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Epidemiology and Management Strategies of Cocoa black pod (*Phytophthora* spp.)

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Abstract

Pathogens of the Straminipile genus *Phytophthora* cause widespread disease fatalities to worldwide cocoa productivity. *Phytophthora megakarya* sources substantial pod rot and losses due to canker in West Africa, although *Phytophthora capsici* and *Phytophthora citrophthora* cause pod decays in Central and South America. The universal and extremely destructive *Phytophthora palmivora* bouts entirely parts of the cocoa tree at all phases of the rising cycle in Ethiopia. This pathogen causes 20 to 30% pod damages through black pod rot, and kills up to 10% of trees annually through stem cankers. *Phytophthora palmivora* has a multipart disease cycle linking several causes of primary inoculum and numerous modes of distribution of subordinate inoculum. This consequences in explosive increases during suitable environmental conditions. The feast of local pathogens must be prohibited by effective quarantine fences. Opposition to all these *Phytophthora* species is characteristically low in commercial cocoa genotypes production. Disease losses can be abridged through combined management practices that comprise pruning and shade management, leaf covering, regular and complete picking, hygiene and pod case removal, suitable fertilizer application and targeted fungicide usage. Wrapping these options to convalesce uptake by smallholders presents a main challenge for the industry.

Keywords – Control – Disease – Epidemics – Production – Spices

Introduction

Cocoa is a food-industrial crop mostly used at chocolate industry and had important role in poverty reduction of miserable regions of the humid tropics. Smallholder farmers cultivate more than 90% of the total cocoa produced in the world (Iwaro et al. 2006). It is foreseeable that about 5 to 6 million farmers from Africa, Asia, Latin America and Oceania produce cocoa. The six major cocoa producing countries are Côted'Ivoire, Ghana, Indonesia, Nigeria, Cameroon and Brazil (Drenth & Guest 2004). In Ethiopia, cocoa is mainly cultivated in southwestern Ethiopia viz., Tepi, Bebeka, Gamadiro and Jimma. The shady conditions in the cropping systems of cocoa coupled with friendly climatic conditions during summer season deliver favorable conditions for the development and spread of Phytophthora diseases. Cocoa black pod, is sparingly thoughtful problem in all areas of the biosphere where cocoa is grown, causing substantial pod losses of up to 30% and killing up to 10% of the trees yearly (Appiah et al. 2003). Among the diseases of cocoa happening in Ethiopia, black pod caused by Phytophthora species is the most widespread and destructive disease.

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The genus *Phytophthora* possibly causes more production losses worldwide than any other disease of cocoa. *P. palmivora* has numerous hundred registered hosts and is of worldwide importance in cocoa, causing universal yield losses up to 20 to 30% and tree demises of up to 10% annually, while individual farms in wetter cocoa-growing parts may suffer entire loss (Erwin & Ribeiro 1996, Drenth & Guest 2004, Ndoumbe et al. 2004). *P. megakarya* is currently the most significant cocoa pathogen in Central and West Africa, repeatedly causing whole loss of pods (Appiah et al. 2003). It is endemic to Equatorial Guinea, Gabon, Cameroon, Togo, Nigeria, and Ghana, and is still in an aggressive phase in adjacent Côte d'Ivoire (Kébé et al. 2002). *P. capsici* and *P. citrophthora* pod rots are shared in Central and South America and might cause important losses under auspicious environments (Erwin & Ribeiro 1996). Other species comprising *P. megasperma* and *P. katsurae* have also been described to cause pod rots. Knowingly, the two major species, *P. palmivora* and *P. megakarya*, invented away from the centre of diversity of cocoa, and are thus "new happenstance" diseases.

