

CONTRIBUTIONS TO THE GENUS PHYTOPHTHORA DE BARY FROM INDIA¹⁾

by

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ABSTRACT

The paper deals with some of the contributions made from India by various research workers towards our knowledge of the fungus genus *Phytophthora* DE BARY, in the fields of morphology, disease production, occurrence and distribution of species, host range, physiology, taxonomy and control measures. Out of the total of fifteen species and five varieties of *Phytophthora* reported from India, five species (viz., *P. arecae*, *P. palmivora*, *P. colocasiae*, *P. parasitica* and *P. infestans*, and four varieties of *P. parasitica*, viz., *P. parasitica* var. *macrospora*, var. *sesami*, var. *piperina* and var. *nicotianae*) assume considerable parasitic roles inciting serious diseases like seedling-blight, wilts, cottony-leaks, foot-rots, blights, bud-rot and rots of fruits, nuts, tubers and corms etc. They are widely distributed in various parts of this country, and are mostly prevalent in rainy seasons. *Phytophthora palmivora*, and *P. parasitica* were found to have a wide host range.

INTRODUCTION

The genus *Phytophthora* was established by DE BARY (1876) with *Phytophthora infestans* (MONTAGNE) DE BARY as the type species. It was included by him in the family Peronosporaceae. Later, it was transferred by FITZPATRICK (1923) to the Pythiaceae because of the indefinite character of the sporangiophore and the development of sporangia in succession. These and other characters of the genus have been well defined recently by BLACKWELL (1949) and by MIDDLETON (1952).

The genus *Phytophthora* DE BARY occupies an important position among fungi due to its close association with the "Father of Mycology" on the one hand and the extremely notorious "Late blight of potato" (*Phytophthora infestans*), an outstanding species of the genus from the economic standpoint on the other hand. The very name "*Phytophthora*" denotes "Plant Destroyer". The genus is

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world-wide and has received considerable attention from a large number of scientists in respect of pathology, biochemical studies, taxonomy, sex behaviour and control. It is capable of inciting destructive and epiphytic diseases like blights, foot-rots, wilts, cankers, seedling blights, damping-off, gummosis, various rots of fruits, tubers and pods in the field as well as in storage. Thus, it has assumed the role of a virulent pathogen due to its capacity of zoosporangia to germinate by liberating zoospores (aquatic habit) as well as by germ tube (terrestrial habit).

The over-riding factor determining the distribution of *Phytophthora* species is, of course, moisture supply, high saturated humidity and rainfall which govern development and spread of the disease in asexual stage in nature. It may be atmospheric moisture or soil moisture or both, depending on the particular species. As a whole, *Phytophthora* species are catholic in their parasitism attacking a great range of plants, trees, shrubs, fruits, tubers, etc. Considered individually, some *Phytophthoras* attack many different kinds of plants, while at the other extreme are those which are confined in their parasitism to a single family, genus or species. Outstanding among the former group are *P. cactorum*, *P. parasitica*, *P. palmivora* and *P. cinnamomi*. In the latter group there are few like *P. colocasiae*, *P. arecae*, and *P. infestans*, etc. Excellent classical works are available on the taxonomy, diagnosis and distribution of the world species of this genus in the treatments of ROSENBAUM (1917), TUCKER (1931 & 1933), LEONIAN (1925, 1934), WATERHOUSE (1956, 1963) and by HICKMAN (1958).

In India, some notable contributions made by various research workers so far, include: BUTLER (1906, 1914), BUTLER & KULKARNI (1913), COLEMAN (1910, 1915), McRAE (1918), DASTUR (1913, 1915, 1916, 1935 & 1948), NARASIMHAN (1922, 1927, 1930 & 1934), SUNDARARAMAN (1924), UPPAL & KAMAT (1936), UPPAL & DESAI (1939), THOMAS et al. (1947), RAMAKRISHNAN & SOUMINI (1948), THOMAS & RAMAKRISHNAN (1948), DESAI (1950), KALE & PRASAD (1957), and recently by RAO, DESAI & KULKARNI (1962, 1963 & 1966).

The present paper summarises the works carried out in India so far, relating to occurrence, distribution of various spp. of *Phytophthora* including their diseases, host range, taxonomy and control. It adds additional detailed literature on this genus with an aim to help the future monographers working on this genus in a broadened way.

