate B
1.	Mucoid growth on YDCA	+	+
2.	Growth at 35°C	+	+
3.	Asculin hydrolysis	+	+
4.	Gelatin liquifaction	+	+
5.	Protein digestion	+	+
6.	Urease production	-	-
7.	Acid from		
	(a) Arabinose	+	+
	(b) Glucose	+	+
	(c) Mannose	+	+

+ = Positive - = Negative

4.4 PATHOGENICITY TESTS

4.4.1 Hypersensitive reaction on tobacco

The bacteria injected to intercellular spaces of Nicotiana tabaccum var. Samsun and Nicotiana glutinosa produced characteristic water soaked lesion after 16 to 24 hours of inoculation, and formed a desiccated light brown necrotic area after 30 hrs (Plate 11).

4.4.2 Pathogenicity of the bacteria to Anthurium plants

The two isolates artificially inoculated to healthy leaves of anthurium plants variety Andes Lipstick by spraying the bacterial culture to the pre-injured leaves was found to be pathogenic to anthurium. The plants started producing water soaked lesion at the margins of the leaf after 14 days of inoculation the spot became brown with age and the lesions coalesced and produced blighted symptom (Plate 12). The brown discolouration later extended to the petiole and led to the defoliation.

The bacterium was reisolated from the infected leaves. On the basis of the various morphological, staining and colony characters on nutrient agar and yeast extract dextrose calcium carbonate agar and biochemical test, it could be inferred that the bacterium isolated from the diseased anthurium leaves as Xanthomonas campestris pv. dieffenbachiae.

Plate 11. Hypersensitive reaction produced by X.c. pv. dieffenbachiae on (1) tobacco leaves (Nicotiana tabaci) and (2) Nicotiana glutinosa.

Plate 12. Leaves of Anthurium andreanum artificially inoculated with X.c. pv. dieffenbachiae showing typical blighting symptoms (Necrosis).

4.5 SURVEY FOR THE INCIDENCE OF BACTERIAL BLIGHT OF ANTHURIUM (*Xanthomonas campestris* pv. *dieffenbachiae*)

The survey conducted on the incidence of bacterial blight in various commercial horticulture nurseries involved in propagation of anthurium plants and production of cutflowers revealed that the disease was present in almost all the nurseries irrespective of the source of planting material (Table 5). Anthurium plants from Sri Lanka, Mauritius and Holland were found to be affected with bacterial blight. However, plants imported from Sri Lanka were found to be highly infected and incidence of disease noticed was 40 per cent. In plants imported from Holland the disease incidence was found to range from 2-20 per cent.

Of the various varieties tested, the variety from Sri Lanka was highly susceptible and incidence was as high as 40 per cent and among the varieties from Holland studied for their susceptibility to bacterial blight Pricilla (15%), Monique (20%), Gloria (7%), Lunette (10%) and Margaretha (12%) were more susceptible as compared to other imported varieties from Holland in which the disease incidence ranged from three to five per cent.

4.6 HOST RANGE OF THE *X. c.* pv. *dieffenbachiae* CAUSING BACTERIAL BLIGHT OF ANTHURIUM

The results of the studies conducted on the host range of the pathogen are presented in the Table 6. The anthurium

Table 5. Survey for the incidence of bacterial blight of anthurium caused by *Xanthomonas campestris* pv *dieffenbachiae*.

Sl. No.	Name of the nursery	Source of plant material	Variety	No. of plants inspected	Percentage incidence of bacterial blight
1.	Kasturi Rangan Bangalore	Sri Lanka	-	250	40.0
		Mauritius	-	100	25.0
2.	Jageer Estate Coorg	Holland	Carino	100	2.5
			Cancan	100	2.0
			Senator	100	3.0
			A.scherzerianum	150	2.5
3.	Noel Agrotech Mangalore	Holland	Monique	100	20.0
			Alex	100	12.0
			Anneke	100	5.0
			Pricilla	100	15.0
			Ingrid	100	5.0
			Lijdia	100	10.0
			Gloria	150	7.0
			Claudia	100	3.0
			Patricia	150	17.0
			Vichris	150	2.5
			Rosette	100	2.5
			Silvia	200	1.0
			Diana	100	2.0
			Nette	100	3.0
			Mauritae	100	5.0
			Sybilla	50	2.5
			Margaretta	100	12.0
4.	Krishnendra Nursery Bangalore	Holland	Fla-Exotica	50	10.0
			Fla-Rose	50	10.0
5.	Prabha Estate Mercara	Holland	*Anthurium andreanum*	100	3.0

Table 5 contd..)

