STATE OF ART OF *PHYTOPHTHORA* DISEASES OF COCOA IN INDIA

Prabha K. Peter and R. ChandraMohanan
Central Plantation Crops Research Institute, Kasaragod, Kerala

Introduction

Cocoa has been found to be a suitable and profitable mixed crop in existing coconut (*Cocos nucifera* L.) and arecanut (*Areca catechu* L.) gardens. At present it is mainly grown in the southern states, *viz.,* Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. With the expansion of area under cocoa and with the increase in the age of the plantations, pests and diseases are becoming more important. Crop losses due to diseases have been identified as one of the major production constraints in all cocoa growing countries. *Phytophthora* is one of the most ubiquitous and destructive plant pathogen of tropical tree crops such as palms, cocoa, citrus and rubber (Chee, 1969). Among the *Phytophthora* diseases of cocoa occurring in India, black pod rot and stem canker are the most important diseases. The incidence and severity of these diseases are increasing coupled with increase in area under cultivation leading to heavy economic loss. *Phytophthora* infects all parts of cocoa plant including seedlings in nurseries. Severe incidence of *Phytophthora* infection of young seedlings leading to high mortality which has been recently observed in high rainfall areas in South India.

Nursery diseases

Seedling blight

Seedling blight or seedling dieback is a major problem in nurseries during rainy season. Younger seedlings are more susceptible to the disease. Defoliation and dieback of seedlings are the characteristic symptoms of the disease (Gregory, 1974).

Phytophthora palmivora (Butl.) has been found to be the causal organism of this disease (ChandraMohanan, 1979). Severe infection of grafted and budded seedlings caused by *P. palmivora* has also been observed in India. In such cases, infection mainly starts from the grafted or budded region and proceeds upwards and downwards. Infection continues to spread internally after the rainy season leading to high mortality (ChandraMohanan and Chowdappa, 1999). Pre- and post- emergence damping off of the seedlings was also noticed in several nurseries especially when sowing of beans was carried out during rainy season. Removal and destruction of infected seedlings from the nursery are very important management practices to check the secondary spread of the disease. The disease incidence can be considerably reduced by improving the drainage facilities in the nursery and by providing proper shade. Drenching the seedlings with Bordeaux mixture or Copper oxychloride just before the onset of monsoon and thereafter at frequent intervals is essential in the effective management of the disease in nurseries with high disease intensity. A combination of seed dressing and soil drench with Kocide at a concentration of 0.91 kg in 45 litres of water was found to be very effective in controlling pre and post-emergence seedling death caused by *P. palmivora* (Asare- Nyako *et al.,* 1972).

Pod rot diseases

Pod rot diseases cause direct loss in yield year after year. Pod rots caused by *Phytophthora palmivora* and *Colletotrichum gloeosporioides* have been recorded as the major diseases occurring in India. Charcoal pod rot caused by *Lasiodiploidia theobromae* occurs throughout the year. However, it has not been observed as a serious problem.

Black pod disease

Black pod disease was first noticed in Guyana and West Indies and referred as black cocoa (Jenman and Harrison, 1897). At present, it is prevalent in all the cocoa growing countries (Zentmyer, 1988). Black pod disease was reported for the first time from India in 1965 (Ramakrishnan and Thankappan, 1965).

ChandraMohanan and Kaveriappa (1981) reported black pod as the major disease of cocoa in India based on the districtwise distribution of cocoa diseases and the percentage of gardens showing disease incidence. Losses from black pod vary from country to country; Nigeria (30%), Brazil (30.8%), Ghana (25-30%), Cameroon (95%), Dominican Republic (10-20%) and Togo (10-80%) (Lass, 1985). In India, the incidence of this has been found to vary from 12.93 to 29.78%, depending upon locality and garden (ChandraMohanan, 1985). Thus, black pod is the most serious disease owing to the heavy economic loss involved.

