F I N A L R E P O R T

Project Title : Path-III (299) Investigations on black pod and canker diseases of Cocoa (*Theobroma cacao* L.)

Project Leader: R.Chandra Mohanan

Associates: B.Ramanujam and P.Chowdappa

R. P. F. III

FINAL REPORT

1. Institute Code No. Path.III(299)

2. I. C. A. R. Code No. Pl-87/9-ICI-H20/2110

3. Name and Address of Research Institute/Centre:
Central Plantation Crops Research Institute
Regional Station,Vittal 574 243, Karnataka

4. Project Title: Investigations on black pod and canker diseases of cocoa (Theobroma cacao L.)

5. Name and Designation of Project Leader: R.Chandra Mohanan,Sr.Scientist

6. Name(s) and Designation(s) of Project Associates including Project Leader and work to be done:

Sl. No.	Name and Designation	Time spent (manmonths)	Work done
1.	R.Chandra Mohanan	43	1) Collection of Phytophthora isolates 2) Screening cocoa accessions 3) Fungicidal trial 4) Maintenance of cultures
2.	B.Ramanujam	13	Collection of samples, isolation of Phytophthora and maintenance of cultures.
3.	P.Chowdappa	31	1) Variability between and within Phytophthora species 2) Screening of Cocoa accessions 3) Maintenance of cultures

7. Location of Research Project with complete address (Division/Section/Sub-Centre)

CPCRI Regional Station, Vittal 574 243,Karnataka

8. Date of start July, 1987

9. Date of termination December, 1995

10. (a) Objectives (Not more than 150 words)

i) To find out the species of Phytophthora causing black pod disease and stem canker in the major cocoa growing regions and the variability within and between the species of Phytophthora

ii) To determine the relative virulence of different species/isolates of Phytophthora

iii) To screen the available cocoa accessions against Phytophthora species.

iv) To evolve suitable measures to manage black pod disease.

(b) Practical Utility including background information (Not more than 150 words)

In India black pod and canker are the major diseases of cocoa which cause considerable yield and plant losses. The incidence of black pod in Dakshina Kannada district of Karnataka was estimated as 20.32. per cent in 1986 (unpublished). In the recent years cocoa canker has been noticed as a serious problem causing heavy tree mortality in the cocoa gardens. The losses from these diseases vary from garden o garden and locality to locality. The above data show that the losses due to these Phytophthora diseases are very high and warrant detailed investigations specially from the control point of view.

Detailed investigations are in progress in several other cocoa gfowing countries on Phytophthora species pathogenic on cocoa and the range of variation within the species. For many years P.palmivora was donsidered to be solely responsible for Phytophthora diseases in cocoa, but later Brassier and Griffin(1979) Kellam and Zentmyer (1982) identified P.megakarya, P.capsici and P.citrophthora as major pathogens of cocoa.

In India cocoa is mainly grown as a mixed crop in the arecanut and coconut gardens. In some areas it has been found mixed cropped with younger rubber plantatio In Karnataka cocoa is also grown in the forest as forest plantation. Detailed studies on the pathogen of black pod and canker of cocoa occurring under different cropping systems will help to understand the involvement of different species/ strains of Phytophthora and the information on their relative virulence will be helpful in the investigations on resistance of cocoa, to these diseases. The use of resistant varieties is the most effective and economic means of controlling these diseases as along term measure. Therefore, it is important to screen available cultivars against Phytophthora spp. collected from the major cocoa growing areas of India, which will help in identifying tolerant/resistant cultivars.

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE

KASARAGOD-670 124, KERALA

R P F III

Project No. Path.III(299)

Date of Start: July.1987

1. Technical Programme:

1. Collection of isolates of Phytophthora spedies causing black pod and canker diseases of cocoa from major cocoa growing areas.

2. Studies on variability between and within Phytophthora species

3. Screening of cocoa accessions against Phytophthora infection

4. Screening of systemic and contact fungicides - In vitro screening and field trials using promising fungicides and cultural practices to control/manage the disease

FINAL REPORT

Investigations on black pod and canker diseases of cocoa (Theobroma cacao L.)

(R.Chandra Mohanan, B.Ramanujam and P.Chowdappa)

Objectives

1. To find out the species of Phytophthora causing black pod disease and stem canker in the major cocoa growing regions and the variability within and between the species of Phytophthora

2. To determine the relative virulence of different species/ isolates of Phytophthora

3. To screen the available cocoa accessions against Phytophthora species

4. To evolve suitable measures to manage black pod disease.

Materials and Methods

Collection of samples and isolation of causal organism:

Samples of cocoa pods and stem showing typical symptoms of black pod disease (bpd) and canker disease respectively were collected from the affected gardens in different localities in Kerala and Karnataka states. A total of 133 samples of infected pods were collected from both the states depending on disease incidence. Of these, 109 samples were collected from Kerala and 24 samples from Karnataka. A total of 28 samples of stem canker disease were collected. The incidence of stem canker was very rare.

The causal organism was isolated on carrot agar medium (CA) and maintained on CA slants by periodical subculturing.

Pathogenicity

Pathogenicity of the 133 isolates of the causal organism of bpd was tested by artificially inoculating detached cocoa pods of Forastero variety. Pathogenicity of 28 canker isolates were tested on 2-year-old cocoa plants.

Identification of causal organism

Cultural and morphological characters of all the fungal isolates were studied to identify the causal organism, to find out the extent of variability among the isolates and to group them based on the extent of similarity/variability. Carrot agar medium was used for

all the studies on cultural and morphological characters.

Compatibility types

The compatibility types of all Phytophthora isolates were determined by pairing each of them with P.palmivora A_1 and P.palmivora A_2. An isolate was considered A_1 mating type when it produced oospores with A_2 and not with A_1. Similarly, a culture was considered as A_2 mating type when it produced oospores with A_1 type and not with A_2.

Variability within and between species

A total of 11 isolates of Phytophthora spp. were selected for detailed studies on the extent of variability. There was no wide variation in cultural and morphological characters of P.palmivora isolates. Hence, only one isolate of P.palmivora was selected for detailed studies. All the five isolates of each species of P.capsici and P.citrophthora were included in the detailed studies on variability as the isolates of these two species were limited in number in the population of Phytophthora and subgroups within these two species have been reported from other cocoa growing countries.

Various characters such as colony characteristics, morphology of sporangium, chlamydospores, oogonia and oospores, repetative DNA polymorphisms, electrophoretic protein profiles, serological relationships and pathogenic variations of the selected 11 isolates were studied.

Colony morphology of the isolates was studied on CA medium. Sporangial characteristics were studied using solid-agar medium-plate method and mycelium-agar disc-in-water method (Al-Hedaithy and Tsao, 1979). Chlamydospore production of the 11 selected isolates was studied on CA and in submerged cultures.

Total DNA was extracted from vegetative mycelium of Phytophthora isolates and digested with restriction enzymes having hexanucleotide recognization sites such as Sal I and Hind III. It was then subjected to agarose gel electrophoresis. The ethidium bromide stained gels were examined under U.V. light. Similarity coefficients were calculated and phenograms generated from similarity coefficients using UPGMA cluster analysis.

Electrophoretic protein banding patterns of the 11 isolates were studied by polyacrylamide gel electrophoresis of soluble mycelial proteins.

Serological relationships of the isolates were also determined. Rabbit antisera were prepared against soluble antigens from vegetative mycelium of one isolate each of P.capsici and P.citrophthora. Antibody specificity was determined by comparing the reactivity with homologous and heterologous antigens prepared from mycelia of the 11 selected isolates.