Sl. No.	Name of the nursery	Source of plant material	Variety	No. of plants inspected	Percentage incidence of bacterial blight
6.	Kibbetha Estate Coorg	Holland	Honduras	50	2.5
			Flarange	50	2.5
7.	Santhosh Thazhattu Bangalore	Holland	Andes-Lipstick	50	5.0
			Lunette	50	2.0
			Pronto	50	2.3
			Honduras	50	3.4
			Hawaii	50	7.0
			Cuba	50	4.2
			Andes No.10	50	3.1
8.	Assistant Director Dept. of Horticulture Bangalore	Holland	Avo-Margretha	50	10.0
			Avo-Nette	50	2.0
			Avo-Tinoria	50	2.5
9.	Payaswani Mangalore	Holland	Avo-Mauricia	100	4.3
			Avo-Margaretha	100	10.5
			Avo-Alexis	100	3.0
			Avo-Leigh	100	2.5
			Avo-Monique	100	17.0
			Avo-Nitte	100	3.0

blight pathogen inoculated to the plants namely Syngonium podophyllum (Plate 13), Syngonium auritium, Dieffenbachia picta (Plate 14), Alocassia sp., Algaonema sp., Monstera deliciosa, Philodendron sp., (Plate 15), Anthurium magnificum (Plate 16) and Anthurium andreanum could infect the plants and produce leaf blight symptom within 20 days of inoculation. However, Scindapsus aureus and Rhodospatha hastata failed to produce any symptom even after two months of inoculation.

4.7 EFFICIENCY OF SEMI-SELECTIVE AND SELECTIVE MEDIA FOR THE GROWTH OF Xanthomonas campestris pv. dieffenbachiae

Among the various selective and semi-selective media tested for their efficiency in supporting the growth of the X.c pv. dieffenbachiae, the Tween medium was found to be most efficient as the number of the bacterial colonies recovered were 267.33, 43 and 5.6 cfu/ml at 10^5, 10^6, 10^7 dilutions respectively as compared to nutrient Agar on which 281, 58 and 6 colonies were recovered at the same dilutions. Even on CS medium 27 and 6 colonies were recovered at 10^5 and 10^6 dilutions respectively.

But the colony diameter was more in CS media (2.16 mm) compared to Tween media (1 mm). Colony characters of X.c. cv. dieffenbachiae on selective or semi-selective media tested are as follows :

Table 6. Host range of *Xanthomonas campestris* pv. *dieffenbachiae* causing bacterial blight of Anthurium.

Name of the plant	Kind of reaction	Kind of symptom	Days taken for symptom production
Aglaonema sp.	Leaf blight	Water soaked lesions and brown spots along the margins of the leaf	20 days
Alocassia indica	Leaf blight	- " -	18 days
Anthurium andreanum	Leaf blight	- " -	14 days
Anthurium magnificum	Leaf blight	- " -	14 days
Dieffenbachia picta	Leaf blight	- " -	20 days
Mostera deliciosa	Leaf blight	- " -	7 days
Philodendron sp.	Leaf blight	- " -	7 days
Rhodospatha hastata	-	-	-
Scindapsus aureus	-	-	-
Syngonium podophyllum	Leaf blight	Water soaked lesions and brownish spots along the margins and inter-coastal regions of the leaf	7 days
Syngonium auritum	Leaf blight	Water soaked lesions and brown spots along the margins of the leaf	21 days

Plate 13. Syngonium podophyllum showing necrotic symptoms due to inoculation of X.c. pv. dieffenbachiae.

Plate 14. Dieffenbachia picta leaves showing marginal necrosis due to the inoculation of X.c. pv. dieffenbachiae.

Plate 15. Philodendron sp. showing necrosis due to the inoculation of X.c. pv. dieffenbachiae.

Plate 16. Anthurium magnificum leaves showing necrotic lesion due to the inoculation of X.c. pv. dieffenbachiae.

Table 7. Growth of Xanthomonas campestris pv. dieffenbachiae on selective and semi-selective media.

Media	Number of colonies recovered			Size (mm) of colony	Colony characters
Dilution	10^7	10^6	10^5		
Tween medium	5.6	43	267.33	1.00	Convex, yellow, shiny and circular
CS medium	0.0	6	27.00	2.16	Convex, red, circular to irregular
BSCAA	0.0	0	0.00	-	-
SX	0.0	0	0.00	-	-
Nutrient agar	6.0	58	281.00	3.00	Convex, yellow, shiny and circular

Plate 17. Small yellow coloured colonies of X.c. pv. dieffenbachiae on Tween medium.

