Chapter

Phytophthora Diseases in Ghana: Threats, Management Options and Prospects

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Abstract

Ghana's agricultural economy is largely dominated by the crop subsector with much focus on the production of tree, arable and vegetable crops. Nevertheless, *Phytophthora* spp. are major threat to the production of these crops contributing significantly to yield reduction. In this review, the main focus will be to look at the threats the pathogen poses to production, economic importance of *Phytophthora* diseases, highlights some *Phytophthora* diseases with limited research in the country but have the potential of affecting crop production, management options and the prospect of developing and deploying biological control strategies considered environmentally friendlier and devoid of human health risks to reduce the effect of this pathogen on crop production as well as reducing the dependency on chemical control option.

Keywords: Biocontrol, Chemical control, Epidemiology, *Phytophthora*, Symptoms

1. Introduction

Plant diseases are of significant importance in plant production globally. From the resource poor small-scale farmer to the most sophisticated commercial grower, plant diseases remain a major source of concern affecting all levels of the farming enterprise contributing significantly towards achieving a reliable world's food systems. It influences decision making process of not only producers but traders, processors and even consumers contributing immensely towards the various components of food systems. Directly, diseases impact negatively on yield and it is estimated that about 16% of global arable food is lost to diseases [1, 2]. Several pathogens cause plant diseases, however, since the infamous Irish potato famine in 1840, the pathogen, *Phytophthora* sp., has been considered the most destructive plant pathogen [3] with more than 80 species in the genus with multiple or diverse host ranges [4, 5]. Several documents have reported on the negative impact of *Phytophthora* diseases on global economy in relation to human suffering, hunger, disease and subsequent death [6, 7]. Yield losses associated with the pathogen is estimated in billions of dollars annually [8, 9].

For years, *Phytophthora* diseases have impacted tremendously on Ghana's agriculture threatening the economic livelihood of farmers most especially those in cocoa production sector. *Phytophthora* pod rot disease commonly known as the Black pod disease (**Figure 1**) caused by *Phytophthora palmivora* and *P. megakarya* is the most destructive cocoa disease worldwide accounting for over 30% pod yield loss through pod rot and 10% tree death [11]. Since the incidence of *Phytophthora* diseases of cocoa were reported in Ghana [12], high yield loss ranging between 60 and 100% has been recorded [12] with the country losing more than a quarter of its 2012 annual output of 850,000MT to *Phytophthora* spp. disease [13]. Continuous destruction of cocoa by *Phytophthora* has compelled most farmers to abandon cocoa production for other crops [14, 15].

Although *Phytophthora* diseases on cocoa have received a lot of attention and well documented in Ghana, reports on their impact on other crops are scanty and highly unavailable except for taro [*Colocasiae esculenta*] which recently has been documented. Since the initial report of taro leaf blight [16] in the Eastern region of Ghana, several researchers [17, 18] have reported the prevalence of *Phytophthora* leaf blight of taro (**Figure 2**) and morphological and genetic variations in isolates of the pathogen from different parts of the country [19]. Apart from reduction in yield, the pathogen is reported to have caused most farmers to shift from taro production to other crops such as sugar cane and rice [17]. Akrofi et al. [20] reported that plants such as *Xanthosoma saggitifolium*, *Musa paradisiaca*, *Carica papaya*, *Ananas comosus*, *Elaeis guinnensis*, *Persia americana* and *Mangifera indica* commonly used as shade plants in cocoa production, served as alternative hosts to *Phytophthora*. This is worrying as little research has so far been geared towards studying the impact of *Phytophthora* on several crops in Ghana. This clearly poses a threat to crop production especially as several reports reveal susceptibility of most of the country's food and cash crops to different *Phytophthora* species leading to massive decline in their production. For example, diseases such as the tomato late blight, pineapple heart rot, and root rot of papaya which are caused by *Phytophthora* species can greatly cause fruit and vegetable insecurity in the event of future outbreak when knowledge on them is low. These challenges and gaps present opportunities for research into *Phytophthora* diseases in the country such as assessing population structure and determining the epidemiology of *Phytophthora* diseases, identifying host ranges and designing management strategies to minimize its impact. Impact studies of the pathogen can also be carried out to quantify their effect on crop production. The aim of this review is not to exhaust all aspects on *Phytophthora* diseases in Ghana but bring to light current and potential threats on some important crops, control options being used by farmers and the need to research and promote the use of biocontrol agents in Ghana. It is believed this review will inspire Plant Pathologists to delve deep into *Phytophthora* research in Ghana.