Growth response of the selected Phytophthora isolates to various antibiotics and fungicides on CA in darkness was studied.

Pathogenic variability of the isolates and susceptibility of cocoa accessions to Phytophthora infection

Nearly mature, but unripe detached pods of 20 cocoa accessions were wound and surface inoculated with sporulating mycelial disks of 11 selected isolates of Phytophthora. Six replicate pods were maintained for each accession and each isolate. Lesion area was recorded.

Natural incidence of stem canker caused by P.palmivora in cocoa accessions introduced from Nigeria, Landas estate, Malaysia, Lalbagh, Bangalore (collections from Kew gardens) and cocoa bud wood nursery were recorded.

Field fungicidal trial against black pod disease (bpd)

Field fungicidal trials were conducted for 5 years to find out the effect of different treatments in the management of bpd. The treatments were 1) Bordeaux mixture (1%), 2) Mancozeb (0.23%), 3) Captafol (0.16%), 4) Fosetyl - Al (0.4%), 5) Ridomil-MZ (0.2%) 6) Copper oxychloride (0.3%), 7) Copper oxychloride (0.5%) - all at monthly interval and 8) Bordeaux mixture (1%) - at 15 days interval 9) Copper oxychloride (0.6%) at bimonthly interval, (10) cultural practices alone and 11) Control. Among the chemical treatments, Mancozeb, Captafol, Fosetyl-Al and Ridomil-MZ were tried only in the initial years. Later they were not included in the trial as they were not very effective and the results were not constant.

The fungicides were sprayed to the cocoa pods on the main stem and branches. The diseased pods in all treatments except control were removed at 15-day-interval. The plants in the treatment - cultural practices were not sprayed with any fungicides, but diseased pods were removed as in the case of other treatments.

The disease incidence on Cherelles, young pods and mature pods was separately recorded at 15-day-interval. The per cent disease incidence was calculated from the number of pods infected out of the total number of pods observed at 15-day-interval.

Results and discussion

Isolation and identification of causal organisms of black pod and canker diseases

Isolation of causal organisms from infected pods yielded 130 isolates of Phytophthora species and three isolates of Pythium vexans de Bary. Isolations from all the 28 samples of stem canker yielded Phytophthora species. Pathogenicity of all isolates of Phytophthora species (158) and P.vexans isolates was established. Symptoms of Pythium pod rot was similar to that of bpd. This is the first report of natural incidence of Pythium pod rot of cocoa.

Based on cultural and morphological characteristics of Phytophthora isolates associated with bpd, 120 isolates were identified as P.palmivora, five as Phytophthora capsici and five as Phytophthora citrophthora. This is the first report of natural incidence of black pod disease caused by P.capsici and P.citrophthora in India.

Of the 120 isolates of P.palmivora, 22 were identified as A_1 and 98 as A_2 compatibility types. Out of the five isolates of P.capsici, four were identified as A_1 and one as A_2 compatibility types. P.citrophthora isolates were found to be sexually sterile. Phytophthora isolates associated with stem canker were identified as P.palmivora - A_2. The size of oognia and oospores of P.palmivora and P.capsici did not vary much indicating this character has little diagnostic value in separating these two species.

Variability within and between species

It was possible to distinguish P.palmivora, P.capsici and P.citrophthora based on colony pattern on CA. P.palmivora produced smooth combed colony while P.capsici isolates exhibited pataloid pattern of growth. But, P.citrophthora isolates produced colonies with no distinct pattern of growth. (Fig.1 & 2) Rate of growth of the isolates on CA varied between and within the species .

(Colony diameter in mm (3 days after inoculation): P.palmivora - 40.66; P.capsici isolates 54.33 to 63.66; P.citrophthora isolates - 52.33 to 54.66)

Sporangia of P.palmivora were formed in sympodial arrangement. The formation of sporangia of P.capsici isolates was in typical umbellate pattern (Fig.3). There was no definite pattern in the formation of sporangia of P.citrophthora. Sporangia of P.palmivora and P.capsici were caducous whereas that of P.citrophthora were persistent. Thus, P.citrophthora could be readily separated from other two species. Sporangia of P.palmivora had broad, short and occluded pedicels whereas sporangia of P.capsici were shed with long and thin pedicels indicating pedicel length as the most important character in distinguishing these two species. When P.palmivora was grown on CA and sporangia produced usingsolid-agar medium-plate

method, the mean pedicel length was 2.90 µm. The mean pedicel length of 5 isolates of P.capsici was 75.4 µm (range 58-90 µm). There was marked variation in sporangial pedicel length within and among different isolates of P.capsici.

Shape, size and length:breadth ratio (L/B ratio) of sporangia were also found to be important characters in differentiating the three species. Sporangia of P.palmivora were ovoid to ellipsoid with rounded base (Fig.4) whereas majority of sporangia of P.capsici were ellipsoidal with tapered base (Fig.5). Sporangia of P.citrophthora were highly variable in shape and often exhibited various distorted shapes (Fig.6). Mean L/B ratio of sporangia of P.palmivora, P.capsici and P.citrophthora on CA were 1.5, 1.8 and 1.7, respectively.

P.palmivora produced chlamydospores readily and abundantly both on CA and on submerged mycelial mats whereas 5 isolates of P.citrophthora and four isolates of P.capsici did not produce chlamydospores either on agar cultures or submerged mycelial mats. However, one isolate of P.capsici produced chlamydospores on submerged mycelial mats.

When total DNA of 11 selected isolates of Phytophthora was digested with restriction enzymes having hexanucleotide recognization sites and subjected to agarose gel electrophoresis, isolates within a species could be identified qualitatively by visual similarity in banding patterns, quantitatively by calculating similarity coefficients and by phenograms generated from similarity coefficients (Fig.7 & 8). Thus the results indicated that DNA polymorphisms were characteristic only at the species level.

Polyacrylamide gel electrophoresis of soluble mycelial proteins provided a reproducible and sensitive finger print for P.palmivora, P.capsici and P.citrophthora (Fig.9). The three species exhibited distinct protein banding patterns. Isolates within P.capsici exhibited largely homogenous banding patterns whereas the five isolates of P.citrophthora showed two recognizable protein banding patterns. Therefore, two electrophoretic groups were identified within P.citrophthora (Fig.10).

The three species of Phytophthora showed distinct serological differences. The five isolates of P.capsici formed two distinct serological groups whereas isolates of P.citrophthora formed a single serological group. P.palmivora was serologically different from P.capsici and P.citrophthora isolates.

Two distinct subgroups among the isolates of P.capsici and P.citrophthora could be distinguished based on their response to antibiotics viz., tetracycline hydrochloride, oxytetracycline hydrochloride, chloramphenicol and streptomycin. Two distinct subgroups within isolates of P.citrophthora were also identified based on their response to fungicides viz., metalaxyl, phosphorus acid and dimethomorph. But there was no much variation among isolates of P.capsici in response to fungicides tested so as to classify them into different groups.

Pathogenic variability

P.palmivora was found to be highly virulent compared to the other two species. Two phenotypic groups were distinguished within each species of P.capsici and P.citrophthora on the basis of lesion size dendrograms.

Screening of cocoa accessions against bpd

The cocoa accessions exhibited marked variation in the degree of resistance to P.palmivora, P.capsici and P.citrophthora (Table 1, Fig.11, Table 2 & 3). The cocoa accession C_{44} (NC 51) was found to be highly tolerant to all the three species of Phytophthora whereas Landas 364 was highly susceptible.

