PAPAW ROOT ROT CAUSED BY *PHYTOPHTHORA PALMIVORA* BUTL.

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SUMMARY.

A severe root rot of papaw (Carica papaya **Gaertn.) in Queensland is caused by** Phytophthora palmivora **Butl.**

Waterlogging is an important predisposing factor in the occurrence of the disease.

In the Brisbane area, soil temperatures are favourable for growth and sporulation of P. palmivora, **except during June, July and August.**

Field evidence suggests that crop rotation reduces the severity of attack.

P. palmivora **isolated from roots proved capable of rotting green papaw fruit, but a similar fruit rot has not been found naturally in Queensland.**

I. INTRODUCTION.

In April 1955 an outbreak of root rot destroyed a 1-year-old planting of papaws near Brisbane, in the south-east of Queensland. Subsequently other outbreaks occurred in the same district, and during 1955 and 1956 losses in this area exceeded 8,000 plants. Further severe losses were experienced near Mackay, in central coastal Queensland.

Root rot of papaws is not new to Queensland, though apparently it was unusually severe in 1955 and 1956. Over 20 years ago Simmonds (1934) isolated a phycomycete from a stem and root rot of papaws and proved its pathogenicity. This organism was in 1935 identified by S. F. Ashby of the Imperial Mycological Institute as *Pythium ultimum* Trow and since then most of the root rot in Queensland has been attributed to this and other species of *Pythium* (Simmonds 1937; Da Costa 1944). Other species of *Pythium* which have recently been isolated from rotting papaw roots are *P. debaryanum* Hesse, *P. oligandrum* Drechsl., *P. vexans* de Bary, *P. irregulare* Buism., *P. spinosum* Saw., and *P. aphanidermatum* (Eds.) Fitzp. Proof of the pathogenicity of these isolates has been attempted only in the case of *P. vexans* and this instance is discussed below.

In other countries species of *Pythium* and *Phytophthora* comprise the characteristic fungus flora associated with papaw root rot. Middleton (1943) listed nine species of *Pythium* from papaw while three species of *Phytophthora* have been recorded from this host in nature. *P. cinnamomi* Rands has been observed from roots only (Bazán de Segura 1951); *P. parasitica* Dast. and *P. palmivora* may attack the roots, stems and fruit (Park 1932; Thompson 1940; Parris 1942).

II. SYMPTOMS.

In the outbreaks of root rot investigated, the symptoms were identical with those described by Wager (1931) as typical of the disease. The leaves turn yellow, wilt, hang limply around the trunk and then fall; eventually only a few small leaves are left at the apex of the tree. Examination of the roots of plants in early stages of infection reveals that generally the rot originates

Fig. 1.

Papaw Plantation Affected by Root Rot. Note the severe losses associated with the depression. Two plants in the foreground show early symptoms.

on the smaller laterals. In the later stages the tap-root also is involved and the whole root system becomes reduced to a soft, shredded, evil-smelling, brown mass. Severely affected plants are easily blown over by strong winds.

Under some conditions these symptoms may be expressed in a matter of days; under others, symptoms develop slowly over weeks or months. Often slightly affected plants make temporary recovery but later succumb to the disease.

III. ETIOLOGY.

Initial isolations on water agar from plants in advanced stages of attack showed that *Pythium vexans* was consistently associated with the rot. However, microscopic examination of pieces of infected root tissue placed overnight in sterile water revealed the presence of large papillate sporangia distinct from the smaller non-papillate sporangia of *P. vexans*. The larger sporangia resembled those of certain species of *Phytophthora,* and to confirm this, isolations from soil were carried out by the apple technique devised by Campbell (1949) for *P. cinnamomi*. These isolations showed that a *Phytophthora,* subsequently identified as *P. palmivora,* was consistently present in soil near affected plants. Later, *P. palmivora* was isolated on water agar from papaw roots in an early stage of decay.

(1) Papaw Inoculations.

In order to determine the relative pathogenicity of *Phytophthora palmivora* and *Pythium vexans* to papaw plants, these fungi were subjected to a glasshouse inoculation test. Also included for comparison were a species of *Fusarium* isolated from rotting papaw rootlets on healthy plants and *Phytophthora cinnamomi* obtained from avocado roots.

