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STATUS AND FUTURE PROSPECTS OF RESEARCH ON DISEASES OF ENSET (*ENSETE VENTRICOSUM*) AND THEIR MANAGEMENT

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ABSTRACT: The production of enset in Ethiopia is limited by a number of constraints of which diseases play a major role. The most important disease is bacterial wilt (BW) caused by *Xanthomonas campestris pv. musacearum*. Cultural practices such as crop sanitation, avoiding the use of contaminated tools and destruction of infected plants are commonly used to manage BW. Since these practices do not offer adequate or complete BW control, research efforts have been made to develop BW resistant enset varieties. However, no success was registered as all enset clones evaluated did not have adequate level of resistance. Currently, efforts are being made to introduce transgenic resistance and bio-intensive integrated disease management options. Enset is also affected by many other diseases of lesser economic importance caused by fungi, nematodes and viruses. Fungal foliar diseases include leaf spot diseases caused by *Phyllostica sp*., *Pyricularia sp*., or *Drechslera sp*. which commonly affect suckers, seedlings and young plants. Leaf spot diseases in older plants are caused by *Cladosporium sp*., *Deightoniella sp*. or *Mycosphaerella musicola*. Wilt and root rot caused by *Sclerotium rolfsii* or *Fusarium oxysporum* are also encountered but rare. In general however, fungal diseases are of minor economic importance as adult enset plants tolerate them. Among the common parasitic nematodes that attack enset are the root lesion nematode caused by *Pratylenchus goodeyi*, the root knot nematode caused by *Meloidogyne spp*. and the leaf nematode caused by *Aphelechoides ensete*. Survey of enset nematodes indicated that *Pratylenchus goodeyi* was the most prevalent followed by *A. ensete* and *Meloidogyne spp*. Finally, a new virus with bacilliform particles causing chlorotic streak and severe stunting of enset has been described. The virus tentatively named Enset leaf streak virus has a double stranded DNA genome of 7163 base pairs and belongs to genus *Badnavirus*, family Caulimoviridae. No other virus including Banana streak OL virus reported from banana in Ethiopia have yet been reported on enset. A nationally coordinated effort assisted by further research should be made to develop integrated management strategies for enset BW by using traditional and new technologies. At the same time, the incidence and extent of damage caused by the other enset diseases should be quantified, and the diseases be prioritized and management options developed before their re-emergence as major threat to enset production due to factors such as climate change.

Key words/phrases: Bacterial wilt, Disease management, Fungi, Nematodes, Viruses.

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INTRODUCTION

Enset (*Ensete ventricosum*) serves as a staple or a co-staple food crop for about 20 million people in southern Ethiopia. The edible parts of the plant are the pseudostem and underground stem (corm) which are mainly pulverized and fermented into a starch-rich products locally called kocho and bulla. In addition, the corm can be harvested at almost any stage of the crop, and cooked and consumed as amicho in the same way with other root and tuber crops, relieving hunger during periods of critical food shortages. In 2013, it was estimated that over 67 million enset trees were harvested from which 15,924,733, 18,604,186.61 and 679,527 quintals of amicho, kocho and bulla, respectively, were expected to be produced from private peasant holdings (CSA, 2013).

Enset is also known for its high productivity and its tolerance to drought. Hence it is considered as one of the priority crops for food security in the country (Fikre Handaro *et al*., 2012). However, the crop faces a number of biotic and abiotic constraints that limit its production. Biotic constraints include diseases caused by bacteria, viruses, nematodes and fungi; insects such as mealy bugs, aphids, jassids and vertebrate pests including mole rats, porcupines, monkeys and wild pigs. Among the major abiotic factors affecting enset production are drought and poor soil fertility. Of all these factors, diseases collectively are known to be one of the most important constraints and thus attracted major research attention in the past. The pathogens that cause these diseases vary in the amount of damage they cause with some causing extreme damage and killing the plants while others have minor or no significant economic effects. Table 1 summarizes enset diseases so far recorded in Ethiopia, the associated pathogens and their current economic importance at national level. In the remaining part of this paper, research results on the diseases of enset caused by different group of pathogens and their management are presented.