REVIEW OF INDIAN LITERATURE

BUTLER (1906) gave a detailed account of some fungal diseases of palms (*Areca catachu*, *Borassus flabellifer* and *Cocos nucifera*) including the one caused by *Phytophthora arecae* from various places

of Mysore (S. India) and suggested (1) spraying with Bordeaux mixture, (2) cutting down the affected trees and burning them, as control measures.

COLEMAN (1909, 1910) undertook an expanded study into the control of Koleroga (rot-disease) of the areca palms, a disease caused by *P. arecae* in Mysore. Spraying the bunches with Bordeaux mixture and resin soap was suggested as the control measure. This finished mixture showed remarkable adhesive power against the torrential rains. In most cases one treatment at the beginning or early in the monsoon was found sufficient to protect the nuts from the disease.

BUTLER & KULKARNI (1913) published a detailed account of Colocasia blight caused by *P. colocasiae* RACIB. They also studied the morphology, pathology and cultural behaviour of this fungus. The disease has been reported from various places like Burma, Rangpur, Pusa, Dehra Dun, Travancore and Bengal etc. They recommended some of the control measures to minimise this disease: (1) Removal and destruction of all blighted leaves in the early stages of attack, (2) Selection and planting of only the round corms, (3) Avoiding the planting in shady and low-lying localities, (4) Preventive spray of Bordeaux mixture before the appearance of the disease, and (5) Practicing strictly sufficient rotations with other crops.

DASTUR (1913) first described *Phytophthora parasitica*, causing a disease of the castor oil plant (*Ricinus communis* L.) in detail and also recorded it on *Sesamum indicum* L. He reported in 1916 a severe disease affecting leaves, flowers, and fruits of *Vincarosea* L., a flowering plant from Pusa and showed that the causal agent was a biologic variety of *P. parasitica* DAST. In the year 1917, this author studied the conditions influencing the distribution of potato blight caused by *P. infestans* in India. Further, in the year 1935, he undertook detailed studies into the various diseases of pan (*Piper belle* L.) in the United Provinces, including a severe foot-rot and wilt disease, caused by *P. parasitica*. He described the causal organism as a biologic variety specific to this host and designated it as *P. parasitica* var. *piperina* DASTUR with its full morphology. A detailed account on potato blight in India was published by this author (1915), the disease being prevalent in the places like Rangpur (Bangal), Bhagalpur (Bihar), Darjeeling, Naini Tal, Shillong and Simla hills, caused by *P. infestans* (MONT.) DE BARY. He suggested some remedial measures which included: (1) Using the diseased-free seeds, preferably obtained from places where the disease is not known, (2) Spraying the potato crop (when 6-8 inches high) with Bordeaux mixture, fermate or dithane etc., (3) Sowing the resistant varieties of potato obtained from the Government Potato Breeding Stations.

McRAE (1918) described *Phytophthora meadii* on *Hevea brasiliensis*. Further, in the year (1922) he studied in detail the pathology of

P. palmivora BUTL. on *Borassus flabellifer* and *Cocos nucifera*. In 1923, he undertook detailed studies on bud-rot of palmyra palms (caused by *P. palmivora*) with the operations of controlling the disease.

NARASIMHAN (1922) gave a detailed account of the works on the koleroga disease of arecanuts caused by *P. arecae* from Mysore.

SUNDARARAMAN & RAMAKRISHNAN (1924) gave a detailed account of "Mahali" (Rot) disease of arecanuts (*Areca catechu*) and coconuts (*Cocos nucifera*) i.e., rotting of nuts and nut-fall in the gardens of Malabar (Madras), caused by *P. arecae*. They recommended cutting and burning off the affected parts and further spraying the trees with Bordeaux mixture, as remedial measures.

NARASIMHAN (1927) recorded some wild hosts for *Phytophthora arecae* from Mysore, viz., *Colocasia antiquorum*, *Bryophyllum calycinum*, *Santalum album*, *Artocarpus integrifolia*, *Mangifera indica*, fruits of *Ficus nitida*, *Jatropha glandulifera*, *Citrus medica*, *C. limonum* and *Hevea brasiliensis*.

MITRA (1929b) found *Phytophthora parasitica* DAST. causing "damping off" disease of cotton seedlings and fruit-rot of guavas and studied these diseases in detail.

SUNDARARAMAN & RAMAKRISHNAN (1928) studied in detail, foot-rot and wilt disease of Antirrhinums (Snapdragons, *Antirrhinum majus*) from Ootacamund (Madras), and described the causal fungus as *Phytophthora pini* var. *antirrhini*, with the details of symptoms and morphology.