Natural incidence of stem canker

Natural incidence of stem canker was observed in the following accessions.

I. Nigerian collections

Sl.No.	Accession No./tree No.	Genotype
1.	NC30/89	P3/P4
2.	NC31/110	P12/P2
3.	NC39/118	T_7/12

II. Cocoa bud wood nursery

Sl.No.	Accession (Genotype)
1.	T12/613/972 Amazon Sea
2.	WBE 6/830 Wari series IIK
3.	Gii 11/4
4.	ICS 95
5.	IMC 67
6.	ICS1
7.	Na33

III. Germplasm introduced from Landas Estate, Malaysia

Sl.No.	Accessions	Tree No.
1.	Pa7 x Na32	4,12,25,102, 111
2.	Jarangan Amel x Pa7	113
3.	Jarangan Amel x Na32	109
4.	Landas 361	94, 110
5.	Landas 358	15,48,76,108,83
6.	Landas 357	91
7.	Landas 356	6,51
8.	Landas 364	18

Black pod disease management

Spraying of Bordeaux mixture (1%) at 15-days interval, Bordeaux mixture (1%) and Copper oxychloride (0.3%) at monthly intervals and copper oxychloride (0.6%) at 2 months interval to the pods along with removal and destruction of infected pods at 15 days interval during the south-west monsoon season were found to be very effective treatments in bpd management. The Ist spray should be given immediately after the pre-monsoon showers. Spraying of Bordeaux mixture (1%) at 15 days interval along with removal and destruction of infected pods was found to be superior to all other treatments.

Proper pruning of cocoa plants and removal and destruction of infected pods at 15 days interval during rainy season without any fungicide spray reduced the disease incidence to 50% compared to control plots. The results of the trials also revealed that in areas with low disease intensity, effective management of bpd can be achieved by proper pruning of cocoa plants and removal and destruction of infected pods at frequent intervals without any fungicide spray.

Conclusions:

1. The investigations on the present status of cocoa *Phytophthora* revealed *P.palmivora*, *P.capsici* and *P.citrophthora* as the causal organisms of bpd in India. This is the first report of natural incidence of bpd caused by *P.capsici* and *P.citrophthora*.

2. *P.palmivora* was found to be the dominant species causing bpd in all cocoa growing areas of Kerala and Karnataka states. Bpd caused by *P.capsici* and *P.citrophthora* was found only in Kerala.

3. Incidence of stem canker was rare. *P.palmivora* was found to be the only species causing stem canker at present.

4. A_1 and A_2 compatibility types were found in the population of *P.palmivora* and *P.capsici*. A_2 compatibility type was predominant in the population of *P.palmivora* whereas A_1 was predominant in *P.capsici*. *P.citrophthora* isolates were found to be sexually sterile.

5. Pod rot caused by *Pythium vexans* was also recorded. Pythium pod rot has not been reported so far from any of the cocoa growing countries.

6. *P.palmivora*, *P.capsici* and *P.citrophthora* exhibited marked variability in cultural, morphological and pathogenic characters, protein profiles, repetitive DNA polymorphism, serological reaction and growth response to fungicides and antibiotics. Two distinct subgroups within *P.capsici* and *P.citrophthora* were identified based on variability between the isolates.

7. The cocoa accession C_{44} was found to be highly tolerant to all the three species of Phytophthora whereas Landas 364 was highly susceptible. In future screening programmes of cocoa accessions the three species of Phytophthora and also representative isolates of subgroups within a species may be included.

8. Effective management of bpd can be achieved by spraying Bordeaux mixture or Copper oxychloride to pods along with removal and destruction of infected pods at frequent intervals.

9. Considering the relative virulence of P.capsici and P.citrophthora in other cocoa growing countries, it may be expected that these two species may become potential pathogens of cocoa and cause severe epidemic in future although, at present, P.palmivora is the predominant species causing bpd of cocoa in India.

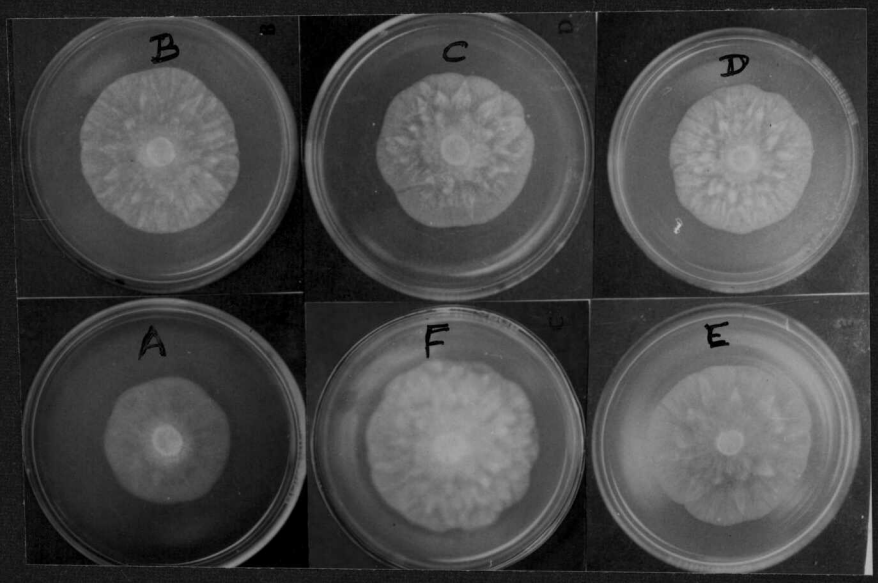

Fig.1. Cultures of P.palmivora (A) and P.capsici isolates (B-F) grown on carrot agar in dark.

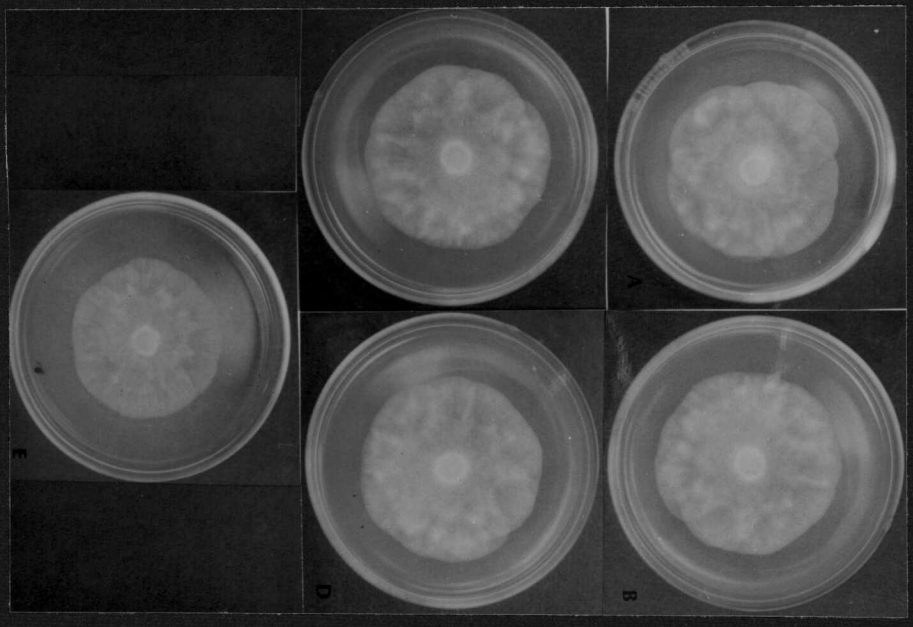

Fig.2. Cultures of P.citrophthora isolates grown on carrot agar in dark.

