On a Phytophthora Rot of Fig.

By

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Contents.

I. Introduction.

The fruit rot of fig has been in occurrence in the Kurasiki region for many years, and in the summer of 1935 it caused the first severe epidemic affecting fig orchards, and was most prevalent on the variety White Genoa. The writers have studied this disease for some time and the results are here given. A part of the results was presented at the eighth annual meeting of the Japanese Society of Agricultural Science. (Nisikado et al., 1937, 1939)

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II. Early Occurrence of the Disease.

K. HARA (1915) first collected the diseased material from the White Genoa variety in the orchard of the Agricultural College of Tokyo Imperial University, in 1909. He named the causal fungus *Kawakamia Carica* HARA. In the same year S. HORI (1915) reported the disease occurring on the variety California Black in the Province of Gumma and applied the name *Phytophthora Fici* HORI, but later altered it to *Phytophthora Carica* (HARA) HORI. The same disease was noted in Formosa in 1914 by K. SAWADA (1916). He also found the disease occurring on the variety California Black. In 1934 TAKIMOTO (1935) observed the disease affecting not only the fruit but also leaves, young stems and leaf-sheaths of fig.

Definite records are lacking but the senior author recollects that in Kurasiki as early as 1916 or 1917, mummified fruits of fig affected by the fungus were found hanging on the trees during late autumn. However, it was not until in recent years the disease had been severe enough to be noticeable.

III. Symptoms of the Disease.

The disease appears usually during the prolonged rainly season and in the places of high humidity. The season usually extends a period from May and June till late in the autumn. The surface of the fruit first becomes dark green or deep purple, depending upon the variety of the infected fig, and has a water soaked appearance having a slight depressed contour. White mouldy growth of the fungus next appears over the spot, and in very moist condition, it takes on a cottony appearance (Figures 1 and 5). The fruit finally becomes soft and drops to the ground. If the weather clears during the progress of the disease, the fruit may remain hanging on the tree, hardened and mummified. Numerous such fruits may remain on the limbs during the harvest period in the fall.

Nearly ripened fruits are especially susceptible to the disease but unripened young fruits may also become infected. The disease is common in the lower part of the tree, but frequently one may find fruits and limbs higher up also affected.

On the leaves, the lesion at the beginning is light brown and rapidly changes to darker brown with an irregular outline (Figures 1 and 4). Occasionally, the lesion follows along the vein and produces an irregular spot. The disease progresses rapidly in the young leaves and twigs, often covering half the leaf; but in the older matured leaves the lesions are more or less limited to 2 to 3 mm. in size.

IV. Morphology of the Fungus.

The morphological description of *Phytophthora Carica* (HARA) HORI given by K. SAWADA (1916) in Japanese is as follows: Aerial hyphae are hyaline, thin-

walled, branched, non-septate, sometimes septate in old hyphae, 3 – 10 μ in diameter ; conidiophores are rarely septate, single or fasciculate, simple or branched beneath the conidium, much resembling aerial hyphae, 360 – 480 μ long, rarely exceeding 1,000 μ, 3.5 – 4.5 μ in diameter ; conidia are hyaline, thin-walled, finely granular, pyriform, oblong, ellipsoid, ovoid or fusoid, 26 – 112 × 16 – 45 μ, with a papilla 4 – 8 μ long, wall contiguous to the conidiophore, often thickened, sometimes falling off with a part of conidiophore, germinating with germ tube or liberating swarm spores.

The conidia taken from naturally infected fruits in Kurasiki, and from artificial culture showed a close conformity with the description of Sawada (cf. Figures 7 – 16). The measurements were however slightly different, 27 – 87 × 17 – 45 μ, a minimum of 27.5 × 20 μ with a length to width ratio of 1.37, and a maximum of 87 × 34 μ with a length to width ratio of 2.41. The conidia germinate by either sending out germ tube or forming swarm spores. The number of swarm spores contained being variable with the size of the conidium. Swarm spores are discharged at maturity and they swim about actively with their two cilia attached oppositely at the two ends. Shortly they come to rest and take on a more spherical appearance with a thickened wall ; they are now resting spores. Resting spores measure 9 – 13 μ and germinate by germ tubes (cf. Figures 13 and 14). After germination the resting spores may still form secondary spores. Frequently the content of the conidia may suddenly become differentiated into swarm spores at the time the germ tubes were being pushed out. Sometimes numerous swarm spores arise from the differentiating content of the conidium ; and these further take on a thick wall and become resting spores in the conidium, germinating independently with their germ tubes. Chlamydospores, 30 – 45 μ across, much resembling oospores were found on host plant and in old cultures. They germinate by germ tube.