Figure 1.
Pods showing symptoms of black pod diseases [10].

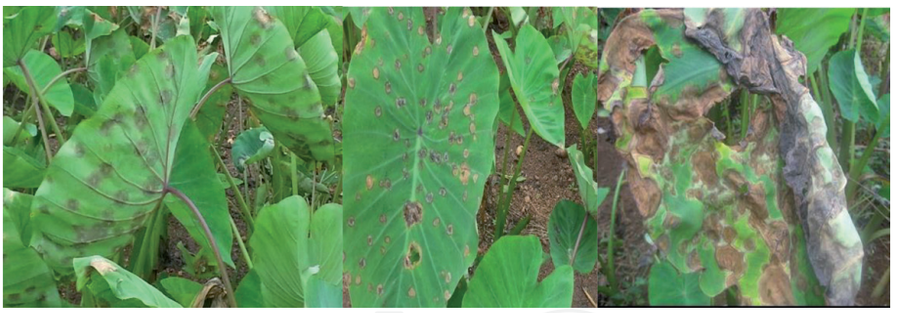

Figure 2.
Symptoms of taro leaf blight [17].

2. *Phytophthora* diseases of economic importance

Characteristics of all host plant impairments, *Phytophthora* diseases generally interrupt with the normal physiological functions of their host thereby reducing productivity and consequently lead to food and economic insecurity among populations which depend on it. Globally, impact of the late blight disease of potato, caused by the *P. infestans* [Mont.] de Bary showed clearly the significance of plant diseases and more especially those caused by *Phytophthora* species. This epidemic led to mass starvation, death and migration of people from Ireland to the United States [21]. In Ghana, the impact of *Phytophthora* diseases is highly prominent and its impact heavily felt in cocoa production. The crop is a major earner for the country accounting for about 67% of household income for about 25–30% of Ghanaians living across the cocoa growing regions [22]. As important as the economic value of cocoa to the country, *Phytophthora palmivora* and *P. megakarya* infections has been reported to cause a stagnating effect on its production. The disease which was first reported in Ghana in 1985 [12], covering an estimated area of about 16, 000 hectares of cocoa farm land is now prevalent across all cocoa growing areas in the country [10]. The black pod disease, caused by *Phytophthora* sp. has been described as the single most destructive limitation to the economic production of cocoa. Apart from the heavy pod loss, *Phytophthora* spp. causes stem canker in cocoa leading to the death of plant [23]. This clearly shows a reduction in plant population and consequently yield of the farm. Omane et al. [16] identified *Phytopthora colocasiae* as causing taro leaf blight disease in the country apart from *Phytophthora palmivora* and *P. megakarya* on cocoa. The disease has been associated with about 90 and 50% leaf and corm yield losses respectively. High incidence and severity of the disease was reported in eleven districts of the semi-deciduous agro ecologies of Ghana [17]. It causes corm rot and invasion of the rot by other pathogens such as *Lasiodiplodia theobromae* causing the corms to blacken in storage [24]. The major characteristic feature of all countries where the disease had been reported is the forced abandonment of taro production by farmers or replanting of fields with crops like sugar cane and rice [17]. This increases food insecurity in taro growing communities as the crop is used as a substitute to major food crops during lean seasons. A survey by [25] revealed high incidence of citrus trunk rot in plantations in Ghana. Reports later showed *Phytophthora citrophthora* as major cause of the disease as it causes citrus gummosis, [26] affecting major *Citrus* species such as sweet orange [*C. sinensis*], lemon [*C. limon*], mandarin [*C. reticulata*], grapefruit [*C. paradisi*], and lime [*C. aurantifolia*] [27]. The pathogen is reported to cause tree cankers leading to death and decline of the tree crop in the field. Despite several interventions by farmers and various stakeholders to possibly eliminate the menace of this disease, it had not been successful which buttressed its economic importance in citrus production [28].

