QUICK WILT DISEASE OF PEPPER *(Piper nigrum Linn)*–I
SYMPTOMATOLOGICAL STUDIES ON THE QUICK WILT DISEASE OF PEPPER

By

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THESIS

Submitted in partial fulfilment of the

requirement for the degree of

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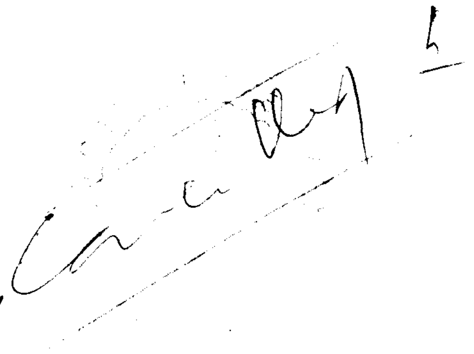
Kerala Agricultural University



Department of Plant Pathology

College of Horticulture

Vellanikkara, Trichur

1978

DECLARATION

I hereby declare that this thesis entitled "Quick wilt disease of pepper-1. Symptomatological studies on the Quick wilt disease of pepper" is a bonafide record of work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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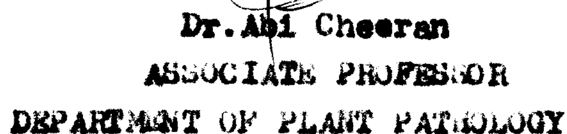

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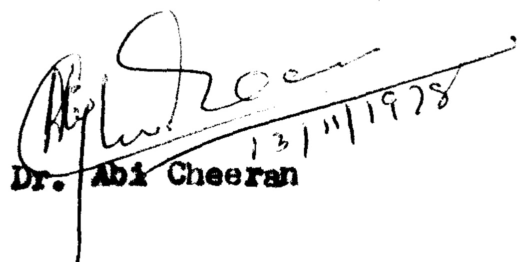

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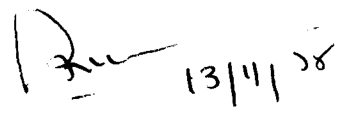

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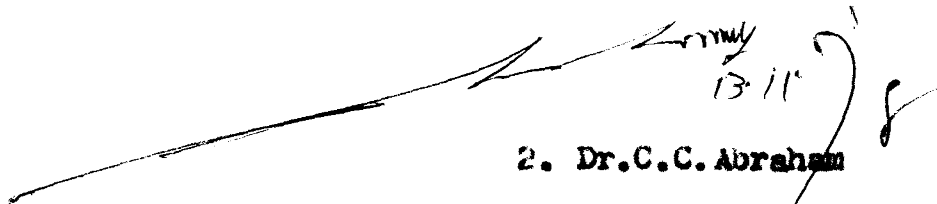

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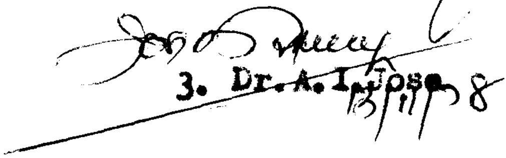

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INTRODUCTION

INTRODUCTION

Pepper (*Piper nigrum* Linn.) belonging to the family *Piperaceae*, is a scandent perennial climber and is a major cash crop in the humid parts of tropical regions. The plant is a native of India and all available evidences show that it has its origin in the moist ever green forests of the Western Ghats; from where it has spread to the other parts of the country.

In India, pepper is cultivated in an area of 113,900 hectares, accounting for an annual production of 31,830 tonnes of black pepper. In 1977-78, the country earned foreign exchange to the tune of 50.05 crores of rupees by the export of pepper. The State of Kerala accounts for 96 per cent of the country's production with 27,560 tonnes from 102,520 hectares.(Mathew, 1978).

The average yield of pepper in the State is only 0.227 kilogram per vine per year, whereas it is four kilogram in Malayasia and three kilogram in Brazil. (Swaminathan, 1978). The reasons for this wide gap between the potential yield and actual yield of the vine in the country has been identified to be the poor genetic stock, premitive management practices and devastating diseases and pests.

Among the diseases, the 'quick wilt' also termed as 'foot rot' caused by the fungus *Phytophthora palmivora* (Butler) Butler is identified as a serious threat to the pepper plantations in all pepper growing tracts of the world. Occurrence of the disease has been reported by Leefmans (1934) from West Borneo, WanderGoot (1934, 1935) from West Borneo, Java and Sumatra, Muller (1936) from Indonesia, Holliday and Mowat (1957, 1963) from Sarawak and Sam Raj and Jose(1966) from India. Sam Raj and Jose (1966) has estimated that 20 per cent of the vines were annually destroyed in Kerala, by this disease.

The disease symptoms as they appear in the field have been described by many workers and some prophylatic control measures have been suggested. But a systematic attempt has not been made so far to describe and define the symptomatology of the disease from its incidence to the culmination, through different stages of development. Again, the correct stage at which the disease can be effectively controlled by the application of fungicides, is yet to be ascertained. The work on these lines will be of immense practical utility since it will help in diagnosing the disease in the

initial stages itself and in ascertaining the stage of the disease at which, the prophylatic control measures will be most efficient and effective. This study was therefore undertaken with the following objectives in view.

(i) To study the symptomatology of the quick wilt disease of pepper right from the entry of the pathogen into the host tissue to the culmination of the host; and

(ii) To ascertain the stage of the disease at which the prophylatic control measures will be effective.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The most important disease of pepper (Piper nigrum Linn.) is the wilt. The same disease has been named differently by different workers. Butler (1906) coined the term wilt for the disease of pepper where there was a rapid death of the plant. Later, Muller (1936) reported a similar type of disease from Dutch East Indies caused by Phytophthora palmivora var. piperis and coined the term foot rot for it. In 1963, Holliday and Mowat also reported a similar disease from Saravak. In India, the disease is known as Quick wilt. This is to differentiate it from another wilt disease of pepper - Slow wilt (which is known outside India as yellowing) where the death of the plant takes place only after two to three years from the initial symptom while Phytophthora wilt, kills the plant within a period of two to three weeks.

The loss in yield due this disease ranged from 10 to 50 per cent as reported by various workers. The loss was estimated to be 10 per cent in West Borneo (Leefmans, 1934), 20 per cent in India (Sam Raj and Jose, 1966) and 50 per cent in Indonesia (Harper, 1974). Holliday and Mowat (1963) assessed a loss of 700 tonnes of black pepper

in Sarawak and Albuquerque (1966) estimated that more than 3000 tonnes of black pepper was destroyed in Amazon region due to this disease.

All parts of the plant at all stages of growth are susceptible to this disease. Three types of symptoms viz., leaf rot, collar rot and root rot are generally observed in a Quick wilt infected plant. Muller (1936) observed inconspicuous greyish brown lesions up to 5 cm in diameter near the tip and margin of the lower leaves during the active spread of the disease. He noticed a few drops of yellowish fluid from the under side of the lesions. Sam Raj and Jose (1966) found small irregular black patches on the diseased leaves. This later rapidly enlarged in size and covered the bulk of the leaf area. They also revealed that injury of host tissue was not a pre-requisite for successful infection.

Holliday and Mowat (1963) and Turner (1969a, 1969b) from Sarawak and Nambiar and Sharma (1976) from India observed zonate lesions on the infected leaves. Turner (1969a) noticed that the leaf lesions on *Piper betle* and pepper had a similar margin. However, zonations were more pronounced on betle vine leaves than on pepper.

Further he observed that on pepper leaves concentric rings were formed only under alternating dry and wet weather conditions.

Leaf surface and maturity affected the development of leaf lesions. Turner (1969b) found that on artificial inoculation more lesions were developed on the under surface of the leaves than on the upper surface. He also noticed that on immature leaves visible lesions, after artificial inoculation, were developed 24 to 36 hours after inoculation, while on mature leaves it took 36 to 48 hours. Exposure to high humidity for a long period of time increased the rate of growth and sporangial development on upper and lower surface of the leaves, being more abundant on the latter. He observed fimbriate lesions during continuously humid conditions and concentrically zoned lesions under alternating wet and dry conditions. He also noticed the shedding of leaves even before the entire lamina becoming necrotic.

Collar rot is the most fatal type of infection in pepper. Early infection of the collar region usually cannot be identified until foliar yellowing starts. A detailed symptomatological study of the collar rot type of infection was conducted by Muller (1936). He

reported that, diseased cortex rapidly turned from dark watery green to black. He also observed that the external symptoms were visible only after a complete decaying and disintegration of the internal tissues. The soft parenchymatous tissues of the cortex and medullary rays quickly decayed, while the xylem remained intact apart from the slight brownish discolouration. The bark often peeled off and the central cylinder split into bundle of loose xylem vessels due to the rotting of connecting tissues. In his observations the infection was usually noticed at a height of 30 cm from the base. Sam Raj and Jose (1966) observed that infection of vine was more common at a height of 25 cm above the ground level and it rarely occurred at any other region of the vine. They also found that as a result of the disease the affected tissues became soft and decayed. The diseased leaves turned pale, flaccid and fall off. Ultimately the plant died. Turner (1969a) observed that the main difference in the symptom of foot rot of betle vine and pepper was that in betle vine defoliation was slight, while it was high in pepper.

Lee (1973) reported about vascular browning at points beyond the site of infection and suggested a

possible involvement of toxin in the development of the disease. He correlated the virulence of the isolate to their toxin production. When pepper plant was immersed in the toxin solution of Phytophthora palmivora it became diseased while Piper colubrinum did not show any symptom. From this, Lee suggested that the toxin of Phytophthora could be used as a marker for testing resistance and susceptibility of pepper varieties against foot rot. Nambiar and Sharma (1976) reported that when the collar region of the plant was infected the necrosis progressed downwards to the underground stem and then to the root system rather than to the upward part of the stem. Sometimes partial death of the side branches alone was noticed when one vertical half of the vine was infected.

In the case of root rot, the degree of damage depends upon the number of roots infected and the extent of rotting. Holliday and Mowat (1957, 1963) reported that the infection started from fine roots of the plant. Once the cortex got infected, the disease spread to the main roots and then to the underground stem. When the stem became infected, visible symptoms appeared on the above ground parts of the plant, i.e., a halt in the growth

of the terminal shoots, wilting, rapid yellowing and shedding of the leaves and small shoots.

Turner (1969a) reported that symptom on the under-ground portion of pepper vine was the development of glistering black lesions, whereas in betle vine the lesions were brown and it penetrated into vascular tissues more deeply. Alconero et al. (1972) noticed infection of roots by zoospore 24 to 48 hours after inoculation. As a result of infection, the root tips darkened and the infection spread acropetally. Roots were completely decayed and shoots wilted within four days. In some pepper plants they observed typical black lesions on the roots without any foliar symptoms. Eventhough the infection was well developed in main root branches, the collar region at the soil line remained healthy.

Muller (1936) was the first to identify the pathogen of foot rot of pepper as *Phytophthora palmivora* var. *piperis*. Later, Vander Goot (1937), Holliday and Mowat (1963), Turner (1969b) and Alconero et al. (1972) also proved that foot rot was caused by *P. palmivora*. Many other workers also isolated *Phytophthora* from infected pepper vines - Venkata Rao, 1929, Leafmans, 1934 and Sam Raj and Jose, 1966.

Turner (1971) compared a large number of isolates from different geographic locations and hosts. From his studies, he concluded that all *Phytophthora* isolate from *Piper* in South East Asia belong to the same species and should be referred to as typical strain of *P. palmivora* (Butler) Butler. However, Tsao and Tumakate (1977) have reported different species of *Phytophthora* causing the same disease.

Turner (1969a) reported that the fungus grows rapidly on oat meal agar medium at 25 to 28°C. Holliday and Mowat (1963) stated that the fungus failed to grow beyond 35°C. Turner (1962) observed the formation of oospore from a single isolate of *Phytophthora* from diseased pepper. Brasier (1969) obtained oospore by artificial inoculation of pepper leaves by different isolates of *Phytophthora*. Oospores were not formed at 30°C and their production was favoured by darkness and low temperature (20°C) and their formation was inhibited by light.

Holliday and Mowat (1963) found that different isolates from pepper differed in their *in vitro* growth, sporangial production and pathogenicity. Turner (1971)

reported that *P. palmivora* from pepper was very specific in its host range. He further showed that *Piper* species tested from South-East Asia were highly susceptible while those from American tropics were resistant or slightly to moderately susceptible. Turner (1973) observed that the age of the isolate has a direct role in the pathogenicity. Most of the twenty-four isolates of the fungus studied by him were moderately to highly pathogenic to pepper in Sarawak.

Muller (1936) reported that the chief source of infection was contaminated soil and diseased plant refuse. Holliday and Mowat (1957, 1963) and Alconero *et al.* (1972) observed that infection started from the fine roots, supporting the fact that the disease was soil borne.

Muller (1936) reported that the symptoms of the disease were more pronounced under high relative humidity (91 to 99%) and low temperature (19 to 23°C). The pathogen remained inactive when the season was dry. Similar observations were reported by Holliday and Mowat (1963), Sam Raj and Jose (1966) and Nambiar and Sharma (1976). Holliday and Mowat (1963) showed that spread of the disease was rapid in Sarawak due to a

continuous wet season coupled with application of large amount of organic fertilizers.