V. Taxonomy of the Fungus.

The fungus was first described by K. Hara (1915) as *Kawakamia Carica* Hara, and S. Hori (1915) working independently announced the fungus under the name of *Phytophthora Fici* Hori. He maintained that the morphological characters as described by Hara would place the fungus in the genus *Phytophthora* and renamed the fungus to *Phytophthora Carica* Hori. In 1916, Hara used *Phytophthora Carica* Hara in his book on diseases of fruit trees. This name was later employed by Saccardo (1926). Sawada (1916) however called the fungus *Phytophthora Carica* (Hara) Hori in his description of Taiwan fungi, making *Kawakamia Carica* Hara and *Phytophthora Fici* Hori its synonyms. Sawada also placed the *Phytophthora* fungus, discovered by A. Moeller (1901) in Brazil and noted by G. W. Wilson (1914), under this classification. Considering from the results of the investigation, the fungus described by Venkata Rao (1916) as *Phytophthora Fici* Venkata Rao, the cause of fig rot in India, is regarded to be identical with the fungus under consideration.

C. M. Tucker (1931) made extensive studies on the genus *Phytophthora* and especially on *Phytophthora palmivora* Butler in Porto Rico. He suggested from the description given by T. Tanaka (1920) that *Phytophthora Carica* (Hara) Hori should be included in the group *Phytophthora palmivora* and made it a synonym. Leonian (1934) has also expressed a similar opinion on this question.

There has been no published account of the formation of oospore by the fungus; the writers were also unable to observe its occurrence. The fungus in question resembles closely with *Phytophthora palmivora* in the characters of conidia and the manners of germination. There was difficulty in comparing the sizes of conidia as they were markedly influenced by slight changes in environmental conditions. Table 1 records the measurements of conidia as they were given by various investigators. The table indicates a small variations in the sizes of conidia, but they seem not to be in the magnitude of being significant enough to be of distinction. It is therefore most appropriate to treat the fungus as a member of *Phytophthora palmivora* Butler, and in this paper this name has been applied.

Table 1.

Comparisons in Size of Conidia of the *Phytophthora* under Consideration and those of *Phytophthora palmivora* Butler.

Species name*	Authors	Range** (μ)	Average*** (μ)
P. palmivora Butler	Limits and average of 23 measurements given by Butler, Peters, Rosenbaum, Reinking, Ashby, Maublanc, Gadd, Thompson, Ocfemia et al., Schwarz, Tucker, McRae and Leonian et al.	27 – 72 × 20 – 53	47.3 × 30.2
P. arecae (Colem.) Pethyb.	Limits and average of 5 measurements given by Sundararaman et al., Gadd, Rosenbaum and Leonian et al.	32 – 70 × 27 – 48	44.8 × 30.8
P. meadii McRae	Limits and average of 8 measurements given by Dastur, McRae and Sharples et al.	21 – 72 × 15 – 44	37.5 × 24.8
P. Carica (Hara) Hori	Measurements given by K. Hara	40–87.5 × 15–32.5	
	„ „ „ S. Hori	34 – 70 × 22 – 44	
	Measurements given by K. Sawada and cited by S. Ito	26 – 112 × 16 – 45	
Phytophthora under consideration	The present writers	27 – 87 × 17 – 45	

Remarks: * According to Tucker (1931) *P. palmivora*, *P. arecae*, *P. meadii* and *P. Carica* are grouped and placed in one species under the name *P. palmivora*.

** In this column are shown the minimum and the maximum dimensions of the measurements given by various authors.

*** The values are the average of the means given by various authors. When a cited paper showed only the range, the mean of the two extremes given was calculated.

The following is a list of names applied to the fungus causing the fruit rot of fig.

Phytophthora palmivora TUCKER

TUCKER, C. M. (1931): Missouri Agr. Exp. Station, Res. Bull. 153, 157 - 164.

Phytophthora Carica (HARA) HORI

HORI, S. (1915): Byôtyûgai Zassi, 2: 1015 - 1017.

Kawakamia Carica HARA

HARA, K. (1915): Nôgyôkoku, 9: 24 - 27.

Phytophthora Fici HORI

HORI, S. (1915): Byôtyûgai Zassi, 2: 930 - 932.

Phytophthora Carica HARA

HARA, K. (1916): Kwadyu Byôgai Ron (Diseases of Fruit Trees), 431 - 436.
SACCARDO, P. A. (1926): Syll. Fung., 24: 37.

Phytophthora Fici VENKATA RAO

VENKATA RAO, M. K. (1916): Journ. Bombay Nat. Hist. Soc., 24: 615.

Phytophthora sp.

MOELLER, A. (1901): Bot. Mitteil. aus den Tropen, Heft IX, 3.
WILSON, G. W. (1914): Mycologia, 4: 77.