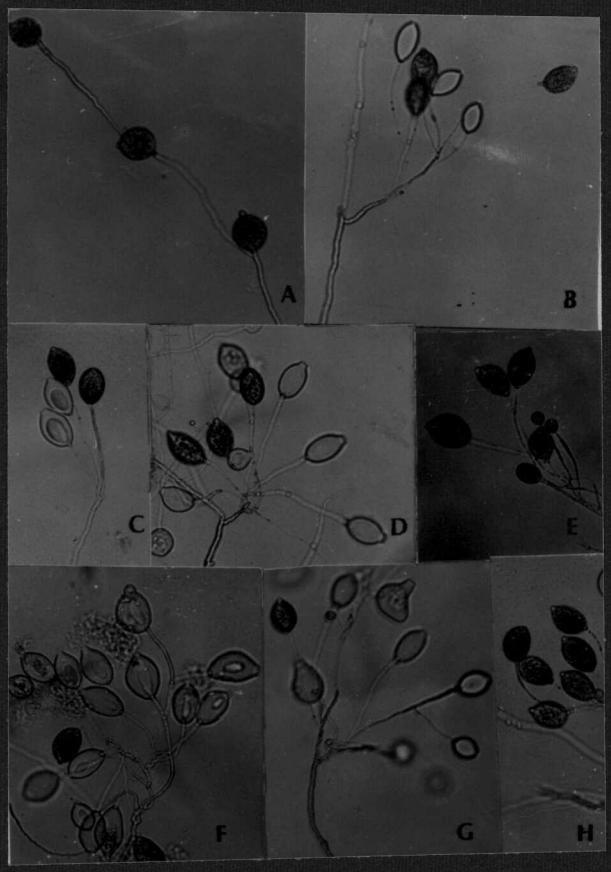

Fig.3. Sporangial ontogeny: Sympodial arrangement in P.palmivora (A) and umbellate arrangement in P.capsici(B-H)

