PHYTOPHTHORA PALMIVORA POD ROT OF CACAO IN PAPUA NEW GUINEA

INVESTIGATIONS 1962—1971

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ABSTRACT

New field infections of P. palmivora *on pods were always present at Keravat in New Britain and no regular high or low incidence seasons occurred during* 1962 *to* 1971. *Incidence was over* 20 *per cent in* 1955-56 *but less than* 3 *per cent in* 1962-65 *and between* 10 *per cent and* 20 *per cent in* 1969-71. *Average annual rainfall for these three periods were* 246, 277 *and* 289 *mm respectively. No adequate records of rainfall type (e.g., drizzle, squall) are available for the first two periods.*

On three occasions in 1963-65 *long distance (beyond* 20 *metres) dispersal, as previously reported from Nigeria, was evident, contrasting with the usual short distance (less than* 4 *m) spread. Control may therefore be directed more economically at individual trees.*

Some obviously susceptible clones have been recorded in the field but it is not clear whether the remainder are escapes or resistant ones.

PREVIOUS STUDIES

The pre-1962 level of incidence (sometimes 25 per cent, Thrower (1960) and van Velsen, unpublished) of *Phytophthora palmivora* pod rot (*Ppr*) on cocoa at Keravat warranted field trials on control of the disease. A trial based on spraying and frequent harvesting found effective overseas (Smith, 1955, Thorold, 1959) was conducted from July, 1962 to September 1965 and was reported by Hicks (1967). Although 3-weekly spraying with Bordeaux mixture resulted in statistically significant control, the practical significance of the results is limited by the low incidence of *Ppr* (4.9 per cent 3-weekly maximum in unsprayed pods over 12 cm long) in this block at that time. The frequent (i.e., weekly compared with the normal three weekly) harvest treatment was ineffective.

LACK OF SEASONAL INCIDENCE

At Agodi and Owena in Nigeria the disease tends to follow a similar course from year to year, less than 3 per cent of the year's *Ppr* being recorded in the January-June period and over 60 per cent in September-November (Thorold, 1955). In Ghana it is also quite seasonal (Lockwood, 1971). With such definite seasons spraying and sanitation can be effective even if applied for only four months of the year.

Monthly incidence from records taken at Keravat mainly for statistical purposes are shown in *Table* 1 for the cuttings of the very susceptible clone K26 during 1962-65 and in *Table* 2 for a mixture of open-pollinated progeny during 1967-71.

It will be noted from the data shown in *Tables* 1 and 2, that no month had consistently less than half the monthly average *Ppr* number for the respective year and each of the six months from November to April scored double the average at least once. Maximum numbers occurred at various times from October to April inclusive. The most consistent pattern is evident for the years 1967 and 1969-71 when June-September periods averaged 12 per cent (range 6 to 20) of their years' *Ppr* total and February to April 43 per cent (30-47).

No regular *Ppr* season is therefore apparent. For the same degree of control it therefore appears that direct spraying or sanitation would be necessary for most of the year at Keravat

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Table 1.—Monthly records of *Ppr* in pods and total number of pods over 12 cm long in K26 cacao cuttings (spacing-pruning trial, Block 708, Keravat)

	1962		1963		1964		1965	
	Ppr	Total	Ppr	Total	Ppr	Total	Ppr	Total
January			4	82*	139	571	152	423
February			f	f	58	149	31	246*
March			f	f	184	278	351	702
April			f	f	101	287	247	671
May			f	f	NA	NA		
June			f	f	NA	NA		
July			32	NA	82	362		
August			195	876	90	224		
September			381	2319	103	466		
October	96	723	336	2005	220	638		
November	78	1524	685	1847	209	734		
December	50	1628	1271	3441	164	547		
"Average"†			260		140			

* 1-3/1/63 and 1-18/2/65 only respectively

† Only where relevant to the text, taking totals of the five f's as 216 and the two NA's as 330, maximum probable sums.

f = Few

NA = Not Available

Table 2.—Monthly counts of *Ppr* in pods and total pods over 12 cm long in a 7/9 acre observation trial on seedling trees planted in 1948 in Block 405, Keravat

Month	1967		1968		1969		1970		1971	
	Ppr	Total	Ppr	Total	Ppr	Total	Ppr	Total	Ppr	Total
January	13	574	147	777	140	964	199	1347	53	636
February	34	415	130	895	165	1216	183	680	67	545
March	74	532			206	705	170	557	121	784
April	53	799			245	1328	62	407	141	692
May	22	838			117	1494	42	526	122	627
June	7	776			11	931	58	433	70	790
July	7	634			6	270	34	280	49	392
August	10	344			35	219	15	319	13	133
September	23	191			31	243	53	447	23	513
October	19	325			44	500	116	498	48	690
November	38	639			114	972	57	363	20	422*
December	44	480			293	534	43	646	28	386*
Average	29	547			117	781	86	542	63	551

* 0.6 of the area sprayed weekly with copper oxide from November 1971.

on blocks with high incidence, certainly for longer than the four months or less in Nigeria or Ghana.