MITRA (1930) reported the occurrence of *P. parasitica* DAST. on the leaves of *Polyalthia longifolia* L.

VENKATARAYAN (1932), reported severe leaf spot and top-rot of Areca palms caused by *P. arecae* and further a seedling blight disease of *Aleurites fordii* HEMSL. caused by *P. palmivora* BUTL. from Mysore (S. India).

AGHARKAR & BANNERJEE (1932) recorded the occurrence of *P. parasitica* DAST. on *Boucerosia diffusa* Wt.

UPPAL, PATEL & KAMAT (1934) included in their list of "Fungi of Bombay", *Phytophthora arecae* (COLEM.) PATHY on leaves, fruits and peduncles of *Areca catechu* L. from North Canara; *P. colocasiae* RACIB. on leaves of *Colocasia antiquorum* SCHOTT from Poona and Bassein, *P. palmivora* BUTL. on stem and fruits of *Citrus sinensis* OSBECK; *P. parasitica* DASTUR on roots of *Piper betle* L. from Malegaon, Poona and Bassein; and on fruits of *Lycopersicon esculentum* MILL. from Poona.

NARASIMHAN (1934) working with "Koleroga" (Rot) disease of Arecanut in Mysore, concluded that areca palms sprayed experimentally with Bordeaux mixture to which cheap local vegetable oil was added as spreaders, remained almost free from this disease (caused by *P. arecae*) though others in the same garden sprayed with Casein Bordeaux mixture became affected. The spray mixture was made by adding half gallon of gingelly (*Sesamum indicum* L.),

ground-nut or safflower (*Carthamus tinctorius* L.) oil to 12.5 gallons of copper sulphate and slowly pouring the fluid (with the oil floating on the surface) into an equal volume of milk of lime stirring vigorously.

Excellent detailed investigations were undertaken by UPPAL & KAMAT (1936) on "Gummosis disease of Citrus" in Bombay Province, caused by *Phytophthora palmivora* BUTLER. These studies included pathology, host-range, cultural and physiological behaviour of the organism, varietal resistance and suitable control measures.

BANERJEE (1937) reported the occurrence of *P. parasitica* DAST. on *Caralluma diffusa* WIGHT, from Calcutta (W. Bengal).

MUNDKUR, PAL & NATH (1937) conducted a number of trials to test the relative susceptibility of some wild and cultivated potato varieties to an epidemic of late blight caused by *P. infestans* at C.P.R.I., Simla (H.P.). They found a number of varieties including *Solanum tuberosum* L. (South American varieties), *S. demissum* LINDL., and *S. neoantipoviczii* BUK. etc., showing high and promising degree of resistance. An extensive research and organisation is now under operation at various regional research sub-stations, mainly dealing with breeding of potatoes and the distribution of such nucleus seeds including studies on fungal and virus diseases and their control. These research sub-stations are located at Hapur (Uttar Pradesh), Darjeeling (West Bengal), Jullandar (Punjab), Poona (Bombay), Nilgiris (Madras), Shillong (Assam), Patna (Bihar), Kufri (Simla), Khed (Poona) and Nanjanad (Ootacamund). Central Potato Research Institute established in the year 1932 at Simla (H.P.) is the main Research Centre. Several new high yielding and disease-free stocks of "Uptodate", "Craig's Defiance" potatoes are being evolved for seed multiplication. Bordeaux mixture, Perenox and Dithane-14 have also been found to be effective in checking late blight infection under conditions prevailing in the plains of India (RANDHAWA, 1958).

The occurrence of *Phytophthora parasitica* DAST. var. *nicotianae* TUCKER on roots and stems of tobacco (*Nicotiana tabacum* L.) was reported by MUNDKUR (1938) from Anakapalli, Salem and Coimbatore districts of Madras State (S. India).

UPPAL & DESAI (1939) did pioneering work on "Koleroga" disease of Arecanuts in North Kanara (Bombay Province), caused by *Phytophthora arecae* (COLEM.) PETHYBR. They demonstrated the presence of heterothallic strains in this species by obtaining abundant oospores by pairing (mating) different strains, isolated from arecanuts growing in different localities. In one case they also observed oospores on the naturally infected nut. Further, they recommended some suitable control measures.