3. Neglected *Phytophthora* diseases on crops of economic importance

Majority of research reports on *Phytophthora* diseases, in Ghana have focused on cocoa, with limited number on taro and citrus and virtually none existing for other crops. The pathogen, however, has been reported to be a great limitation to the production of many crops produced globally. Various species of *Phytophthora* cause varying degrees of damage to fruits, legumes, orchards and vegetable crops. The pathogen is responsible for several plant diseases such as late blight, root, stem and fruit rots in several crop species from different families such as Bromeliaceae [*Ananas comosus*, Pineapple], Caricaceae [*Carica papaya*- Pawpaw], Sterculiaceae [*Cola nitida*-bitter cola and *Sterculia tragacantha*], Agavaceae [*Dracaena manni*], Arecaceae [*Elaeis guinneensis*-African oil palm], Apocynaceae [*Funtumia elastic* -West African Rubber tree], Anacardiceae [*Magnifera indica*-Mango], Musaceae [*Musa x paradisiaca*], Lauraceae [*Persia americana*-Avocado], Euphobiaceae [*Ricinodendron heudelotii*-njanysa] and *Inviigia* sp. [20], although reports on disease assessment, prevalence and economic importance have not been established in Ghana. In several countries where *Phytophthora* diseases have been assessed and reported in any crop species, pre and post-harvest losses due to even latent infections during transportation and storage has been huge. Akrofi et al. [20] reported the role of some economic crops on cocoa farms in black pod disease epidemiology. Since these economic plants serves as alternative host to *Phytopthora* species on cocoa farms, then the potential of a possible disease outbreak due to *Phytophthora* cannot be ignored. Fresh fruits and vegetable crops produced in Ghana are exported to several countries for foreign exchange. *Phytophthora* infections can therefore lead to the rejection of these produce at various quarantine checks at points of entry. Furthermore, any delay in the transport of infected fruits or other produce to their destination of use will lead to huge loss as disease development is very fast when conditions are favorable.

It is worth noting that *Phytophthora* disease does not only have impact on the produce but also on the general cost of production. With the objective to manage the severity of the infestation of the pathogens, most farmers employ several methods among which chemical method of control is most preferred due to the quick result it provides. The cost of acquiring these chemicals in the long run increases the production cost of the farmer. Chemicals used in controlling most of these diseases in most cases turn to react with the environment. This leads to the contamination of water bodies and destruction of other useful microorganisms in the ecosystem. *Phytophthora* diseases have the potential of threatening the agricultural economy of the country with the potential to cause food insecurity. Therefore, serious attention needs to be paid to the disease to limit the menace of its impact on the agriculture enterprise.

4. Epidemiology and symptoms of *Phytophthora* diseases

Impact of climate conditions on the incidence and severity of the *Phytophthora* spp. have been reported [29]. Ndoumbe'-Nkeng [30] postulated that high levels rainfall, higher relative humidity, and lower atmospheric temperatures are known to be the main conditions favorable for the development of Phytophhtora diseases. In agreement to this, Deberdt et al. [29] also observed a significant positive correlation between rainfall and incidence of the *P. megakarya* pod rot. It has been observed in Ghana that the occurrence of the disease is between July and October across the cocoa growing areas [15, 31]. According to [32], Phythophtora disease cycle is denoted by a parasitic phase which occurs during wet and dry seasons.