On July 11, 1955, each of the four fungi was inoculated into three potted papaw plants 18 in. high; three plants were left uninoculated as controls. Soil was scraped away from the base of each plant, which was scarified with a scalpel. A block ($\frac{1}{2}$-in. square) of an actively growing potato dextrose agar culture of the fungus was placed against the damaged plant surface, the soil returned and the pot watered immediately. Watering was continued to keep the plants growing normally.

The three plants inoculated with *P. palmivora* exhibited root rot symptoms after 9, 16, and 23 days respectively (Fig. 2). A severe rot commenced at ground level and gradually extended down to the root system and some six inches up the stem. On the other hand, plants inoculated with *P. vexans, Fusarium* sp., and *P. cinnamomi,* and uninoculated control plants, were still healthy on Oct. 27, about 14 weeks after commencement of the experiment. Re-isolations from the margin of rotting areas confirmed that *P. palmivora* was the pathogenic organism.

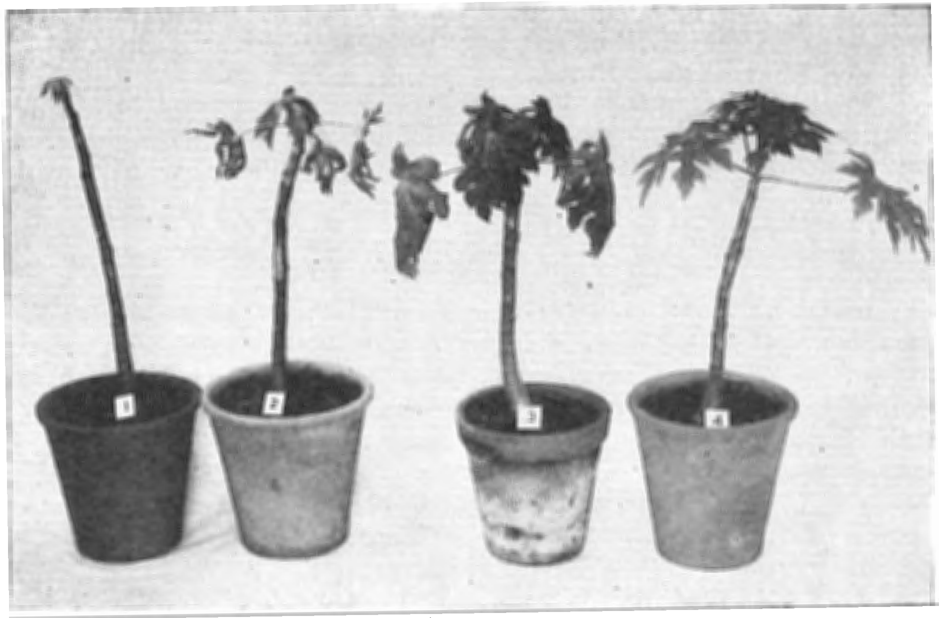

Fig. 2.

Progressive Development of Symptoms 23 days after Inoculation with *P. palmivora*. Plant 4 Uninoculated.

(2) Waterlogging Experiment.

In preliminary experiments it had been found that only when *P. palmivora* was placed in contact with the injured base of the papaw plant did root rot symptoms develop. Uninjured plants growing in inoculated soil remained healthy, as also did plants which had their surface lateral roots slashed with a scalpel. Apparently some other predisposing factor was necessary for development of severe root rot. Field observations had indicated the importance of waterlogging in the occurrence of outbreaks of root rot. To study the effect of this factor a further experiment was carried out, using the healthy plants previously inoculated with *P. vexans* and the three uninoculated controls.

On Oct. 27, two plants in each series were inoculated with *P. palmivora* on cornmeal-sand medium, while sterile cornmeal-sand was added to the third. The plants were watered immediately, and subsequent watering was carried out so as to keep the plants growing normally. No root rot symptoms developed up to Dec. 9, six weeks after inoculation.