Turner (1967, 1972) noted the pathogen of pepper foot rot in the faeces of giant African snail (*Achatina fulica*) and antrums. This type of spread was important during the dry weather when the normal rapid spread of the disease does not occur. Muller (1936), Holliday and Mowat (1963) and Anonymous (1965) suggested that the disease could be transmitted through rain and wind. Washing trials conducted in Sarawak on the root system of pepper plants from the infected pepper gardens showed that foot rot could be transmitted by root contact (Anonymous, 1965). Important reservoir of *Phytophthora* infection was the soil (Hickman, 1958). Holliday and Mowat (1963) observed that *P. palmivora* from pepper survived for about fifteen weeks in soil. When fresh vines were planted in the place of affected vines after six months it did not contract infection. This showed the low saprophytic ability of the pathogen.

As general control measure of the disease, Muller (1936), Holliday and Mowat (1963) and Anonymous (1976) have stressed the need for adopting phytosanitory measures under field conditions to reduce the inoculum.

These included isolation of the infected plants from the surrounding healthy vines, ensuring better drainage facilities, burning infected vines and good field sanitation.

Muller (1936) recommended the following control measures. (a) Fortnightly application of one per cent Bordeaux mixture (b) shallow drain trenches with catch pits and intervals to prevent the rain water from running off over the soil surface (c) watering with five to ten litres of one per cent copper sulphate solution per sq.m. It was found that 0.001 per cent copper sulphate in irrigation water was adequate to kill the pathogen under controlled conditions (Anonymous, 1965). Holliday and Mowat (1963) and Harper (1974) reported that wilt infection was reduced with heavy dose of copper oxide (perenox) and cuprous oxide (50%) respectively.

Drenching, pasting and spraying of Bordeaux mixture controlled or prevented the spread of the disease (Anonymous, 1976; Nambiar and Sharma 1976, 1977).

Turner (1969b) failed to eradicate the established infection by the fungicides like Bordeaux mixture -

one per cent, cuprous oxide - 0.2 per cent, copper oxychloride - 0.2 per cent, Zineb - 0.2 per cent, phenyl mercury acetate - 0.2 per cent, triphenyltin hydroxide - 0.2 per cent, Thiram - 0.2 per cent and Maneb + nickel sulphate hexahydrate. However, Thiram decreased the rate of spread of leaf lesion. In contrast, all the fungicides excepting Zineb, Thiram and Maneb + nickel sulphate, prevented lesion formation when leaves were treated before being inoculated. Turner (1970) observed good protection comparable to copper by using Ferbam and Antracol. Among the fungicides tested by him, Brunolex and Nectryl were the most effective soil fungicides against foot rot on pepper. Captafol was found to be useful as a soil drench against *P. palmivora* on pepper in Sarawak (Anonymous, 1972). However, it was not effective in India (Nambiar and Sharma, 1977). Belger (1977) reported that soil sterilization with Basamid-G prior to replanting was good to save the plant from infection.

MATERIALS AND METHODS

MATERIALS AND METHODS

1. Location of the experiments

All the experiments were conducted at the Pepper Research Station, Vellanikkara, Trichur attached to the Horticultural College.

2. Plants used

The entire work on symptomatology and control of Quick wilt of pepper was conducted on 1½ year old Panniyoor-1 variety of pepper (*Piper nigrum* Linn.). Panniyoor-1 is a hybrid from a cross between 'Uthiramkotta' (female parent) and 'Cheriyakaniyakadan' (male parent). The rooted cuttings of pepper used for this experiment were obtained from the Pepper Research Station, Panniyoor. All the seedlings were raised under uniform conditions of growth in pots.

3. Isolation and purification of the fungus

The fungus causing the disease was isolated from the infected leaves and vines of pepper by using standard isolation methods (Ricker and Ricker, 1936). The fungus was grown on oat meal agar (60 g oats, 20 g

agar-agar and 1000 ml distilled water) and potato dextrose agar (200 g of potato, 20 g dextrose, 20 g agar-agar and 1000 ml distilled water). Single zoospore isolations were done according to the method developed by Rawlins (1933).

4. Microscopic studies of the pathogen

Microscopic drawings of the pathogen were done using Olympus research microscope with maximum possible magnification.

5. Inoculation studies

5.1 Culture used

One week old culture of *Phytophthora palmivora* (Butl) Butl. isolated from the diseased pepper leaves and vines and maintained in oat meal agar was used for inoculation studies.

5.2 Inoculum

Zoospore suspensions were prepared by putting one week old culture in sterile water for three days. After three days fungal mycelia were separated by filtering through a fine muslin cloth. Zoospore suspension was obtained from the filtrate. The suspension containing five zoospores per low power (15x X 10)

microscopic field were used for inoculation studies. In control, instead of zoospore suspension the plants were sprayed with sterile water.

The inoculation experiments were conducted during June to August, 1978 when the atmospheric temperature and relative humidity ranged between 21 to 28°C and 90 to 98 per cent respectively.

5.3 Inoculation on leaves

For inoculating, the zoospore suspension was sprayed on upper and lower surfaces of the leaves of different age groups. The sprayed plants were kept under observation to study the symptom development. In another set of experiment, culture bits of 5 mm diameter containing mycelia and sporangia of the fungus were placed on the leaves and covered by moist cotton wool. In a third set of experiment, detached leaves were sprayed with zoospore suspension on upper or lower surfaces of the mature and immature leaves to study the pattern of disease development on leaves (Turner, 1969b). The sprayed leaves were placed in sterile petridishes for symptom development. The leaves sprayed with sterile water were kept as check.

5.4 Inoculation on stem and branches

Vines were inoculated at collar region and also at different parts of the vine. For inoculating, sterile cotton wool soaked in zoospore suspension was placed on the stem and branches. To prevent drying up of the cotton pads sterile water was sprayed on to it occasionally. Uninoculated vines served as the check. Wherever, there were more than one branches on a vine, one branch was kept as the check. Plants were observed for a period of twenty days. Symptoms were graded as follows.

0 - No symptoms
1 - Flaccidity of the younger leaves
2 - Yellowing and drooping of younger leaves and flaccidity of the matured leaves
3 - Drying of the leaves
4 - Defoliation
5 - Death of the vines

5.5 Root inoculation studies

Soil around the vines was removed till the root system was exposed. Fifty ml of the zoospore suspension was poured on the exposed roots and covered

with moist cotton wool. Plant roots drenched with sterile water was kept as check. Small bits of root sample were taken and symptoms were studied at a regular interval of 48 hours from the date of inoculation till the death of the plant. Symptoms were graded as described above.

6. Fungicidal treatments

The following fungicides were used for the study.

1. Agallol - 30 - (3% Mercury as Methoxy ethyl mercury chloride) - 0.2%
2. Bayer 5072 - 70 WP (p-dimethylamino-benzenediazo sodium sulfonate) - 0.2%
3. Thiride-75 WP (75% Thiram-tetra methyl thiuram disulphide) - 0.2%
4. Dithane Z-78 - 75 WP (75% Zinc ethylene bisdithio carbamate) - 0.2%
5. Dithane M-45 - (16% Manganese - 2% Zinc-Ethylene bis-dithio carbamate 62%) - 0.2%
6. Ziride - 80 WP (80% Zinc dimethyldithio carbamate) - 0.2%
7. Bordeaux mixture - 1%

The same fungicides at the same concentration were used for bio-assay studies, for detached leaf experiments and for pot culture studies.

6.1 Bio-assay of fungicides

The method perfected by Zentmayer (1955) was used. Radial growth and cultural characters of the fungus were observed for a period of one week.

6.2 Eradicant test on detached leaves

Fungicidal trials on detached pepper leaves against *P. palmivora* were done according to the method perfected by Turner (1969b).

6.3 Pot culture studies

Pot culture studies were carried out in plants grown in earthen pots of uniform size. In the first set of experiment the fungicides were applied before artificially inoculating the plant. In other set, the plants were first inoculated and then treated with fungicides at different intervals. The fungicides were applied in the following manner.

i) Fungicidal application two hours before inoculation with fungus.

ii) Fungicidal application three days before inoculation with fungus.

iii) Fungicidal application six days before inoculation with fungus.

iv) Fungicidal application nine days before inoculation with fungus.

v) Fungicidal application one day after inoculation with fungus.

vi) Fungicidal application two days after inoculation with fungus.

Irrespective of the type of inoculation all fungicides, except Agallol, were sprayed on the plant and drenched in soil. While Agallol was used only for drenching.

The intensity of root infection after application of fungicide was graded as follows.

0 - Not infected

1 - Fine roots infected

2 - Flaccidity of leaves

3 - Death of the vine

All the experiments were carried out with adequate number of replications.

RESULTS

RESULTS

1. Causal organism

Phytophthora palmivora (Butler) Butler, the pathogen causing Quick wilt of pepper was isolated and studied in culture and host tissues.

PHYTOPHTHORA PALMIVORA (Butler) Butler. 1919
Sci. Rep. Agric. Res. Inst. Pusa, 1918-1919; 82

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Meded. inst. Pl.Ziekt; Batavia, 88: 70; 1936.
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Mycelium hyaline, coenocytic, intercellular, sometimes intracellular. Usually haustoria passing to the host cells, hyphae large, profusely branched up to 6 to 10 μ

in diameter, often irregularly swollen, thick walled chlamydospores abundant in oat meal agar. Sporangiophore 3 to 6 µ in diameter, usually branched. The sporangia terminal, occasionally intercallery (Fig.1). Sporangium spherical to ovoid when young (Fig.2), lemonshaped, obpyriform, ovoid or ellipsoid when matured (Fig. 3), measuring 25 to 65 µ (average 50 µ) diameter. Apex broadly papillate with a shallow apical thickening up to 10 µ occluded by septal plug. They germinate readily in water. The zoospores first come out through the apical opening in mass (Fig.4), swim, come to rest and get encysted. The encysted zoospores measure 7 to 10 µ diameter. The sexual reproductive organs were not observed either in cultures or in the host tissues.

2. Symptomatology

2.1 On leaves

On artificial inoculation the first visible symptom noticed on the leaves was pale coloured water soaked regions in the infection court. This usually appeared within a period of 24 hours after inoculation. This water soaked area turned to light brown and then to dark brown within one to two days. Subsequently the infected region showed the signs of rotting. Once the