Phytophthora spp. over-seasons on pod husks, in the soil, leaf debris and or roots or shade plants [33]. When conditions are favorable [mostly during the rainy season], there is a germination of the fungi sporangia, followed by the releasing of motile zoospores of the *Phythophtora* mostly in free water and quickly spread to cause destruction of host plant. *Phytophthora megakarya* and *P. palmivora* for example undergoes series of developmental phases to form the disease cycle (**Figure 3**). Symptoms of *Phytophthora* infections can be observed on every part of an infected plant mostly under wet or humid conditions. In almost all foliar diseases resulting from *Phytophthora* infection, the appearance of small translucent spot are the initial symptoms which later appears as brown to darkened spots of lesions on the affected parts [11]. These spots coalesce as environmental conditions favors it. In cocoa for example, infected pods result in browning, blackening, shriveling up, or total rotting of the pod [20]. Infected roots cause plants to pull up easily from the soil due to root

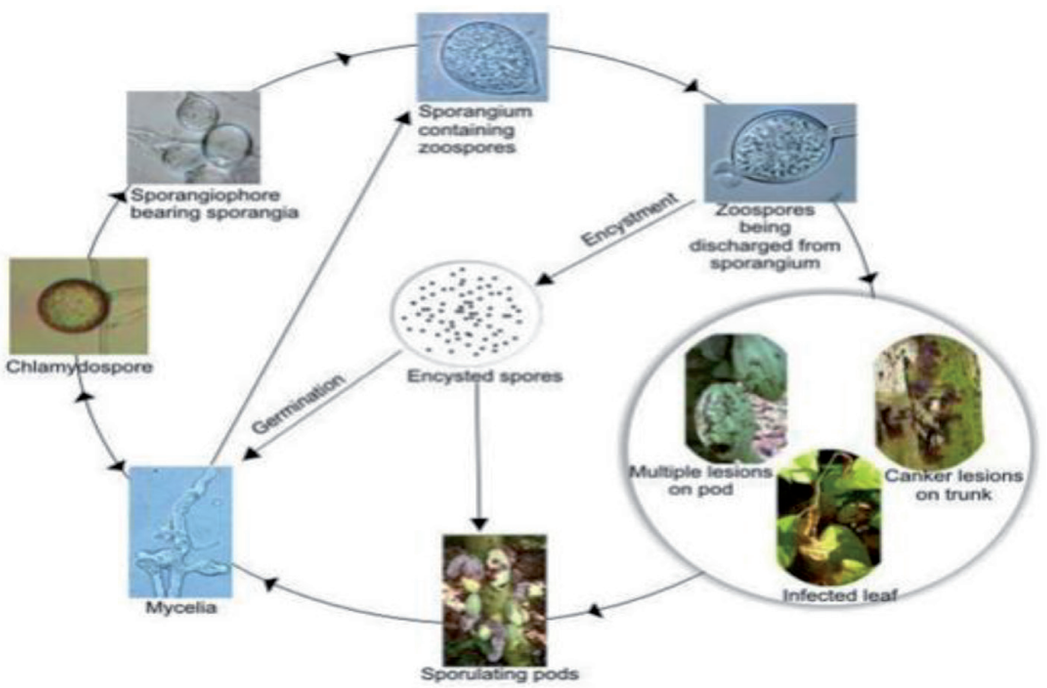

Figure 3.
Disease cycle of P. megakarya on cocoa [20].

Figure 4.
Stem canker of cocoa [www.pestnet.org].