Pods of all ages are susceptible to the disease. The infection appears as one or more small, chocolate brown circular lesion(s) anywhere on the pod surface. Within four to seven days, the lesion enlarges assuming an elliptical shape. As the lesion advances, a whitish growth of the fungus consisting of mycelia and sporangia is produced over the dark brown pod surface. The lesion increases rapidly and covers the whole pod surface. After about 15 days of infection, the whole pod and beans are invaded by the fungus and the pod turns black in colour. By this time, several saprophytic microorganisms colonize the rotten pod. The beans in ripe pod may escape partly or wholly from infection as the beans get separated from the pod husk on ripening (Gregory, 1974; Thorold, 1975).

The sporangia are spread by rain splashes, insects and rodents (Thorold, 1975). Tent building ants and scolytid beetles have also been reported as agents carrying sporangia from diseased pods to healthy pods (Mc Gregor and Moxon, 1985). Thus, the disease spreads, from pods at the lower part of the trunk to that at the upper part and branches in a climbing up pattern.

Periodic removal and destruction of infected pods alone will help to reduce the disease incidence to the extent of 50%. Spraying of Bordeaux mixture (1%) at 15 days interval starting from the onset of south-west monsoon along with periodic removal of infected pods is effective in controlling the disease in severely affected gardens. Experiments conducted during last several years revealed that the disease can be effectively controlled by the use of copper based fungicides (ChandraMohanan, 2002).

From the results of screening of 51 cultivars for *P. palmivora* resistance in Costa Rica, nine cultivars *viz.,* EET 59, EET 376, UF 713, UF 715, SCA 6, SCA 12, Pound 7, Catongo and Diamantes 800 have been found to be exhibiting promising degree of resistance (Lawrence, 1978). As *P. palmivora* is the only species reported in Costa Rica, the results may still be valid for that country. Studies conducted in Java have indicated that the cocoa accessions DRC 16, SCA 6, SCA 12, and ICS 6 were resistant to *Phytophthora* pod rot. However, in India, the cocoa Accession C 78 has been found to be comparatively less susceptible to wound inoculation by *P. palmivora.* (ChandraMohanan, 1982). Later, based on the studies on inoculation of detached cocoa pods of 20 accessions with *P. palmivora, P. capsici* and *P. citrophthora.* Chowdappa and ChandraMohanan (1997) reported that the accessions C 44 and C 79 were highly tolerant to all the three species of *Phytophthora* whereas Landas 364 is highly susceptible.

Stem and foliar infection

Stem canker

The term canker is generally used for a disease symptom in which there is sharply limited necrosis of the cortical tissue (Ainsworth and Bisby, 1961), but cocoa canker is not a sharply limited necrosis. Canker was first recognized in Sri Lanka (Willis and Green, 1897) and Rorer (1910) reported the occurrence of canker in a number of cocoa growing countries from 1897 to 1907, when *P. palmivora* was described and its authentic investigation began. In India, stem canker was first reported in 1978 in cocoa plants grown as mixed crop in arecanut garden in Karnataka state (ChandraMohanan, 1978).

Stem canker appears at different parts of the tree including jorquette and fan branches. This disease is difficult to detect in the early stages of development. The symptoms on the surface of bark can be detected only by close examination. The size and shape of external lesions as well as symptoms on the external bark vary. The external symptom appears as greyish brown water soaked lesion with a broad dark brown to black margin. A reddish brown liquid oozing out from such lesions dries up and forms a rusty deposit (Gregory, 1974).

Cankers also develop without any external symptom mainly on seedlings of two or three years and on branches of trees. Such infected seedlings appear weak. Such cankers can be detected only by examining the internal tissue. When the outer bark of canker infected portion of the stem is removed, the tissues beneath always show a characteristic reddish brown discolouration. Lesions in the internal tissues coalesce leading to extensive rotting. The infection spreads from the cortical tissues to the vascular tissues and reaches the wood. Wood infection appears as greyish brown to black discolouration with black streaks. When canker girdles the stem, dieback occurs. Leaves wilt, turn yellow and fall off. Pods also show wilting. Finally the whole tree dies. Spread of infection in the internal bark is faster than the spread in the surface of bark (Rao and ChandraMohanan, 1993 and 1995).