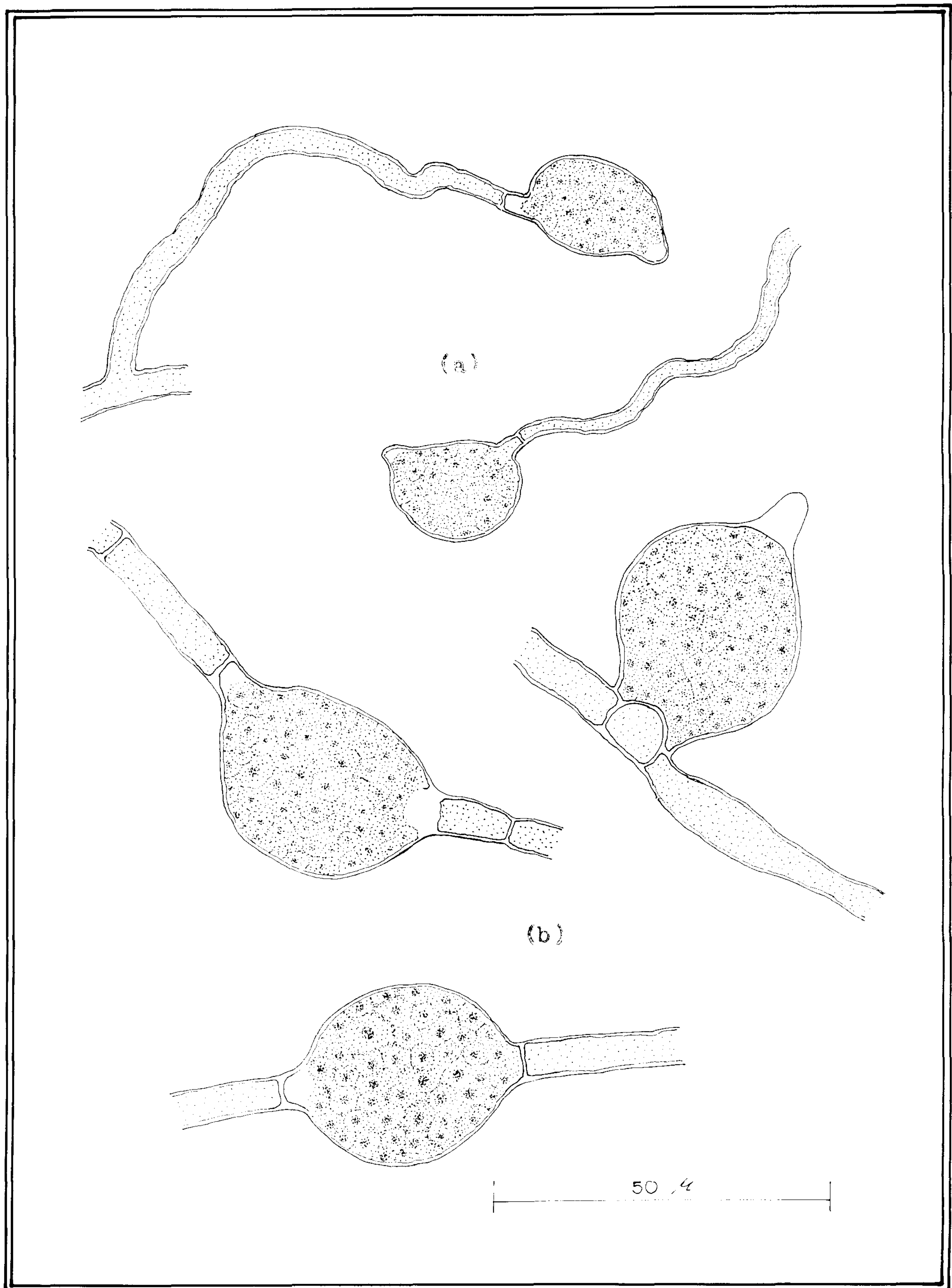

FIG 1
Phytophthora palmivora
(a) Terminal sporangia (b) Intercalary sporangia

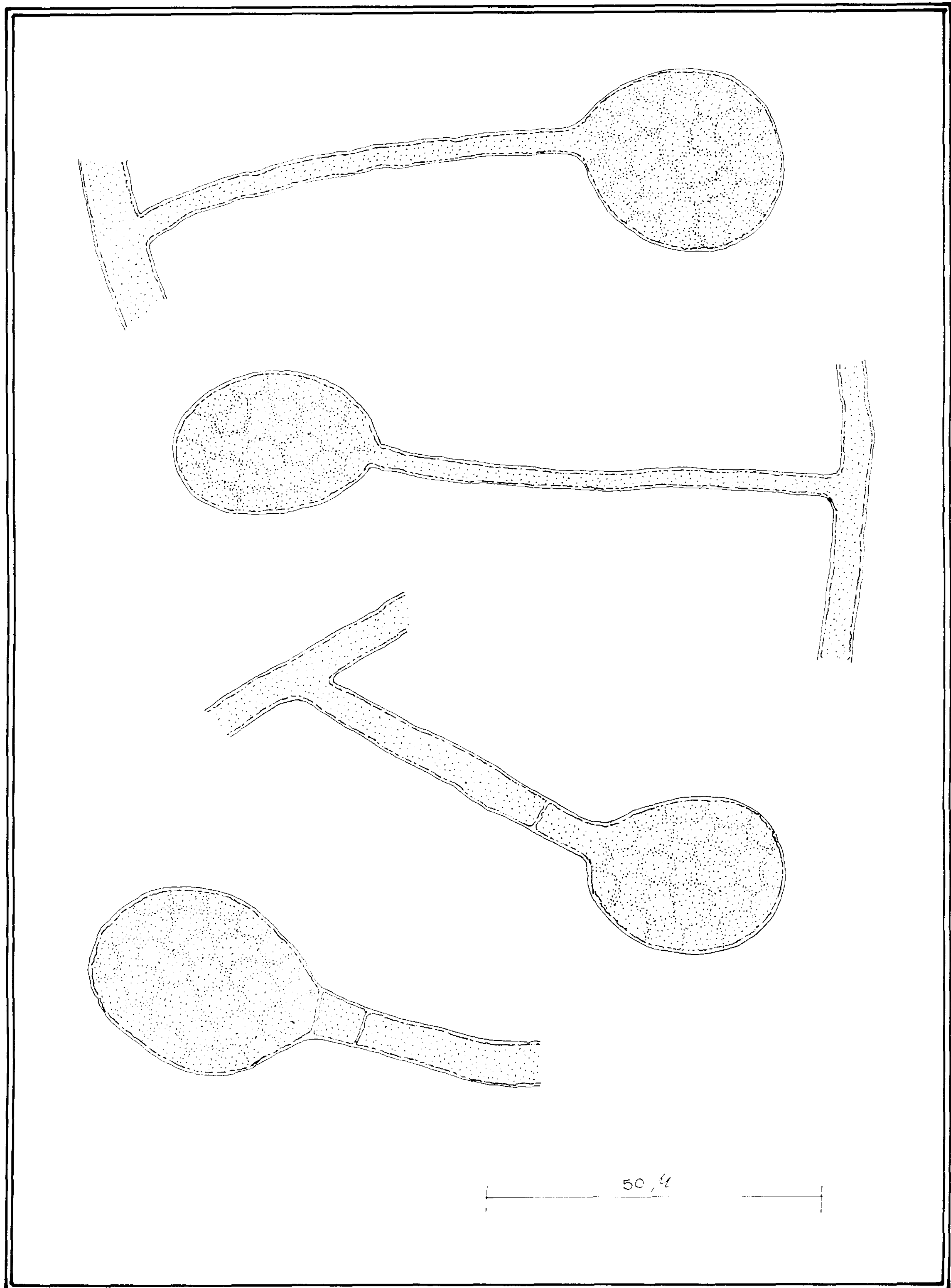

FIG 2
Phytophthora palmivora
Young developing terminal sporangia

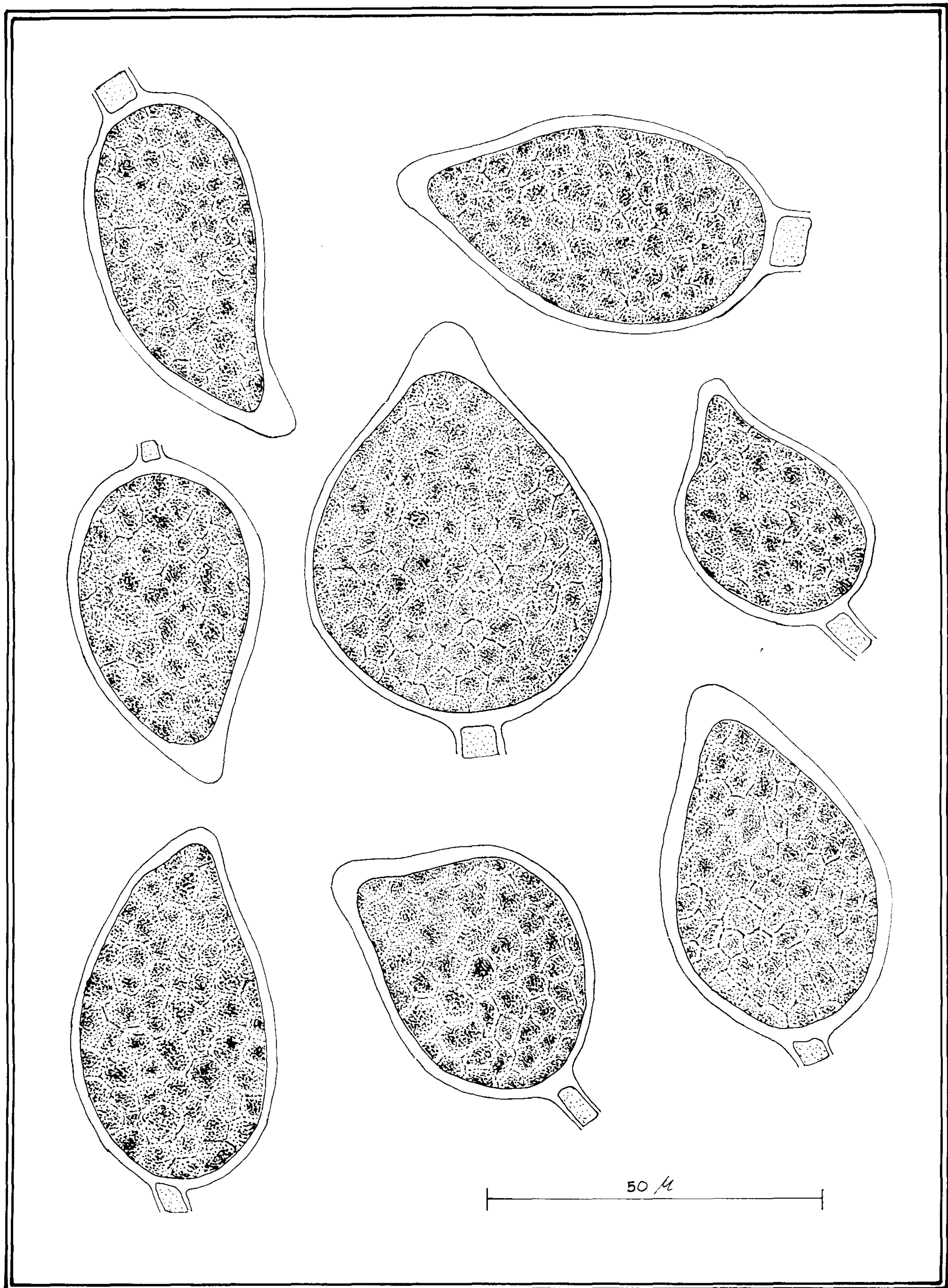

FIG 3

Phytophthora palmivora

Different shape of matured deciduous sporangia

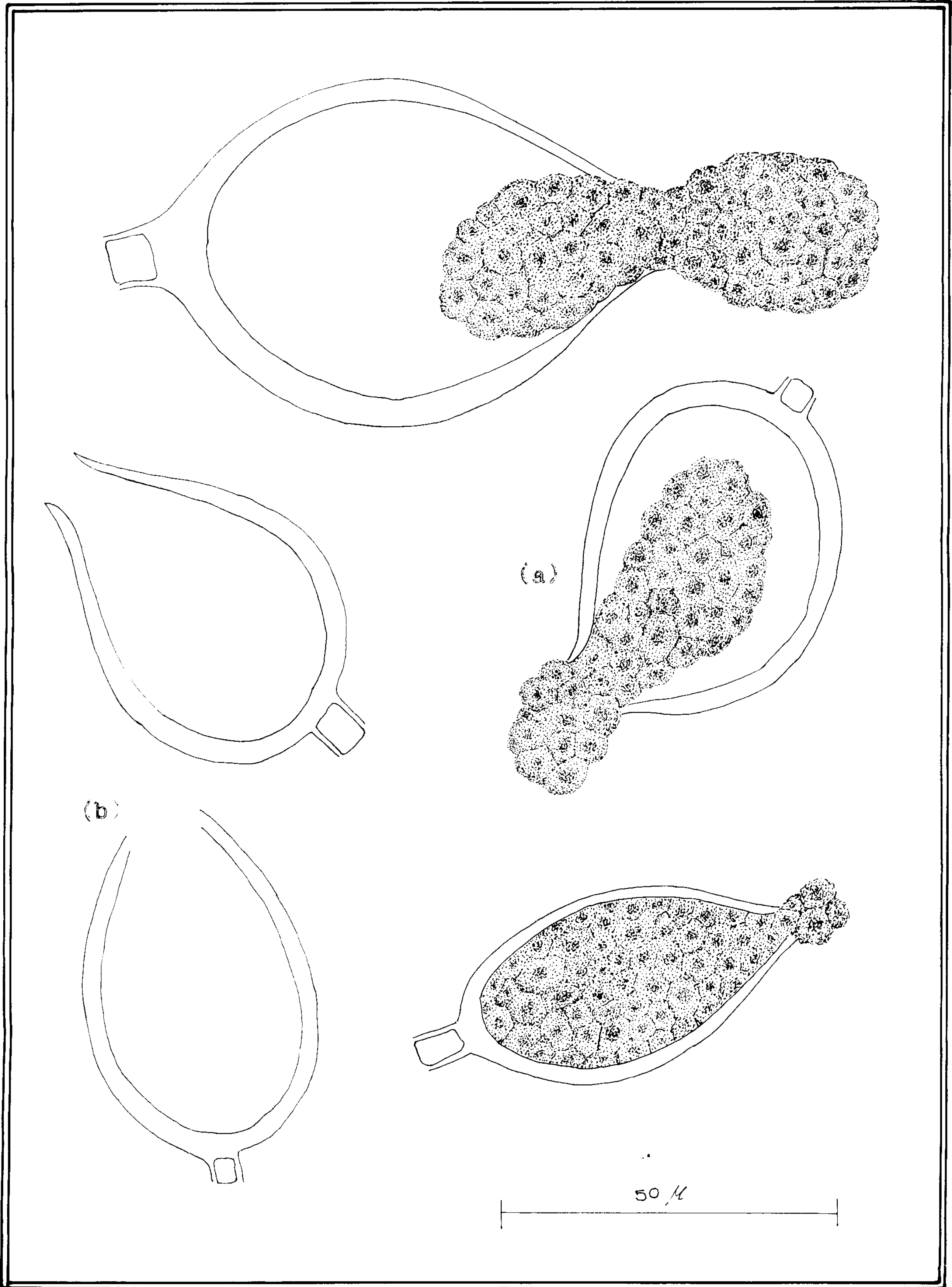

FIG 4

Phytophthora palmivora

(a) Germinating sporangia (b) Empty sporangia

rotting started, the spread of the disease was rapid and covered the entire leaf area within a short period. A fully developed lesion had a holo necrotic centre surrounded by a brown plesio necrotic zone which in turn was surrounded by yellow halo which slowly diffused to healthy tissues. The halo was well defined and clear when the development of the lesions was slow. Lesions coalesced or single lesion, rapidly expanded and covered the large area of the leaf (Table 1). The size of the lesions varied from 20 to 80 mm in diameter (Plate I to VII). The time taken for lesion development varied from 24 to 48 hours depending upon the maturity of the leaves (Table 2). Immature leaves took infection more easily than the matured ones. When the matured leaves were injured before inoculation, the time taken for the symptom development was almost same as that observed on uninjured immature leaves.

Generally the lesions spread in a circular fashion, but occasionally they spread longitudinally along the vein. When the lesions spread longitudinally along the mid-rib, the non-infected portion of the leaves get twisted markedly. Most of the lesions were circular with indefinite margins. Irregular lesions were also observed.