VI. Pathogenicity of the Fungus.

The pathogenicity of the fungus on fruits other than the fig was reported by HORI (1915), SAWADA (1916) and TAKIMOTO (1935). The authors likewise conducted experiments by inoculating fruits, young leaves and unfolding buds of fig as well as fruits of apple, Japanese pear, persimmon, eggplant and potato tubers with the pure cultures of the fungus. The results obtained were as follows:

1. Inoculation experiment on fig.

A. Fruit. The surface of the fruit was sterilized with a wad of cotton dipped in 50% alcohol, and the fungus was inoculated at the surface with or without making artificial wounds. The material was placed in deep PETRI dishes provided with moistened filter paper on the inner surface of the lid and was kept in a incubator held at a optimum temperature. The result is given in Table 2. The wounded fruits when compared with the unwounded fruits showed a more rapid spread of the lesions; however, in either case, entire fruit became affected after 2 - 4 days with an appearance of cottony mycelium over the whole fruit in 4 - 7 days. (See Table 2 on next page)

In determining the relationship between the age and the susceptibility of the fruit to the disease, unripened green fruit, slightly ripened yellowish green fruit, and half ripened yellow fruit were selected for inoculation with or without the application of artificial wound. The results of this experiment were that the wounded fruits regardless of age, all developed the disease to the same degree; while in unwounded fruits the disease was less severe when younger the fruit.

Table 2.

Results of Inoculations on Figs with *Phytophthora palmivora* Butler.

I. Inoculated on September 27, 1935.
Result taken after four days' incubation.

	Yellow fruits		Yellowish green fruits		Green fruits		Average	
	Infection	Size of spots	Infection	Size of spots	Infection	Size of spots	Infection	Size of spots
		mm.		mm.		mm.		mm.
Pricked wounds	—	—	7:7	40.0	5:7	35.0	12:14	37.9
Scratched wounds	4:4	47.5	7:7	44.3	4.6	42.5	15:17	44.7
Without wounds	4:4	40.0	7:7	35.0	—	—	11:11	39.6
Control	0:4	0	—	—	—	—	0:4	0

II. Inoculated on October 4, 1935.
Result taken after 5 days of incubation.

	Yellow fruits		Green fruits		Average	
	Infection	Size of spots	Infection	Size of spots	Infection	Size of spots
		mm.		mm.		mm.
Cut wounds	9:9	33.9	27:27	38.1	36:36	37.1
Without wounds	9:9	41.7	27:27	25.2	36:36	29.3

The experiment on the relationship between the temperature and the size of the diseased spot was made by using the fungus isolate No. 1041 on green figs. The results given in Table 3 were taken after incubating at constant temperatures. The disease appeared and developed rapidly at the most favorable temperature for the fungus.

Table 3.

Results of Inoculations on Figs with *Phytophthora palmivora* Butler.

I. Inoculated on cut wounds, July 28, 1936.

Results after	Temperature	Infection	Size of spots
2 days	24°C.	18:18	15 – 40 mm.; average 31.1 mm.
„	30°	9:9	25 – 40 mm.; „ 32.3 mm.
3 days	24°	18:18	Mycelium covered all the surface of the fruits.
„	30°	9:9	Ditto

II. Inoculated on cut wounds, August 11, 1936.

2 days	30°C.	24:24	
3 days	„	24:24	Mycelium covered all the surface of the fruits.

III. Inoculated without wounds, August 7, 1936.

Results after	Temperature	Infection	Size of spots
3 days	24°C.	17 : 24	18 – 40 mm.; average 28.6 mm.
4 days	„	20 : 24	30 – 75 mm.; „ 42.7 mm.

B. Leaves. In this experiment, twigs with leaves were placed in the wide mouth glass container and after inoculating them, bell jars were put over the containers to maintain a uniform high humidity; and from time to time, spray of water was also given. As in the previous experiment with fruit, leaves of various stages in the development were selected. They were further divide into artificially wounded and unwounded. It was found as indicated in Table 4 that leaves of all stages in the development were susceptible to the disease, but in general the lesions were smaller in the aged leaves.

Comparative inoculations on the upper and lower sides of the leaves were also performed; and it was found as shown in II and III of Table 4, that both

Table 4.

Results of Inoculations on Leaves and Young shoots of Fig with *Phytophthora palmivora* Butler.

I. Inoculated on October 2, 1936.
Result taken after three days' incubation.

	On young buds and shoots		On not aged leaves		On aged leaves		Remarks
	Infection	Size of spots	Infection	Size of spots	Infection	Size of spots	
		mm.		mm.		mm.	
Pricked wounds	—	—	26 : 26	19.0	18 : 18	10.3	Cut shoots, put in glass bottles, were inoculated with the pure culture
Scratched wounds	—	—	22 : 22	19.7	—	—	
Without wounds	9 : 9	24.4	14 : 14	13.0	2 : 3	6.0	
Control	0 : 4	0	0 : 4	0	0 : 4	0	

II. Inoculated on October 4, 1936.
Result taken after three days' incubation.

	On young, not aged leaves				On aged leaves			
	Upper side		Under side		Upper side		Under side	
	Infection	Size of spots	Infection	Size of spots	Infection	Size of spots	Infection	Size of spots
		mm.		mm.		mm.		mm.
Scratched wounds	0 : 4	0	28 : 28	15.7	0 : 5	0	4 : 4	+
Without wounds	0 : 5	0	3 : 6	6.0	0 : 5	0	4 : 4	4.5
Control	0 : 4	0	0 : 4	0	0 : 4	0	0 : 4	0