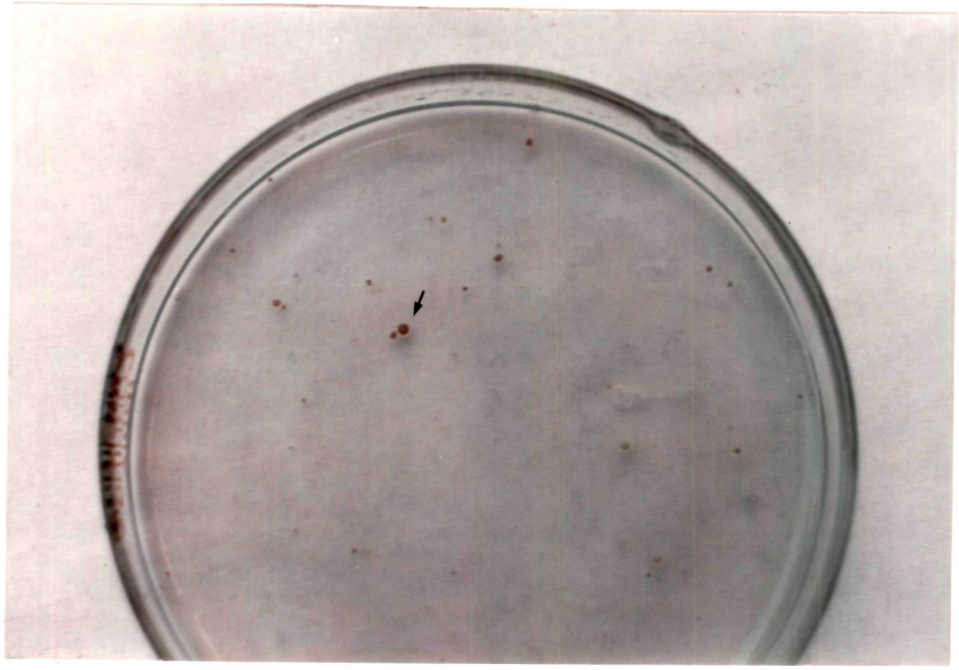

Plate 18. Minute red coloured colonies of X.c. pv. dieffenbachiae on CS medium.

Tween medium : The colonies were small convex, yellow, shiny and circular (Plate 17).

CS medium : The colonies where convex, red circular to irregular and bigger in size (Plate 18).

4.8 SURVIVAL OF THE BACTERIUM CAUSING BACTERIAL BLIGHT OF ANTHURIUM

The data on the survival of the pathogen (X.c. pv. dieffenbachiae) in the soil under in vivo condition is presented in Table 8 and 9. The soil samples collected from each treatment at an interval of seven days and assayed for the population of the pathogen by dilution plating technique using Tween medium semi-selective medium (Plate 19). The colonies on Tween medium were yellow, convex, circular and small, which was identified as Xanthomonas campestris pv. dieffenbachiae in our earlier experiment.

It can be noticed from the data that pure culture mixed with soil, failed to survive beyond six weeks. The population of the pathogen in the first week was 2.4 x 10^4 cfu/g which gradually declined to 0.16 x 10_1 cfu/g in the seventh week. However, in the eighth week no bacterial pathogen could be recovered. A similar trend, in the decline of population was recorded in other treatments. When infected material was mixed with soil, the bacteria was detected till nineth week. However the pathogen survived for 10 weeks and 13 week in the infected material was placed at

Table 8. Survival of Xanthomonas campestris pv.dieffenbachiae in infected leaves mixed with soil under in vivo condition (population in cfu/g of soil).

Weeks	Infected plant material		
	Placed on the surface of soil	Placed at 9 cm depth in soil	Mixed with the soil
1	25.11×10^4	15.91×10^4	8.42×10^4
2	14.00×10^4	15.50×10^4	6.61×10^4
3	14.00×10^4	11.42×10^4	2.30×10^4
4	17.50×10^3	13.00×10^3	8.00×10^3
5	12.60×10^3	9.10×10^3	6.20×10^3
6	6.00×10^3	6.40×10^3	4.80×10^3
7	3.50×10^3	2.86×10^3	2.10×10^3
8	7.00×10^2	5.54×10^2	2.10×10^2
9	0.70×10^2	0.58×10^2	0.40×10^2
10	0.45×10^2	0.83×10^1	0
11	0.23×10^2	0	0
12	0.11×10^2	0	0
13	0.55×10^1	0	0
14	0	0	0

Fig 1: Survival of X.c. pv. dieffenbachiae in the soil under in -vivo condition

Table 9. Survival of *Xanthomonas campestris* pv *dieffenbachiae* in infested soil.

Weeks	Population recovered (cfu/g of soil)
1	2.4×10^4
2	2.3×10^4
3	8.5×10^2
4	2.1×10^2
5	0.8×10^2
6	0.2×10^1
7	0.16×10^1
8	0

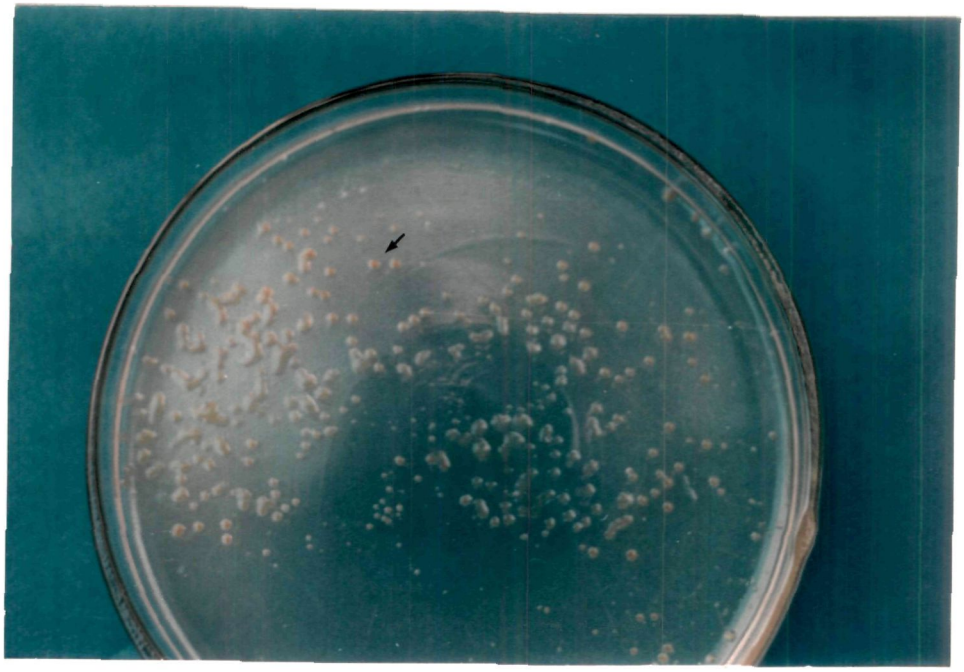

Plate 19. Colonies of X.c. pv. dieffenbachiae on Tween medium recovered from the infected leaves debris burried in soil.