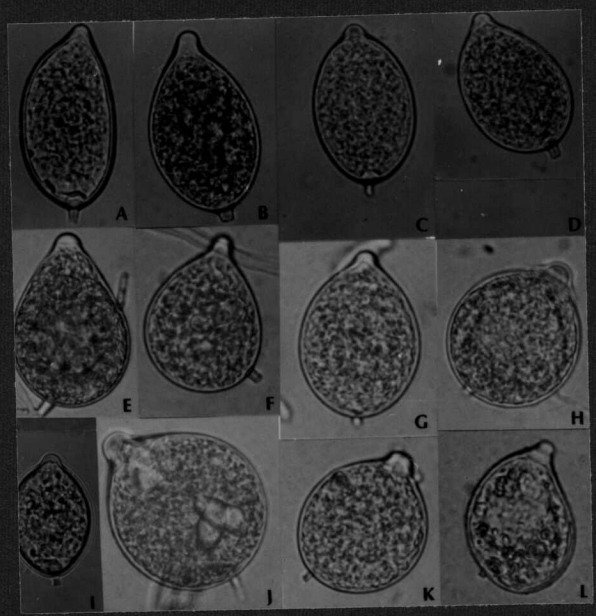

Fig.4. Sporangia of P.palmivora

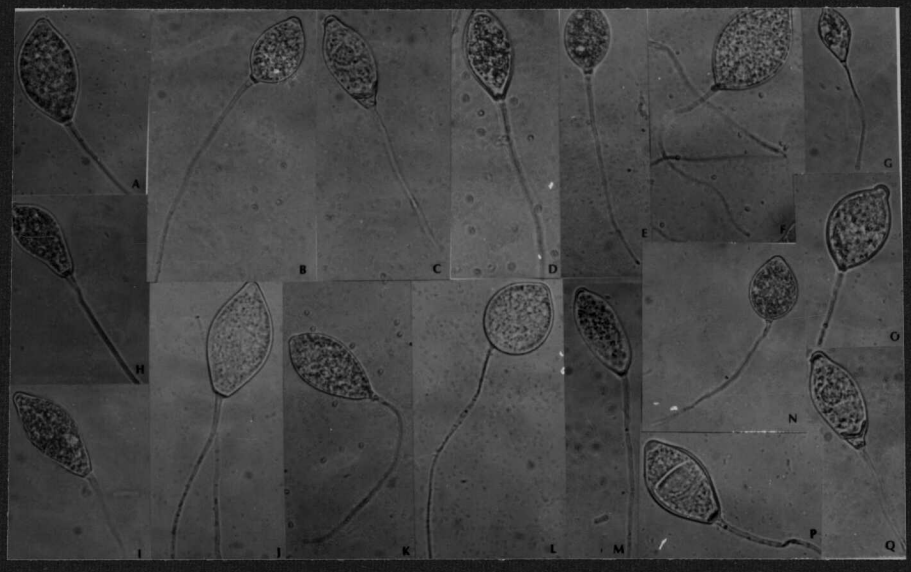

Fig.5. Sporangia of P.capsici isolates

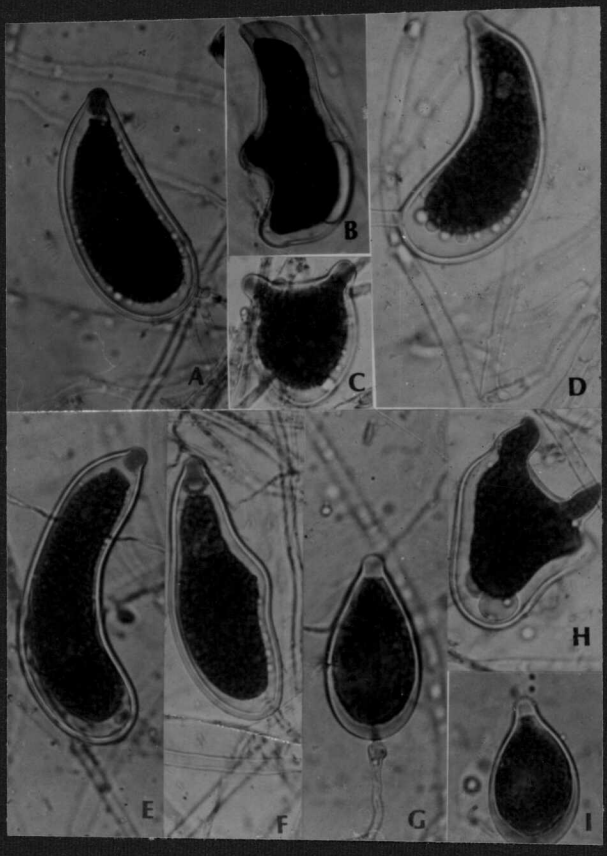

Fig.6. Sporangia of P.citrophthora isolates

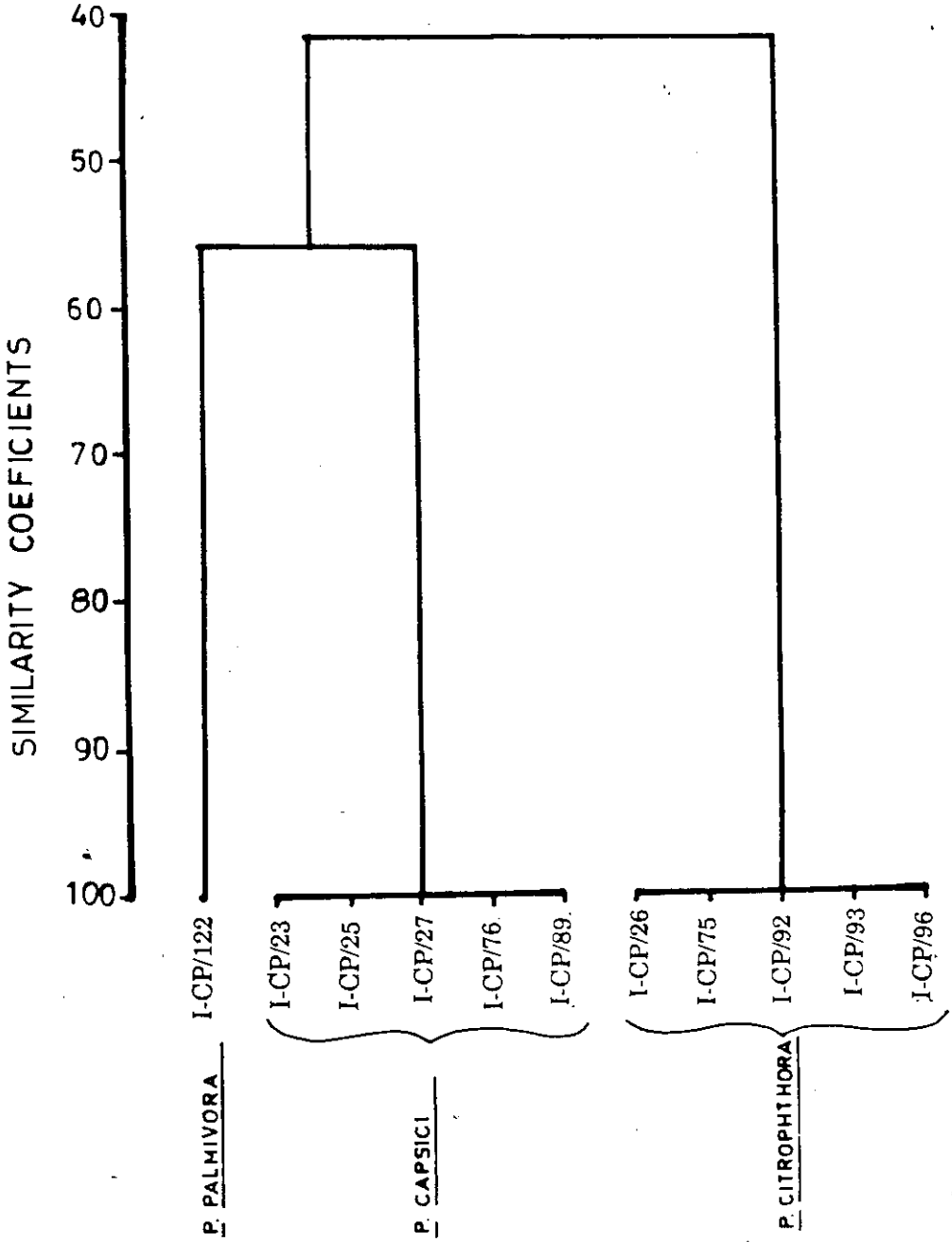

Fig. 7. A UPGMA cluster analysis of three *Phytophthora* species based on similarity coefficients calculated from the electrophoretic patterns of total DNA digested with restriction enzyme, Sal I.

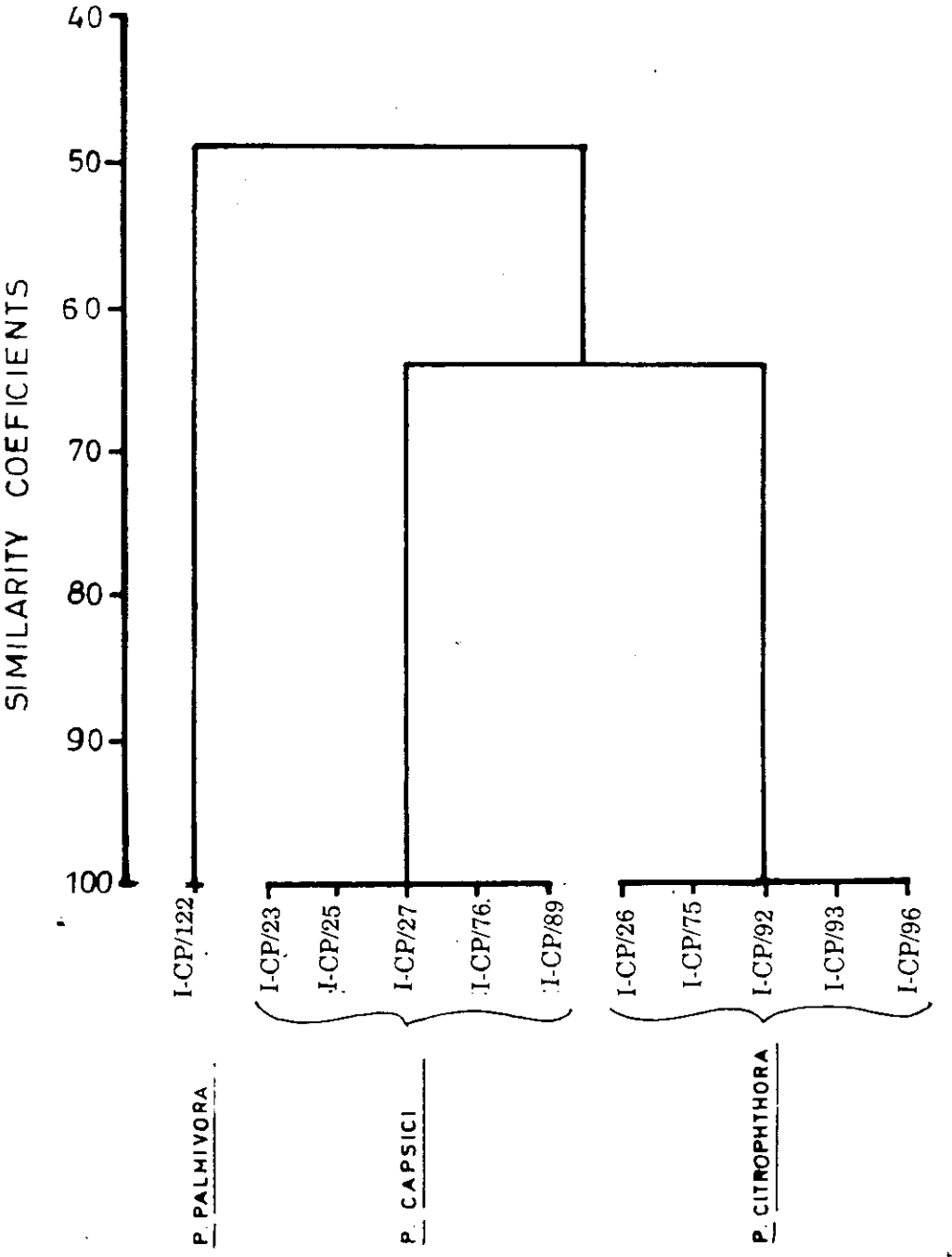

Fig. 8. A UPGMA cluster analysis of three *Phytophthora* species based on similarity coefficients calculated from the electrophoretic patterns of total DNA digested with restriction enzyme, Hind III.