III. Inoculated* on October 11, 1936.

	Results after 1 day				Result after 2 days			
	Upper side		Under side		Upper side		Under side	
	Infection	Size of spots	Infection	Size of spots	Infection	Size of spots	Infection	Size of spots
Very young leaves	0:8	—	3:3	+	5:8	++	3:3	+++
Young leaves	0:16	—	14:15	+++	13:16	++	15:15	+++
Matured leaves	0:9	—	15:17	++	6:9	++	17:17	+++

* Unwounded leaves were inoculated by spore suspension.

surfaces were invaded with the disease, but developing more rapidly and severely on the lower side of the leaves. The study also brought out the fact that the fungus' entrance into the host was not limited to the stomata alone. The difference in the development of the cuticle and the presence of hairs in the two surfaces can be given as the facters in the variation but further detailed studies on this question is required.

2. Inoculation experiment on other fruits.

Works of HORI (1915), SAWADA (1916) and TAKIMOTO (1935) clearly indicate that the fungus can be made to attack fruits other than figs. In the present work, fruits of tomato, Japanese pear (Nizisseiki), persimmon (Hûyû), eggplant and potato tubers were inoculated. The results are on Tables 5, 6 and 7, and proved that all fruits tested became diseased. Aerial mycelium was abundant on tomato but was not as great on pear and potato tubers. On eggplant and persimmon, although definitely showed the symptoms of the disease, the fungus mycelium was not visible until the fruits were sectioned. (cf. Fig. 2 and Fig. 6)

The fruit rot fungus of fig, *Phytophthora palmivora*, and that of eggplant, *Phytophthora Melongenae* were inoculated on to fruits of eggplant and potato tubers and their symptoms were compared. The results are summarized in Tables 6 and 7. The fungus causing the eggplant rot developed abundant aerial mycelium on eggplant even to the extent of completely covering the surface of the fruit; whereas in the case of the fig rotting fungus the formation of the aerial mycelium was not as great and even after 10 days of incubation the surface of the fruit was still visible. (Fig. 3). On the surface of fig fruits, both fungi formed the cottony aerial mycelium, the eggplant fungus developing at slightly slower rate. There was a difference in the size of the affected portion in the case of the potato tubers; in 3 days, the eggplant fungus formed numerous circular black spots surrounding the point of inoculation to a diameter of 30 mm., while the fig fungus made uniform dark brown discolored spot 12 mm. in diameter.

Summarizing the results in short, the fig rot fungus affects the fruit, leaves, and young developing buds of fig, forming the characteristic diseased spots with or without the application of artificial wound at the time of inoculation. If the

Table 5.

Results of Inoculations on Fruits of Pear, Apple and Persimmon with *Phytophthora palmivora* Butler.

Samples: Ripe fruits of pear, apple (Nizisseiki) and persimmon (Hûyû).
Date of inoculation: October 2, 1935.

Fruit	Incubation period	Scratched wounds		Without wounds
		Infection	Size and character of the spot	Infection
Pear	3 days	8 : 16	Spots 35 mm. in diam., no aerial hyphae.	0 : 4
	5 „	16 : 16	Some spots fused together, the margins being indistinct. Aerial hyphae formed.	0 : 4
	7 „	16 : 16	The lesions were covered with aerial hyphae.	1 : 4
Apple	3 days	8 : 16	Spots small, no aerial hyphae.	0 : 4
	5 „	16 : 16	Spots 27.5 mm. in diam., no aerial hyphae.	0 : 4
	7 „	16 : 16	No aerial hyphae.	3 : 4
Persimmon	3 days	6 : 16	Spots 8 – 13 mm., no aerial hyphae.	0 : 4
	5 „	12 : 16	Spots 17.8 mm., no aerial hyphae.	0 : 4
	7 „	12 : 16	No aerial hyphae.	2 : 4

Table 6.

Results of Inoculations on Egg-Plants with *Phytophthora palmivora* Butler and *P. Melongenae* Sawada.

Inoculated on October 8, 1936.
Result taken after 2, 3, 4 and 10 days at 24° and 27°C. respectively.

Species	Incubation period	Results at Temperature	
		24°C.	27°C.
Phytoph. palmivora	2 days	No macroscopical lesions, but with aerial hyphae.	Same as at 24°C.
	3 „	Infection 3 : 5; lesions 16 – 40 mm.	8 : 10; 19 – 38 mm.
	4 „	With copious aerial hyphae. No spore formation.	Same as at 24°C.
	10 „	Copious aerial hyphae covered all the surface of the fruits.	Ditto
Phytoph. Melongenae	2 days	Macroscopical lesions, but no aerial hyphae.	Same as at 24°C.
	3 „	Infection 4 : 6; lesions 10.9 – 21.7 mm.	6 : 6; 24.2 – 29.0 mm.
	4 „	Copious, high aerial hyphae covered all the surface of the fruits.	Same as at 24°C.
	10 „	Very copious aerial hyphae covered all the surface of the fruits densely.	Ditto

Table 7.