LONG TERM INCIDENCE CHANGES

Estimates of the general incidence levels of *Ppr* in pods over 12 cm long at Keravat over much of the 1955-1971 interval are shown together with total rainfall in *Table* 3.

The results show that even taking full account of variation between estimates, it remains clear that incidence was much lower in the 1962-65 period than in 1955-56 and 1969-71. In 1962-65 only the K26 clone (*Table* 1) and a few others (between 0 and 3 according to various estimates) of 60 under observation had incidence of *Ppr* above 3 per cent.

Although Thrower (1960) and Hicks (unpublished details of the 1962-65 trial) at Keravat found strong positive correlations between *Ppr* incidence and total rainfall taking unit intervals of 30 days or less, the data from *Table* 3 show that some years of high incidence had about the same or lower rainfall than years of much lower incidence. It appears that some factor other than total rainfall is significant over these long periods. Temperature, atmospheric humidity and bright sunshine records have also been examined but none have indicated why incidence in 1962-65 was so low.

The author wonders whether there were more periods of extended drizzle (which are inadequately recorded on available pluviometers) in 1967-71 than in 1962-65. In future visual observations on these periods will be recorded with emphasis on determining the effect of duration rather than intensity of rain on the incidence of the disease.

DISPERSION

Thorold (1955) found gradients of both short (less than 4 m) and long (over 180 m) distance dispersion and asserted that these resulted respectively from rain splash and airborne (less frequent) dispersal of sporangia.

Materials

There were large, apparently uninfected, areas of young heavily bearing cacao at Keravat in 1962 (*Figure* 1).

The seed of the cocoa in Blocks 108, 309 and 2010 had been selected mainly on yielding ability of the parent (mother) trees, and planted in small plots at random with respect to resistance to *Ppr*. The cacao in Blocks 3010 and 708 had been planted as cuttings selected on the yielding ability of the parent trees, and sections of these blocks consisted largely of one clone of one grade of susceptibility, although over the whole block there were clones with a fairly continuous range of susceptibilities.

The spacing-pruning trial (two areas marked S in *Figure* 3) consisted of 20 small plots of trees of the KA5-104 clone, each surrounded and separated by single guard lines of trees of the very susceptible clone K26 which can be considered evenly distributed throughout this area. The remainder of Block 708 (Clone test series I-V) consisted of rectangular sections, each planted predominantly with a single clone (184 trees) with single six tree plots of nine other clones evenly spaced within it.

Table 3.—Rainfall and estimated *Phytophthora* pod rot incidence on cacao at Keravat

Period	Average Annual Rainfall (mm)	Estimated Average Incidence* (pods over 12 mm long)
1955-56	2460	Above 20%†
1959-61	3050	Between 5% and 25%‡
1962-65	2770	Below 3%
1967	3150	Between 3% and 10%
1969-71	2890	Between 10% and 20%

* After considering how the recorded level of incidence may vary according to observers, assessment methods, clones, shade, sanitation, spread and other factors, the author is 99 per cent confident that an estimate of average incidence for each period specified in column 1 would have been between the limits shown in column 3.

† Derived from Thrower (1960).

‡ Derived from van Velsen's figures (Hicks 1967).