Based on the cultural and morphological characters of 25 isolates of *Phytophthora* collected from four major cocoa growing taluks in Dakshina Kannada district, Rao (1989) reported *P. palmivora* as the species causing stem canker of cocoa in this district. The external symptoms of canker are noticed from December after the rainy season. The canker often develops from the pods infected by *P. palmivora.* Infection from the pods spreads to the peduncle and then to the cushion and bark causing canker. Recently severe incidence of stem cankers has been noticed in several cocoa gardens, especially in cocoa garden with sprinkler or flood irrigation. As black pod disease affected pods are main source of stem infection such infected pods should be removed and destroyed. Stem canker can be controlled in the initial stages by the excision of diseased bark followed by wound dressing with Bordeaux paste or any other copper fungicide. High yielding cocoa trees and rare germplasm collections with advanced stages of canker disease can be rejuvenated by cutting the whole tree well below the canker lesion and allowing a fresh chupon to develop from the basal portion of the stem (ChandraMohanan, 2002; Gregory, 1974).

Chupon blight and twig dieback

Chupon blight and twig dieback are caused by *P. palmivora*. The infection usually initiates in the axils of leaves at the tip of twigs or chupons. It appears as water soaked lesions. Infection also starts anywhere on the leaf blade or petiole and extends backwards into the stem. In any case the chief characteristic symptom is the appearance of water soaked lesion, which soon turns dark brown to black. The lesions coalesce to form bigger lesions. The lesion on stem spreads longitudinally in all directions and turns dark brown to black and shrunken. When the lesions girdle the stem, the portion above the point of infection wilts showing twig dieback or chupon blight. Lesions on leaves generally start from the apex or margin of the leaves, more at the apical portion and usually enlarge and coalesce forming large blighted areas. It leads to much defoliation and dieback (ChandraMohanan *et al.,* 1979; ChandraMohanan, 1994).

Status of *Phytophthora* in cocoa in India

The causal organism of black pod disease was identified as a species of *Phytophthora* when it was first reported from India. It has been reported that the sporangia were pear shaped or ovoid with prominent apical papilla and measured 52 x 31µm (27x16µm-77x44µm) (Ramakrishnan and Thankappan, 1965). When the other *Phytophthora* disease *viz.,* canker, seedling dieback, chupon blight and twig dieback were first reported the causal organism was identified as *P. palmivora* (ChandraMohanan *et al.,* 1979). But, at that time detailed studies on the causal organism were not carried out. A preliminary attempt to study the characters of the causal organism was made when stem canker of cocoa was noticed in India. *P. palmivora* MF_1 (now, *P. palmivora*) has been reported as the causal organism of cocoa canker in India based on the studies on the isolates collected from few gardens in Karnataka State (ChandraMohanan, 1978). Based on this study it has been reported that the fungus grew well and produced sporangia and chlamydospores abundantly on potato dextrose agar and oatmeal agar media at room temperature ranging from 25.5 to 29.0ºC. The sporangia were ellipsoidal or ovoid, caduceus and papillate with a length/ breadth ratio 1.3-2.0 (usually 1.6). The stalk of the sporangium was short and thick.