Results of Inoculations on Egg-Plant Fruits and Potato Tubers with *Phytophthora palmivora* Butler and *P. Melongenae* Sawada.

I. Inoculated on September 18, 1936.

Inoculations on	Methods of inoculation	Results after	*P. palmivora* (Isolate No. 1042)	*P. Melongenae* (Isolate No. 335)
Egg plant fruits	Wounds	2 days	Infection 0:16.	Infection 12:12; lesions 24.4 mm.
		3 „	„ 0:16.	Lesions 42.9mm. with white aerial hyphae.
		4 „	„ 0:16.	As above, lesions 70 mm.
Potato tubers	Cut surface	2 days	Infection 4:4.	Infection 3:3; lesions 21 mm.
		3 „	Infection 4:4; lesions 11.3 mm. with slight aerial hyphae.	Lesions 29 mm., with aerial hyphae.
		4 „	Lesions 15.5 mm.	As above.
	Wounds	2 days	Infection 0:4.	Infection 0:3.
		3 „	Lesions 12 mm.	Black specks appeared around the inoculum.
		4 „	„ 25 mm.	Aerial hyphae appeared from lenticels.

II. Inoculated on September 22, 1936.

Inoculations on	Inoculation methods	Results after	*P. palmivora* (Strain No. 1041)	*P. palmivora* (Strain No. 1042)	*P. Melongenae* (Strain No. 335)
Egg plant fruits	Wounds	2 days	Infection 6:6; lesions 23.5 mm.	Infection 0:6.	Infection 5:6; lesions 16.2 mm.
		4 „	Lesions 42.5 mm.	„ 0:6.	Infection 6:6; lesions 51.7 mm.
		5 „	Lesions covered all the surface of fruits.	„ 0:6.	Long copious aerial hyphae covered all the surface.
	Without wounds	2 days			Infection 6:6; lesions 11.7 mm.
		4 „			Lesions 49.2 mm.
		5 „			Copious aerial hyphae.
Potato tubers	Wounds	2 days		Infection 6:6; lesions 19.8 mm.	Slight discoloration around the inoculum.
		4 „		Lesions 41.7 mm.	Blackening at lenticels.
		5 „		Lesions enlarged, with aerial hyphae.	As above.

conditions are very favorable for the fungus, the fruits are readily reduced to soft decay. It also attacks fruits of apple, Japanese pear (Nizisseiki), persimmon (Hûyû), eggplant, and tubers of potato, forming the characteristic disease spots. On potatoes, however, the disease did not develop as rapidly, nor did it formed abundant aerial mycelium as in the case of the eggplant fungus.

VII. Physiology of the Fungus.

1. Effect of temperature and culture medium on the growth of the fungus mycelium.

On reviewing literatures upon the growth of the fungus *Phytophthora palmivora* in relation to temperature, we noted that Reinking (1923) found the fungi, which were isolated from cacao and coconut, unable to develop at temperatures lower than 12°C. and greater than 32°C.; and had the optimum of 27°C. Gadd (1924) found 20–25°C. as the optimum temperature for the development of the swarm spores. Seal (1928) mentions 28–32°C. as the optimum temperature for the growth of the fungus, the maximum temperature varying greatly with the type of culture medium used; and noted a still good growth at even 38°C. Ashby (1929) maintains that the optimum temperature is between 27° and 28°C.; and Tucker (1931), 27.5–30°C. with the maximum of 32–35°C.

Table 8.

Effects of Temperature and Culture Media on the Mycelial Growth of *Phytophthora palmivora* Butler. (I)

Fungus studied: Isolate No. 1042 and No. 1041, grown on malt-extract agar.