On this date, the pots were submerged in water so that the bases of the plants were covered. Three days later, the pots were removed and allowed to drain. Within two days of removal from the water, all plants, including the controls, showed early symptoms of root rot—that is, the lower leaves

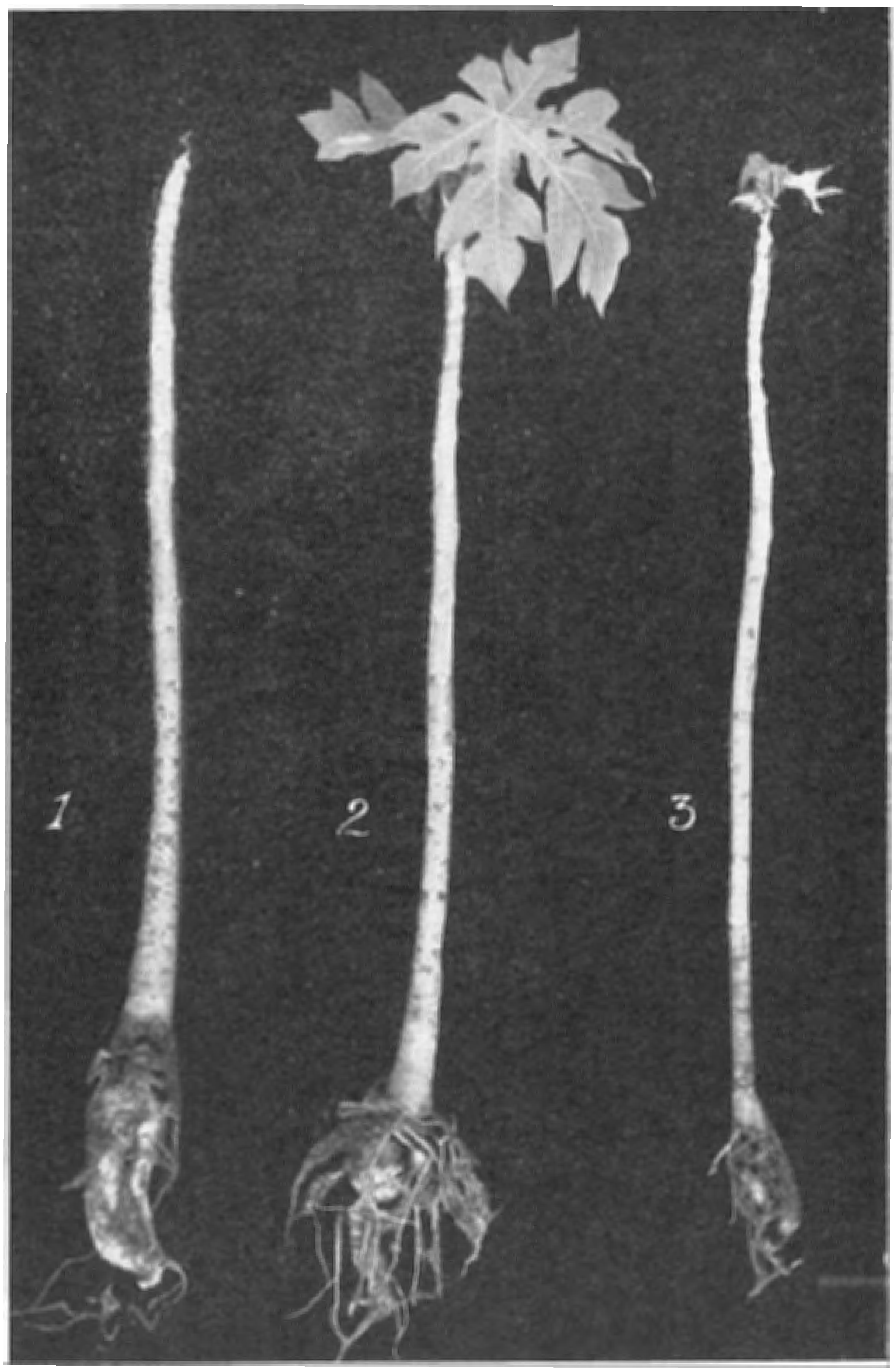

Fig. 3.

Effect of Three Days' Waterlogging on Papaw Plants Growing in Soil Inoculated with *P. palmivora* (Plants 1 and 3) and Uninoculated Soil (Plant 2).

yellowed, wilted and fell. However, subsequent observation revealed that the rate of defoliation was greater with those plants inoculated with *P. palmivora* than with control plants. After three weeks the latter still had two large healthy leaves while inoculated plants were completely leafless (Fig. 3).