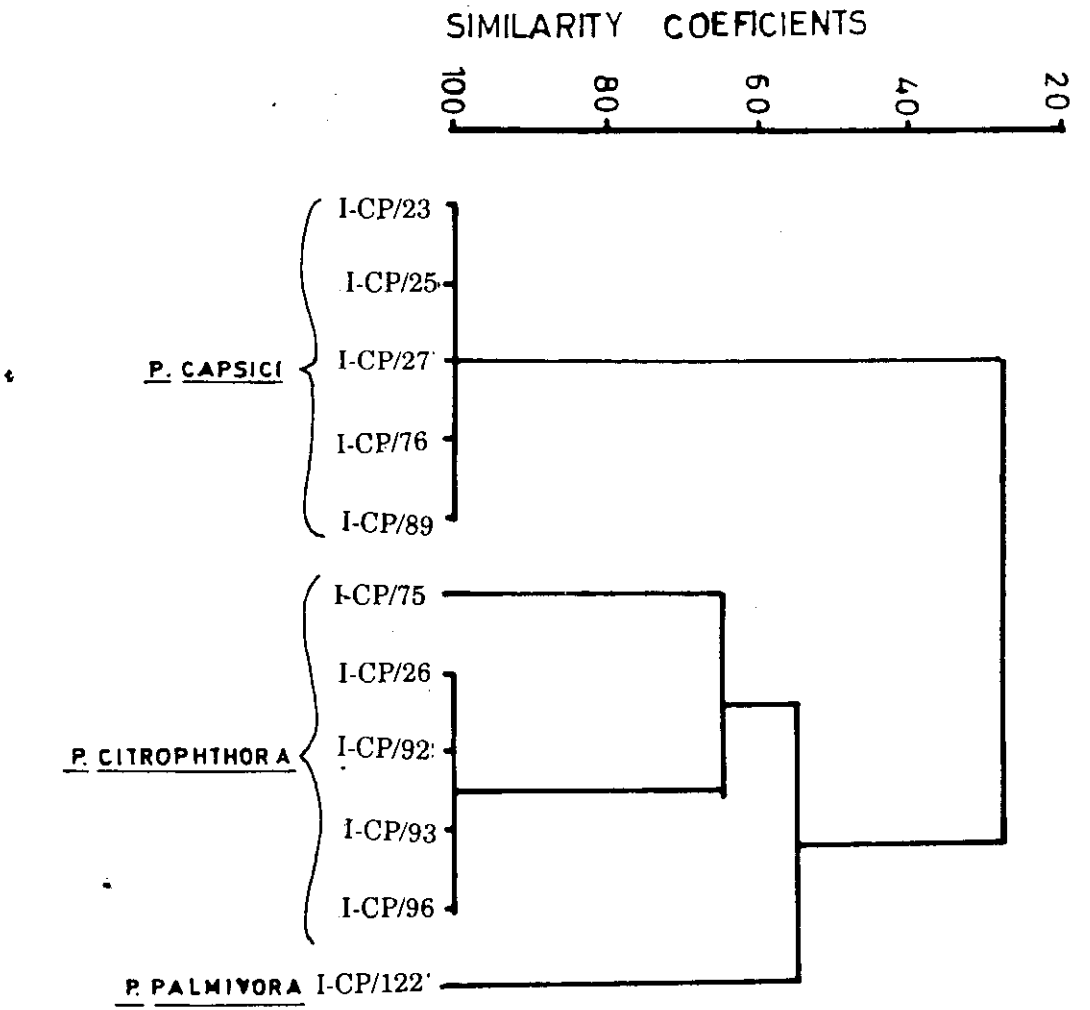

Fig. 9. A UPGMA cluster analysis of three *Phytophthora* species based on similarity coefficients calculated from the electrophoretic patterns of total proteins.

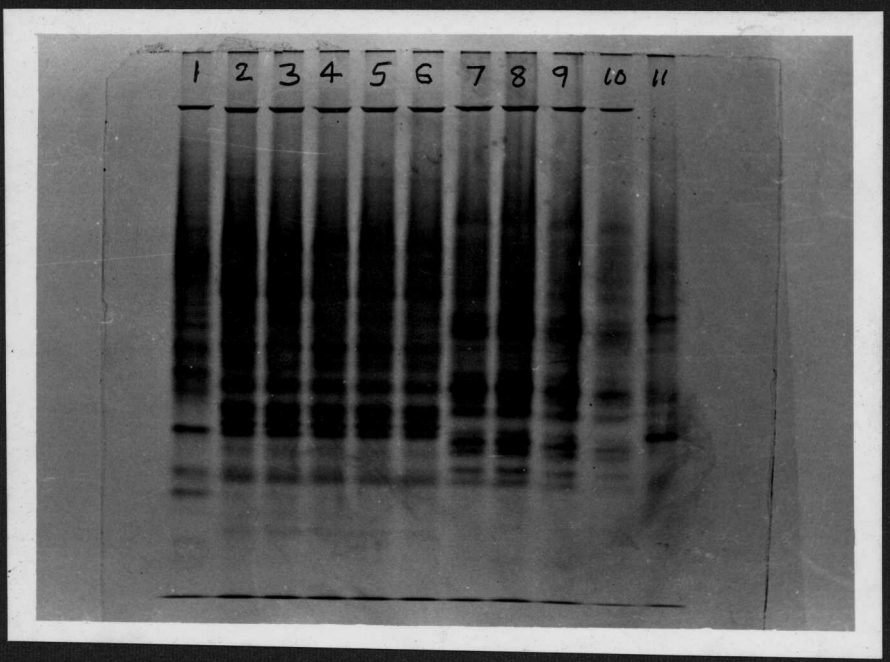

Fig.10. Polyacrylamide gel electrophoresis of native proteins of *P.palmivora*, *P.capsici* isolates (2, 3, 4, 5, 6) and *P.citrophthora* isolates (7, 8, 9, 10, 11)

Table 1. Inoculation of detached pods of 20 cocoa accessions with mycelial disk of *P. palmivora*

Cocoa accessions	*Lesion area (cm^2) seven days after inoculation		Mycelial index[a] on wound inoculated pods	No. of sporangial[b] on wound inoculated pods
	Wound inoculation	Surface inoculation (Unwound inoculation)		
Redaxil	102.13	79.32	2.23	4.03
Landas 364	237.66	69.42	2.27	4.14
Landas 356	150.71	53.00	2.23	4.22
Landas 358	171.06	85.39	2.23	4.21
Landas 365	142.89	36.44	2.23	4.15
Jarangan Amel x Pa_7	126.77	58.38	2.23	4.17
Jarangan Amel x Na_{32}	105.20	67.64	2.23	4.21
Jarangan Pa7 x Na_{37}	142.13	132.65	1.91	4.12
Pa_7 x Na_{32}	182.93	60.48	2.07	4.11
Amel x Na_{33}	162.42	33.51	2.15	4.16
Amel x Na_{32}	177.45	85.65	2.08	4.13
W6 56 (T63)910	143.60	81.57	1.73	3.42
T86 2	134.94	96.43	1.41	3.25
P6 x P4	147.59	70.04	1.73	3.65
T7/12	115.21	24.43	1.00	3.60
P1 x P7	122.13	52.28	1.73	3.50
T85-5 x Na_{32}	113.10	58.83	1.13	3.00
P7 x P6	87.03	63.52	2.27	3.97
C79	182.55	11.44	1.27	3.39
C44	71.92	3.46	1.00	3.47