Disease symptoms and pathogen biology

The utmost noticeable symptom produced by *Phytophthora* spp. is pod rot or dark pod. Pod lesions initiate as small, firm, black spots on every part of the pod, at any phase of pod growth. Lesions develop quickly casing the whole pod superficial and internal tissues, comprising the beans, of vulnerable genotypes in a few days. Occupied pods shrink to form a mummified pod, which in the occasion of *P. palmivora* delivers a container of inoculum for at least 3 years (Dennis & Konam 1994). Beneath humid circumstances a sole pod may yield up to 4 million sporangia (containing motile zoospores) that are dispersed by rain, ants, flying insects, rodents, bats, and flying foxes; on polluted collecting and pruning tools; and in contaminated soil (Dennis & Konam 1994). Pod rot indications due to *P. megakarya* are very alike but symptoms seem quicker and sporulation is usually more plentiful (Appiah et al. 2003).

Phytophtora palmivora and *P. megakarya* contaminate bark, flower cushions, and chupons producing cankers. Cankers at the base of the stem might range to the main roots. Canker lesions are concealed by the bark but often radiate a reddish gum or pollute flower cushions, murder the flowers. Rasping the external of the bark discloses a distinct dispersal reddish lesion in the internal bark that frequently does not enter deep into the wood. The significance of *Phytophthora* stem canker is perhaps undervalued, as cankers decrease tree potency and pod loud capacity, thus plummeting yield. Cankers may also deliver vital source of inoculum for pod deterioration (Guest et al. 1994). Canker growth is often related with stem and bark borers, including the longicorn beetle (*Glenea* spp.) and *Pantorhytes* spp., which might be attracted to them. Girdling cankers cause the unexpected death of up to 10% of trees every year, dropping production and impressive an extra cost in growing and lost production as replanted trees mature.

In humid circumstances, *P. palmivora* also causes new growth and leaf blight. Contagions of fine roots are also common, though these seem to be more significant as a source of inoculum than as a cause of severe injury to the tree, mainly if a leaf mulch layer is existent. Sexual reproduction needs two mating types (A1 and A2) in the heterothallic species *P. megakarya* and *P. palmivora*, but oospores are seldom observed in nature, probably because reverse mating types are seldom found together (Appiah et al. 2003). There is some indication of natural hybrids where well-matched mating types of *P. palmivora* and *P. megakarya* co-exist (Espirito et al. 2001). The pathogen usually exists as mycelium and chlamydospores (thick-walled resilient spores) in diseased plant material, usually roots, cankers or mummified pods (*P. palmivora*), or in the soil (*P. megakarya*) (Konam & Guest 2002).

Epidemiology

Even though symptoms seem year-round, the greatest severe spates coincide with the proliferation of sporangia and insect vectors during the rainy period. In the attendance of moisture, sporangia release the infective propagules, zoospores. Zoospores need 20 to 30 min in free water on plant exteriors before they encyst, sprout, and enter host tissues. Beneath favorable conditions sporangia grow within 48 h of infection. As a soilborne pathogen that contaminates the midair parts of cocoa trees, the main epidemiological enquiry is how the pathogen reaches into the awning. *P. palmivora* lives less than 10 months in soil as a saprophyte, contingent on the ground shelter (Konam & Guest 2002). Rain splash, aerosols, polluted equipment, rodents, and ants are possible mechanisms of inoculum movement into the canopy. Though, rain splash spreading of *P. palmivora* from the soil superficial or loads of pod cases is restricted to 75 cm, and there is little evidence to indicate that aerosols are formed under the relatively secure canopy of cocoa trees. Formerly in the canopy, reservoirs of inoculum are established in cankers, in diseased flower cushions and mummified pods. Yet, in their exhaustive study in Nigeria, Drenth & Guest (2004) decided that when all the known pathogen distribution mechanisms were tallied, up to 40% of pod rot lesions resulted from "no obvious source".