Later, Sreenivasan and ChandraMohanan (1984) reported that only one species, *Phytophthora palmivora* was found associated with cocoa in Dakshina Kannada district of Karnataka State, based on their studies on morphological characters of *Phytophthora* isolated from 80 samples each of pod and soil, 60 leaf and 40 shoot samples collected from cocoa gardens occurring in different localities. Sastry and Hegde (1989) studied the characteristics of cocoa *Phytophthora* collected from multistoried cropping system involving cardamom as one of the component crops in Uttar Kannada district of Karnataka and identified this isolate as *Phytophthora meadii* Mc Rae. But, detailed studies involving isolates collected from various localities in Uttar Kannada district are necessary to find out whether *P. meadii* is the major species causing black pod disease in this area. *P. meadii* isolate of cardamom received from Indian Cardamom Research Institute, Myladumpara, Kerala was found to be pathogenic on detached and wounded cocoa pods, on artificial inoculation. So, there are chances of *P. meadii* causing black pod disease of cocoa in multistoried cropping system with cardamom as one of the intercrops.

Systematic studies on the *Phytophthora* causing black pod disease in Kerala and Karnataka states were started in 1989 at CPCRI, RS, Vittal. Out of the 130 isolates of *Phytophthora* spp. collected from different localities in Kerala and Karnataka, 120 isolates were identified as *P. palmivora.* (Chowdappa and ChandraMohanan, 1993). Detailed studies on the remaining ten isolates of *Phytophthora* isolated from black pod disease samples collected from Kerala, five isolates were identified as *Phytophthora capsici* (Chowdappa *et al.,* 1993) and five isolates as *Phytophthora citrophthora* (Chowdappa and ChandraMohanan, 1996). In India, both A_1 and A_2 mating types were found among *P. palmivora* and *P. capsici* population. A_2 mating type was predominant in *P. palmivora* and A_1 in *P. capsici* (ChandraMohanan and Chowdappa, 1999). The occurrence of both mating types of different species in same locality reveals the possibility of intra-and inter-specific hybridization in nature and formation of new strains.

P. palmivora was the only species recognized as the causal organism of black pod disease of cocoa in India till 1993. Now, it is recognized that though *P. palmivora* is the predominant species causing black pod disease in this country, *P. capsici* and *P. citrophthora* also cause natural incidence of black pod disease in some of the localities in Kerala state. When these studies were conducted cocoa cultivation was mainly concentrated in Kerala and Dakshina Kannada district of Karnataka covering an area of only about 16,000 ha. Therefore, studies on *Phytophthora* associated with black pod disease were confined to the isolates collected from a limited area.

Conclusion and future thrust

Stem canker is a serious problem as it leads to the death of cocoa plant. No attempt has been made so far to find out any other species of *Phytophtora* causing canker or to find out the variability if any within *Phytophthora* species causing stem canker. Morphological and genetical analysis have shown that *P. palmivora* isolates exhibited high level of relatedness but having wide intra species variability (Manalo, 2000). Thus, a perusal of available literature revealed that studies conducted by the earlier workers in India were based on *Phytophthora* isolates of black pod disease collected from limited area and that they were mainly depending on cultural and morphological characters for variability studies. Detailed studies on molecular characterization have not been conducted so far with the *Phytophthora* isolates of cocoa collected from different agro-climatic regions of India.

Phytophthora disease has a large economic impact on cocoa production and consequently farmer's income. Several fungicides have been tried for the control of black pod disease in other cocoa growing countries. But detailed studies have not been conducted so far, on the management of stem canker in most of the cocoa growing countries. Prophylactic spraying of Bordeaux mixture is recommended as a