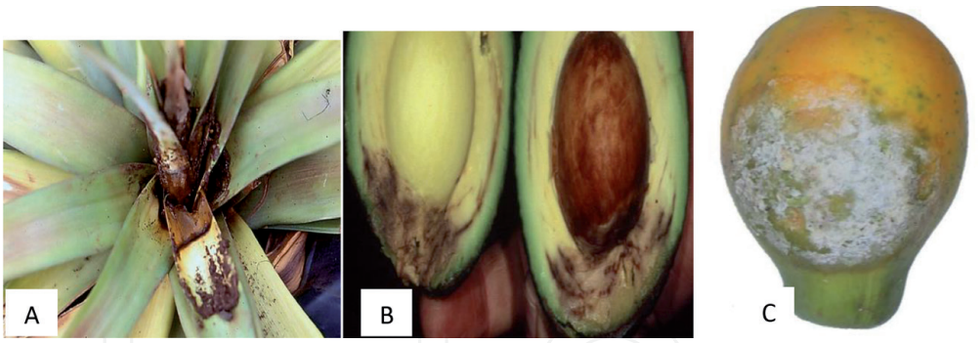

Figure 5.
Symptoms of Phytophthora *infection causing pineapple heart rot (A), Avocado fruit rot (B) and Papaya fruit rot (C). [34, 35] (https://www2.ipm.ucanr.edu/agriculture/avocado/Phytophthora-fruit-rot/).*

rot and loss. In most instances, mycelial growth covers infected plant parts areas under moist conditions. *Phytophthora* diseases can also cause cankers (**Figure 4**), fruit rots (**Figure 5**) and leaf blight (**Figure 2**).

5. Management of *Phytophthora* diseases

Crop disease management is one of the heaviest cost burdens in the crop production enterprise. The neglect of diseased farms without control or management interventions can cause a serious loss to the farmer. Management of plant diseases aims at either attacking the pathogen directly or creating a condition that will be unfavorable for its establishment and development. Achieving this calls for the employment of several possible control methods and strategies.

For years, various fungicides have been employed in the control of *Phytophthora* diseases most especially black pod disease in cocoa [36–39] and recently *Phytophthora* leaf blight of taro in the country [40, 41]. The chemical control relies mainly on copper-based fungicides and systemic fungicides such as metalaxyl and phosphonates. Among them are Kocides 101 [77% cupric hydroxides], Cocoabre Sandox [56% cuprious oxides], Copper Nordox 50 [50% cuprous oxide], Copper Nordox 75 [Copper oxide] Champion [77% cupric hydroxide], Ridomil 72 plus [12% metalaxyl and 60% cuprous oxide] among others for the control of *P. palmivora* and *P. megakarya*, the two main causal agents of *Phytophthora* pod rot of cocoa [42]. The effectiveness of fungicide for the control of *Phytophthora* disease, however, depends on factors such as the climatic conditions at the time and location of application, the crop variety, and pathogen species among others like social and economic considerations [38]. To be able to achieve an effective chemical control of *P. megakarya*, fungicides have to be sprayed at shorter intervals. In agreement with this, [15] reported that whiles a by-weekly application was recommended in Cameroon due to high and frequent rainfall, an average of 4-weeks intervals in Ghana was effective. This deference could be attributed to the differences in the frequency and amount of rainfall in Cameroon and Ghana. Chemical control in most cases have been reported to be costly. This makes chemical control unattractive to many peasant farmers. However, this approach could be cost effective when crop price is comparatively high and the crop is also under a low disease pressure [14].

Cultural control strategies according to [43], is one of the ancient strategies in the management of plant diseases. It is the strategic use of the day-to-day farm practices to either inhibit, obstruct the establishment, growth and development of the pathogen. Cultural control system has proved not only to increase yield but also created the conducive environment for efficient performance of applied fungicides [44]. To the

low-income farmers, cultural control is the most cost-effective disease management approach. This is because it does not require any extra cost apart from that which has already been the situation. For instance, early harvesting, removal of infected pods and pruning of infected branches reduces the inoculum load present by the primary or secondary infection. As postulated by [32], the appropriate tree spacing improves aeration, reduces huge canopy humidity and also keeps leaf mulch or litter in check. However, Luterbacher [45] in contrast of this report also reported that leaf litter has no major impact in reducing cocoa pod infection from soil inoculum. Despite the promising impact of this method, it was also observed that the sole implementation of this approach could be labour intensive and thus needed to be complemented with other control methods [30, 31, 46].