CD(P = 0.05) : Lesion size on wounded cocoa pods = 25.35

Lesion size on unwounded cocoa pods = 19.93

Mycelial index = 0.76

No. of sporangia = 0.14

* Mean of six replications

a) Data transformed into square root transformation before analysis

b) Data transformed into logarithmic transformation before analysis

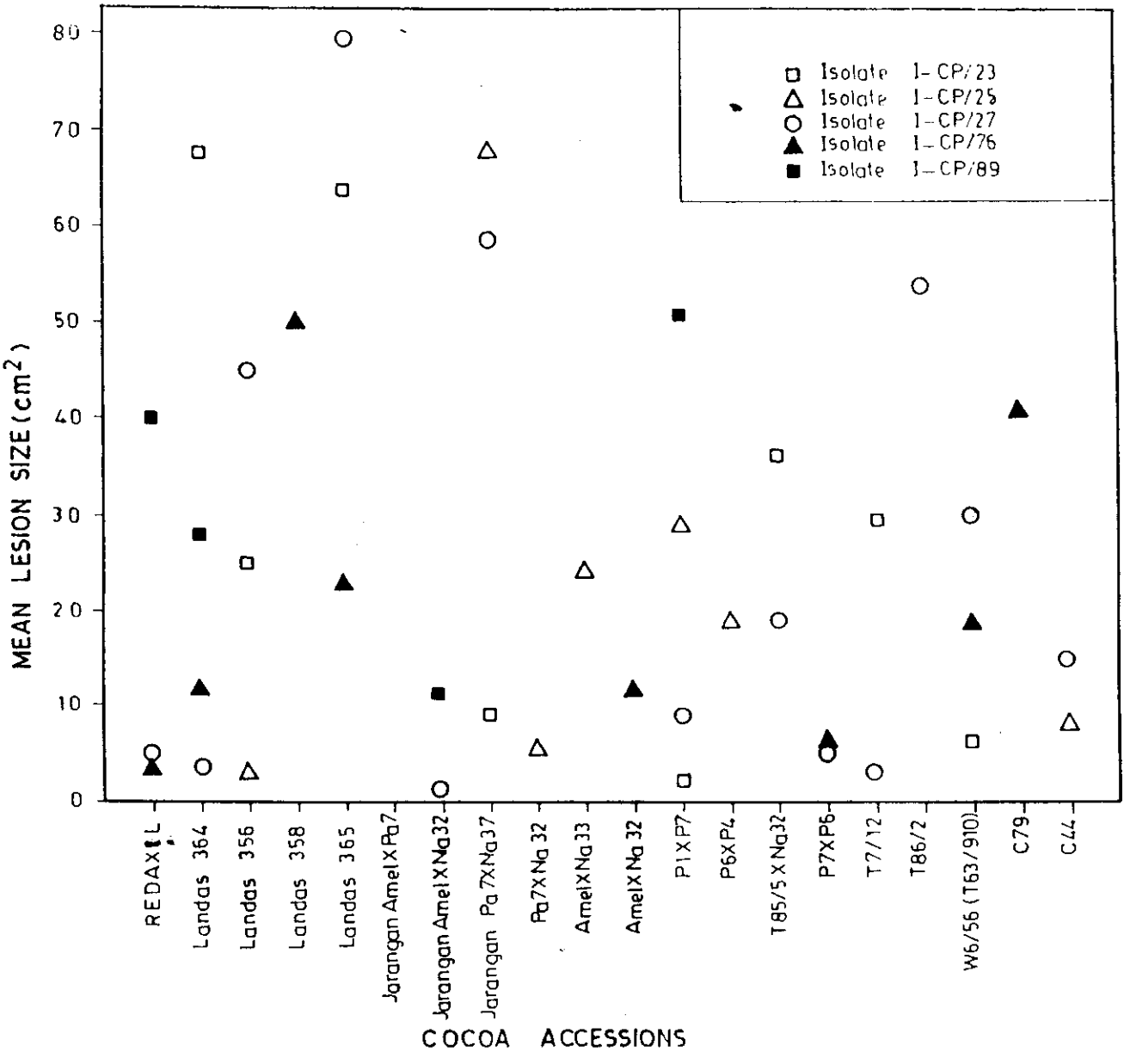

Fig.11. Lesion area (cm^2) on unwounded pods of 20 cocoa accessions inoculated with five isolates of *P. capsici*.

Table 2. Wound inoculation of detached pods of 20 cocoa accessions with mycelial disk of five isolates of *P. capsici*

Sl. No.	Cocoa accessions	*Lesion area (cm^2) seven days after inoculation					Accession mean
		P. capsici isolates					
		I-CP/23	I-CP/25	I-CP/27	I-CP/76	I-CP/89	
1.	Redaxil	66.09	60.07	58.30	80.65	82.88	69.60
2.	Landas 364	109.88	74.01	27.99	99.88	101.02	82.54
3.	Landas 356	193.06	217.78	181.60	207.08	238.75	207.65
4.	Landas 358	159.07	153.20	145.20	138.58	117.34	142.68
5.	Landas 365	79.20	187.54	186.74	174.69	51.48	135.93
6.	Jarangan Amel x Pa_7	136.26	123.63	119.40	122.18	0.54	100.40
7.	Jarangan Amel x Na_{32}	129.12	125.65	138.86	153.78	23.67	114,22
8.	Jarangan Pa7 x Na_{37}	145.28	125.96	155.59	163.12	37.98	125.58
9.	Pa_7 x Na_{32}	187.05	169.96	144.30	192.92	53.40	149.52
10.	Amel x Na_{33}	170.89	177.16	191.94	190.64	147.80	175.68
11.	Amel x Na_{32}	155.19	168.70	148.69	165.97	160.78	159.86
12.	W6/56 (T63)910	147.00	164.16	175.11	144.34	185.83	163.29
13.	T86/2	157.55	163.93	155.10	153.96	108.09	147.92
14.	P6 x P4	82.70	133.33	134.18	67.57	56.68	94.89
15.	T7/12	100.21	122.70	146.83	100.94	107.30	115.60
16.	P1 x P7	121.23	130.05	132.25	114.06	118.10	123.14
17.	T85/5 x Na_{32}	145.35	131.46	114.93	131.76	78.92	120.44
18.	P7 x P6	149.80	116.37	141.83	123.84	109.71	128.31
19.	C79	129.81	103.13	127.51	112.64	113.77	117.37
20.	C44	97.00	91.62	105.25	94.41	86.55	94.96
Isolate mean		133.09	137.07	136.58	136.64	99.02	-

CD(P = 0.05) : Accessions = 16.69
Isolates = 8.34
Accessions x isolates = 37.33

Table 3. Inoculation of detached pods of 20 cocoa accessions with mycelial disk of *P. citrophthora* isolates