Table 1

Inoculation studies on leaves

Days after inoculation	Number of leaves/diameter in mm of leaf lesion size										Relative humidity %		Temperature °C		Rainfall
	I	II	III	IV	V	VI	VII	VIII	IX	X	Maximum	Minimum	Maximum	Minimum	mm
1	10.0	12.5	10.5	10.0	8.0	8.0	4.0	9.1	10.8	0	97	93	28.3	23.2	62.3
2	10.4	20.5	15.0	10.0	10.0	10.3	4.4	11.0	20.0	6.6	95	86	25.1	22.7	43.7
3	10.6	30.3	15.5	20.0	10.9	16.0	7.0	15.4	28.0	10.8	95	76	27.1	22.9	13.0
4	10.6	30.3	18.5	20.6	20.3	25.0	10.0	18.7	30.0	13.0	94	83	28.9	23.2	1.9
5	19.5	33.5	21.7	30.0	40.8	29.5	10.5	df	37.5	27.0	95	78	28.8	23.2	9.6
6	20.0	35.0	51.5	43.5	df	50.0	10.6	-	50.7	45.6	95	79	28.8	23.1	8.1
7	df	47.8	60.0	50.0	-	53.6	20.0	-	57.0	53.0	93	75	29.4	21.6	2.8
8	-	70.0	73.4	61.4	-	df	30.8	-	72.0	df	96	79	30.0	22.5	43.3
9	-	df	80.0	df	-	-	50.0	-	79.0	-	95	92	28.1	22.4	48.3
10	-	-	df	-	-	-	df	-	df	-	97	88	28.6	22.3	11.4

df - defoliated

Plate I

Stages in the development of leaf lesion - two days after inoculation.

PLATE :- I

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Plate II

Stages in the development of leaf lesion - three days after inoculation.

PLATE :- II

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Plate III

Stages in the development of leaf lesion - four days after inocculation.

PLATE :- III

Plate IV

Stages in the development of leaf lesion - five days after inoculation.

PLATE:- IV

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Plate V

Stages in the development of leaf lesion - six days after inoculation.

PLATE :- V

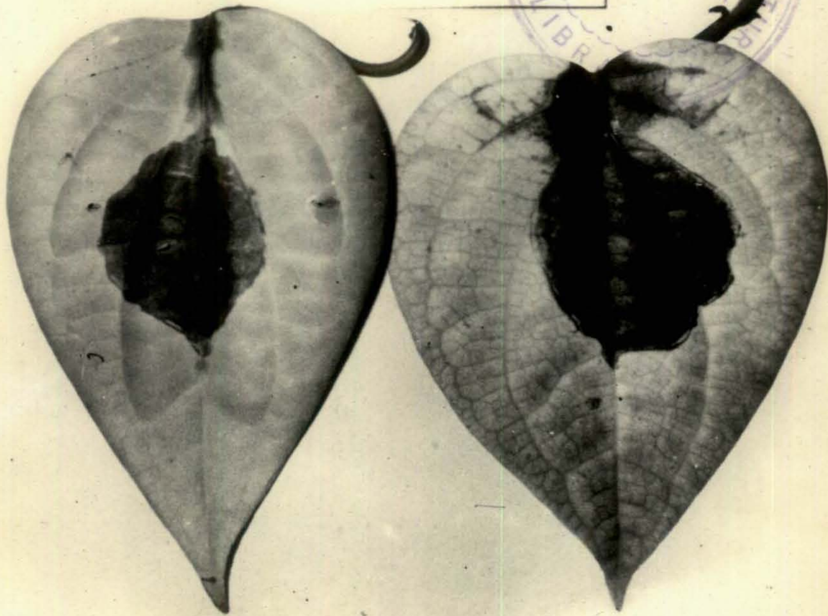

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Plate VI

Stages in the development of leaf lesion - seven days after inoculation.

PLATE :- VI

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Plate VII

Stages in the development of leaf lesion - eight days after inoculation.

PLATE :- VII

8^{15} day

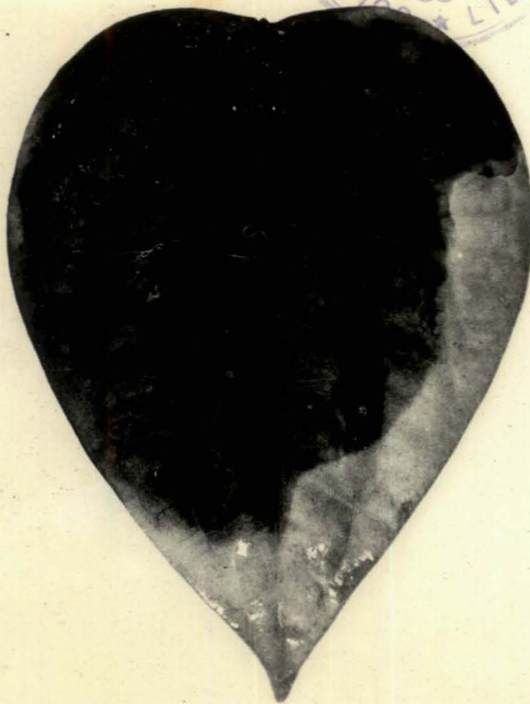

Table 2

Effect of maturity of pepper leaves on symptom development after inoculation with *P. palmivora*

Stages of leaf	Sl. No.	Number of leaves	Time of expression of first visible symptom after inoculation/number of leaves infected			
			12 hours	24 hours	36 hours	48 hours
Mature	1	10	0	3	3	4
	2	10	0	2	5	3
	3	10	0	1	6	3
	4	10	0	9	3	7
	5	10	0	1	9	0
	6	10	0	4	5	1
	7	10	0	0	4	6
	8	10	0	0	0	6
	9	10	0	3	6	1
	10	10	0	1	7	2
Immature	1	10	0	10	0	0
	2	10	0	7	3	0
	3	10	0	6	3	1
	4	10	0	10	0	0
	5	10	0	5	5	0
	6	10	0	9	1	0
	7	10	0	4	6	0
	8	10	0	8	2	0
	9	10	0	10	0	0
	10	10	0	7	3	0

Under continuous wet conditions the lesions were uniformly dark brown in colour and without zonations while with alternate dry and wet conditions zonations were noticed on the leaf lesions (Plate VIII).

Five to ten days after the appearance of first symptom defoliation usually took place (Table 1). Under low temperature and high humidity conditions the enlargement of lesions was faster and leaf shedding followed within four to seven days after the appearance of initial symptom. This quick expansion of lesions and defoliation took place when the relative humidity was high (90 to 97%) and temperature ranged between 24 to 26°C. The symptom expression was more pronounced on the upper surface than on the lower surface of the leaves.

Though the pathogen entered the leaf tissue both through the upper and lower surfaces, the entry was more marked through the lower surface. When the pathogen was inoculated separately on both the sides of mature and immature leaves, more number of lesions were observed on the leaves inoculated through lower surface (Table 3).

2.2 On stem and branches

When zoospore suspensions were sprayed on the stem and branches infections were observed very rarely.

Plate VIII

Zonations on the leaf lesion.

PLATE :- VIII

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Table 3

Effect of maturity and surfaces of leaves on symptom development

Stages of leaf	Surfaces of leaves inoculated	Number of leaves inoculated	*Number of lesions developed	Average number of lesions per leaf	Ratio of lesions on upper:lower surface	Ratio of lesions on mature:immature leaf surface	
						Upper	Lower
Mature	Upper	100	20	0.2	1:9.3	1:11.3	
	Lower	100	185	1.85			
Immature	Upper	100	225	2.25	1:3.7		1:4.5
	Lower	100	836	8.36			

* Number of lesions counted 48 hours after inoculation

But uniform infections were noticed when sterile cotton wool dipped in thick zoospore suspension was tied around the stem and branches.

The initial symptom on the stem was the appearance of a water soaked region similar to that observed on the leaf. This water soaked region turned dark brown within two to three days. The spread was more circular than longitudinal. The infected region appeared wet and slimy to touch. Three to six days after inoculation, flaccidity of younger leaves occurred which was followed by yellowing of younger leaves and flaccidity of matured leaves. Later all the leaves drooped (Table 4 and Plate IX). When the rotting of the internal tissues became severe, the leaves shed and twigs either got separated at nodes or dried above the infected region (Plate X). Occasionally the vines split at the infected area.

Transverse section of the freshly infected regions, showed vascular discolouration beyond the point of infection. Later, the soft parenchymatous tissues of the cortex and medullary rays decayed and the xylem vessels turned brown. Intensity of cortical

Table 4
Inoculation studies on stem

Days after inoculation	Number of stem/infection grades															Relative humidity%		Temperature °C		Rainfall
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	Maximum	Minimum	Maximum	Minimum	mm
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	94	84	28.8	23.8	0.5
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	93	75	29.8	23.2	0.9
3	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	96	77	28.4	23.0	18.1
4	1	1	1	0	1	0	1	0	1	1	1	1	0	0	0	96	93	28.5	22.2	82.3
5	1	1	2	1	1	1	2	0	2	1	1	1	1	0	1	97	79	25.5	22.2	23.9
6	2	1	2	2	1	1	2	0	2	1	1	1	1	1	1	96	92	28.6	27.7	39.3
7	2	1	2	2	1	1	3	1	2	2	1	2	2	1	2	98	83	28.9	22.5	129.6
8	3	2	2	2	1	1	3	1	2	2	1	2	2	1	2	98	83	26.0	22.2	55.0
9	3	2	3	3	2	1	4	2	3	2	2	2	3	1	3	95	94	26.7	23.2	20.6
10	4	2	3	3	2	2	4	2	3	3	3	2	3	2	3	97	71	29.9	28.4	25.4
11	4	3	4	3	3	2	4	2	4	3	3	3	3	2	4	96	75	30.0	23.0	Trace
12	4	3	5	3	3	3	5	3	5	3	3	4	4	3	4	94	74	29.6	23.4	2.1
13	5	3	-	3	3	3	-	3	-	3	4	5	4	4	5	93	70	29.6	21.6	18.2
14	-	3	-	3	3	3	-	3	-	4	4	-	4	5	-	92	74	29.3	22.9	0.4
15	-	4	-	3	3	3	-	3	-	4	4	-	5	-	-	93	74	29.1	22.6	12.7
16	-	4	-	3	4	4	-	4	-	4	4	-	-	-	-	94	76	29.6	23.4	1.8
17	-	4	-	3	4	4	-	4	-	4	5	-	-	-	-	92	77	25.7	23.3	10.3
18	-	5	-	4	4	4	-	5	-	4	-	-	-	-	-	96	79	28.9	23.6	70.3
19	-	-	-	4	5	4	-	-	-	5	-	-	-	-	-	91	85	28.7	23.8	6.8
20	-	-	-	5	-	5	-	-	-	-	-	-	-	-	-	96	90	28.2	23.0	41.7

Plate IX

Drooping of leaves due to stem infection.