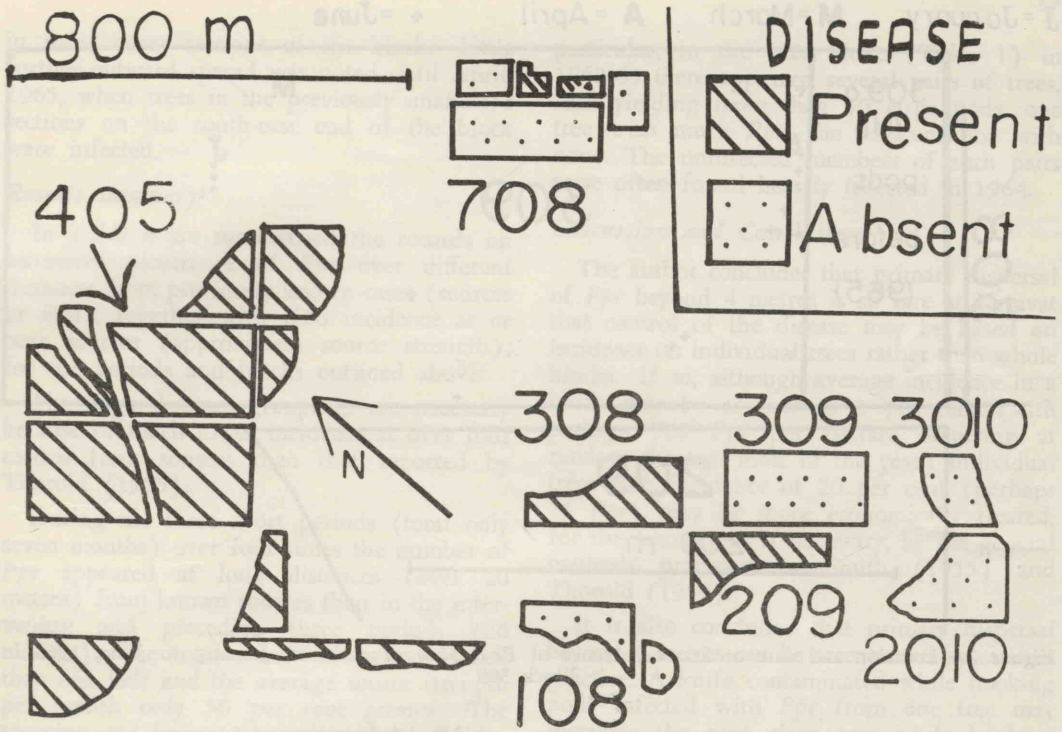

Figure 1.—Distribution of *Phytophthora* pod rot in bearing cacao at Keravat in 1962. Block 405, in the middle of a group of infected blocks, is arrowed

Observations

In order to observe the unassisted (i.e., from natural foci) spread of *Ppr*, all the trees in these areas were checked at least monthly and the presence of the disease recorded.

Some pods were maturing on the trees all the time, with ratios within clones usually less than 8:1 between the high and low month yields. Ratios as high as 3441:149 (23:1) as shown in *Table* 1, were rather unusual.

In the period October, 1962 to June, 1965 no *Ppr* was found in Block 3010. In Block 2010 three widely separate trees, each with one to three cases, were found in April, 1964, and two others in the succeeding 14 months.

In Block 108, three adjacent trees became infected between January and July, 1963. Newly infected trees were found at distances of 13, 14, 16, 16, 26 and 39 metres respectively from them in August, September and October of 1963. Observations were discontinued after a group of three trees at the end of the block over 100 metres from those previously affected, was found infected in April, 1964.

In Block 309 no *Ppr* was noted prior to January, 1965. The records from then on are shown in *Figure* 2. There was a marked increase in the number of infected trees in April, May and June, 1965 with many of the June infected trees within 20 metres of ones infected earlier.

The spread of *Ppr* through Block 708 is illustrated in *Figure* 3. Although it is apparent that the clones differed in susceptibility to *Ppr*, the sequence of epidemics in Block 708 is still fairly clear.

For the first three months from November, 1962 to January, 1963 *Ppr* in Block 708 was confined to small areas of the spacing-pruning trial only. All infected pods were harvested weekly and left on the ground. After January, 1963 counting was discontinued while incidence was very low, until July, 1963 when 32 cases were seen, all within the previously affected area. Thenceforth, only approximately 50 per cent of the infected pods in the block were removed at 3-weekly intervals. By 3rd October, 1963 cases were noted on trees scattered over the remainder of the spacing-pruning trial and