Table 1. Enset diseases and associated pathogens reported in Ethiopia.

Disease	Pathogen(s)	Economic importance
Bacterial Wilt	*Xanthomonas campestris. musacearum*	Major
Corm rot	Unidentified bacteria suspected	Minor
Leaf nematodes	*Aphlencoides ensete*, A. sp.	Moderate
Root lesion nematodes	*Pratylenchus goodeyii, P. zeae,., Trichodorus* spp, *Helicotlybchus* spp., etc.	Moderate
Root knot nematodes	*Melodogyne* spp	Minor
Virus- leaf streak and mosaic	Enset leaf streak virus	Moderate
Fungal leaf spot	*Mycosphaerella musicola, Phyllosticta* spp., *Pyricularia* spp., *Drechslera* spp., *Cephalosporium* spp. ,*Deightoniella* sp. *Phoma* spp., *Selenophoma* spp., *Septoria* spp., *Thielaviopsis* spp. *Cylindrocladium quinqueseplatum*	Minor
Fungal root rot/wilt	*Sclerotium rolfsii* *Fusarium oxysporum*	Minor

CURRENT STATUS AND FUTURE PROSPECTS OF ENSET DISEASES

Bacterial diseases

Bacterial wilt (BW) caused by *Xanthomonas campestris pv. musacearum* is by far the most economically important disease of enset. A lethal wilt of enset in Ethiopia presumed to be the first report of the disease was first recognized by Castellani (1939), who reported it as threatening enset production. It was also stated in the report that the disease is similar to Moko bacterial wilt and that it could be transmitted from enset to banana, with a slower disease development (Castellani, 1939). However, the description of the causal agent of the disease as bacterial was described 30 years later by Dagnachew Yirgou and Bradbury (1968) who coined the name *Xanthomonas musacearum* to the pathogen. The same pathogen was later isolated from banana with similar wilt symptoms in the enset-growing region of southwest Ethiopia (Dagnachew Yirgou and Bradbury, 1974). These authors recommended that great care should be taken to minimize the spread of the wilt to banana in Ethiopia and other parts of the world where it could pose a serious problem. The disease nevertheless was later reported on banana in Uganda in 2001 (Tushemereirwe *et al*., 2004) where it rapidly became a serious threat to its production later spreading to many other banana growing countries in Eastern Africa (Tripathi *et al*., 2009).

Since the recognition of the bacterial nature of enset wilt disease in Ethiopia, considerable research efforts have been made to further understand the pathogen and disease epidemiology in order to develop management options. Similar efforts were made during the last decade in other countries growing banana, particularly in Eastern Africa where the disease was considered a major production constraint. The main research achievements on bacterial wilt disease of enset or banana over the last decades can be summarized as follows:

1. The geographical distribution of the disease in enset and banana growing areas of Ethiopia and banana growing areas elsewhere was determined through repeated surveys. In Ethiopia, it is now established that the disease occurs in all enset growing areas although the incidence and severity varies among locations and years.
2. The causal bacteria have been characterized in detail using morphological, biochemical physiological and molecular tools. These included pathogenicity and hypersensitivity tests in various plant hosts, studies on pathogen variability in space and time and nucleotide sequencing of whole genome of *Xanthomonas campestris pv musacearum* in laboratories abroad.
3. Main methods of the natural spread of the disease and means of pathogen survival have been established for enset in Ethiopia and banana elsewhere, although there is a knowledge gap on biological vectors of BW pathogen. Such information has been the basis for the sanitation-based control measures adopted to check BW disease on the two crops.
4. Reliable diagnostic methods have been developed to efficiently detect and identify the pathogen. The most recent developments in this area include development and use of semi-selective media, antibody-based tests including Enzyme-linked immunosorbent assay and fast lateral flow devices that are made commercially available, and PCR-based protocols.
5. Evaluation of various enset clones for genetic resistance from enset have been conducted and promising results were obtained. In addition, efforts are being made to develop transgenic enset varieties with BW resistance.