D - Diseased vine

H - Healthy vine

PLATE :- IX

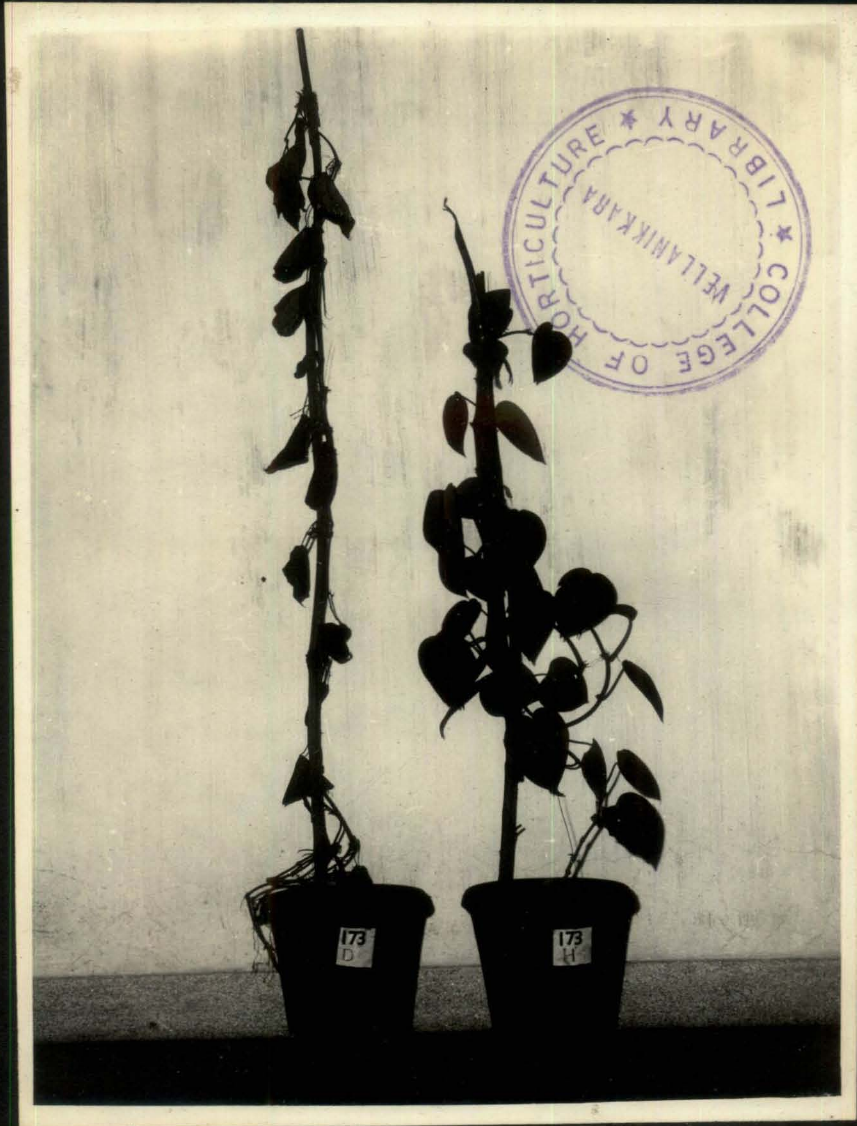

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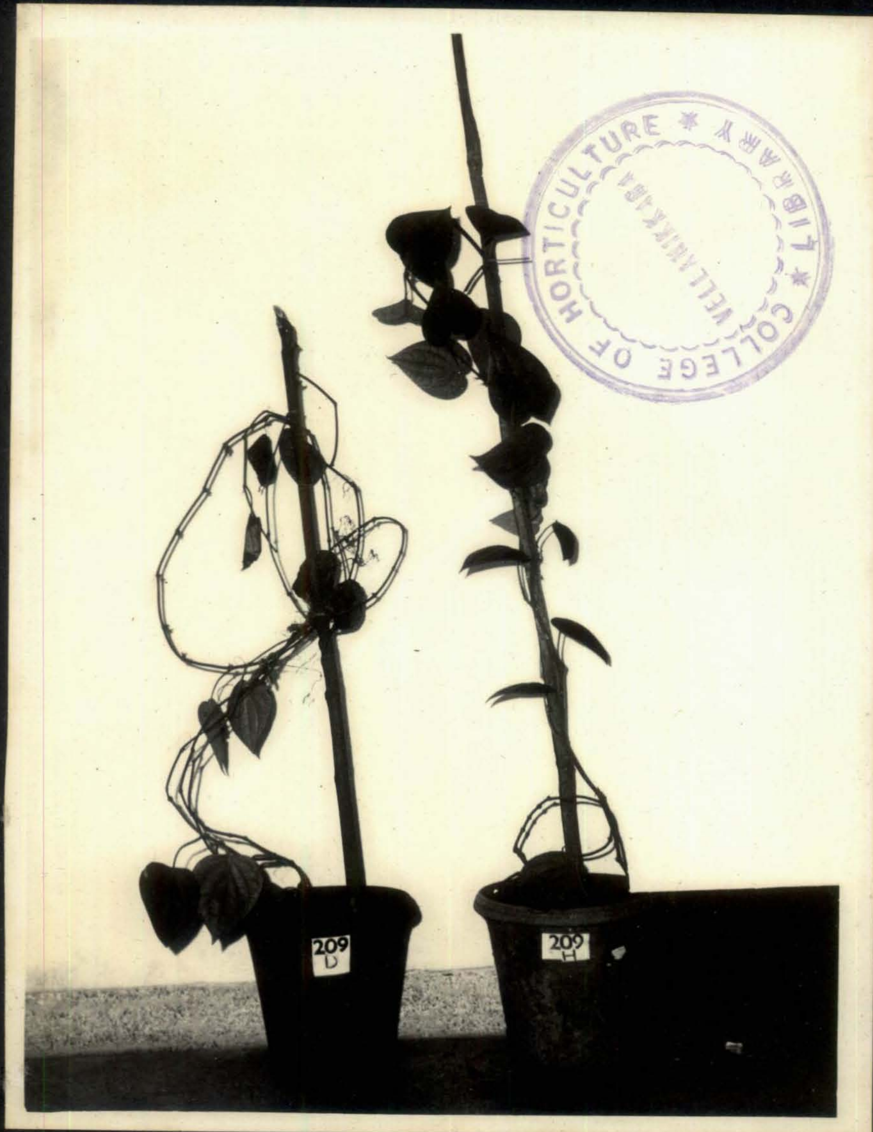
Plate X

Defoliation due to stem infection

D - Diseased vine

H - Healthy vine

PLATE:- X



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tissue disintegration increased as the disease progressed. Vascular disintegration up to a height of 100 cm beyond the point of infection was noticed. With a further spread of infection, the bark often peeled off and the central portion split into bundle of loose xylem vessels due to the rotting of conductive tissues. The rotting generally progressed upward.(Plate XI) The region below the infected portion remained healthy for a few days and then it slowly decayed. Death of the plant took place within 12 to 20 days after inoculation in the main stem. (Plate XII).

The symptoms on the branches were similar to that observed in the main stem. The collar region took infection more easily than any other part of the stem. When there were more than one branches, only the inoculated branches got infected and other branches of the vine remained healthy (Plate XIII).

2.3 On root s

Infection on the root system was noticed 24 to 48 hours after inoculation. Initial symptom was brownish discolouration of the tip of the fine roots. This discolouration gradually spread upwards and affected

Plate XI

Progress of rotting due to stem infection.

PLATE:- XI

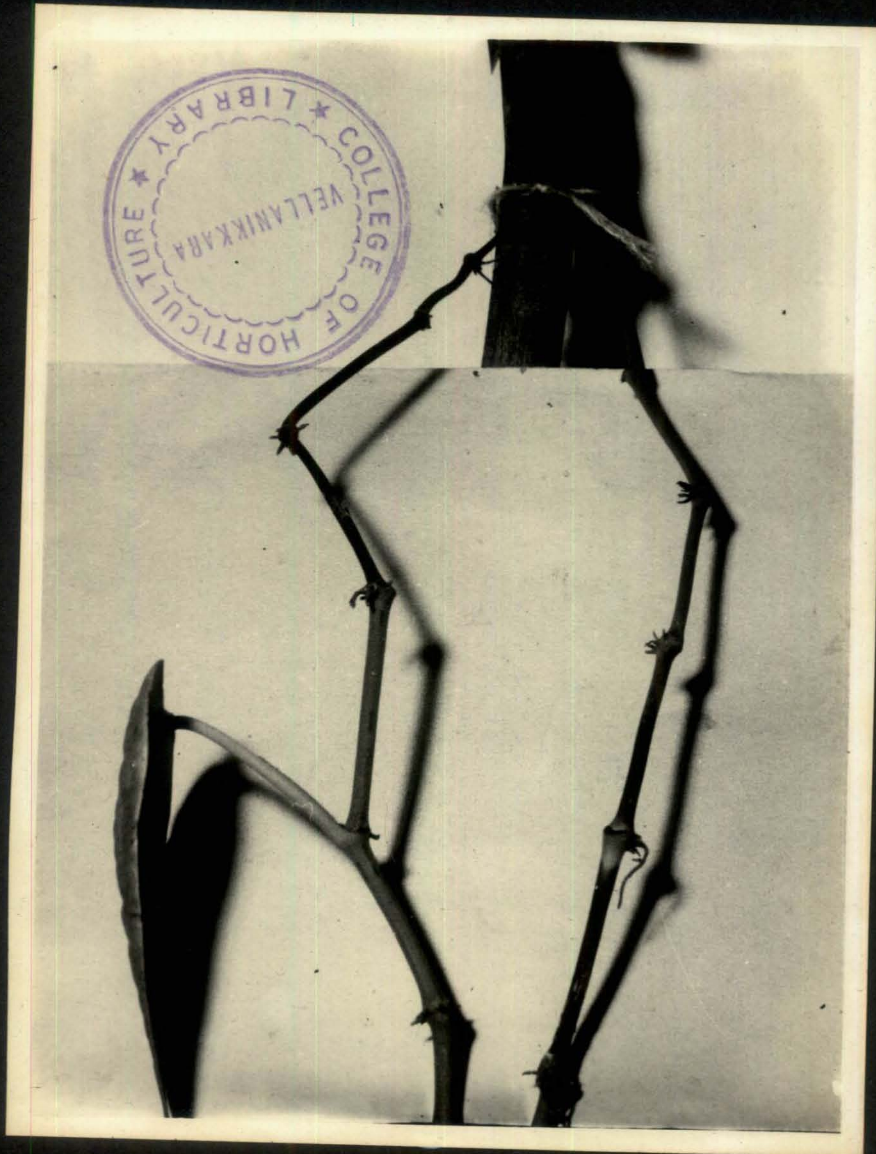

Plate XII

Death of vines due to stem infection

D - Diseased vine

H - Healthy vine

PLATE :- XII

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Plate XIII
Branch infection symptom

PLATE:- XIII

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the branches and the main roots within a few days. On the fine roots, discolouration was noticed as a black streak on the outside of the cortex. But in branches and main roots definite brown lesions were observed which spread both ways. From the main root the rotting spread to the underground stem. The entire root system of the infected vine decayed within 12 to 20 days of inoculation.

Transverse section of freshly infected root showed vascular discolouration. When the disease advanced, the cell wall of the conductive tissues collapsed, the tissues disintegrated and cortex started rotting. The discolouration of vascular tissue was observed up-to a distance of 25 cm away fram the point of infection.

The detectable symptoms on the stem and leaves as a result of root infection were noticed only when infection spread from the root-lets to the main branches of the roots and to the underground stem. The first visible symptom on the aerial part due to root infection was similar to that found with vine infection (Table 5 and Plate XIV). Later the leaves drooped and on the lower leaves, irregular blackish patch developed near

Table 5
Inoculation studies on roots

Days after inoculation	Number of plants/infection grades															Relative humidity%		Temperature °C		Rainfall
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	Maximum	Minimum	Maximum	Minimum	mm
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96	87	26.3	22.7	58.9
2	0	1	0	0	1	0	1	0	0	1	1	1	0	0	0	91	91	26.7	23.2	6.9
3	0	1	0	0	1	1	1	0	0	1	1	1	1	0	1	97	74	29.2	22.7	13.3
4	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	93	84	30.1	22.3	1.6
5	1	2	1	1	2	1	1	1	1	2	2	1	1	1	2	94	79	27.4	21.1	24.3
6	1	2	1	1	2	2	2	2	1	2	3	2	1	1	2	96	94	28.5	22.5	25.6
7.	1	2	1	2	2	2	2	3	1	2	3	2	2	1	2	91	73	28.1	22.8	5.9
8	1	2	2	3	2	2	2	3	2	3	3	2	2	1	3	96	70	29.8	22.7	8.8
9	1	3	2	4	2	3	2	3	2	3	3	3	3	2	3	94	84	29.8	23.8	0.5
10	2	3	2	4	2	3	3	4	3	3	3	3	4	2	4	93	75	29.8	23.2	0.9
11	2	3	3	4	3	3	3	4	3	4	4	3	4	3	4	96	77	28.4	23.0	18.1
12	2	3	3	5	3	4	3	5	3	5	4	3	5	3	4	96	93	28.5	22.2	82.3
13	3	4	3	-	4	4	3	-	3	-	4	3	-	3	4	97	79	25.5	22.2	23.9
14	3	4	3	-	4	5	3	-	4	-	4	3	-	3	4	96	92	28.6	21.7	39.3
15	3	5	4	-	4	-	4	-	4	-	5	3	-	3	5	98	83	28.9	22.5	129.6
16	4	-	4	-	5	-	4	-	4	-	-	4	-	4	-	98	83	26.0	22.2	55.0
17	4	-	5	-	-	-	5	-	5	-	-	4	-	4	-	95	94	26.7	23.2	20.6
18	4	-	-	-	-	-	-	-	-	-	-	4	-	4	-	97	71	29.9	28.4	25.4
19	4	-	-	-	-	-	-	-	-	-	-	4	-	5	-	96	75	30.0	23.7	Trace
20	5	-	-	-	-	-	-	-	-	-	-	5	-	-	-	94	74	29.6	23.4	2.1

Plate XIV

Drooping of leaves due to root infection

D - Diseased vine

H - Healthy vine

PLATE :- XIV

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the petiole region. This was followed by shedding of leaves and small branches at nodal region (Plate XV). Defoliation was not noticed under dry condition. Under this condition the drooped and dried up leaves remained on the vines without shedding(Plate XVI). All these symptoms appeared within 12 to 20 days after the entry of the pathogen to the root system of the plant.

3. Fungicidal treatments

3.1 Bio-assay

The results of the bio-assay studies indicate that among the seven fungicides tested, four fungicides viz., Bordeaux mixture, Agallol, Bayer 5072 and Thiride were effective in completely checking the growth of the fungus at the concentration tried. The other three fungicides were effective in checking the fungal growth during the first three days and the fungus grew after that and at the end of seven days the media incorporated with these fungicides supported a fungal growth of 34 to 48 mm in diameter (Table 6).

3.2 On leaves

3.2.1 Two hours before inoculation by P.palmivora

No symptom was developed on the leaves when

Plate XV

Shedding of leaves and small branches due to root infection

D - Diseased

H - Healthy

PLATE:- XV

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Plate XVI

Death of vine without defoliation due to
root infection

29 - Diseased vine

PLATE:- XVI

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Table 6

Effect of fungicides on the growth of *P. palmivora* in media

Fungicides	Development of the fungal growth (diameter in mm)							Nature of growth
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	
Bordeaux mixture	5*	5	5	5	5	5	5	No
Agallol - 30	5	5	5	5	5	5	5	No
Bayer 5072	5	5	5	5	5	5	5	No
Thiride	5	5	5	5	5	5	5	No
Ziride	5	5	5	36.0	42.0	46.0	48.0	Sparce
Dithane Z-78	5	5	5	5	27.2	32.0	34.0	Sparce
Dithane M-45	5	5	5	20.0	24.0	36.0	42.0	Sparce
Control	5	24.0	36.6	70.0	90.0	90.0	90.0	Profuse and Dense

* Diameter of the fungal disc used for inoculation.

the different fungicides were sprayed two hours before the inoculation of the leaves with fungal propagules (Table 7). No difference in the fungicidal treatment was noticed since all the fungicides were effective in completely killing the pathogen.