With frequent travel and trade within Ghanaian cities and regions, the fast spread of *Phytophthora megakarya* has been linked to the movement of plant materials from one district to another [15, 23]. This poses a high risk as several plant diseases are moved from infected regions to an uninfected region. Quarantine method could be adopted to overcome this menace. The quarantine system of plant disease control ensures that agriculture and natural resources in a localized area or district or region are safeguarded against the entry of disease pathogens. This will help to ensure an abundant, high-quality, and varied food supply within the territory and beyond.

6. Novel approaches to control *Phytophthora* diseases in Ghana: success, challenges and prospects

In the management of *Phytophthora* diseases in Ghana, especially cocoa diseases, much emphasis has been laid on chemical and cultural control as against other control options such as biological control. In the chemical control of *Phytophthora* disease, there has not been only an over reliance but an abuse of synthetic fungicides which have both health and environmental effects although the strategy is quicker, reliable and effective [47]. Utilization of control option such as biological control is not only imperative but possible, since there are numerous reported cases of biological control attempts [48–51]. Biological control strategy if harnessed will not only become a complementary but also an alternative for the control of *Phytophthora* disease as it is considered as an environmentally friendly form of disease control [52]. Biological control is the judicious use of an antagonist, its parts or product (antibiotic/secondary metabolite) to inhibit, prevent or control plant diseases. Directly, it protects their host using mechanisms such as competition for nutrients, root colonization and competition for infection sites, secretion of extracellular lytic enzymes and hyperparasitism, and induction of plant resistance. Indirectly, it promotes plant growth thereby protecting the plant from pathogen's attack [53, 54]. Not much reported success stories on the use of biocontrol agents against *Phytophthora* diseases in Ghana, but several attempts such as identifying microbial antagonists, botanicals, and resistant varieties have been initiated which needs to be appreciated.

There have been reports on the use of natural agents against *P. palmivora* and *P. megakarya* in Ghana especially *in vitro.* Not much work have been done in the field. The first of such reports was by Attafuah [55] who demonstrated that there was an inhibition of *P. palmivora* by an isolate of *Pseudomonas aeruginosa* [Schröter] Migula on cocoa husk *in vitro.* It was reported that the antagonist was isolated from cocoa mealybug, *Planococcoides njalensis* Laing and tested against *P. palmivora*. It was through the effort and the works of Attafuah that formed the basis for Odamtten and Clerk [56] to work with *Aspergillus niger* and *Trichoderma viride*. Their results showed that

metabolites of *A. niger* and *T. viride* inhibited zoospore motility, direct germination and indirect germination of sporangia, mycelial growth, sporulation and sporangial size of *P. palmivora in vitro*. Akrasi [57] isolated and identified eight *Bacillus* species strains from yam rhizosphere which were antagonistic to *P. palmivora*, the causal agent of cocoa pod rot disease (Black pod disease as being referred to in Ghana). Akrasi [57] elucidated that the filtrates of the rhizobacteria were fungitoxic and thermostable when exposed to temperature of about 121°C during autoclaving. He also reported that the filtrates of the bacteria were comparable in their effect to two fungicides, Thiophanate Methyl [Topsin M 70 WP] and Ridomil 72 plus [72% WP].

Based on the findings of Akrasi [57], [58] applied the promising rhizobacteria as protectant on cocoa pods and reported that that both broth culture and culture filtrate of the rhizobacterium isolates applied, completely inhibited *P. palmivora* infection and lesion development on detached cocoa pods. In recent studies, the rhizobacterium was identified as *Bacillus amyloliquefaciens* and field studies conducted alongside with two other antagonist viz. *Aspergillus* and *Penicillium* spp. showed these three antagonists as having potential to be developed as biocontrol agents against the black pod disease of cocoa [59].