Prevention and control of bacterial wilt of enset

Cultural practices

Despite the considerable research efforts made on enset bacterial wilt in Ethiopia, there is still inadequate information on the epidemiology of the disease particularly on its field spread by insect or other biological vectors (Fikre Handaro *et al*., 2012). Lack of such information, together with the perennial nature of the plant and absence of natural resistance, have hampered the development of effective control measures. Consequently, management options have focused on methods that reduce the initial inoculum and subsequent spread of the pathogen. The main method practiced to manage enset BW in Ethiopia is the use of cultural practices such as crop sanitation, avoiding the use of contaminated tools, destruction of infected plants by burying or burning, crop rotation and restricting the movement of infected plant materials (Dagnachew Yirgou and Bradbury, 1968; Dereje Ashagari, 1985; Quimio and Mesfin Tessera, 1996). These efforts, usually supported by campaign to create awareness of farmers, have significantly reduced enset BW incidence and thus the subsequent crop loss when implemented on a pilot scale on farmers' fields by a multidisciplinary team of experts (Million Tadesse *et al*., 2003; Fikre Handaro *et al*., 2012). However, the adoption of such practices by many farmers has been inconsistent as they are labour intensive and demand continuous follow up which the farmers are often reluctant or unable to apply effectively. Moreover, the approach has not been scaled up to result in meaningful disease management at the national level.

Genetic resistance

The implementation of the cultural practices to control enset bacterial wilt did not result in complete management of the disease and hence the use of resistant varieties was considered as the best option as was the case in many other bacterial diseases of plants. Subsequently, considerable research efforts have been made over the last two to select and develop BW resistant enset clones either by experimentally exposing enset clones to bacteria inoculum in greenhouse or under field condition (Gizachew Welde-Michael *et al*., 2008; Fikre Handaro and Alemar Said, 2016). Some enset clones such as Mazia, Genticha, Badedeti either showed recovery after inoculation or lesser disease incidence compared to susceptible checks. The level of resistance was however not satisfactory to be recommended for practical use or incorporated into breeding programs as results obtained in various experiments were inconsistent perhaps due to variations in the bacterial

strains used or variable amount of inoculum applied in each experiment. Furthermore, the clones which had some level of resistance did not have the desired culinary quality and other desirable agronomic traits sought by the farmers. The problem was further compounded by the absence of national capacity to cross or breed this highly sterile perennial crop to combine such useful traits in a clone or clones preferred by farmers.

In the absence of adequate natural resistance to BW, developing resistant enset varieties using transgenic methods was thought to be another viable option. This approach was initiated based on encouraging results obtained by scientists in Uganda who have successfully transformed banana to express two genes namely hypersensitive response-assisting protein gene (*hrap*) and a plant ferredoxin-like protein gene (*Pflp*) from sweet pepper (*Capsicum annuum*) to provide resistance against bacterial wilt (Namukwaya *et al*., 2012; Tripathi *et al*., 2010). In this work, many banana lines that showed 100% resistance to either of the two genes have been identified and are currently being tested for gene stability and durability of resistance under advanced field trials in Uganda and Kenya. Since the pathogen causing BW on enset and banana is the same, a collaborative research project was initiated in recent years between Ethiopian scientists and scientist working on transgenic banana in East Africa to expand the impressive results obtained on banana to enset. Progress made so far in this collaborative work include development of regeneration protocols for some enset clones establishment of Agrobacterium-mediated transformation system and obtaining some enset transformant lines (Matheka *et al*., 2016,; Tripathi *et al*., 2017). Further research under contained greenhouse and confined field trial is planned in Ethiopia for which permission is required from national biosafety regulatory authorities. Hence, it is reasonable to hope that transgenic BW resistant enset varieties will be made available in Ethiopia in the near future.

Biological control

Biological control of bacterial plant diseases by microorganisms especially actinomycetes, rhizobacteria and other endophytes have been reported as efficient options for disease management elsewhere. Following the same trend, a number of microorganisms have been evaluated for the potential role in the management of enset bacterial wilt. These include lactic acid bacteria, pseudomonads, growth promoting bacteria, *Trichoderma* sp, endophytes, and streptomycetes that have shown some promising results under *in vitro* conditions. In addition, some botanicals (leaf and seed

extracts) were also evaluated and found promising. However, many of the biocontrol agents were ineffective or inconsistent at best in controlling BW when evaluated under field conditions. Recently efforts are being made to evaluate bio-intensive integrated disease management which includes a number of biocontrol agents, plant extracts and plant growth promoting microorganisms.