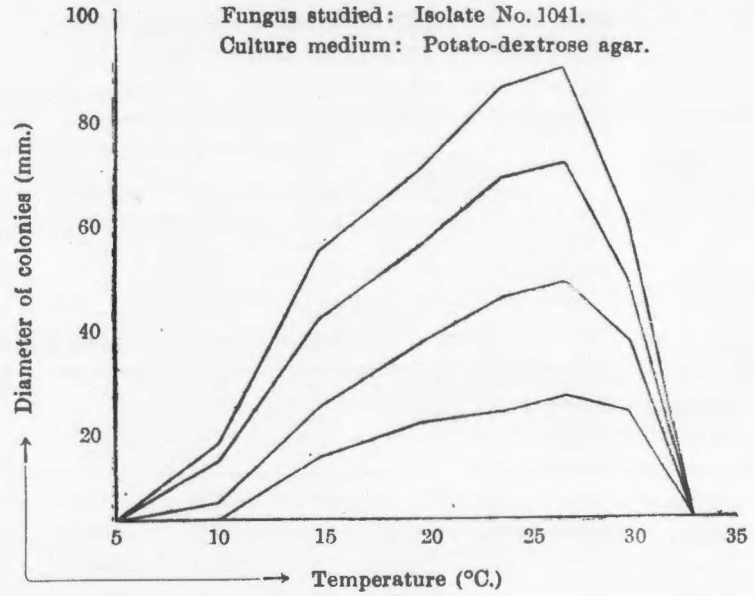
Isolate No.	Culture medium	Date	Temperature	Diameter of lesions or colonies			
				2 days	4 days	6 days	8 days
				mm.	mm.	mm.	mm.
			20°C.	0.9	19.6	36.7	
No. 1041	Fig fruits	October 6, 1936	24°	1.1	34.3	—	
			27°	3.2	36.7	—	
			30°	0.5	17.5	31.7	
			20°	0	10.2	21.4	35.8
No. 1041	Malt-ext. agar	August 11, 1936	24°	0	7.5	13.2	32.0
			30°	0	1.6	5.4	13.0
			24°	—	22.8	41.2	65.2
No. 1041	Ditto	September 18, 1936	27°	—	17.6	37.8	60.8
			30°	—	16.0	32.8	53.8
			33°	—	0	0	0
			20°	12.0	27.6	46.2	64.8
No. 1041	Potato decoc. agar	August 11, 1936	24°	15.2	35.4	56.2	69.4
			30°	15.0	39.0	59.6	71.8

Table 8. (Continued)

Isolate No.	Culture medium	Date	Temperature	Diameter of lesions or colonies			
				2 days	4 days	6 days	8 days
				mm.	mm.	mm.	mm.
No. 1042	Potato decoc. agar	August 6, 1937	10°C.	0	0	0	3.2
			15°	0	7.8	11.8	21.0
			20°	0	18.0	32.4	44.2
			24°	0	23.0	38.2	55.4
			30°	4.0	20.4	34.4	53.8
			35°	0	0	0	0
No. 1041	Ditto	September 18, 1937	24°		39.7	60.0	83.3
			27°		38.6	57.8	81.6
			30°		39.2	60.2	86.3
			33°		0	0	0
No. 1042	Ditto	September 18, 1937	24°		25.7	43.0	66.0
			27°		24.8	41.5	57.0
			30°		10.0	25.0	37.0
			33°		0	0	0

Text-Figure 1.

Temperature Relations to the Mycelial Growth of *Phytophthora palmivora* Butler.



Experiments were conducted to determine the relationship of temperature and culture media such as green fig fruit, potato agar and 3% malt-extract on the development of the fungus. The results are shown in Tables 8 and 9. The curves

Table 9.

Effect of Temperature and Culture Medium to the Mycelial Growth of *Phytophthora palmivora* Butler. (II)

Isolate No.	Culture medium	Diameter of colonies after	Temperature (C.)								
			5°	10°	15°	20°	24°	27°	30°	33°	35°
			mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
		1 day	0	0	0.6	4.5	4.5	5.8	3.0	0	0
		3 days	0	0	12.3	18.8	20.7	24.0	21.0	0	0
No. 1041	Potato agar	5 „	0	3.3	22.3	34.3	43.0	45.8	34.5	0	0
		7 „	0	11.7	38.9	53.0	66.0	68.8	45.8	0	0
		9 „	0	14.7	52.0	67.5	83.5	87.3	57.0	0	0
		11 „	0	22.7	71.7	87.5	107.3	113.5	73.0	0	0
		1 day	0	0	5.0	2.0	2.3	4.8	2.9	0	0
		3 days	0	0	12.6	19.0	19.5	24.0	21.7	0	0
No. 1042	Ditto	5 „	0	5.3	21.9	30.5	32.8	41.8	34.0	0	0
		7 „	0	8.3	33.9	46.3	49.0	60.8	47.4	0	0
		9 „	0	11.0	42.4	60.0	64.0	73.5	56.3	0	0
		11 „	0	16.0	56.9	80.0	86.3	97.8	80.0	0	0
		1 day	0	0	0	1.3	2.5	2.5	1.3	0	0
		3 days	0	0	4.5	12.0	16.0	13.3	8.8	0	0
No. 1041	Malt-ext. agar	5 „	0	0	13.0	29.8	36.0	30.5	19.8	0	0
		7 „	0	0	29.3	48.3	56.8	44.3	31.3	0	0
		9 „	0	0	43.8	68.8	76.0	56.5	45.5	0	0
		11 „	0	0	60.3	87.3	97.2	74.5	57.8	0	0
		1 day	0	0	0	0	0	0.3	1.0	0	0
		3 days	0	0	2.3	2.7	3.0	7.0	5.3	0	0
No. 1042	Ditto	5 „	0	0	8.1	15.5	14.3	20.5	17.5	0	0
		7 „	0	0	24.7	32.8	28.3	34.0	30.0	0	0
		9 „	0	0	35.3	49.0	45.7	47.1	41.3	0	0
		11 „	0	0	52.4	66.0	65.7	61.7	52.8	0	0

in Text-Figure 1 are drawn from the data given in Table 9 using fungus isolate No. 1041 on potato agar medium. There was no growth in 1 week at 10°C. but slightly at 15°C. It seems from this that the minimum temperature lies somewhere between 10° and 15°C. There was a good growth at 30°C. but none at 33°C., and would indicate that the maximum temperature lies between 32° and 33°C. The maximum growth occurred at 24 - 30°C. and the optimum is suspected to be about 27°C. This result corresponds closely to the results of Reinking (1923), Seal (1928), Ashby (1929) and Tucker (1931) on *Phytophthora palmivora*.