Cocoa accession	*Lesion area (cm^2) seven days after inoculation											
	Wound inoculation					Accession mean	Unwound inoculation					Accession mean
	I-CP/26	I-CP/75	I-CP/92	I-CP/93	I-CP/96		I-CP/26	I-CP/75	I-CP/92	I-CP/93	I-CP/96	
Redaxil'	96.79	103.49	119.52	94.44	87.58	100.36	17.39	19.58	62.60	53.40	20.80	34.75
Landas 364	221.03	185.20	247.72	241.93	224.37	224.05	38.22	61.85	96.09	77.39	81.84	71.09
Landas 356	182.69	213.58	227.78	164.99	171.73	192.15	33.11	30.95	63.72	30.32	11.09	33.84
Landas 358	183.49	115.40	160.77	164.17	123.79	149.52	118.58	77.14	99.65	53.75	49.78	79.78
Landas 365	166.55	203.16	174.14	183.50	142.99	173.67	55.95	16.43	46.84	45.91	51.10	43.24
Jarangan Amel x Pa_7	136.54	129.98	154.76	130.51	113.36	133.03	39.30	52.59	42.80	21.42	0.00	31.22
Jarangan Amel x Na_{32}	133.61	142.41	169.89	126.56	140.82	142.65	29.34	63.46	106.40	56.80	47.71	60.74
Jarangan Pa7 x Na_{37}	158.87	138.85	150.46	134.16	153.61	147.19	93.52	60.94	89.09	0.00	83.05	65.32
Pa7 x Na_{32}	176.22	156.93	180.65	197.60	174.42	177.16	24.50	58.46	20.21	47.57	48.19	39.78
Amel x Na_{33}	178.52	201.71	166.51	147.21	176.44	173.88	41.18	37.12	56.07	28.91	54.33	43.56
Amel x Na_{32}	157.13	138.90	171.41	173.44	157.79	159.73	47.76	36.61	57.80	39.76	40.69	44.52
W6/56 (T63)910	141.88	134.53	170.59	146.61	134.84	145.69	54.20	47.06	38.42	15.52	22.13	35.47
T86/2	140.68	165.86	121.43	124.88	104.29	131.43	9.99	8.45	89.68	67.99	26.23	40.47
P6 x P4	110.77	119.03	136.57	83.08	97.31	109.35	14.92	24.70	40.30	28.98	16.23	25.03
T7/12	104.56	130.06	149.34	126.54	155.14	133.13	12.17	21.36	34.81	17.02	10.68	19.21
P1 x P7	104.89	99.84	140.57	120.02	123.21	99.84	28.70	49.86	27.03	37.70	33.63	35.38
T85/5 x Na_{32}	110.28	135.63	126.42	127.90	127.31	125.51	15.80	42.92	25.66	20.87	21.18	25.28
P7 x P6	121.82	118.16	150.50	120.46	121.87	126.56	27.43	56.24	41.09	18.59	14.11	31.49
C79	125.43	113.78	185.85	107.87	144.28	135.44	40.08	32.32	0.00	8.90	0.00	16.26
C44	79.22	84.40	82.85	81.50	68.92	71.38	11.65	17.66	6.12	9.27	4.84	9.91
Isolate mean	141.55	141.58	157.34	139.77	137.20	-	38.18	40.30	52.22	34.00	31.89	-

Wound inoculation

CD(P = 0.05) : Accessions = 12.43
Isolates = 6.21
Accessions x Isolates = 27.61

Unwound inoculation

CD(P = 0.05) : Accessions = 13.01
Isolates = 6.50
Accessions x Isolates = 29.09

* Mean of six replications

PUBLICATIONS

Research papers

1. Chowdappa,P., Chandra Mohanan, R. and Ramanujam,B.(1993). Occurrence of *Phytophthora capsici* on cocoa in Kerala. *Indian Phytopath.* 46: 92-93.

2. Chowdappa,P., and Chandra Mohanan,R (1993). *Pythium vexans* from cocoa. *Indian Phytopath.* 46: 261.

3. Chowdappa,P. and Chandra Mohanan,R. 1993. Morphological variability among isolates of *Phytophthora palmivora* causing black pod disease of cocoa in India. *J.Plant. Crops* (Supplement) 21: 129-133.

4. Chowdappa,P. and Chandra Mohanan,R. (1995). Electrophoretic protein patterns of three species of *Phytophthora* associated with black pod disease of cocoa (*Theobroma cacao* L.). *J.Biosci.* 20:637-644.

5. Chandra Mohanan, R and Chowdappa,P. (1995). Cocoa diseases and current strategies for their control. *Proc. First National Seminar on Development of cocoa Industry in India.* 8th Oct.1995, Bangalore 35-43.

6. Chowdappa,P. and Chandra Mohanan,R (1993). Pathogenic variability among the isolates of *Phytophthora capsici* causing black pod disease of cocoa in India. *Proc. 11th International Cocoa Research Conference.* 18-24, July,1993 (In Press)

7. Chandra Mohanan,R. and Chowdappa,P.(1994). *Phytophthora* associated with cocoa. *Proc.National Group Meeting on Phytophthora disease of Horticultural Crops,* 21-23 Sept,1994, Calicut, Kerala (In Press).

8. Chowdappa,P. and Chandra Mohanan,R.(1996). Occurrence of *Phytophthora citrophthora* on cocoa in India. *Trop.Agric.* (Trinidad) 73: 2:158-160. (IN PRESS)

9. Moorthy,V.K. and Chandra Mohanan,R.1996. Seasonal variation in contamination of spawn and yield of *Pleurotus sajor-caju* (Fr.) Singer in a commercial farm in costal Karnataka. *Mushroom Res.* 5: 23-28.

Books

1. Chandra Mohanan,R.1987. 'Cocoa Diseases and their control measures'. In: *Cocoa* (Kannada) CAMPCO, Mangalore. 55 pp.

2. Chandra Mohanan, R. 1994. Diseases of Cocoa In: *Advances in Horticulture* Vol.10 - Plantation and Spice Crops Part 2 (1994). Eds. K.L.Chandha and P.Rethinam. Malhotra Publishing House, New Delhi pp.1001-1014.

13. Approximate expenditure incurred in the Project: (Give reasons for variation, if any, from original estimated cost)

Approximate expenditure from July 1987 to Dec.1995 = Rs.6,83,860/-

The project was first approved for 3 years

The variation from original estimated cost is due to extension of the project beyond 3 years with addition of more items of work

14. Publications and material (one copy each to be supplied with this proforma)

a) Research papers Separate sheet attached

b) Popular articles

c) Reports

d) Seminars and workshops (Relevant to the Project) in which the Scientists have participated:

e) Material developed (such as new varieties of crops or breeds of farm animals, implements, products, etc.)

1. Phytophthora palmivora, P.capsici and P.citrophthora were identified as causal organisms of black pod disease
2. The cocoa accession C44 was found to be highly tolerant to the three species of Phytophthora
3. Effective black pod disease management can be achieved by spraying Bordeaux mixture (1%) or Copper oxychloride (0.3%) to the pods along with removal and destruction of infected pods.

15. Details (Nos. etc.) of Field/Laboratory Note books and final material and their location

1) Experimental log Book - 1
2) Field Note Book - 3
3) Register for recording field trial data-1

] At CPCRI (RS) Vittal

4) Project file — 1
5) Associate file - 2

16. Comments/suggestions of Project Leader regarding possible future line of work that may be taken up arising of this project:

Future line of work

1. **Epidemiology of Phytophthora diseases of cocoa grown under different cropping systems**
2. **Crop loss due to black pod and canker diseases**
3. **Status of Phytophthora associated with stem canker and seedling dieback of cocoa**
4. **Effect of biocides in controlling Phytophthora Diseases.**

17. Signatures with name of Project Leader and Associates:

R.Chandra Mohanan (Project Leader)

B.Ramanujam (Associate)

P.Chowdappa (Associate)

18. Signature (with comments, if any) of Head of Division/Section/Station:

19. Signature (with comments, if any) of Director:

Director

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