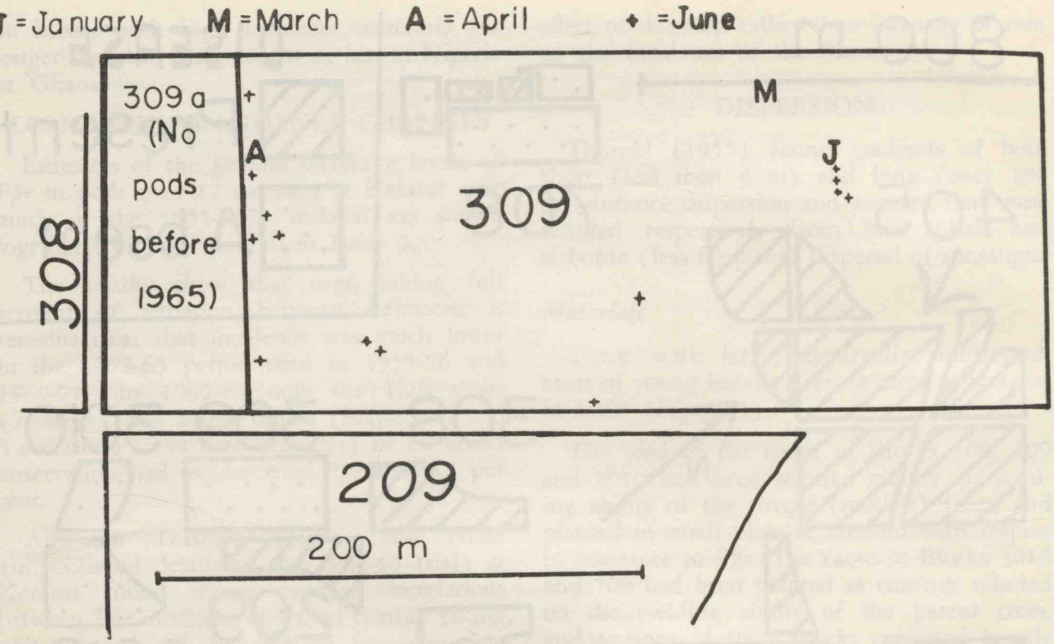

Figure 2.—Location and date of first occurrence of *Phytophthora* pod rot, January to June, 1965 in Block 309

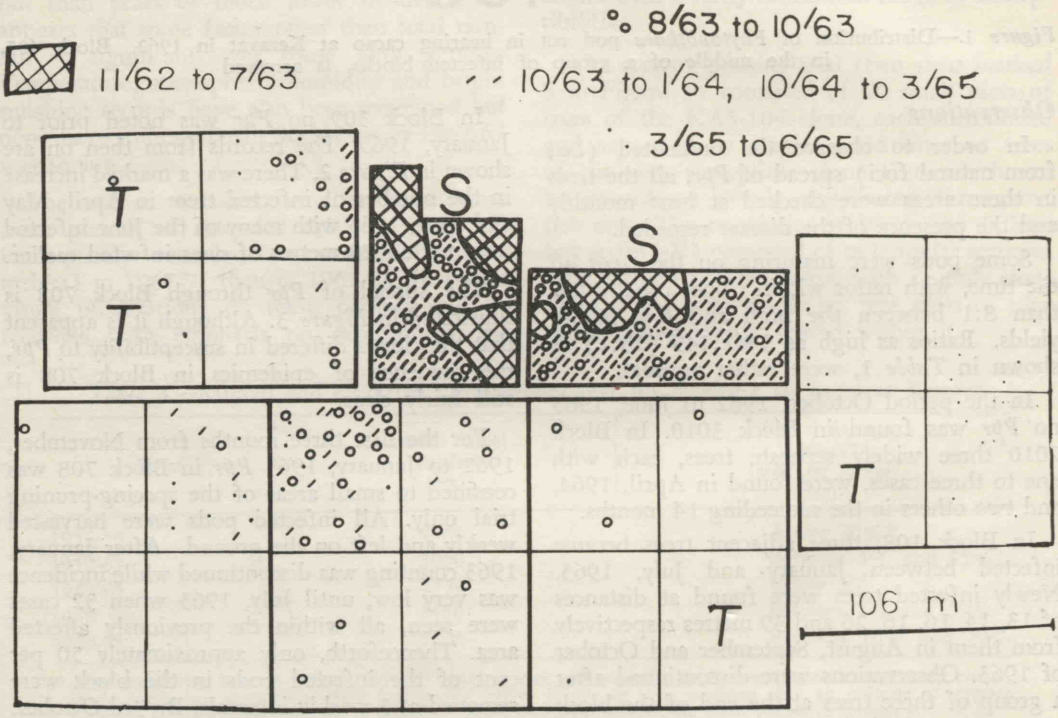

Figure 3.—Dates and location where *Phytophthora* pod rot was first seen in Block 708. Except for the spacing-pruning trial, S, symbols represent individual trees (T = few pods produced)

in some other sections of the block. Little further outward spread was noted until April, 1965, when trees in the previously unaffected sections on the south-east end of the block were infected.

Results summary

In *Table* 4 are summarised the records on successive occurrence of *Ppr* over different distances from previously known cases (sources or foci), together with K26 incidence at or near sources (approximate source strength), for the periods and blocks outlined above.