2. Influence of external conditions on the in spore formation.

A. Formation of conidia. The disease occurs during the prolonged wet period but during this period there are very little conidia formed. By placing ino-

culated figs in deep PETRI dishes, mycelia are formed profusely over the fruits in 2-4 days. At this time if the lids are replaced with paper covers, conidia are produced in abundance giving a powdery appearance to the developing mass. This result showed that some drying or slight movement of air is necessary for conidial formation.

B. Development of oogonium. As will be described subsequently, the fungus failed to form oogonium on any of the substratum used. HARA (1915) had described the oogonium, but SAWADA (1916) expressed that what HARA saw was not the oogonium but the chlamydospore. The lack of oogonial stage was used as one of the criteria in the taxonomy of the genus by TUCKER (1931). The writers also attempted to determine the sexual stage of the fungus by using the green pea decoction medium as suggested by LEONIAN (1936). The medium was prepared as follows: 130 g. of green pea was boiled with 800 cc. of water for 1 hour; the liquid was decanted, filtered, and set aside; the remaining residue was again boiled for 30 minutes with 300 cc. of water and filtered. The two filtrates obtained were combined and sterilized for use.

Bits of agar cultures of isolates Nos. 1041, 1042, and 355 were transferred to the green pea liquid medium and cultured for 10 days. The mycelia thus formed were taken out, washed, and transferred to hole glasses (33 mm. in diameter), each containing drops of sterile water with a small quantity of green pea liquid medium added. The mycelium of the fungus was studied under this condition after 1 week of incubation at 24°C., and was found that the oogonium was not formed by the 3 isolates used.

VIII. Control.

The character of the fungus would suggest the close relationship of pathogenicity to the formation of swarm spores; and in the field the disease is severe just after the rain. Orchards in wet areas should be avoided. It is highly important to keep the air in good circulation and to allow sufficient sunlight to reach each tree. The primary infection in the spring arises from the diseased fruits remaining on the ground. The fungus may be carried by air currents or more commonly during rainly period by water splashed up by rain drops on to healthy fruits and leaves. To avoid infection by the latter means it is highly important to keep the lower limbs well trimmed, leaving a sufficient distance between the soil and the plant parts. Bordeaux mixture (0.6% of cupper sulphate) sprayed in July also controls the disease quite effectively.

IX. Summary.

1. The present paper deals with the morphology, physiology, and pathogenicity of the fungus causing the fruit rot disease of fig. The observations and results of the experiment are given.

2. The causal fungus of the fruit rot of fig, commonly known as *Phytophthora Carica* (HARA) HORI, is referred as *Phytophthora palmivora* BUTLER, as has been suggested by workers in the United States of America.

3. According to the inoculation experiments, the fungus affects the fruit, leaves and young buds of fig, either with or without the accompaniment of artificial wounds, and also other fruits such as apple, Japanese pear, persimmon, eggplant, and tubers of potatoes.

4. The minimum temperature for the development of the fungus is 5 – 10°C.; the optimum, 27°C.; and the maximum, 32 – 33°C.

5. The conidia formed better when slight drying and movement of air accompanied the culture. The sexual stage of the fungus was not observed, even when cultured on LEONIAN's green pea decoction medium.

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Explanation of Plates.

Fig. 1. Fig branches with fruits, affected by *Phytophthora palmivora* BUTLER, showing the characteristic white lesions.

Fig. 2. Discolored lesions on Japanese pear (Nizziseiki) inoculated with *Phytophthora palmivora* BUTL. A result after 6 days' incubation.

Fig. 3. A and B, fruit rot of eggplant formed after inoculating with *Phytophthora palmivora* BUTL. and *Phytophthora Melongenae* SAW. respectively. A result after 4 days' incubation.

Fig. 4. Fig leaves affected by *Phytophthora palmivora* BUTL., showing the characteristic brown lesions.

Fig. 5. A fig branch with fruits, affected by *Phytophthora palmivora* BUTL., showing the characteristic white lesions.

Fig. 6. A and B, discolored lesions on cut surface of potato tubers inoculated with *Phytophthora palmivora* BUTL. and *Phytophthora Melongenae* SAW., respectively. A result after 4 days' incubation.