9 cm depth and on the surface respectively. There was a gradual decline in the population in these treatments also.

4.9 EVALUATION OF THE EFFECT OF ANTIBIOTICS/BACTERICIDES ON THE GROWTH OF X.c. cv. dieffenbachiae

4.9.1 In vitro evaluation of antibiotics/bactericides on the growth of X.c. pv. dieffenbachiae

The results presented in the Table 10 on the efficiency of various antibiotics/bactericides inhibiting the growth of bacterium revealed that, antibacterial chemicals used in the experiment inhibited the growth of X.c. pv. dieffenbachiae by producing a zone of inhibition around the filter paper disc dipped in the respective chemicals. Among the antibiotics tested, streptocycline produced a highest inhibition zone of 23.30 mm followed by paushamycin (20.80 mm) (Plate 20) and streptomycin sulphate (19.50 mm) at 500 ppm, whereas, bacterimycin failed to produce any inhibition. Copper oxychloride (2000 ppm) and Emisan-6 (1000 ppm) were also effective to some extent in inhibiting the growth of the bacterium by producing a inhibition zone of 17.63 mm and 10.00 mm respectively (Plate 21), but bavistin failed to show any inhibition.

4.9.2 In vivo evaluation of chemicals on Xanthomonas campestris pv. dieffenbachiae

The results presented in the Table 11 on the efficiency of various chemicals on percentage recovery of infected

Table 10. Effect of antibiotics and bactericides on the growth of *Xanthomonas campestris* pv. *dieffenbachiae* under *in vitro* conditions.

Name of chemical	Concentration (ppm)	Inhibition zone mean dia (mm)
Streptocycline	500	23.30
	400	19.80
	300	19.50
Streptomycin sulfate	500	19.50
	400	15.43
	300	11.86
Paushamycin	500	20.80
	400	16.15
	300	12.50
Bacterimycin	500	0.00
	400	0.00
	300	0.00
Bavistin	500	0.00
	400	0.00
	300	0.00
Copper oxychloride	3000	17.63
	2000	11.00
Emisan-6	2000	10.00
	1000	6.22
Control (without chemical)	-	0.00

S.Em± = 0.6049
CD at 1% = 2.3132

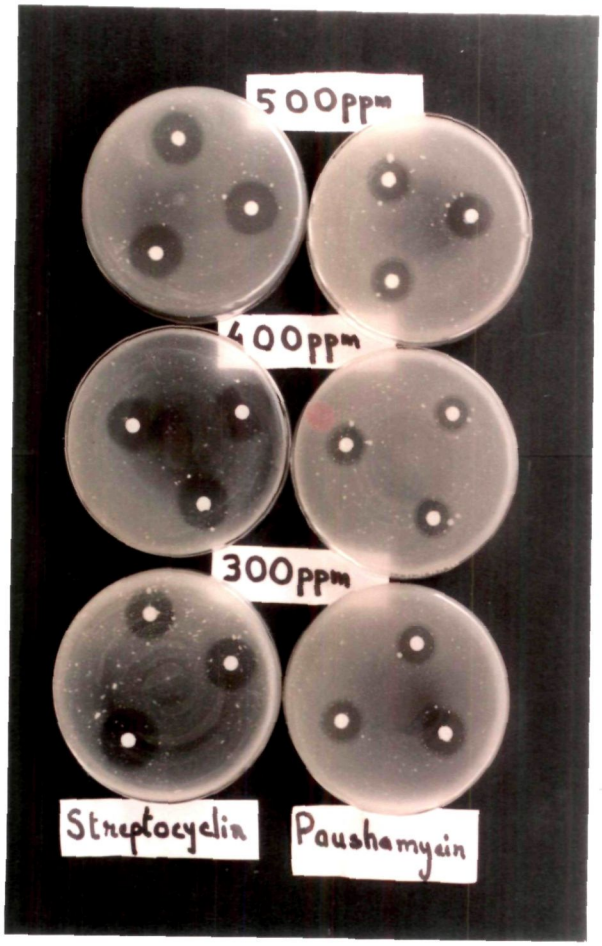

Plate 20. Effect of X.c. pv. dieffenbachiae by Streptocycline and paushamycin at 500 ppm, 400 ppm and 300 ppm. Note the inhibition zones around filtered paper disc dipped in antibiotic solution at different concentration as used.

Plate 21. In vitro effect of streptomycin sulphate (500 ppm), copperoxychloride (200 ppm) and emisan-6 (1000 ppm) on the growth of X.c. pv. dieffenbachiae.

Table 11. Effect of antibiotic and bactericides on the development of root-rot due to *Xanthomonas campestris* pv. *dieffenbachiae* in vivo.