MARUDARAJAN (1941) made detailed observations on the production of sexual organs in paired cultures of *Phytophthora* spp. of the "palmivora" group. Oospore formation in paired cultures in various combinations of 6 isolates of *Phytophthora* spp., viz.: *P. arecae*,

(obtained from *Areca catechu*), *P. palmivora* BUTL. (obtained from 3 hosts, *Borassus flabellifer*, *Cocos nucifera* and *Citrus nobilis*), *P. faberi* MAUBL. (obtained from *Theobroma cacao*) and *P. meadii* McRAE (isolated from *Hevea brasiliensis*), were studied. It was concluded that three of these isolates belonged to *Phytophthora palmivora* and three others to *P. faberi*, *P. meadii*, and *P. arecae* respectively.

SAKSENA & BHARGAVA (1943) reported the studies on nitrogen and vitamin nutrition of *Phytophthora phaseoli* THAXTER.

SINGH (1943), studying some diseases of fruits in Kumaon and Chaubatia (U.P.) reported *P. cactorum* (LEB. & COHN) SCHROET. on *Pyrus communis* and *Prunus armeniaca*.

From the well known orange growing tracts of Coorg (S. India), DEVARAJAN & AIYAPPA (1945) reported a severe leaf-fall and fruit-rot disease of oranges (*Citrus aurantium*) due to *Phytophthora palmivora* BUTL. They suggested some control measures which included: (1) Collection of fallen leaves and fruits of the previous year and destroying by burning, (2) A single spraying in late May with 1 % Bordeaux mixture which prevents the onset of the disease, (3) Avoiding weaker strengths of Bordeaux mixtures as it was a complete failure.

CHOWDHURY (1945) reported a heart or stem-rot disease of pineapples (*Ananas cosmosus* (L.) MERR.) caused by a strain of *Phytophthora parasitica* DAST. from Surma valley (Assam). In the next year (1946), he described a wilt disease of this crop, caused by the same fungus. Both the diseases were prevalent during the period of excessive rainfall. Some control measures suggested by him were: (1) Providing best drainage, (2) Avoiding wounding of the planting material, (3) Dipping the planting material in Bordeaux mixture of 2 : 2 : 50, 4 : 4 : 50 and 5 : 5 : 50 strengths, and (4) Avoiding planting of weak materials.

ASTHANA (1947) worked out in detail the foot-rot and leaf-rot diseases of *Piper betle* L. and their control in Central Provinces and Berar, caused by *P. parasitica* var. *piperina* DAST. He suggested some of the control measures which checked the disease fairly: (1) Just before planting, the cuttings should be dipped in 2 : 2 : 50 Bordeaux mixture for one hour and further undertaking periodical sprayings, (2) Diseased vines should be carefully and systematically uprooted and subsequently destroyed by burning, (3) Picking and destroying the affected leaves, (4) Keeping the vines bare of leaves upto a height of one foot from the soil surface, (5) Soil application of 4 : 4 : 50 Bordeaux mixture, (6) Using strictly disease-free cuttings or setts of Stork, (7) Avoiding low-lying, water-logged fields, (8) Providing good drainage and finally, (9) Not lowering the vines during rainy season.

BALAKRISHNAN (1947) reported stem rot disease of tree tomato (*Cyphomandra betacea* SENDT.) and *Carica papaya* L. caused by *Phytophthora palmivora* BUTL. from the Fruit Research Stations at

Burliar and Nilgiris (Madras State). He further showed that *C. betacea* isolate is a plus (+) strain of *Phytophthora palmivora* and the other (i.e., obtained from *Carica papaya*) is minus (—) strain. In the same year, the author reported seedling blight of *Hibiscus esculentus* L. caused by *P. palmivora* from Coimbatore (Madras). Again in the same year, with KRISHNAMURTHY he reported seedling blight of Safflower (*Carthamus tinctorius*) by *P. palmivora*.

RAMAKRISHNAN & SOUMINI (1947) studied a fruit-rot of tomato caused by *P. palmivora* from Madras State.

THOMAS et al. (1947) with their detailed investigations concluded that *Phytophthora arecae*, *P. meadii*, *P. faberi* and *P. parasitica* var. *nicotianae* are to be merged with *P. palmivora* as they were found to be morphologically similar and did not exhibit any constant and reliable differences from *P. palmivora* and further, readily produced oospores when paired with it. This species is heterothallic, but homothallism has been reported in some isolates.

MEHROTRA (1948 to 1953) studied in detail the physiology and cytology of some spp. of *Phytophthora* from Allahabad (India). RAMAKRISHNAN & SOUMINI (1948) reported a severe wilt disease of *Pyrethrum* (*Chrysanthemum cinerariaefolium*) in the plantations from Nilgiris and Pulney hills and further from Kodaicanal (Madras), caused by *Phytophthora cambivora* (PETRI) BUISMAN.