On Dec. 29, all plants were removed from their pots, the amount of root rot assessed, and isolations made to determine associated organisms. The results are given in Table 1. Severe root rotting occurred only when P. *palmivora* was present during waterlogging.

Table 1.

EFFECT OF THREE DAYS' WATERLOGGING ON ROOT ROT SYMPTOMS.

Original Crown Inoculation 11-7-55.	Subsequent Soil Inoculation 27-10-55.	Healthy Leaves 29-12-55.	Rot Symptoms 29-12-55.			Pythiaceous Fungus Reisolated.
			Laterals.	Taproot.	Base.	
P. vexans ..	*P. palmivora*	0	Severe	Severe	Severe	*P. palmivora*
P. vexans ..	*P. palmivora*	0	Severe	Severe	Severe	*P. palmivora*
P. vexans ..	Nil	2	Moderate	Moderate	Slight	*P. vexans*
Nil	*P. palmivora*	0	Severe	Moderate	Severe	*P. palmivora*
Nil	*P. palmivora*	0	Severe	Severe	Severe	*P. palmivora*
Nil	Nil	2	Slight	Slight	Absent	Nil

(3) Papaw Fruit Inoculations.

While *P. palmivora* has been shown to be responsible for severe outbreaks of root rot in Queensland, there has been no record of the fruit rot reported from the Pacific islands of Fiji (Campbell 1925; Simmonds 1925) and Samoa (Smith 1955). Inoculations were therefore carried out to determine if the root rot isolate of *P. palmivora* was a potential fruit pathogen.

Eight immature papaw fruit were surface sterilized with 95 per cent. ethyl alcohol. On each fruit three inoculation sites were chosen and on half of the fruit these were lacerated with a scalpel. Inoculation of two sites on each fruit was carried out by applying blocks from the margin of a P.D.A. culture of *P. palmivora*. After inoculation the fruit was placed in a moist chamber for seven days and then examined.

P. palmivora was pathogenic to wounded green papaws in all eight cases. The symptoms of the rot were a firm, slightly yellowish rot of the white flesh, which extended about three inches across the fruit in five days. The surface of the lesion became slightly wrinkled and covered with a powdery material (Fig. 4), which was found to consist of masses of chlamydospores. In the case of the intact inoculation sites, infection was secured in two out of eight inoculations. Uninoculated sites remained unaffected.

Fig. 4.

Green Papaw Fruit Inoculated with *P. palmivora* Isolated from Rotted Roots.

These results with *P. palmivora* agree with those obtained by Parris (1942) with *P. parasiticæ.* This author found that *P. parasitica* is essentially a wound parasite, but will infect wound-free fruits, stems, roots and leaves if they are kept in a moist atmosphere following inoculation.

IV. PREDISPOSING CONDITIONS.

The available evidence indicates that at least five factors influence the occurrence of papaw root rot. These are soil moisture, temperature, damage to the roots, age of the plants, and previous cropping history of the soil.

(1) Soil Moisture.

Wager (1931) and Simmonds (1937) stated that excessive soil moisture is a common predisposing condition in the occurrence of papaw root rot and base rot, and that plantings on soils with impeded drainage are particularly liable to attack. These claims are borne out by the waterlogging experiment described above and by numerous field observations. In natural occurrences, it is common for the disease to originate in the gullies, or in the poorer drained portions of a plantation where water accumulates, and to spread out to adjacent areas if wet weather continues (Fig. 1).

Soil texture influences the severity of the disease, apparently by its effect on internal drainage. Clay soils appear to be more subject to root rot than sandy soils, although where heavy subsoils occur beneath the latter the taproot may rot away, leaving the plant to subsist on surface laterals.

(2) Temperature.

According to Ashby (1929), *Phytophthora palmivora* is a tropical species which has an optimum temperature for mycelial growth on agar media of 27–28 deg. C., and which forms sporangia freely at temperatures between 20 deg. and 30 deg. C. in two or three days. On this information it would be expected that soil temperatures between 20 deg. and 30 deg. C. would be conducive to attacks of root rot.

To determine during which months of the year root rot is likely to be a problem in the Brisbane area, the mean monthly temperatures for soil one foot below ground level, obtained through the courtesy of the Commonwealth Meteorological Bureau, were compared with multiple temperature incubator data on the growth of *P. palmivora* on cornmeal agar.