Antibiotic/ Bactericides	Concentration applied (ppm)	No. of plants treated	No. of plants recovered after 30 days	Recovery (%)
Emisan-6	2000	20	0	0
Copper oxychloride	3000	20	8	40
Streptocycline	500	20	12	60
Control (water)	-	20	0	0

Anthurium suckers revealed that copper oxychloride and streptocycline were effective. Among these chemical copper oxy chloride showed the highest recovery of 60 per cent at 3000 ppm followed by streptocycline (40%) at 500 ppm and emisan-6 at 2000 ppm showed no recovery after 30 days of planting, when the antibiotic/bactericide were applied as root dip to plants showing root-rot due to bacterial infection.

4.9.3 Effect of antibiotics and copper oxychloride on the development of bacterial blight of Anthurium

The results presented in Table 12 shows the effect of antibiotics and copper oxychloride sprays on infected Anthurium plants under field condition.

Streptomycin sulphate (500 ppm), streptocycline (500 ppm) and paushamycin (500 ppm) showed infection on four to five plants out of ten plants and an average of two infected leaves in each plant with one lesion per leaf measuring 5.5 mm, 3.2 mm and 4.5 mm in size respectively, whereas copper oxychloride spray conceded infection on seven plants out of ten plants sprayed with two infected leaves and about two lesion per leaf of 20 mm in size. The control showed nineinfected plants from ten plants with an average of three infected leaves out of five and four lesions per leaf measuring 51 mm size, further the spathe was also found to be infected.

Table 12. Effect of antibiotics and copper oxychloride spray on the development of bacterial blight of anthurium.

Antibiotic/ Bactericide	Concentration (ppm)	No. of plants sprayed	No. of plants infected	No. of leaves/ plant	No. of leaves infected	No. of lesions/ leaf	Size of lesion (mm)	Spathe infection
Streptomycin sulphate	500	10	4	5	2	1	5.5	-
Streptocycline	500	10	5	5	2	1	3.2	-
Paushamycin	500	10	5	6	2	1	4.5	-
Copper oxychloride	3000	10	7	4	2	2	20.0	-
Control	-	10	9	5	3	4	51.0	+

4.10 EFFECT OF PLANT EXTRACT ON THE GROWTH OF *Xanthomonas campestris* pv. *dieffenbachiae*

The extract obtained from garlic, ocimum, citronella, adathoda and neem were investigated for their effect on the growth of X.c. pv. *dieffenbachiae* and the data is presented in the Table 13.

There was a significant difference among the treatments of the five plant extracts tested, garlic extract was found to be the most effective (28.00 mm) in inhibiting the growth of the pathogen (Plate 22) followed by ocimum (Plate 23) and citronella by producing an inhibition zone of 26.50 and 13.50, respectively. The extracts from adathoda and neem oil were not effective in inhibiting the pathogen.

Table 13. Effect of plant extract on the growth of *Xanthomonas campestris* pv. *dieffenbachiae* under *in vitro* conditions.

Plant extract	Inhibition zone (mm)
Adathoda zeylanica	0.00
Allium sativa	28.00
Azadirachta indica	0.00
Ocimum sanctum	26.50
Cymbopogan winterianus	13.50
Control	0.00

S.Em± = 0.5270
CD at 1% = 2.2771

Plate 22. Inhibiting effect of garlic extract on X. c. pv. dieffenbachiae under in vitro.

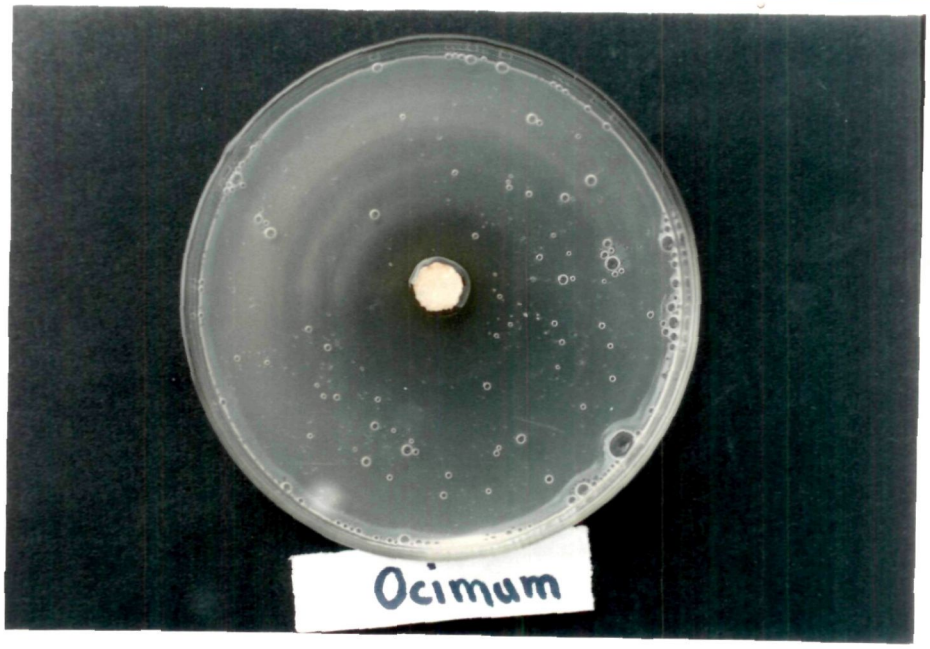

Plate 23. Inhibiting effect of Ocimum extract on X. c. pv. dieffenbachiae.