THOMAS & RAMAKRISHNAN (1948), who made detailed physiological studies of authentic cultures of *Phytophthora colocasiae* RACIB., *P. parasitica* DAST., its varieties and *P. palmivora* BUTLER and other isolates from *Agave wightii*, *Ricinus communis*, (from Coimbatore, Madras) and *Artocarpus incisa*, (South Kanara, Madras), concluded that these cannot be separated and should be merged with the oldest known species *P. colocasiae* RACIB. In the same year, LAL (1948) listed reports of occurrence of late blight of potato in the plains of U.P., and Bihar was surveyed by VASUDEVA & AZAD (1949).

DASTUR (1948) described *Phytophthora himalayensis*, a new species causing tuber rot of potato at Kufri (8000' alt.) of Simla hills, and gave full morphological characters and taxonomy. He studied in detail the late blight of potatoes caused by *P. infestans* at various places of Northern India (Kufri and Simla Hills, 6000–8000' altitude) and also at places like Darjeeling, Shillong and Nilgiris of South India. His studies mainly included: epidemics, spread of the disease, varieties affected and control measures. In the same year, he further published expanded accounts of late blight of potatoes.

MUNDKUR (1949) made further contributions on morphology, cytology and development of sex organs of *Phytophthora himalayensis* DAST.

PATEL, KAMAT & BHIDE (1949), reported, in their list of "Fungi of Bombay", *Phytophthora parasitica* DAST., as pathogenic to fruits,

tubers and plants of *Lycopersicon esculentum* and *Solanum tuberosum*; plants of *Clarkia elegans*, *Gossypium hirsutum*, *Opuntia* sp., *Ricinus communis*, *Sesamum indicum* and fruits of *Malus sylvestris*, *Solanum melongena*, and *Psidium guajava*, all from Poona.

VENKATAKRISHNAIAH (1950) observed a rot of French beans (*Phaseolus vulgaris* L.) during rainy season in low lying fields of Bangalore (India) caused by *P. parasitica* DAST. He suggested that the disease could be controlled by picking out early all the infected pods (mostly the pods lying close to the soil in the fields) and subsequently spraying the plants thoroughly with 1% Bordeaux mixture twice or thrice as desired.

DESAI (1950) worked out in detail the relation of food to oospore production in *Phytophthora arecae*, when studying with a number of isolates obtained from Areca gardens of Kanara district (South India). He obtained abundant oospores in mixed heterothallic cultures of *P. arecae*. Further, he demonstrated that heterothallic strains (Like Nilekani and Tyagali strains) of *P. arecae* which were supposed to have lost their capacity for oospore production, regained a capacity to produce oospores copiously by being passed through live host tissue (natural food) or by being cultured on "French bean agar".

RAMAKRISHNAN (1951) reported *P. cinnamomi* RANDS, on stems and roots of *Cinchona ledgeriana* MOENS and *C. succirubra* PAV. from Annamalais (Madras). The fungus was found causing cankers on the stem, and further a collar rot and root rot finally resulting in the drying of the branches or death of plants. The incidence was severe after the South-West monsoon.

SEETHALAKSHMI & RAMAKRISHNAN (1953) described *Phytophthora cyperi-bulbosi* causing leaf blight of *Cyperus bulbosus* VAHL. from Coimbatore (Madras), together with a detailed account of its morphological characters.

GOVINDARAO & KOTESHWARARAO (1956) studied seedling blight and "Black Shank" disease of tobacco caused by *P. parasitica* var. *nicotianae* (VAN BREDA DE HAAN) TUCKER, from Guntur District, a nucleus centre for the production of Virginia tobacco.

RAMAKRISHNAN & SEETHALAKSHMI (1956) gave descriptions of five strains of *P. arecae* (isolated from diseased fruits of *Areca catechu*) from different parts of South Kanara and found three to be homothallic strains producing oospores on carrot agar, while the remaining two were heterothallic producing oospores with an isolate from betle vine (*Piper betle*). In pathology, all the five strains infected fruits of Areca, egg plant, leaves of *Jatropha curcas*, coconut and papaw seedlings. In the same year, they reported some new host records for *P. palmivora*, viz., *Areca lutescens* (bud rot), *Bougainvillea spectabilis* (leaf and flower blight), *Capsicum grossum* (fruit rot), *Hibiscus esculentus* (flower and fruit rot) and *Mimosa hexandra* (seedling blight) from Madras.