general recommendation for the control of black pod disease in India. However, no attempt has been so far made in India to develop integrated disease management practices for the two important diseases of cocoa. Application of copper based and other fungicides, commonly used to control the diseases, is expensive and not completely effective (Lass, 1985). Although chemical control methods have been developed to reduce yield losses from black pod disease, they are expensive and often beyond the reach of average cocoa farmers in developing countries (Tan and Tan, 1990). It may also be noted that, studies on any of the cocoa *Phytophthora* diseases have not been conducted in India after 1995, though cocoa cultivation has expanded to new areas year after year, *vis-a-vis* increase in incidence and severity of black pod and stem canker. Though there are reports on *Phytophthora* infection of cocoa roots (Gregory, 1974), no studies have been conducted in this line in our country. Infected fruits and soil may serve as inoculum reservoir. Therefore, soil phase of *Phytophthora* should also be given importance. Occurrence and intensity of *Phytophthora* diseases of cocoa vary very much from locality to locality as well as with the cropping systems. To have a better understanding to the disease severity, detailed studies on the climatic factors and disease intensity are necessary. Analysis of the diversity of pathogen will reveal the taxonomic status of *Phytophthora* species of cocoa in our country. Phenotypic and molecular characterization would clarify the pathogenic variability of the different isolates. The accurate identification of *Phytophthora* species occurring in different agro-climatic regions is a prerequisite to disease control. The economic loss due to black pod and stem canker diseases warrants to evolve economically viable and easy to adopt integrated disease management practices. Such ecofriendly and economically viable management practices only will be received and practiced by cocoa growers.

REFERENCES

1. Ainsworth, G.C. and Bisby, G.R. 1961. *Dictionary of the fungi.* CMI, Kew 547 p.
2. Asare-Nyako, A., Amponash, J.D. and Nuamah, G.E.A. 1972. Nursery diseases of cocoa in Ghana I. Pre and post emergence deaths of seedlings caused by *Phytophthora palmivora. Ghana Journal of Agricultural Sciences* 5: 127-133.
3. ChandraMohanan, R. 1978. Cacao canker caused by *Phytophthora palmivora. Plant Dis. Reporter* 62: 1080- 1082.
4. ChandraMohanan, R.1979. Cocoa seedling dieback. *Indian Cocoa, Arecanut and Spices Journal* 3: 5-6.
5. ChandraMohanan, R. 1982. Studies on the reaction of pods of different cocoa accessions to *Phytophthora palmivora. Planter (Kuala Lumpur)* 58: 99-103.
6. ChandraMohanan, R. 1985. Incidence of cocoa black pod disease in Dakshina Kannada District (Karnataka) - a major cocoa growing area in India. *Indian Cocoa, Arecanut and Spices Journal* 8: 91-92.
7. ChandraMohanan, R. 1994. Diseases of Cocoa. In: *Advances in Horticulture* Vol. 10 - *Plantation and Spice Crops Part* 2. Eds. K.L.Chadha and P.Rethinam. Malhothra Publishing House, New Delhi. pp. 1001 - 1014.
8. ChandraMohanan, R. 2002. Diseases. *In:* Cocoa. Balasimha, D(Ed). CPCRI Kasaragod, Kerala. pp. 88-107.
9. ChandraMohanan, R. and Chowdappa, P. 1999. Important diseases of cocoa and their management. In: *IPM system in Agriculture* Vol. 6 - Cash Crops. Eds. R.K. Upadhyay, K.G. Mukerji and O.P. Dubey. Aditya Books Pvt. Ltd., New Delhi, India. pp. 401- 421
10. ChandraMohanan, R. and Kaveriappa, K.M. 1981 Occurrence and distribution of cocoa diseases in South India. *Proc. 8th International Cocoa Research Conf.* 18-23, Oct., 1981. Cartagena, Columbia. pp. 445-449
11. ChandraMohanan, R., Anandaraj, M. and Joshi, Y. 1979. Studies on *Phytophthora* diseases of cacao occurring in India. *In: Proc. PLACROSYM II,* 1979, Ootacamund, India. pp. 335-342.

12. Chee, K.H. 1969. Variability of *Phytophthora* species from *Hevea brasiliensis. Transactions of the British Mycological Society* 52: 425-436.

13. Chowdappa, P. and ChandraMohanan, R. 1993. Pathogenic variability among the isolates of *P. capsici* causing balck pod disease of cocoa in India. In: *Proc.* 11th *International Cocoa Research Conference,* 18-24, July, 1993, Yamayssocikro Colo D'Ivore.