DISCUSSION

V. DISCUSSION

Anthurium is an important cutflower crop which has recently come into economic prominence in Karnataka. The plants are in great demand among home gardeners and their cut flowers have good market within the state and abroad. Among the large number of species belonging to genus Anthurium only some species are of economic importance and Anthurium andreanum Linden is the most important cutflower crop. This flowering plant suffer from a serious bacterial disease which has been found to be a major constraint in the successful cutlivation of this crop. In recent year consequent to the importing of exotic varieties of anthurium for commercial cultivation and export purpose, the disease has assumed a major proportion and is becoming a serious threat for production of anthurium plants in and around Bangalore. Hence, detailed studies regarding the identity of the causal organism, host range, survival and control measures were undertaken, results are discussed hereunder.

Symptomatology

The symptoms appeared in the form of minute water soaked lesion at the margin which later on become brown and necrotic surrounded by yellow chlorotic halo. These lesions increased in size and progressively moves towards the center of the lamina. The infection finally moves to the petiole which becomes brown, rot and easily breaks off from the stem.

The stem shows browning, later become black and rot. Sometimes, severe infection lead to rotting of roots and wilting of plant.

Hayward (1972) in the first report on the incidence of bacterial blight of Anthurium from Hawaii recorded similar symptoms. He reported that disease presents an angular pale brown necrotic spot, 1 to 3 mm in size surrounded by yellow chlorotic halo. Sometimes lesions were angular and vein limited or irregular extending along the midrib.

Necrotic spot with halo, mainly towards the margin of the leaves and spathe were commonly observed, infection of petiole reaching the stem and rhizome causing death of the plant were the other symptoms noticed (Guevara and Debrot, 1984; Cooksey, 1985; Pohronezny et al., 1985).

Identification of the bacteria

Both the isolates were found to be rod shaped Gram negative, monotrichous, noncapsulated and non-acid fast. Both the isolates hydrolysed gelatin, asculin, produced hydrogen sulphide, digested protein and were negative for nitrate, urease activity and indole production. Production of acid from sugars, glucose, fructose, arabinose, mannose, maltose, lactose, cellobiose, sucrose and trehalose was noticed but could not utilize manitol and glycerol. On nutrient agar and yeast extract dextrose calcium carbonate

agar the bacterial isolates produced deep yellow coloured colony, viscous, irregular to round and slimy. Both the isolates made good growth at 35°C. Thus on the basis of various physiological, morphological and cultural studies the two isolates were identified as Xanthomonas campestris as per Starr (1983) and Schaad and Stall (1988).

Pathogenicity studies

The two isolates produced typical hypersensitive reaction, in the form of desiccated light brown necrotic area on Nicotiana tabaci var. Samsun and Nicotiana glutinosa within 30 hours.

The two isolates induced water soaked lesion on the margin of the leaf in atificially inoculated anthurium plants after 14 days of inoculation and these lesions become necrotic and brown in about 20 days. Thus proving the two isolates were pathogenic to Anthurium.

Thus on the basis of the pathogenicity test the two bacterial isolates obtained from diseased anthurium plant, have been identified to be a pv. dieffenbachiae. On the basis of similar characteristics pertaining to morphological, physiological, biochemical and pathogenic studies the bacterium causing leaf spot/blight symptom were designated as X c pv. dieffenbachiae by various workers. Mc Culloch and Pirone (1939), Mc Fadden (1967), Hayward (1972), Guevara and

Debrot (1984), Cooksey (1985), Pohronezny et al. (1985), Bonner et al. (1987), Dickey and Zumoff (1987), Pohronezny et al. (1990), Chase et al. (1992), Lipp et al. (1992), Wells et al. (1993) designated the bacterium causing bacterial blight in anthuriums as Xanthomonas campestris pv dieffenbachiae.

Survey for the incidence of bacterial blight

Survey for the incidence of bacterial blight in various horticultural nurseries, in Karnataka revealed that irrespective of the source of material, disease was observed on plants imported from Sri Lanka, Holland and Mauritius. Among the various exotic varieties imported from Holland, highest incidence of bacterial blight was noticed on variety Monique (20%).

Host range

Host range studies conducted to find out the ability of Xanthomonas campestris pv. dieffenbachiae to cause disease in other plant belonging to family araceae, it was observed that out of ten plant species belonging to family araceae inoculated with X. c. pv dieffenbachiae under artificial condition two host plants Scindapsus aureus and Rhodospatha hastata did not take infection. Whereas Syngonium podophyllum, Syngonium auritium, Dieffenbachia picta, Alocasia indica, Aglaonema sp., Monstera deliciosa and

Philodendron sp. were infected by pathogen, indicating that it has a broad host range (Table 6). However the time taken for the bacteria to cause infection varied, Syngonium auritium and Dieffenbachia picta took 20 and 21 days respectively to express symptom. While Syngonium podophyllum, Monstera deliciosa and Philodendron sp., took only seven days. In all the cases, water soaked lesion and brown necrotic spot were the characteristic symptoms. However, McFadden (1962) observed that, of the various plant belonging to aroids inoculated in his studies only two plant Aglaonema and Dieffenbachiae was susceptible Wehlburg in 1969, succeeded in inoculating Syngonium sp. The results of the present investigation agree with reports of Hayward (1972) who succeeded in infecting Philodendron oxycardium and Dieffenbachia picta with X.c. pv. dieffenbachiae. Cooksey (1985), Dickey and Zumoff (1987), Graham et al. (1990) succeeded in obtaining Dieffenbachia maculata and two other species of Philodendron. Chase et al. (1992) reported Syngonium podophyllum and Aglaonema commullatum as host for X. c. pv. dieffenbachiae. Lipp et al. (1992) reported that anthurium strains were more virulent and have broad host range as compared to strain of X.c. pv. dieffenbachiae from other aroid namely Syngonium.