The current report from Papua New Guinea that hovering beetles transport inoculum into the canopy, and particularly to pods, may resolution the origin of contagions with "no obvious source", and needs validation in other cocoa growing parts (Konam & Guest 2004). Beetles colonize *Phytophthora* lesions on pods of vulnerable cultivars more speedily and more comprehensively than on less defenseless cultivars, and empathy of the factors involved, probably attractants in vulnerable genotypes or repellents in resilient genotypes, could be valuable for breeding agendas. However, the soilborne stage of *P. megakarya* is dominant. Root contagions maintain a reservoir of inoculum that discharges zoospores into the soil surface water. Zoospores feast by rain splash, stepwise up the plant, from pods neighboring to the ground till the whole tree is affected. *P. megakarya* does not persist in mummified pods but remains viable in bark and sapwood for numerous months and in infected wreckage for at least 18 months (Appiah et al. 2003).

Disease management

Quarantine

Although *P. palmivora* is universally disseminated, pathogenic variability within the species occurs and the introduction of exotic isolates postures a significant risk to cocoa production (Appiah et al. 2003, Drenth & Guest 2004). Efforts would be made to avoid the movement of *Phytophthora* spp., mainly *P. megakarya* from West Africa to other cocoa-growing regions including Ethiopia. The movement of soil between cocoa-growing parts must be eluded and cocoa germplasm must be swapped thorough intermediate quarantine services (Kébé et al. 2002).

Resistance

Breeding for resistance bargains the best durable management approach; but, progress integrating durable resistance into cultivars with essential agronomic and quality characteristics has been sluggish. As a hereditarily variable perennial tree, cocoa development presents significant challenges to breeders. Furthermore, most breeding programs have attentive on yield and quality under concentrated management regimes and congruently low rates of disease, thus ignoring the impact of disease on yields under smallholder farm circumstances. Amelonado-type Lower Amazon and Upper Amazon varieties appear less vulnerable to *Phytophthora* than Trinitario and Criollo types, and are extensively used in breeding programs (Iwaro et al. 2006). Consistent screening assays for resistance using removed leaves or pods have been established and associate well with field observations of pod rot incidence (Iwaro et al. 1997, Iwaro et al. 2005, Tahi et al. 2007). These assays are now used in breeding programs to detect and reject highly disposed progenies.

Resistance to *Phytophthora* has been recognized as additive and polygenic (Despréaux et al. 1989, Flament et al. 2001) and does not seem specific for at least the two most significant species of *Phytophthora*, *P. palmivora* and *P. megakarya* (Nyassé et al. 2007). A number of dissimilar quantitative trait loci (QTLs) for resistance to *Phytophthora* have been known in leaf disk, pod inoculation, and field studies, though so far none of these markers seem constantly (Flament et al. 2001). However, with further growth and better precision, marker aided selection for resistance should support future cocoa breeding programs. Another approach to detecting resistance is to seek out healthy single trees amid the great variety of genotypes on farms under high normal disease pressure. The genetic variety resultant from germplasm introductions over time and natural crossing has created stunning instances of segregation for dissimilar levels of vulnerability in adjacent trees (Konam & Guest 2002). Once known and confirmed in genotype-environment trials, these individuals can be castoff to provide budwood for farm revamp and for insertion in breeding programs.

Biological control

There has been wide research into the finding and application of traditional inundated natural control agents against *Phytophthora* infections of cocoa. Even though there have been numerous reports of antagonistic and mycoparasitic fungi hindering the development of *Phytophthora* in vitro, no commercial products have been unconfined or extensively adopted by cocoa farmers. The short life cycle, phenomenal generative capacity, multifaceted disease cycle, and zoospore motility of *Phytophthora* produces explosive epiphytotics in cocoa have so far reduced inundated biological control agents unsuccessful.

The detection and growth of antagonistic endophytes compromises more promise. Endophytic fungi are naturally conveyed from mature trees to seedlings in the normal cocoa forest ecosystem, but they eventually vanish from plantations. Current evidence recommends that antagonistic endophytes re-introduced into cocoa persevere and guard the tree against *Phytophthora* (Aryantha et al. 2000). Endophytes might play vital role in integrated disease and pest management plans. Biological conquest and antagonism following the use of coverings and composts recovers soil health and microbial activity and suppresses *Phytophthora*, and these approaches are also significant components of joined management programs (Aryantha et al. 2000, Konam & Guest 2002).