Fig. 7 – 11. Various forms of conidia of *Phytophthora palmivora* BUTL. produced on fig fruits. (×800)

Fig. 12 – 13. Germination of swarm spores within the conidium in *Phytophthora palmivora* BUTL. (×800)

Fig. 14. Germination of swarm spores of *Phytophthora palmivora* BUTL. after escaping from the mother conidium. (×800)

Fig. 15 – 16. Conidia of *Phytophthora palmivora* BUTL. formed on potato-glucose agar. (×800)

Fig. 17. Conidia of *Phytophthora Melongenae* SAW. (×800).

Fig. 18. Germination of swarm spores of *Phytophthora Melongenae* SAW. (×800)

Fig. 19. Germination of swarm spores of *Phytophthora Melongenae* SAW. after escaping from the mother conidium. (×800)

PLATE XXVIII.

Fig. 1.

Fig. 2.

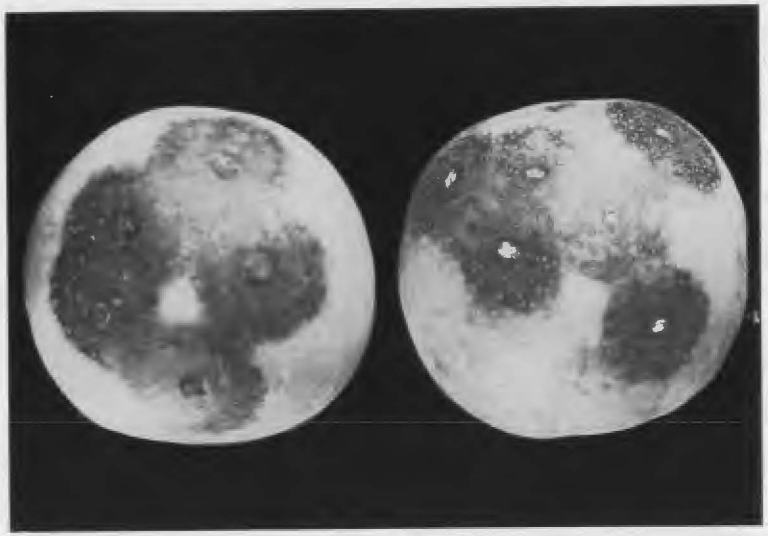

Fig. 3.

A B

PLATE XXIX.

Fig. 4.

Fig. 5.

Fig. 6.

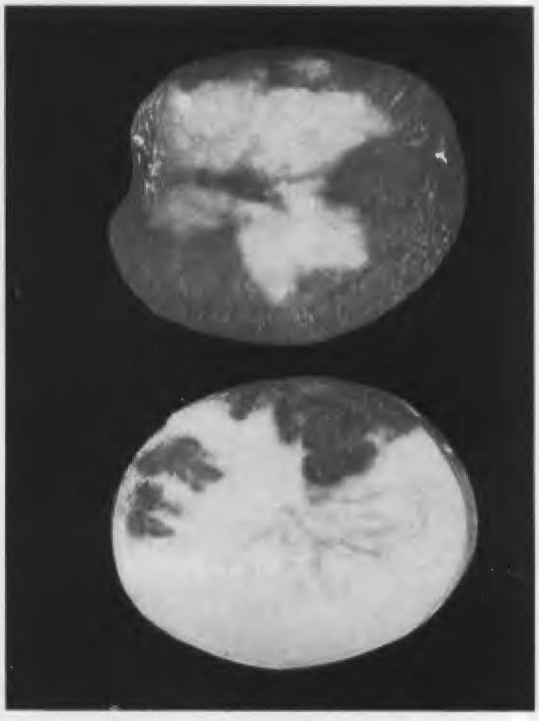

PLATE XXX.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

PLATE XXXI.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 17.

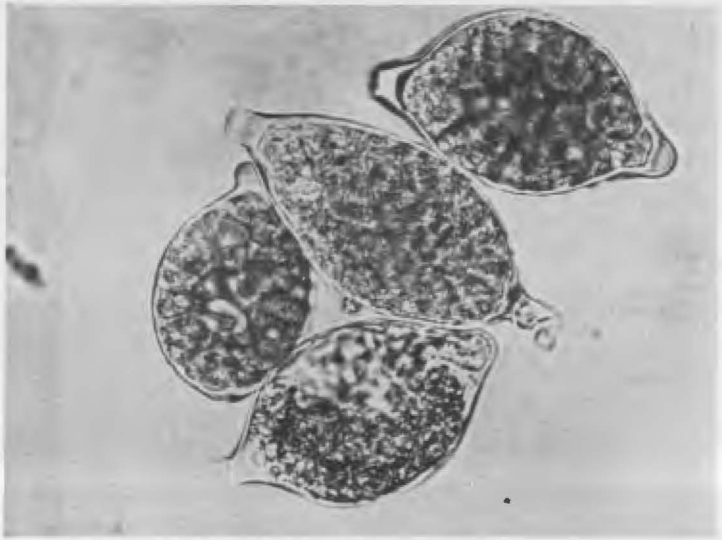

Fig. 18.

Fig. 19.