From Agricultural Institute, Anand (Gujarat), a new variety of

P. parasitica viz., var. *sesami* PRASAD, was erected by KALE & PRASAD (1957) on the basis of parasitic specificity on the host, while studying *Phytophthora* blight of *Sesamum* (*Sesamum orientale* L.) in detail which was serious in Gujarat State.

ARYA (1959) published a note on the pathology of an isolate of *P. palmivora* BUTL. on *Bougainvillea spectabilis* WILLD., collected from various gardens of Jodhpur (India). Inoculation experiments with *P. palmivora* on *Quisqualis indica*, *Impatiens balsamina*, and *Zinnia elegans* developed a little infection. Whereas, the infection was 100 % in case of its natural host.

KUMARARAJ & BHIDE (1959) described "damping-off" of Cashewnut (*Anacardium occidentale* L.) seedlings caused by *P. palmivora* BUTL. from Poona, the disease being originally collected from Cashewnut nursery in Vengurla of Ratnagiri district of Maharashtra State. In the same year, SINGH (1959) noted the occurrence of *P. palmivora* on leaves of *Ficus religiosa* causing a rot disease, from Ranchi. (Bihar).

RAMAKRISHNAN (1960) in his "Notes on some fungi from South India — VIII" from Rubber Research Board, Kottayam (Kerala) included *P. palmivora*, causing severe defoliation of *Artocarpus hirsuta*.

DESHMUKH & CHIBBER (1960) in their study of field resistance of varieties of *Colocasia antiquorum* to blight disease (*Phytophthora colocasiae*) at Central Potato Research Institute, Simla, found Ahina, (a variety of *Colocasia*) quite resistant.

PAHARIA & MATHUR (1961) discovered *Amorphophallus campanulatus* BLUME (Elephant foot yam) as a new host for *P. colocasiae* RACIB. from the Central Potato Research Institute, Sub-station, Patna (Bihar). Young plantation of yams (an important vegetable crop) was severely attacked by a foliage blight. The intensity of blight was greater in shady places than open fields.

RAO, V. G. et al. (1962 a & b) published two new fruit rot diseases of *Anona squamosa* L. and *Achras sapota* L. from Gholvad, Dahanu talukas of Thana district (Bombay) and also from Poona; caused by *Phytophthora parasitica* DAST. var. *macrospora* ASHBY and *P. palmivora* BUTLER respectively. The diseases have been found severe during monsoon seasons, thus bringing considerable economic loss of the valuable fruits.

With an extensive survey for post-harvest diseases of various fruits and vegetables in different markets of Poona and Bombay, RAO (1966) reported various types of cottony-leaks, fruit rots etc., caused by *Phytophthora parasitica* DAST. The various hosts noted were: *Solanum tuberosum*, *Phaseolus vulgaris*, *Pisum sativum*, *Solanum melongena*, *Lycopersicon esculentum*, *Dolichos lablab*, *Capsicum annuum*, *Psidium guajava*, *Artocarpus integrifolia*, *Carica papaya*, and *Anona squamosa*. He further observed fruit rots of *Citrus reticulata*, and *Achras sapota*, caused by a strain of *Phytophthora palmivora* BUTL.

RAO, DESAI & KULKARNI (1966 a to d) undertook detailed investigations into the physiology, cultural behaviour and pathological studies of two species of *Phytophthora* viz., *P. palmivora* and *P. parasitica* var. *macrospora*, causing fruit rots of *Achras sapota* and *Anona squamosa* from Poona.

Finally, recently SEHGAL & PRASAD (1966) studied in detail the *Phytophthora* blight disease of *Sesamum* occurring in Rajasthan for a number of years to find out the survival of the fungus and its perennation during the absence of its crop. Their studies revealed that the fungus survived in the soil in the form of mycelium or chlamydo-spores as it did not form oospores. Direct isolations of the fungus from the infected soil were also possible by using ripe