Selective/semi-selective media

Studies conducted on the growth of two isolates on semi-selective media revealed that both the isolates failed

to grow on SX and BSCAA medium. Whereas highest recovery of colonies were observed on Tween medium (267.3 x 10^5) as compared to nutrient agar (281.00 x 10^5). Though bacterial colonies were also recovered on Cellobiose starch (CS) medium but recovery of the colonies were less (27 x 10^5). However on CS medium bacteria produced bigger colonies 2.16 mm which were red and circular to irregular in shape. However, Chase et al. (1988 and 1992) reported that few strains of X c pv dieffenbachiae grew well on SX and nutrient agar medium. The results of the finding with regard to CS medium agree with the reports several earlier workers; Norman and Alvarez (1989), Chase et al. (1992) and Lipp et al. (1992) who obtained X c pv dieffenbachiae on CS medium and the colonies were large. As regarded the growth of bacteria on Tween medium, our findings concur with the reports of Schaad and Stall (1988).

Survival of Xanthomonas campestris pv. dieffenbachiae in soil

The bacteria failed to survive beyond seventh week in infested soil maintained at room temperature as revealed by recovery of colonies at different intervals of time (Table 9). Only 16 colonies were detected on 7th week and no bacteria colony was recovered on eighth week onwards. However, the bacteria survived in infested plant debris placed on surface of soil for 13 weeks and in infected plant debris burried in soil at 9 cm depth it survived for only ten

weeks (8.3 cfu/g). While it survived for only nine weeks in plant debris were uniformly mixed with soil and bacteria recovered were only 40 cfu/g. In all the treatment there was a gradual decline of bacterial colonies from first week onwards.

Mc Culloch and Pirone (1939) reported that the bacterial culture could remain for four months at room temperature while it remained viable for six month at 4°C. While Tanabe (1990) reported that X c pv. dieffenbachiae survived for several months culture on MS medium. Norman and Alvarez (1994b) observed that pathogen can remain in latent state for more than one year in infected shoots. Xanthomonas campestris pv. vignicola causal agent of bacterial blight of cowpea and Xanthomonas campestris pv. vesicatoria causal agent of bacterial spot of tomato survived for a very short period when mixed with soil and in plant debris burried in soil at various depths [Khan (1996) and Ravikumar and Khan (1996)]. Indicating that Xanthomonas cannot survive for long time in infested soil or plant debris mixed with soil. The reason that X c pv. dieffenbachiae could survive only for six weeks in infested soil and for 9 to 10 weeks in plant debris mixed with soil could be due to the competition with other soil microflora or due to antagonistic activity of other microorganism present in soil or due to decomposition of plant debris in soil. Buddenhagen (1965) and Jones et al.

(1986) also observed that Xanthomonas survived for a short period either in infested soil or on infected plant debris either mixed or burried in different depths and they opined it due to decomposition of organic matter in soil or due to the action of antagonistic microorganisms or due to the weathering action.

Hence the source of survival and spread of pathogen could be the propagative material in which pathogen survive in latent form. However, the infected leaf material which are torn and fall on ground under field condition could also serve as source of survival and infection to a limited extent.

Effect of antibiotics/bactericides

In vitro studies conducted to test the efficacy of various antibiotic and bactericides under in vitro condition indicated that Streptocycline (500 ppm) was very effective followed by Paushamycin at the same concentration producing inhibition zone of 23.3 mm and 20.8 mm respectively. However bacteremycin was not effective. Among the bactericide tested copper oxychloride at 3000 ppm was found to inhibit the growth and produced an inhibition zone of 17.63 mm and emisan-6 was less effective.

In vivo studies carried out to test the efficacy of antibiotic and bactericides applied as root dip to affected

plants with root-rot caused by Xanthomonas campestris pv. dieffenbachiae indicated that Streptocycline was very effective in controlling the disease. Out of 20 plants dipped in Streptocycline solution 12 plants recovered in 30 days thus 60 per cent of plants recovered in 30 days after dipping roots in antibiotic solution, while in copper oxychloride (3000 ppm) only 40 per cent plants recovered and Emisan-6 gave no control at all.