3.2.2 <u>Three days before inoculation by *P. palmivora*</u>

The efficacy of different fungicides when sprayed on leaves three days before inoculation are presented in Table 8 and 9. Bordeaux mixture was the only fungicide which restricted the fungus from causing the disease. All the other fungicides were better than the control and controlled the disease to varying degree. However, these fungicides were not significantly different from one another.

3.2.3 <u>Six days before inoculation by *P. palmivora*</u>

None of the fungicides was effective in completely checking the disease when the fungicides were sprayed six days before the inoculation of the pathogen (Table 10 and 11). But all fungicides were better than the control. Among the fungicides, Bordeaux mixture gave the best and Dithane M-45 and Dithane Z-78 the least control of the disease.

Table 7

Effect of fungicidal treatment on the control of *P. palmivora* on leaves; leaves treated two hours before inoculation

Fungicides	Treatment Nos.	*Number of plants	Number of leaves inoculated	Number of leaves infected
Bordeaux mixture	T1	30	300	0
Bayer 5072	T2	30	300	0
Ziride	T3	30	300	0
Dithane Z-78	T4	30	300	0
Thiride	T5	30	300	0
Dithane M-45	T6	30	300	0
Control	T7	30	300	300

* Total of three replications

Table 8

Effect of fungicidal treatment on the control of *P. palmivora* on leaves; leaves treated three days before inoculation

Fungicides	Treat-ment Numbers	*Number of plants	Number of leaves inoculated	Number of leaves infected	Mean of infection
Bordeaux mixture	T1	30	300	0	0
Bayer 5072	T2	30	300	69	23.00
Ziride	T3	30	300	82	27.33
Dithane Z-78	T4	30	300	60	20.00
Thiride	T5	30	300	50	16.77
Dithane M-45	T6	30	300	112	37.33
Control	T7	30	300	300	100.00
F. ratio					191.68**
C.D. (0.05)					8.02

* Total of three replications

** Significant at 5 per cent level

Table 9

Effect of fungicidal treatment on the control of *P. palmivora* on leaves; leaves treated three days before inoculation.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	18720.95	20		
Block	2.38	2	1.19	< 1
Treatments	18474.95	6	3079.16	191.68
Error	243.62	12	20.30	

Ranking T1 T5 T4 T2 T3 T6 T7

Table 10

Effect of fungicidal treatment on the control of *P. palmovora* on leaves; leaves treated six days before inoculation

Fungicides	Treat- ment Numbers	*Number of plants	Number of leaves inoculated	Number of leaves infected	Mean of infection
Bordeaux mixture	T1	30	300	35	11.67
Bayer 5072	T2	30	300	76	25.33
Ziride	T3	30	300	166	55.33
Dithane Z-78	T4	30	300	220	73.33
Thiride	T5	30	300	110	36.67
Dithane M-45	T6	30	300	239	79.67
Control	T7	30	300	300	100.00
F. ratio					163.41**
C.D. (0.05)					7.67

* Total of three replications

** Significant at 5 per cent level

Table 11

Effect of fungicidal treatment on the control of *P. palmivora* on leaves; leaves treated six days before inoculation

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	18415.14	20		
Block	5.43	2	2.72	<1
Treatments	18487.14	6	3031.19	163.41
Error	222.57	12	18.55	

Ranking T1 T2 T5 T3 $\overline{\text{T4 T6}}$ T7

3.2.4 Nine days before inoculation by *P.palmivora*

When the fungicides were sprayed nine days before inoculation, the disease control obtained was lesser than when the fungicides were sprayed three days before inoculation. However, the intensity of disease was lesser in fungicide treated plants than in control. On Bordeaux mixture applied plants, the infection mean was only 29.33 while with Dithane M-45 it was 95 (Table 12 and 13).

3.2.5 One day and two days after inoculation by *P.palmivora*

None of the fungicide proved effective in completely eradicating the pathogen. However, when the fungicides were applied one day after inoculation, they reduced the infection to some extent (Table 14 and 15). Among the fungicides, Bordeaux mixture, Bayer 5072 and Ziride were superior to other fungicides.

When the fungicides were applied two days after inoculation, the control observed was comparatively inferior to that observed when it was applied one day after inoculation (Table 14 and 15). Compared to a mean infection rate of 2.33, 3.33 and 5.33 on leaves applied with Bordeaux mixture, Bayer 5072 and Ziride

Table 12

Effect of fungicidal treatment on the control of *P. palmivora* on leaves; leaves treated nine days before inoculation

Fungicides	Treatment Numbers	*Number of plants	Number of leaves inoculated	Number of leaves infected	Mean of infection
Bordeaux mixture	T1	30	300	88	29.33
Bayer 5072	T2	30	300	179	59.67
Ziride	T3	30	300	232	77.33
Dithane Z-78	T4	30	300	279	93.00
Thiride	T5	30	300	242	80.67
Dithane M-45	T6	30	300	285	95.00
Control	T7	30	300	300	100.00
F. ratio					294.48**
C.D. (0.05)					4.46

* Total of three replication

** Significant at 5 per cent level

Table 13

Effect of fungicidal treatment on the control of *P. palmivora* on leaves; leaves treated nine days before inoculation.

Analysis of variance table

Source	S. S.	df.	Variance	F.
Total	11157.14	20		
Block	3.43	2	1.72	< 1
Treatments	11078.47	6	1846.41	294.48
Error	75.24	12		

Ranking T1 T2 T3 T5 T4 T6 T7

Table 14

Effect of fungicidal treatment on the control of *P. palmivora* on leaves; leaves treated one day and two days after inoculation

Fungicides	Treatment Nos.	One day after inoculation				Two days after inoculation			
		*Number of plants	Number of leaves inoculated	Number of leaves infected	Mean of infection	*Number of plants	Number of leaves inoculated	Number of leaves infected	Mean of infection
Bordeaux mixture	T1	30	300	7	2.33	30	300	62	20.67
Bayer 5072	T2	30	300	10	3.33	30	300	85	28.33
Ziride	T3	30	300	16	5.33	30	300	156	52.00
Dithane Z-78	T4	30	300	97	32.33	30	300	222	74.00
Thiride	T5	30	300	79	26.33	30	300	176	58.67
Dithane M-45	T6	30	300	110	36.67	30	300	260	86.67
Control	T7	30	300	300	100.00	30	300	300	100.00
F.ratio					136.15**				134.81**
C.D. (0.05)					9.05				7.66

* Total of three replications
** Significant at 5 per cent level

Table 15 (a)

Effect of fungicidal treatment on the control of *P. palmivora* on leaves; leaves treated one day after inoculation.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	21485.24	20		
Block	35.53	2	17.77	<1
Treatments	21139.24	6	3523.21	136.19
Error	310.47	12	25.87	

Ranking T1 T2 T3 T5 T4 T6 T7

Table 15 (b)

Effect of fungicidal treatment on the control of *P. palmivora* on leaves; leaves treated two days after inoculation.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	15604.95	20		
Block	8.66	2	4.33	<1
Treatments	15368.28	6	2561.38	134.81
Error	228.01	12	19.00	

Ranking T1 T2 T3 T5 T4 T6 T7

one day after inoculation, the corresponding value for the above fungicides when applied two days after inoculation were 20.67, 28.33 and 52.67 respectively. The mean infection rate observed in control was 100.

3.2.6 Eradicant test on detached leaves

The results of the study is given in Table 16. It is evident from the table that none of the fungicide eradicated the pathogen once it established in the host tissue. But all fungicides has checked the quick development of the lesion when compared to the untreated leaves. The average diameter of lesion on the first day after spraying with Bordeaux mixture, Bayer 5072 and Thiride were 8.5, 7 and 8 respectively. The corresponding figures of the above lesions on fifth day after treatments were 32.0, 13.5 and 28.0 respectively. The diameter of lesion on untreated control leaves on the first day and fifth day were 9.7 and 56.7. This shows that Bayer 5072 have better eradicant action than the other fungicides.

3.3 On vines

3.3.1 Two hours before inoculation by P. palmivora

As was observed with leaves, all the fungicides were uniformly effective in checking the disease development

Table 16

Eradicant tests on detached leaves;
effect of fungicides on lesion enlargement

Fungicides	* Average diameter of leaf lesion before spraying (in mm)	Average diameter of leaf lesion after fungicidal spraying (in mm)				
		1st day	2nd day	3rd day	4th day	5th day
Bordeaux mixture	7.5	8.5	12.0	19.0	25.0	32.0
Bayer 5072	7.0	7.0	7.6	8.9	11.7	13.5
Thiride	7.4	8.0	10.0	15.0	21.0	28.0
Ziride	6.9	7.6	9.0	15.0	21.0	31.0
Dithane Z-78	7.0	8.5	11.5	18.8	25.8	35.0
Dithane M-45	7.0	8.8	16.6	29.0	36.0	45.6
Control	7.4	9.7	17.0	30.5	41.0	56.7

* Average of 10 leaves

in vines when they were treated with fungicides two hours before inoculation (Table 17).

3.3.2 Three days before inoculation by *P. palmivora*

The protective effect of Bordeaux mixture and Bayer 5072 were pronounced when they were treated on the vines three days before inoculation. Both the fungicides completely inhibited symptom development. The protective ability of Dithane Z-78 was poor and the vines treated with this fungicide showed a mean infection rate of 5.67. However, Dithane Z-78 was better than the control. (Table 18 and 19).

3.3.3. Six days before inoculation by *P. palmivora*

Among the six fungicides tried on the vines only Bordeaux mixture was effective in completely preventing the infection, when the fungicides were treated six days before inoculation (Table 20 and 21). Compared to the check other fungicides were effective in varying order. Bayer 5072 with mean infection rate of 1.33 and Dithane M-45 with infection rate of 6.33 were the best and least effective fungicides respectively.

Table 17

Effect of fungicidal treatment on the control of *P. palmivora* on vines; vines treated two hours before inoculation

Fungicides	Treatment Nos.	*Number of plants	Number of plants inoculated	Number of plants infected
Bordeaux mixture	T1	30	30	0
Bayer 5072	T2	30	30	0
Ziride	T3	30	30	0
Dithane Z-78	T4	30	30	0
Thiride	T5	30	30	0
Dithane M-45	T6	30	30	0
Control	T7	30	30	22

* Average of three replications

Table 18

Effect of fungicidal treatment on the control of *P. palmivora* on vines; vines treated three days before inoculation

Fungicides	Treatment Nos.	*Number of plants	Number of plants inoculated	Number of plants infected	Means of infection
Bordeaux mixture	T1	30	30	0	0
Bayer 5072	T2	30	30	0	0
Ziride	T3	30	30	8	2.67
Dithane Z-78	T4	30	30	17	5.67
Thiride	T5	30	30	12	4.33
Dithane M-45	T6	30	30	13	4.33
Control	T7	30	30	23	7.67
F. ratio					19.15**
C.D. (0.05)					2.01

* Average of three replications
** Significant at 5 per cent level

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Table 19

Effect of fungicidal treatment on the control of *P.palmivora* on vines; vines treated three days before inoculation.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	181.24	20		
Block	20.10	6	10.05	7.91
Treatments	145.91	2	24.32	19.15
Error	15.23	12	1.27	

Ranking $\overline{T1 \quad T2}$ T3 $\overline{T5 \quad T6}$ T4 T7

Table 20

Effect of fungicidal treatment on the control of *P. palmivora* on vines; vines treated six days before inoculation.

Fungicides	Treat- ment Nos.	*Number of plants	Number of plants inoculated	Number of plants infected	Means of infection
Bordeaux mixture	T1	30	30	0	0
Bayer 5072	T2	30	30	4	1.33
Ziride	T3	30	30	15	5.00
Dithane Z-78	T4	30	30	18	6.00
Thiride	T5	30	30	12	4.00
Dithane M-45	T6	30	30	19	6.33
Control	T7	30	30	22	7.33
F.ratio					11.89**
C.D.(0.05)					1.88

* Average of three replications
** Significant at 5 per cent level

Table 21

Effect of fungicidal treatment on the control of *P. palmivora* on vines; vines treated six days before inoculation.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	162.29	20		
Block	122.29	6	20.38	18.20
Treatments	26.58	2	13.29	11.87
Error	13.42	12	1.12	

Ranking T1 T2 T5 T3 T4 T6 T7

3.3.4 Nine days before inoculation by P.palmivora

Bordeaux mixture and Bayer 5072 were the only fungicides found effective in checking the vine infection when they were applied nine days before inoculation (Table 22 and 23). All the other fungicides did not reduce disease infection appreciably compared to control.

3.3.5 One day and two days after inoculation by P.palmivora

The eradicant action of the different fungicides were complete when they were treated on the vines, one day after inoculation (Table 24).

The eradicant action of the fungicides when sprayed two days after inoculation was not as pronounced as that observed when the fungicides were sprayed one day after inoculation. The mean infection rate of Bordeaux mixture, Bayer 5072 and Thiride were 2.33, 4.00, 4.00 and these were significantly better than the other treatments. The fungicides Ziride, Dithane M-45, and Dithane Z-78 were not effective in checking the disease as they were on par with the control(Table 24 and 25).

3.4 On roots

3.4.1 Two hours before inoculation by P.palmivora

All the fungicides except Dithane M-45 completely

Table 22

Effect of fungicidal treatment on the control of P.palmivora on vines; vines treated nine days before inoculation.