TABLE I
Important diseases incited by various spp. of *Phytophthora*

<i>Phytophthora</i> spp.	Diseases
<i>P. arecae</i> (COLEMAN) PETHYBRIDGE	Koleroga or Mahali disease (Rot) of Arecanuts (<i>Areca catechu</i> L.), <i>Borassus flabellifer</i> and coconuts (<i>Cocos nucifera</i> L.)
<i>P. cambivora</i> (PETRI) BUISMAN	Causing a severe wilt disease of Pyrethrums, (<i>Chrysanthemum cinerariaefolium</i>)
<i>P. colocasiae</i> RACIBORSKI	Causing rotting of corms and blight of leaves in <i>Colocasia antiquorum</i> SCHOTT.
<i>P. cyperi-bulbosi</i> SEETHA. & RAMAKR.	Causing leaf blight of <i>Cyperus bulbosus</i> VAHL. and <i>C. rotundatus</i> L.
<i>P. himalayensis</i> DASTUR	Causing tuber rot of <i>Solanum tuberosum</i> L. in Kufri and Simla Hills, 8000' altitude.
<i>P. infestans</i> (MONT.) DE BARY	Causing late blight of potatoes (<i>Solanum tuberosum</i> L. in the hills of Himalayas)
<i>P. palmivora</i> BUTLER	Causing bud-rot and top rot of Palmyra-palm (<i>Borassus flabellifer</i> L.) and coconut palm (<i>Cocos nucifera</i> L.)
<i>P. parasitica</i> DASTUR	Causing damping-off and blight of <i>Ricinus communis</i> L., <i>Gossypium hirsutum</i> L., and also boll-rot of cotton at later state.
<i>P. parasitica</i> var. <i>macrospora</i> ASHBY	Causing severe fruit-drop and rot disease of Custard apple (<i>Anona squamosa</i>), mostly severe in monsoon season.
<i>P. parasitica</i> DAST. var. <i>nicotianae</i> TUCKER.	Causing foot-rot and "Black Shank" disease of tobacco (<i>Nicotiana tabacum</i> L.)
<i>P. parasitica</i> DAST. var. <i>piperina</i> DASTUR.	Causing foot-rot and wilt in <i>Piper betle</i> L.
<i>P. parasitica</i> DAST. var. <i>sesami</i> PRASAD	Causing blight of <i>Sesamum orientale</i> L.
<i>P. pini</i> LEON. var. <i>antirrhini</i> SUNDAR. & RAMAKR.	Causing collar-rot and wilt in Antirrhinums (<i>Antirrhinum majus</i> L.)

TABLE II
Morphology of various spp. of *Phytophthora*, their hosts and diseases.

<i>Phytophthora</i> spp.	Host	Disease	Morphology	Authors
<i>P. arecae</i>	<i>Areca catechu</i>	Nut-rot	Sporangia, 30—70 × 26—43 μ; oospores amphigynous, 23—26 μ in diam.	COLEMAN (1910)
<i>P. cactorum</i>	<i>Pyrus communis</i> <i>Prunus armeniaca</i>	Fruit-rot	Sporangia, 34.5 × 27 μ average. Oospores 27 μ in diam.	SINGH (1943)
<i>P. colocasiae</i>	<i>Colocasia an- tiquorum</i>	Leaf-blight and Corm-rot	Sporangia, 38—60 × 18—26 μ. Chlamydospores 30 μ in diam. Oospores amphigynous 20—28 (23) μ in diam., in Frenchbean agar.	BUTLER & KULKARNI (1913)
<i>P. cyperi-bulbo- sis</i>	<i>Cyperus bulbosus</i> & <i>C. rotundatus</i>	Leaf-blight	Sporangia, 23—50 × 20—34 (40 × 25) μ. Oospores paragynous 16 × 12 μ in diam. Oogonia 31—50 (40) μ in diam.	SEETALAKSHMI & RAMAKRISHNAN (1953)
<i>P. himalayensis</i>	<i>Solanum- tuberosum</i>	Tuber-rot	Sporangia not seen on host, but formed on sterilised ants in water. 29.0—50 × 22.0—36.0 μ. Sporangia germinating conidially, zoospores not developed. Oospores amphigynous 15—45 (21) μ in diam. Oogonia 19—50 (35—2) μ in diam.	DASTUR (1948)
<i>P. palmivora</i>	<i>Achras sapota</i>	Fruit-drop and rot	Sporangia 31.6—76.6 × 22.2—36.4 (53.5 × 29.3) μ. Chlamydospores 14.2—51.2 (34.3) μ in diam. Oospores not observed either on host or in culture.	RAO <i>et al.</i> (1962a)
<i>P. palmivora</i>	<i>Citrus sinensis</i>	Gummosis	Sporangia 55 × 28 μ average. Chlamydospores 32 μ in diam. Oospores not found.	UPPAL & KAMAT (1936)
<i>P. palmivora</i>	<i>Anacardium oc- cidentale</i>	Damping-off	Sporangia 27.7—85.2 × 23.2—44.1 (50.7 × 34) μ. Chlamydospores 18—50 (36) μ in diam. Oospores not observed.	KUMARARAJ & BHIDE (1962)

TABLE II (Cont.)