A trial conducted in the farm by spraying antibiotics namely streptomycin sulphate, streptocycline and paushamycin at 500 ppm and copper oxychloride at 3000 ppm at 15 days interval revealed that streptocycline, streptomycin and paushamycin were very effective as lesions were noticed in two leaves out of five. And also the number of lesions noticed were only one per leaf and the size of the lesion also was very small (about 3 to 5 mm). While 50 per cent of leaves were effected in copper oxychloride spray plants. The lesion size was big, measuring 20 mm in size. In control three out of five leaves were found to be infected and the size of the lessions were fairly big apart from the fact that spathe was infected, while no spathe infection was noticed in antibiotics or copper oxychloride sprayed plants. The results agree with the finding of previous workers namely Robbs (1960), Hayward (1972), Knauss (1972), Chase (1992) and Balakrishnan et al. (1996) who reported that Streptomycin

sulphate spray (200 ppm) or oxytetracyclin sprayed at same concentration was effective in suppressing the development of bacterial blight in the plants.

While Knauss et al. (1972) stated that Streptomycin sulphate at 200-400 ppm on Philodendron oxycardium failed to arrest the development of bacterial blight due to X c pv. dieffenbachiae. The reason attributed by him was the development of resistance by the bacteria to streptomycin sulphate.

Biological control

The garlic extract was found to be highly inhibitory to growth of pathogen as it produce maximum inhibitory zone of 28 mm followed by ocimum 26.5 mm and citronella. While root extract of adathoda and neem extract had no effect on the pathogen. Inhibitory effect of garlic extract against various phytopathogenic bacteria has been well established by various workers viz., on Pseudomonas solanacearum by Khan (1974), Hutagalung (1988), Hanudin and Djatnika (1989) and on Xanthomonas campestris pv. oryzae by Grainge et al. (1985).

Plant extract of medicinal value are known to have inhibitory effect on wide range of microorganisms (Shivashankara Rao and Nigam, 1978). Inhibitory activity against phytopathogenic bacteria by essential oils extracted

from Calendula officinalis and Thymus serphyllum was highest against Corynebacterium michiganensis pv. michiganensis and Xanthomonas campestris pv. phaseoli (MishenKova et al., 1983), Garg and Kasera (1984) also reported the antibacterial effect of essential oil extracted from Anacardium occidentale against four Gram positive and eighteen Gram negative bacteria including Pseudomonas mangiferae and Xanthomonas campestris.

SUMMARY

VI. SUMMARY

The bacterial blight of anthurium has become a major constraint in the successful commercial cultivation of anthurium in and around Bangalore. The symptom appeared on the leaf margins as water soaked lesions which later enlarged and became brown with a yellow halo. These lesions coalesced blighting the leaf lamina which led to torn and distorted appearance. The infection through the petiole spread to the stem and to the entire plant . The spathe and spadix also expressed necrotic spots. The stem of the infected plants showed browning, was also noticed with rotting and some times root-rot.

The isolations made from the infected anthurium plants yielded yellow, mucoid, shining, slimy convex and odourless colonies on nutrient agar and yeast extract dextrose calcium carbonate agar.

The bacteria was found to be rod shaped Gram negative, monotrichous, noncapsulated and non-acid fast. It also hydrolysed gelatin, asculin, produced hydrogen sulphide, digested protein and utilized various sugars. Based on these cultural, morphological and physiological characters the bacteria isolated from blighted anthurium plant was identified as Xanthomonas campestris.

Hypersensitive reaction was induced on Nicotiana tabaci var. samsun and N.glutinosa within 30 hr. Artificially inoculated anthurium with the bacterium, showed symptoms in 14 days. Thus the bacterium was identified to be Xanthomonas campestris pv. dieffenbachiae.

In the survey conducted in various commercial nurseries in Karnataka, all the nurseries recorded the incidence of bacterial blight in the range of 2 to 40 per cent.

The studies conducted on host range under artificial conditions revealed that the isolates from anthurium had a broad host range. Many aroids like Syngonium spp., Dieffenbachia picta, Alocasia sp., Aglaonema sp., Monstera deliciosa and Philodendron sp. were found to be infected and showed marginal necrosis of the leaf in 7 to 20 days.

The Tween medium was found to be the most efficient with a higher number of bacteria recovered (267.3×10^5 cfu/ml) followed by Cellobiose-starch medium (27×10^5 cfu/ml).

The studies conducted to invesigate the source of inoculum indicated that the soil played a limited role as the source of inoculum for causing the disease. The bacteria in the infested soil did not survive for more than six weeks, whereas in the infected leaves placed on the soil the bacterium survived upto 13 weeks. The bacterium failed to

survive beyond the 10 and 9 weeks when the infected leaves were burried at 9 cm depth and mixed with soil respectively.

In vitro conditions revealed that streptocycline at 500 ppm was most effective followed by paushamycin at the same concentration producing inhibitory zones of 23.3 mm and 20.80 mm respectively.

In vivo studies carried out to test efficacy of antibiotics and fungicides as root dip of X c pv. dieffenbachiae infected anthurium revealed that streptocycline (500 ppm) was most effective with 60 per cent recovery in 30 days followed by copper oxychloride (3000 ppm) with a recovery per cent of 40 per cent under greenhouse conditions.

In the field, trails conducted to record the efficiency of various antibiotics and bactericides to control anthurium blight revealed that streptomycin sulphate (500 ppm), streptocycline (500 ppm) and paushamycin (500 ppm) were very effective. Copper oxychloride at 3000 ppm also controlled the disease to a certain extent.

Laboratory assay on the effect of different plant extracts revealed that the extract of Allium sativum pearls was highly effective in inhibiting the pathogen, followed by Ocimum sanctum and Cymbopogan winterianus.

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