Fungicides	Treat- ment Nos.	*Number of plants	Number of plants inoculated	Number of plants infected	Means of infection
Bordeaux mixture	T1	30	30	5	1.67
Bayer 5072	T2	30	30	6	2.00
Ziride	T3	30	30	18	6.00
Dithane Z-78	T4	30	30	21	7.00
Thiride	T5	30	30	17	5.67
Dithane M-45	T6	30	30	20	6.67
Control	T7	30	30	22	7.33
F.ratio					5.98**
C.D.(0.05)					2.98

* Average of three replications
** Significant at 1 per cent level

Table 23

Effect of fungicidal treatment on the control of *P. palmivora* on vines; vines treated nine days before inoculation.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	137.24	20		
Block	2.95	2	1.45	<1
Treatments	100.57	6	16.76	5.96
Error	33.72	12	2.81	

Ranking T1 T2 T5 T3 T6 T4 T7

Table 24

Effect of fungicidal treatment on the control of *P.palmivora* on vines; vines treated one day and two days after inoculation

Fungicides	Treatment Nos.	One day after inoculation				Two days after inoculation			
		*Number of plants	Number of plants inoculated	Number of plants infected	Means of infection	*Number of plants	Number of plants inoculated	Number of plants infected	Means of infection
Bordeaux mixture	T1	30	30	0	0	30	30	7	2.33
Bayer 5072	T2	30	30	0	0	30	30	12	4.00
Ziride	T3	30	30	0	0	30	30	16	5.33
Dithane Z-78	T4	30	30	0	0	30	30	20	6.67
Thiride	T5	30	30	0	0	30	30	12	4.00
Dithane M-45	T6	30	30	0	0	30	30	18	6.00
Control	T7	30	30	25	8.33	30	30	21	7.00
F. ratio									3.0**
C.D. (0.05)									2.99

* Total of three replications

** Significant at 1 per cent level

Table 25

Effect of fungicidal treatment on the control of *P. palmivora* on vines; vines treated two days after inoculation.

Analysis of variance table

Source	S. S.	df.	Variance	F.
Total	84.75	20		
Block	0.09	2	0.0045	<1
Treatments	50.95	6	8.49	3.0
Error	33.91	12	2.83	

Ranking T1 T2 T5 T3 T6 T4 T7

protected the roots from *Phytophthora* infection when the roots were treated with fungicides two hours before inoculation(Table 26). However, even Dithane M-45 with a mean infection rate of 0.23 was better than the control (mean infection rate 2.27).

3.4.2 Three days before inoculation by *P. palmivora*

The protective effect of different fungicides to root infection, when the roots were treated three days before inoculation is presented in the Table 27 and 28. The results show that Agallol, Bordeaux mixture and Bayer 5072 with 0.37, 0.40 and 0.63 mean infection rates were better than other treatments. Dithane M-45 was least effective in checking the infection.

3.4.3 Six days before inoculation by *P. palmivora*

The protectant property of Agallol was reduced when it was applied six days before inoculation compared to the protection it gave, when it was drenched three days before inoculation (Table 29 and 30).

3.4.4 Nine days before inoculation by *P. palmivora*

When the roots were exposed to the fungal propagules nine days after fungicidal treatments, the

Table 26

Effect of fungicidal treatment on the control of *P. palmivora* on roots; roots treated two hours before inoculation

Fungicides	Treat-ment Nos.	*Number of plants	Infection grading				Average infection index
			0	1	2	3	
Bordeaux mixture	T1	30	30	0	0	0	0
Agallol-3 G.	T2	30	30	0	0	0	0
Bayer 5072	T3	30	30	0	0	0	0
Ziride	T4	30	30	0	0	0	0
Dithane Z-78	T5	30	30	0	0	0	0
Thiride	T6	30	30	0	0	0	0
Dithane M-45	T7	30	24	5	1	0	0.23
Control	T8	30	3	2	9	16	2.27

* Total of three replications

Table 27

Effect of fungicidal treatment on the control of *P. palmivora* on roots; roots treated three days before inoculation

Fungicides	Treatment Nos.	*Number of plants	Infection grading				Average infection index
			0	1	2	3	
Bordeaux mixture	T1	30	20	8	2	0	0.40
Agallol-3 G	T2	30	20	9	1	0	0.37
Bayer 5072	T3	30	15	11	4	0	0.63
Ziride	T4	30	12	8	6	4	0.97
Dithane Z-78	T5	30	10	6	9	5	1.23
Thiride	T6	30	14	7	6	3	0.90
Dithane M-45	T7	30	5	6	8	11	1.80
Control	T8	30	2	2	4	22	2.53
F. ratio							34.58**
C.D. (0.05)							0.384

* Total of three replications
** Significant at 5 per cent level

Table 28

Effect of fungicidal treatment on the control of *P. palmivora* on roots; roots treated three days before inoculation.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	12.57	23		
Block	0.30	2	0.15	3.125
Treatments	11.60	7	1.66	34.580
Error	0.67	14	0.048	

Ranking T2 T1 T3 T6 T4 T5 T7 T8

Table 29

Effect of fungicidal treatment on the control of *P. palmivora* on roots; roots treated six days before inoculation

Fungicides	Treatment Nos.	*Number of plants	Infection grading				Average infection index
			0	1	2	3	
Bordeaux mixture	T1	30	13	7	7	3	1.00
Agallol-3 G	T2	30	8	7	8	7	1.47
Bayer 5072	T3	30	10	8	9	3	1.17
Ziride	T4	30	5	8	6	11	1.80
Dithane Z-78	T5	30	5	6	9	10	1.80
Thiride	T6	30	7	9	9	5	1.40
Dithane M-45	T7	30	3	6	10	11	1.97
Control	T8	30	3	2	6	19	2.37
F. ratio							23.12**
C.D. (0.05)							0.283

* Total of three replications
** Significant at 5 per cent level

Table 30

Effect of fungicidal treatment on the control of *P. palmivora* on roots; roots treated six days before inoculation.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	4.68	23		
Block	0.11	2	0.055	2.12
Treatments	4.21	7	0.601	23.12
Error	0.36	14	0.026	

Ranking (T1 T3) (T6 T2) (T4 T5 T7) T8

number of plants infected varied (Table 31 and 32) with the different fungicides. Bordeaux mixture, Thiride and Bayer 5072 with a mean infection rate of 1.27, 1.40 and 1.43 respectively were significantly better than the other treatments and control. All the fungicides though better than the control did not differ significantly one another.

3.4.5 One day and two days after inoculation by P.palmivora

There was no marked difference when the roots were treated with the fungicides one day and two days after inoculation. All fungicides except Dithane M-45 were effective in completely checking the disease. With Dithane M-45, the infection index of 0.73 and 1.10 for one day and two days of inoculation though poorer than other fungicides were better than the control (Table 33).

Table 31

Effect of fungicidal treatment on the control of *P. palmivora* on roots; roots treated nine days before inoculation

Fungicides	Treat-ment Nos.	*Number of plants	Infection grading				Average infection index
			0	1	2	3	
Bordeaux mixture	T1	30	7	12	7	4	1.27
Agallol-3 G	T2	30	6	9	10	5	1.47
Bayer 5072	T3	30	7	10	7	6	1.43
Ziride	T4	30	3	8	9	10	1.87
Dithane Z-78	T5	30	6	4	10	10	1.83
Thiride	T6	30	8	8	9	5	1.37
Dithane M-45	T7	30	4	3	11	12	2.10
Control	T8	30	0	4	10	16	2.40
F. ratio							19.66**
C.D. (0.05)							0.277

* Total of three replications

** Significant at 5 per cent level

Table 32

Effect of fungicidal treatment on the control of *P. palmivora* on roots; roots treated nine days before inoculation.

Analysis of variance table

Source	S.S.	df.	Variance	F.
Total	3.75	23		
Block	0.05	2	0.025	<1
Treatments	0.35	7	0.479	19.16
Error	0.35	14	0.025	

Ranking $\overline{T1 \quad T6 \quad T3}$ $\overline{T2 \quad T5 \quad T4 \quad T7}$ T8

Table 33

Effect of fungicidal treatment on the control of *P. palmivora* on roots; roots treated one and two days after inoculation.

Fungicides	Treatment Nos.	*Number of plants	One day after inoculation: Infection grading 0	1	2	3	Average disease index	Two days after inoculation: *Number of plants	Infection grading 0	1	2	3	Average infection index
Bordeaux mixture	T1	30	30	0	0	0	0	30	30	0	0	0	0
Agallol-3 G	T2	30	30	0	0	0	0	30	30	0	0	0	0
Bayer 5072	T3	30	30	0	0	0	0	30	30	0	0	0	0
Ziride	T4	30	30	0	0	0	0	30	30	0	0	0	0
Dithane Z-78	T5	30	30	0	0	0	0	30	30	0	0	0	0
Thiride	T6	30	30	0	0	0	0	30	30	0	0	0	0
Dithane M-45	T7	30	18	3	8	1	0.73	30	14	4	7	5	1.10
Control	T8	30	1	3	9	17	2.40	30	1	6	7	16	2.33

* Total of three replications

DISCUSSION

DISCUSSION

The symptomatology of the Quick wilt disease of pepper was described by many workers under field conditions. But even now the complete symptomatology of the disease has not been properly understood. In the present investigation an attempt was made to study the complete symptoms of the disease from the initial stages to the complete death of the plant.

The first visible symptom on leaves after the inoculation was noticed within a period of 24 to 36 hours on immature leaves and 24 to 48 hours on mature leaves. On the stem and branches the expression of initial symptom was delayed when compared to the leaves (two to five days). The initial symptom on fine roots was noticed within 24 to 48 hours of inoculation. Turner (1969b) observed the initial symptom on the detached immature and mature leaves within 24 to 36 and 36 to 48 hours respectively. This is almost in agreement with the present findings. The delay in the expression of initial symptom on the mature leaves may be due to thick and hard epidermal layers of upper surface of the leaves which may obstruct the easy penetration of the pathogen. This is supported by the observation that the time taken by injured mature leaves to take infection was the

same as that in immature leaves. Thick, hard cuticle and epidermal layers of the stem and branches also delayed the expression of initial symptom. Alconero *et al*. (1972) observed the first visible symptom within 12 to 14 hours on wounded stem. The difference in the time taken for the expression of initial symptoms in the present study and that observed by Alconero *et al*. (1972) may be attributed to the fact that the latter placed the pathogen on the wounded portion and it helped the pathogen in easy penetration to the hard host tissues. They also reported infection of fine roots within 24 to 48 hours. A similar finding was recorded in the present investigation also.

The initial visible symptom of the disease on the leaves was pale coloured water soaked regions. Similar observation was also recorded by Nambiar and Sharma (1976). However, Muller (1936) noticed dark green patches on leaves within 12 to 14 hours of inoculation with the zoospores. But in the present studies such symptoms were not noticed. Initial symptoms on stem and branch were same as that observed on leaves. The development of water soaked regions in the infection court may be due to the secretion of macerating enzymes

by the pathogen (Brown, 1965 and Wood, 1967). According to them several chemical substances can macerate epidermal tissues; these substances might have been secreted by the pathogen for softening the host tissues for easy penetration. Unlike in leaves and vines, the initial visible symptom on the root was a brownish discolouration. This may be due to the fact that, on the roots even if the water soaked regions were present it would not have been clear due to the soft and fleshy nature of fine roots.

On the leaves the lesion development was more on the lower surface, compared to the upper surface, when both surfaces were inoculated under uniform conditions (Table 3). Similar observations were made by Turner (1969b). The increased lesions on the lower surface may be due to the larger number of stomata, thin cuticle and more accumulation of moisture on the lower surface as it is not directly exposed to the sunlight. The possibility of washing off of the inoculum from the smooth and glossy upper surface of the leaves cannot also be ruled out.

The water soaked regions in the infection court of the leaf, stem and branches were converted from light green to light brown and finally to dark brown coloured necrotic area within one to two days, indicating colonisation of the pathogen in the host tissues. This necrotic areas on the leaves enlarged with signs of wet rotting. A fully developed lesion had a holonecrotic centre surrounded by brown plesionecrotic area which in turn surrounded by yellow halo which slowly diffused to the adjacent healthy tissues. Under high humidity condition the lesions developed quickly with a fringed margin. Turner (1969b) also observed similar type of leaf symptoms. The development of holo-necrotic area may be due to the collapse of cell walls by the action of pectic and cellulose decomposing enzyme or some other toxic principles which might have been secreted by the pathogen during its development in the host tissue. Brown (1965) and Wood (1967) also recorded similar findings working with P. infestans. Cunningham (1928) and Akai (1951) reported that the probable reason for browning of the tissues in plesionecrotic area may be a partial collapsing and disintegration of the tissues. Various follicolous pathogens have been reported to produce toxins in vitro

(Ludwig, 1960; Wheeler and Luke, 1963; Kalyanasundaram and Charudattan 1966; Wood, 1967; Owans, 1969). The yellow halo surrounding the lesion indicate a possible role of some toxic principles produced by the pathogen during their growth, diffusing to the healthy tissues far ahead the area of colonization.

Yellow halo surrounding the lesions was not noticed when the lesions developed and enlarged rapidly under saturated humid conditions. A probable reason for the absence of yellow halo under high humid condition may be that the growth rate of the pathogen under such a suitable condition may be at a faster rate - even faster than the diffusion rate of the toxin.

The circular development of the lesions was more common in the case of leaf infection. The circular development of the lesions may be due to the radial growth of the pathogen inside the host tissue from the infection court. Muller (1936), Holliday and Mowat (1963), Turner (1969a and 1969b) and Nambiar and Sharma (1976) also observed similar necrotic lesion development on pepper leaves. The expansion of lesions along the veins or in the tissues between the veins was also noticed very rarely. Such symptoms were not noticed by earlier workers.