Fungicides

Chemicals are extensively suggested for *Phytophthora* control, but their efficiency is variable, mainly during high-disease pressure in the rainy period. The execution of recommendations is usually yield- and price-sensitive. Protectant sprays of copper-based fungicides, along with the systemic fungicide metalaxyl, at 3 or 4 weekly intermissions are often recommended, however rarely lucrative (Guest et al. 1994). Yearly trunk injections of the low-cost inorganic salt potassium phosphonate are very effective against *P. palmivora*, mainly in tumbling cankers, in very drizzly areas of Papua New Guinea (PNG) (Guest et al. 1994), and in Ghana against both *P. palmivora* and *P. megakarya* (Opoku et al. 2007). Canker management can also be achieved by rasping surface bark to expose the canker, then picture the affected part with a copper fungicide.

Integrated management

Disease management approaches must focus on eradicating sources of initial inoculum, in avoiding the movement of inoculum from the soil to the canopy, and in dropping the production of ancillary inoculum. Likewise, unlike *P. palmivora*, the development of *P. megakarya* is inhibited by light. Shade and canopy management practices that rise light and airflow inside the canopy, such as proper spacing, pruning, and weed management, are also likely to rise flowering and pod development. Repeated and whole harvesting, sanitation, and proper disposal of pod mummies, diseased pods, and pod husks will decrease the levels of inoculum and flying beetle vectors. Loads of pod husks offer breeding sites for insect vectors and waste husks should be buried, preferably with the addition of supplements that promote microbial activity and fast decomposition, such as chicken manure (Aryantha et al. 2000). Hygiene should also include elimination of ant tents (soil tunnels built on the trunk surface by ants) that feast inoculum into the canopy. Leaf litter coverings and ground mulches reduce disease by presenting a obstruction to rain splash and by promoting the microbial breakdown of *Phytophthora*-infected residues (Konam & Guest 2002).

Attention is needed to completely integrate *Phytophthora* management into whole farm management. While cultural control has been shown to be effective in parts of Ghana and Ethiopia where *P. palmivora* is the only reason of black pod, canopy management, weed rheostat, and repeated harvesting alone did not control *P. megakarya* in Cameroon (Ndoumbe et al. 2004). But, when integrated with fungicide applications, hygiene provides valuable control of both *Phytophthora* species (Opoku et al. 2007). Combined disease management practices offer the finest promise of effective control of *Phytophthora* spp.; but, these strategies depend on a thorough understanding of the ecology of the pathogen, the cropping cycle of the host beneath local conditions and the education and vibrant participation of farmers.

Conclusions

This review discloses that black pod disease infestation on cocoa is very dangerous and its one the primary cause of low production. If not taken care of, this disease infestation can lead to desertion of cocoa farms and production in Ethiopia. Black pod infestation affect cocoa production and also yield of farmers per year. This disease infestation have impacts on the quantity and quality of cocoa beans, also it have effect on health of the crop and finally livelihood. So far diverse control strategies have been implemented against the pathogen; however, there is not at all sole effective control measure against the pathogen.

Therefore, undertaking integrated disease management tactic is critical. Thus, more exertion should be made to increase the soil health, availability of clean planting to minimize the transfer of latently infected planting material from area to area by creating quarantine center, increase farmers' knowledge on appropriate production system, etc. to control the damage caused by the pathogen both at regional and national level. Combined disease management options must be developed and promoted for smallholders in each cocoa producing areas of Ethiopia. *P. megakarya* postures a significant threat to cocoa-growing areas, and a concerted integrated worldwide breeding program is in development to identify possible sources of resistance and other choices for management.

The intricate issues of *Phytophthora*, soil health and sustainability of production essential to be addressed in coming research. Healthy soils are branded by high organic matter and plant nutrient fillings, plentiful and diverse microbial activity, best drainage and physical structure, and small levels of pathogen inoculum. Sympathetic how to achieve and maintain healthy soils on cocoa farms is important to satisfying higher yields and inferior levels of disease, whereas minimizing ecological damage.

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