Table 2.

COMPARISON OF MEAN MONTHLY SOIL TEMPERATURES WITH THE GROWTH OF *P. palmivora* AT THE CORRESPONDING TEMPERATURES.

Month.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean monthly soil temperature (°C.) at 1 ft.	28	27	26	23	20	17	15	17	20	23	26	27
Growth in mm. in 24 hours at corresponding temperature	10	10	10	8	7	5	3	5	7	8	10	10

Table 2 shows that usually only during June, July and August are temperatures so low that mycelial growth of *P. palmivora* is reduced by half or more of the maximum.

In an attempt to determine the effect of temperature on sporulation of *P. palmivora* the following procedure was carried out:—

Three millilitres of sterile water was placed in each of 20 petri dishes (10 cm. diameter) and into each of these were placed five plugs (6 mm. diameter) taken from the margins of young P.D.A. cultures of the fungus. The petri dish cultures were incubated for three days over a range of 20 temperatures between 7 deg. C. and 43 deg. C., and then examined with the low power of a monocular microscope for the occurrence of sporulation. The results are given in Table 3.

Table 3.

TEMPERATURE REQUIREMENTS FOR SPORULATION OF *P. palmivora*.

Temperature (°C.).	7–17.	18–23.	24–27.	28.	30–43.
Sporulation	Absent	Slight*	Moderate†	Slight*	Absent

* Approximately 1–3 chlamydospores and sporangia per field.
† Approximately 4–12 chlamydospores and sporangia per field.

The months of June, July and August, with soil temperatures below 18 deg. C., and possibly May and September as well, appear unfavourable for sporulation of the fungus. It has been claimed by growers that root rot is less severe during the cold months.

Severe outbreaks of the disease in the Brisbane area have been most frequent in the months of March and April, which, apart from being wet, have temperatures near the optimum for growth and sporulation of *P. palmivora*.

(3) Damage to the Roots.

Phytophthora parasitica was found by Parris (1942) to be essentially a wound parasite of the papaw, and this also appears to be the case with the closely related *P. palmivora*.

In a preliminary pathogenicity trial, *P. palmivora* failed to cause visible rot when inoculated into soil near unwounded papaw plants. Under normal growing conditions, only when inoculum was placed against the damaged base of the stem, as described for the first experiment, did plants develop appreciable rot and eventually die.

It would be expected that strong winds, by severely buffeting plants, would cause root damage and predispose plants to attack, if other factors favouring fungus activity operated. Such is apparently the case during periods of cyclonic weather, when gale-force winds and heavy prolonged rainfall coincide. It is after such periods that the most severe outbreaks have been recorded.

(4) Age of Plants.

Young trees have been found to be more subject to root rot than older trees. Large trees, besides having larger and more extensive root systems than smaller trees, appear to have larger food reserves and a better opportunity of re-establishing themselves after losing a proportion of their roots.

(5) Crop Rotation.

Crop rotation has long been recognised as a common and successful procedure for control of some soil-borne diseases (Garrett 1944), and evidence collected in this investigation indicates that papaw root rot, also, is amenable to control by this means.

In one instance, an old papaw plantation was cut out, and, together with an adjacent area which had carried volunteer grasses and weeds for several years, planted with young papaws. A year later, following a cyclone, plants on the old papaw land were severely attacked by root rot, while those on previously spelled land initially displayed no symptoms of disease. At a distance, the margin between the two sections could be seen as a straight line. The reason for this difference may have been a build-up of *P. palmivora* on the dying roots of the previous papaw planting.

Further, little success has attended replanting of sites where papaws have recently died from root rot. In one instance it was reported that four successive replant crops had died out in quick succession over a wet period. This furnishes additional evidence of the adverse effect of replanting land without adequate crop rotation.

V. CONTROL.

No experiments on the control of papaw root rot on a field scale have been conducted. It might be expected that the installation of subsurface drainage would considerably reduce the risk of waterlogging and the associated root rot, but the cost of this would be too high for most growers. The more practicable surface drainage should be practised.

Crop rotation appears to be effective in reducing the initial intensity of infection but does not provide protection against infection under conditions of prolonged waterlogging.

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