Apart from the numerous inorganic pesticides, reports on the use of plant-based fungicides against *Phytophthora* in Ghana is limited. However, Awuah [60] postulated that natural substances from plants possess antimicrobial effects that could be potentially used in the control of *Phytophthora* diseases. This was based on the fact that, crude steam distillate of *Ocimum gratissimum* completely inhibited the growth of the pathogen and prevented black pod development on detached cocoa pods. The author further reported that the use of *Cymbopogon citratus* and *O. gratissimum* against the black pod pathogen in the field were effective against the black pod pathogen comparable to Kocide 101 [60].

For years several attempts have been made in the identification, breeding and selection of germplasm especially in cocoa for resistance to *P. palmivora* and *P. megakarya*. The use of such traditional breeding techniques for the breeding of cocoa resistance to *P. palmivora* and *P. megakarya* has been of little success. There is a well-documented reports on screening of cocoa accessions for resistance to *P. palmivora* [61]. There was also a programme to assess the existing cocoa germplasm in Ghana for resistance or tolerance to *P. megakarya* [62]. However, [63] reported that there were no cocoa genotypes with immunity to the black pod disease pathogens in Ghana. Modern breeding approaches are currently employed to determinine the mode of inheritance, combining ability and heritability of resistance to *P. palmivora* and *P. megakarya* in cocoa germplasm [64]. Cocoa hybrids such as Alpha B36xPa7/808, Pa7/808 pound 7 and Alpha B36 xT65/326 were identified to possess different levels of resistance against major cocoa diseases [65]. With respect to taro, some germplasm have shown high level of tolerance to *P. colocasie* [19, 66].

The main challenges confronting the development and use of biological control as complementary/alternative to chemical control options in Ghana are the lack of Government initiative to promote biological control as against the importation and use of synthetic fungicides that have health and environmental effect. In some countries, there are policies to promote the use of biological control agents for the control of plant diseases. Through the National Research Initiative and other USDA programmes, research funds are made available for funding biological control activities. Among such funds are the Section 406 programme, IR-4, Regional IPM grants, and Integrated Organic Programme. Funds are also made available to stimulate the development of commercial ventures for the small business innovative research [SBIR] programmes [67]. The Government of Ghana therefore has to make it as a policy to promote research and encourage the usage of novel control options to complement the use of chemicals in an integrated manner. Scientific research in

Ghana on biological control needs to be coordinated leading to the establishment of Biological Control Community of Practice to encourage effective research and promotion of biocontrol agents. Farmers and other stakeholders need continuous education to raise their awareness on the dangers of abusing synthetic pesticides and its effect on health and the environment.

Notwithstanding the challenges, the future looks bright for the development of biological control and other control strategies in the country to mitigate the effects of *Phytophthora* due to the fact that awareness on the impact of the pathogen on crop production is gaining attention and research to characterized the structures and functions of biological control agents, pathogens, and host plants at molecular, cellular, organismal, and ecological levels are gradually receiving attention of plant pathologists and breeders in the country. To ensure that world food becomes safer in the next decade, then there should be increase in demand for safer pesticide in Agriculture and the solution should therefore be a biological control in an integrated management [IM] systems.

7. Conclusion

Phytophthora disease and its impact as a potential cause of food insecurity is something that every economy has to seriously take into consideration. It affects a wide range of crops; fruits, vegetables, legumes, root and tubers. It causes total yield loss, both in the field, transport or even in storage due to latent infection. Despite the threat posed by this pathogen, limited studies have been carried out on most crops in Ghana. In this chapter, we able to elucidate the various crops that are affected by the pathogen, the effort being made to manage it, the prospect of using biocontrol agents against the use of chemical fungicides due to their effect on the environment and humans. The review has also thrown more light on how concentration has been on *Phytophthora* pod rot disease of cocoa at the neglect of other equally important diseases caused by the pathogen. Highlighting the challenges confronting the use biocontrol as an option, the main issue addressed was lack of governmental policy to promote this practice and insufficient funding to promote research on *Phytophthora*. More attention is therefore needed with the aim of limiting its impact on food and tree crops production in Ghana.

Conflict of interest

Authors declare no competing interest.

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