14. Chowdappa, P. and ChandraMohanan, R. 1996. Occurrence of *Phytophthora citrophthora* on cocoa in India. *Trop. Agric. (Trinidad*) 73: 158-160.

15. Chowdappa, P. and ChandraMohanan, R. 1997. Taxonomy of *Phytophthora* spp. causing black pod disease of cocoa (*Theobroma cacao L.*) *J. Plantn. Crops.* 25: 127 - 145.

16. Chowdappa, P., ChandraMohanan, R. and Ramanujam, B. 1993. Occurrence of *Phytophthora capsici* on cocoa in Kerala. *Indian Phytopath.* 46: 92-93

17. Gregory, P.H.1974. *Phytophthora diseases of cocoa.* Longman groups Ltd., London. 348 p.

18. Jenman, G.S. and Harrison, J.B. 1897. Pests affecting cocoa plantations. In: *British Guyana report on the agricultural work in the botanical Gardens for the years 1893-4-5,* George Town, Demarara. 127 p.

19. Lass, R.A. 1985. Diseases. In: Cocoa (eds. G.A.R. Wood and R.A. Lass) Longman, London. pp. 265-305

20. Lawrence, J.S. 1978. Screening of cacao cultivars for resistance to *Phytophthora palmivora* in the collection of CATIE, Costa Rica *Revista Theobroma (Brazil*) 8: 125-131.

21. Manalo, G.G. 2000. Morphological and genetic diversities of P.palmivora Butl. isolated from coconut (Cocos nucifera L.). *M.Sc. Thesis.* Laguna College, The Philippines. 64 p.

22. Mc Gregor, A. and Moxon, J.E. 1985. Potential for biological control of tent building species of ants associated with *P. palmivora* pod rot of cocoa in Papua New Guinea. *Annals of Applied Biology* 107: 271-277.

23. Ramakrishnan, K. and Thankappan, M. 1965. First report of black pod disease of cocoa in India. *South Indian Hort.* 13: 33-34.

24. Rao, G.K.R. and ChandraMohanan, R. 1993. Symptomatology of stem canker of cocoa in India. *The Planter (Kuala Lumpur)* 69: 153-158.

25. Rao, G.K.R. and ChandraMohanan, R. 1995. Incidence of stem canker of cocoa grown under different cropping systems. *Indian Cocoa, Arecanut and Spices Journal* 19: 35-37.

26. Rao, G.K.R. 1989. Fungi associated with stem canker of cocoa. *M. Phil. Dissertation.* Mangalore University, Mangalagantothri, Mangalore. 101 p.

27. Rorer, J.B. 1910. The relation of black rot of cocoa pods to the canker of cocoa tree. *Bulletin Department of Agriculture,* Trinidad, Tobago 9: 38.

28. Sastry, M.L.N. and Hegde, R.K. 1989. Variability of *Phytophthora* species obtained from plantation of Karnataka. *Indian Phytopath.* 42: 421-425.

29. Sreenivasan, T.N. and ChandraMohanan, R. 1984. *Phytophthora* associated with cocoa (*Theobromae cacao* L.) in South Kanara district, Karnataka, India. *Tropical Agric.* (Trinidad) 61: 186-187.

30. Tan, G.Y and Tan, W.K. 1990. Additive inheritance of resistance to pod rot caused by *P.palmivora* in cocoa. *Theoretical and Applied Genetics* 80: 258-264

31. Thorold, C.A. 1975. *Diseases of cocoa.* Claredon Press, Oxford. 423 p.

32. Willis, J.C. and Green, E.E.1897. The cacao canker. *Tropical Agriculturist (Trinidad)* 17: 272-273.

33. Zentmyer, G.A. 1988. Taxonomic relationships and distribution of *Phytophthora* causing black pod disease of cocoa. In: *Proceedings of 10th International Cocoa Research Conference,* Douala, Cameroon. pp. 291-295.