Initial development of lesions on the branches, stem and roots was also circular in shape. On the stem the lesion spread and covered the entire circumference. The lesion development on branches and stem was both upward and downward. But the upward development of lesions was more rapid than the downward spread from the site of infection. On the roots only upward spread of the lesions was observed. The upward spread of lesions on stem and roots may be due to the upward pull of xylem vessels. Dastur (1935) on betle vine, Muller (1936); Holliday and Mowat (1963); Rupel et al. (1965) and Alconero et al. (1972) on pepper also observed similar type of spread of lesions. However, Nambiar and Sharma (1976) stated that the necrosis progressed downwards.

Vascular discolouration beyond the colonized region of host tissue was observed in branches, stem and roots. This phenomena indicates a possible involvement of some toxic metabolites during pathogenesis. Hussain and Kelman (1959) reported that the pathogen causing foot and root rot degrade both pectic and cellulose substances by enzymatic actions and very rarely by toxins. Lee (1973) also observed similar vascular necrosis and detected some toxic metabolites of the pathogen in liquid

culture. This culture filtrate was used by him to screen pepper varieties against the foot rot disease. Mycolaminarans, B-1-3 glucans from the culture filtrates of *Phytophthora cinnamomi*, *P. palmivora* and *P. megasperma* var. *sojae* were separated by Keen *et al.* (1975). Phytotoxic nature of the toxin on soyabean, cocao and tomato was also established by them. In the light of the above findings it is reasonable to assume that *P. palmivora* which infects the pepper plant can also produce some toxins. Further studies on this respect is needed to correlate the toxin production and the disease incidence.

Zonations on the leaf lesions were noticed when alternate wet and dry conditions prevailed during the spread of the lesions. Dry and hot hours of the day reduced the growth of the pathogen in the leaf tissues while the growth was faster when the atmosphere became cool and wet. This type of zonation was also observed by Dastur (1935) in *Piper betle* leaf infected by *Phytophthora*. Holliday and Mowat (1963); Turner (1969a and 1969b) and Nambiar and Sharma (1976) also observed similar zonations on the leaf lesions of *Phytophthora* attacked pepper leaves.

Defoliation of leaves was an important symptom of Quick wilt. This occurred during the pathogenesis irrespective of the point of infection. But the process of defoliation was different with leaf infection and with infection on other parts of the vines.

When the pathogen infected the leaves defoliation took place within five to ten days of infection depending upon the climatic conditions and maturity of leaves. The size of the lesions had no influence on defoliation. Under, wet humid condition, even a spot of size 20 mm in diameter on leaf resulted callus formation on the petiole and subsequent defoliation.

Development of flaccidity, drooping and defoliation of leaves were the marked symptoms during the progress of the disease when the infection was on stem, branches, or roots. The flaccidity symptoms on the leaves may be due to the damage occurred to the conductive tissues, resulting in the obstruction of upward movement of water. The time taken for the development of flaccidity symptoms varied according to the nature of infection. The development of flaccidity symptoms on

pepper vines were also noticed when the pathogen attacked roots or collar regions(Muller 1936; Holliday and Mowat 1963; Turner 1969a and Nambiar and Sharma 1976). Followed by the flaccidity symptoms, all the leaves above the infected region became pale. Under wet humid condition the leaves fall off. Defoliation was not noticed under dry condition. Under this condition the drooped and dried up leaves remained on the vines without shedding. The reason for defoliation under wet humid condition and drying under warm period is not clearly known.

Several workers attempted to control the Quick wilt disease of pepper by using fungicides (Muller, 1936; Holliday and Mowat, 1963; Anonymous, 1965 and 1976; Turner 1969b and 1971; Harper, 1974; Nambiar and Sharma 1976 and Belger, 1977). But the results obtained by them were not consistent. Muller (1936), Turner (1969b), Anonymous (1976) and Nambiar and Sharma (1976) stressed the necessity of prophylatic spraying of fungicides against the disease. However, they did not study the effect of fungicidal treatment before and after artificial inoculation with the pathogen.

The bio-assay studies using *P. palmivora* as the test organism showed that all the fungicides used completely checked the fungal growth for the first three days. However, fungal growth was noticed in media incorporated with Dithane M-45, Dithane Z-78 and Ziride, after three days. Probably the fungus might have degraded the fungicide into non-toxic compounds or the degraded fungicide might have been less toxic to the fungus. The check in fungal growth by the other fungicides used was complete throughout the period under observation. A similar study conducted by Wilson *et al.* (1974) with *Phytophthora* species isolated from cardamom showed the effectiveness of several fungicides in checking the growth of the fungus *in vitro*.

All the fungicides when sprayed or drenched two hours before inoculation completely checked the development of the disease. However, Dithane M-45 treatment of roots failed to check the disease completely. When the fungus was inoculated on the surface where the fungicide was sprayed two hours before the inoculation, the propogules were actually placed on the undegraded fungicide and this killed or inhibited the propagules effectively.

A probable reason for not getting complete control with Dithane M-45 can be attributed to the improper coverage of the fungicide on the root surface.

In general, on aerial parts, the disease control obtained was better when the fungicides were applied just before inoculation. As the time gap between fungicidal spray and inoculation time increased, there was a progressive reduction in the control of the disease obtained. The control obtained was maximum when the fungicides were applied two hours before inoculation. The fungicidal property slowly eroded with time and when the inoculation was done nine days after fungicidal application the control obtained was comparatively poor. Even Bordeaux mixture which gave complete control of the disease when applied three days before inoculation gave only 88 and 70 per cent control when the leaves were inoculated six and nine days respectively after the treatment. Almost a similar trend was noticed with other fungicides also. These observations show that the fungicides might have been washed off during the heavy rains which were frequent during the experiment. Even fungicides with good sticking property got washed off during heavy rain. Burchfield and Goenega (1957)

found that first 0.5 inches of rain removed 10 per cent of Bordeaux mixture deposits from the leaves and only 70 per cent of initial residue remained after eight inches of rain. During the period of experiment the total rainfall received was 34 inches. This explains the poor fungicidal property of most of the fungicide. One interesting observation noticed during the course of the study was with Bayer 5072 fungicide. This fungicide was inferior to Thiride and Dithane Z-78 when they were sprayed on the 3rd day. While when they were compared on 6th day and on 9th day Bayer 5072 proved much better than all other fungicides except Bordeaux mixture. Bayer 5072 is a systemic xylem transportable fungicide (Hills, 1962) and so, once the fungicide has gained entry into the plants it controls the disease for a longer period of time. The systemic action of Bayer 5072 is further proved in the eradicant tests conducted with the detached leaves (Table 16). The lesion size of Bayer 5072 treated leaf was 7 mm one day after the fungicidal treatment. This increased slowly and on the 5th day after fungicidal treatment it was only 13.5 mm. The corresponding figures for Bordeaux mixture treated leaves were 8.5 and 32.0 mm respectively. This shows

that the eradicant property of Bayer 5072 is effective under laboratory conditions while it is not so effective under field conditions. Probable reasons for this are its deterioration and inactivation by illumination (Hills and Leach, 1962) and its poor sticking property on the plant surface.

The detached leaf experiment also showed that other fungicides except Dithane M-45 are as effective as Bordeaux mixture in checking the established infection. The poor performance of these fungicides, which have faired better under laboratory conditions shows that these fungicides are either deteriorated or they have poor sticking property compared to Bordeaux mixture. Further studies on these lines will give more light on this aspect.

Almost similar trends were observed when the vines were treated with different fungicides. Bordeaux mixture and Bayer 5072 completely checked the disease on the third day. On the ninth day also they were far superior to other fungicides. On the ninth day the effect of treatments with fungicides other than Bordeaux mixture and Bayer 5072 was not significantly

different from the control. The vines of 1½ year old pepper plant used in the present study was very smooth and therefore the fungicides might have washed off at a faster rate from the vines than from the leaves. Only those fungicides with good sticking or penetrating property remained on the vines.

When the fungicides were drenched in soil, it was possible to control the disease even up to a period of nine days. All the fungicides were better than the control. On the third day, Agallol was the best fungicide in checking the disease, while on the ninth and sixth day Agallol was inferior to Bordeaux mixture, Thiride and Bayer 5072. This clearly indicates the unstable nature of Agallol. The degradation of mercury fungicides in soil was reported by Kimura and Miller (1964). Bordeaux mixture, Thiride and Bayer 5072 were uniformly effective, when the fungicides were applied to the soil three to nine days before inoculation of the roots. Richardson (1954) found that Thiram persisted in sandy soil for over two months. This may probably be due to the fact that the fungicides in the colloidal form might have been adsorbed on the root and soil surface and there would be lesser leaching

compared to that observed in above ground parts. The effectiveness of Bordeaux mixture against Quick wilt of pepper was reported by Muller (1936), Anonymous (1976) and Nambiar and Sharma (1976). Similar observations were also made by Sundara Raman (1929), Dastur (1935), Subramanian and Venkata Rao (1970), Antony Raj *et al.* (1973) and Narasimhan *et al.* (1976) working with fungicidal control of betle vine wilt.

The results clearly showed that in general fungicides were more effective when they were drenched in the soil compared to spraying on aerial parts during heavy and continuous rain. On the aerial parts, the control obtained was better when fungicides were applied just before inoculation than they were applied two days before. This shows that it is not due to poor fungicidal property that the disease on the above ground parts were not controlled but because the fungicides were not retained on these parts.

SUMMARY

SUMMARY

1. The study was conducted at the Pepper Research Station, Vellanikkara, Trichur.

2. Panniyoor-1 variety of pepper was used for the investigation.

3. The causal agent of the disease (quick wilt or foot rot) was found to be *Phytophthora palmivora* (Butler) Butl. Koch's posulates were established.

4. The first visible symptom noticed on the leaves was the development of a water soaked region within 24 hours of inoculation. Immature leaves took infection more easily than mature leaves. A fully developed lesion had a holonecrotic centre surrounded by plesionecrotic zone with brown colour which in turn was surrounded by yellow halo slowly diffusing to healthy tissues. Zonations on lesion were noticed during the alternate wet and dry conditions. Defoliation of infected leaves took place within four to ten days.

5. Disease development was more when the leaf was inoculated on the lower surface.

6. Initial symptom on stem and branches was the same as that on leaves which appeared two to five days after inoculation. Foliar symptoms and collapse of entire plant were noticed within 12 to 20 days after inoculation on stem and branches.

7. The plants took infection more easily near the collar region.

8. Rotting generally progressed upwards and the region below the infected portion remained healthy during the initial stages of the infection.

9. Infection on the fine roots took place within 24 to 48 hours of inoculation. The infection spread from the fine roots to the branch, main roots and other parts of the plants. The entire plant collapsed within 12 to 20 days after inoculation.

10. Out of the seven fungicides tested, four fungicides viz., Bordeaux mixture, Agallol, Bayer 5072 and Thiride completely inhibited the growth of the fungus *in vitro*.

11. All the fungicides tested checked the disease completely when they were applied two hours before inoculation.

12. Control obtained was better when fungicides were applied just before inoculation. As the gap between time of inoculation and fungicidal spray increased, there was progressive decrease on the control of the disease.

13. None of the fungicide was effective in eradicating the established infection when they were sprayed one or two days after inoculation on leaves, but Bayer 5072 checked the spread of lesions considerably.

14. On the vines the fungicides checked the pathogen when applied one day after inoculation. While on roots, all fungicides except Dithane M-45 controlled the disease when drenched either 24 or 48 hours after inoculation.

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QUICK WILT DISEASE OF PEPPER *(Piper nigrum Linn)*–I
SYMPTOMATOLOGICAL STUDIES ON THE QUICK WILT DISEASE OF PEPPER

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ABSTRACT OF A THESIS

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ABSTRACT

The present study on the quick wilt disease of pepper caused by *Phytophthora palmivora* (Butler) Butler was conducted at the Pepper Research Station, Vellanikkara using Panniyoor-1 pepper variety.

The objectives of the investigations were to study the symptoms of the disease and to find out suitable control measures using fungicides.

The first visible symptom on leaf, stem and root was noticed 24 to 48 hours; two to five days and 24 to 48 hours respectively after inoculation, depending on the maturity of the plant part.

A fully developed lesion had a dark brown hononecrotic centre and plesionecrotic boarder surrounded by yellow halo. The yellow halo was not noticed during prolonged wet and humid conditions. Under these conditions lesions was uniformly brown in colour. Zonations were noticed during the alternate wet and dry conditions. On the stem, branches and roots symptom usually developed as a uniformly brown and dark coloured lesions.

Pathogen entered mainly though lower surface of the leaf.

After infection, defoliation took place within five to ten days. Development of flaccidity, drooping and defoliation of the leaves were the marked symptoms during the progress of disease when the stem, branches or roots were infected.

All the fungicides tested checked the growth of the fungus *in vitro* for a period of three days. The fungicides when sprayed or drenched two hours before inoculation completely checked the disease. However, there was mild infection on plant where Dithane M-45 was used for drenching the soil. As the interval between the fungicidal spray and inoculation prolonged there was progressive reduction in the control of the disease.

None of the fungicides was able to eradicate completely the established pathogen on leaves.

When fungicides were applied one day after inoculation there was complete control of the disease on stem. While the control was not complete when it was applied two days after inoculation.

All the fungicides except Dithane M-45 completely checked the development of the disease when they were drenched in soil.