<i>Phytophthora</i> spp.	Host	Disease	Morphology	Authors
<i>P. parasitica</i>	<i>Phaseolus vulgaris</i> <i>Pisum sativum</i> <i>Dolichos lablab</i> <i>Psidium guajava</i> <i>Capsicum annuum</i> <i>Lycopersicon esculentum</i> <i>Solanum melongena</i> <i>Solanum tuberosum</i> <i>Artocarpus integrifolia</i> & <i>Carica papaya</i>	Cottony-leak of various pods and rots of various fruits and vegetables in the markets	Sporangia measure, 32—47 × 21—38 μ . Chlamydospores measure 20—42 μ in diameter. Oospores were not observed either on hosts or in culture.	RAO, V. G. (1964)
<i>P. parasitica</i> var. <i>piperina</i>	<i>Piper betle</i>	Foot-rot and wilt	Sporangia 30—63.3 × 20.4—40.8 μ . Oospores seen, and measure 17.8—53.1 (20.1) μ in diam. Oospores amphigynous.	DASTUR (1935)
<i>P. parasitica</i> var. <i>macrospora</i>	<i>Anona squamosa</i>	Fruit drop & fruit-rot	Sporangia 28.8—53.4 × 15.4—24.8 (40.4 × 19.2) μ . Chlamydospores 19—38.2 (27.7) μ in diam. Oospores amphigynous, 16—25 (21) μ in diam.	RAO, V. G. et al. (1962b)
<i>P. pini</i> var. <i>antirrhini</i>	<i>Antirrhinum majus</i>	Collar-rot and wilt	Sporangia, 18—66.8 × 12—42.8 (41 × 30) μ . Chlamydospores nil. Oospores, 26.2 μ in diam. Oogonia 30.87 μ in diam.	SUNDARARAMAN & RAMAKRISHNAN (1928)

tomato fruits as baits. Seeds of the infected fruits were also found playing some role in the initiation and spread of disease in new localities in a dormant condition.

The results of some of the detailed investigations reported above are briefly summarised in Tables I and II.

From the foregoing detailed review of literature it is apparent that various types of investigations were undertaken in India so far, on this important fungus genus "*Phytophthora*", dealing with reports of new species, new varieties, pathological and physiological studies including control measures.

The present contribution dealing with such an extensive and consolidated review of works on the genus *Phytophthora* DE BARY, constitutes possibly the first of its kind from India, dealing with various types of diseases, morphology, host-range, pathology and control measures.

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Addendum

Since this paper was in press, the following five recent references were noted and have been included here to make the paper a complete review (Author).

1. AGARWALA, R. K. & SHARMA, V. C. (1968) Storage rot diseases of apple. *Indian Phytopath.* 21: 294—298.
(Reported storage rot of apples caused by *Phytophthora cactorum* Lebert-Cohn, form Himachal Pradesh).

* Originals not seen.

2. AGNIHOTHRUDU, V. (1968) A root rot of grapes in Andhra Pradesh. *Curr. Sci.*, 37: 292—294.
(Reported root rot of grapes incited by *Phytophthora cinnamomi* Rands from Hyderabad-Dn (A.P.).)
3. MANTRI, J. M. & DESHPANDE, K. B. (1966) Two new species of *Phytophthora* from India. *Sydowia* 20: 28—32 (Issued 1968).
(Reported two new spp. of *Phytophthora*, viz. *P. irritabilis* and *P. rubra* inciting water-soaked lesions on French bean pods in storage at Aurangabad (M.S., India).)
4. RAO, V. G. & ULLASA, B. A. (1969) A new *Phytophthora* blossom blight of *Gerbera* from India. *Indian Phytopath.* (Submitted).
Reported blossom-blight of *Gerbera jamesonii* for the first time from Poona, incited by *Phytophthora palmivora* BUTL.).
5. SURYANARAYANA, D. & PATHAK, S. R. (1968) Foot-blight, a new disease of gram. *F.A.O., Pl. Prot. Bull.*, 16(4): 71—73.
(Reported *Phytophthora megasperma* DRECHS., as the causal agent of foot-blight of Gram, from Hissar, Punjab).