The large distance groupings are necessary because of much lower incidence at over four metres from sources than that reported by Thorold (1955).

During the three short periods (total only seven months) over four times the number of *Ppr* appeared at long distances (over 20 metres) from known sources than in the intervening and preceding three periods (26 months). The total source strength was less than one half and the average source strength per month only 50 per cent greater. The spraying and frequent harvesting trial (Hicks, 1967) records (unpublished) showed that conditions during the stated short periods would have favoured no more than an average of double the normal monthly incidence. Average numbers of large pods on the trees were also about the same for the two sets of periods.

Observations at Keravat generally show the relative absence of long distance dispersal with many cases of escape for over a year. In particular, in the K26 clone (*Table* 1) in 1962-63 there appeared several pairs of trees, each yielding more than 50 large pods, one tree with much *Ppr*, the adjacent one with none. The uninfected members of such pairs were often found heavily infected in 1964.

Discussion and Conclusions

The author concludes that primary dispersal of *Ppr* beyond 4 metres is so rare at Keravat that control of the disease may be based on incidence on individual trees rather than whole blocks. If so, although average incidence in a block may be as low as 3 per cent (with perhaps 700 *Ppr* per hectare occurring at random through most of the year) individual trees with incidence of 20 per cent (perhaps 25 *Ppr*) may be more economically treated, for the whole year if necessary, by the general methods proposed by Smith (1955) and Thorold (1959).

It is also concluded that primary dispersal beyond 4 metres can be accentuated by careless practice. A knife contaminated while hooking pods infected with *Ppr* from one tree may inoculate the next clean tree while hooking pods rotted from other causes.

Although Thorold (1953) published figures showing nonrandom distribution of *Ppr* neither his nor any other publication seen has emphasised individual trees as targets of control.

RESISTANCE

Thrower (1960) published results of field trials and laboratory tests in 1955-57 showing that pods from some cacao trees were more

Table 4.—Number of new *Ppr* cases recorded at intervals from cases recorded within six months previously (sources) October, 1962 to June, 1965. Numbers expected from source strengths (calculated from bottom line) are in parentheses, e.g., (80 + 49) × 1800/(1800 + 4300) = 38

Interval	Short Periods 8-10/63, 4/64, 4-6/65 (7 Months Total)	Remaining Periods (26 Months Total)	Significance (Chi squared contingency)
Over 20 m	55 (20)	13 (48)	Less than 0.001
4 m to 20 m	80 (38)	49 (91)	Less than 0.001
Less than 4 m (from Table 1 and unpublished records)	Less than 1800	More than 4300	—

resistant to *Ppr* than those from others. In particular, he classed K23-102 as very susceptible (between 40 and 100 per cent incidence in the field) and K5 as resistant (5-10 per cent).

Laboratory tests (unpublished) between 1962 and 1965 show some correlation with Thrower's results.

Because of low incidence the surveys on blocks of cuttings in 1962-67 revealed no significant resistance. A block of cuttings from the "very susceptible" K23-102 had been planted in 1958 in Block 708, separated by a 6-metre wide roadway from the clone K26 in the spacing-pruning trial (*Table* 1). It bore over 10,000 pods, none found infected, in the 1962-65 period, while trees of two other clones planted within the block were infected. The surviving mother tree in Block 405 yielded 832 pods, only one with *Ppr*, in the period January, 1967 to April, 1968 and January, 1969 to September, 1970. In 1971 when 11.4 per cent average infection was recorded in the Block 405 trial the K23-102 mother tree and cuttings from it continued to have less than 0.5 per cent *Ppr* while cuttings from the "resistant" K5 had over 10 per cent infection.

Surveys were resumed on blocks of cuttings in 1969. From December, 1969 to March, 1970 two or more plots each bearing over 100 pods were checked for each of eleven clones. The incidence ranges between plots for the clones were 5-54, 1-3, 4-10, 22-30, 0-1, 1-3, 1-4, 4-86, 11-46, 0-4 and 0-56 per cent. They were checked thereafter when the author expected an incidence maximum. The 4-10 and 1-4 clones changed the most to 31 and 44 respectively in April 1971. Variation between adjacent trees within plots was much higher showing further that even readings from blocks of cuttings for one year appear insufficient for assessing general resistance/susceptibility levels. Further readings are therefore necessary to classify any clone with consistently less than 20 per cent field infection as "resistant" but those with over 20 per cent field infection in some years may be classed as "susceptible".

The undisturbed pods on some cuttings have been sprayed with zoospore suspensions. Of those tested only the clone K82 has had low incidence both naturally and following such artificial inoculation.

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