Apart from BW, bacterial corm rot is widely distributed and known to kill both young and mature enset plants. Bacterial corm rot disease was reported in 1991 as important disease affecting enset production. In advanced stage of the disease, the plant easily topples over when pushed, and a rotten corm is observed (Quimio and Mesfin Tessera, 1996). The causative agent has not been identified so far.

In conclusion, despite considerable research effort made to understand and manage enset bacterial wilt, the disease continues to be the most important constraint limiting enset production. This is mainly due to the shortage of control options that can be easily and widely applied by the farming community. Efforts to integrate available management options based on cultural practices with innovative strategies including conventional or transgenic resistance and the use of proven biocontrol agents should be strengthened to develop efficient, economic and sustainable management options. There are still a number of issues that need to be addressed by research (Fikre Handaro *et al*., 2012). The role of insect vectors, vertebrate pests (mole rates and porcupine), bats and domestic animals such as cattle in the transmission of the disease has not yet been adequately investigated. The survival nature of the pathogen during fermentation of enset mass into primary food products and the role of the latter products in the transmission of the pathogen has not been well determined. One of the major challenges is the lack of adequate knowledge of the epidemiology of the pathogen, which had been done only in such fragmented way.

Nematode diseases

Plant-parasitic nematodes are tiny worms that live mainly in soil and plant parts including roots, leaves and stems. They cause diseases in plants by puncturing the cell and removing the contents using a hollow stylet in their mouth cavity. The common nematodes that attack enset are the root lesion nematodes, the root knot nematodes and the leaf nematodes.

Root lesion nematode disease of enset is caused mainly by *Pratylenchus goodeyi* and to a lesser extent *P. zeae* (Peregrine and Bridge, 1992; Mesfin Mesfin Bogale *et al*., 2004). These nematodes were known to cause toppling of enset plants during windy days due to severe root rotting and damage of enset roots (Mesfin Tessera *et al*., 2009). Mesfin Bogale *et al*. (2004) during an intensive field survey observed that enset cultivars differed in their reaction to *P. goodeyii* and recommended that the clones should be screened for resistance to these nematodes under greenhouse and field conditions. A significant increase in BW incidence was observed in plants that had been previously infected with root lesion or leaf nematodes when compared to those without nematode infection (Meku Shehabu *et al*., 2010; Tiedt *et al*., 1999). Similarly, surveys also indicated that nematode diseases are mostly found in association with bacterial wilt of enset and thus may play a role in development and severity of the disease. The nematodes possibly increase the susceptibility of enset plants to the bacterial wilt by damaging roots and, even play a role in the transmission of the wilt disease (Quimio and Mesfin Tessera, 1996). It was suspected that the root damage creates wounds that act as entry points for bacteria from the surrounding soil.

Leaf nematodes cause what is referred to as black leaf streaks of enset. The disease is caused by *Aphelencoides ensete* (Swart *et al.*, 2000) which mainly attacks leaves of suckers and young seedlings causing immature death of the leaves. Leaf nematodes are found in all enset growing zones (O' Bannon, 1975; Wondirad Mandefro and Kifle Dagne, 2000; Mesfin Bogale *et al*., 2004).

Root knot nematode diseases of enset are caused by three *Melodogyne* species: *M. incognita, M. javanica* and *M. ethiopica* (O'Bannon, 1975; Wondirad Mandefro and Kifle Dagne, 2000; Mesfin Bogale *et al*., 2004). A study showed that the Ethiopian population of all the three species were found to be highly polymorphic in perinial pattern morphology and stylet length (Wondirad Mandefro and Kifle Dagne, 2000).

A quantitative survey conducted by Mesfin Bogale *et al*. (2004) indicated that the predominant nematode species observed in enset roots was *Pratylenchus goodeyi* followed by *Aphelenchoides ensete* and *Meloidogyne* spp. (Table 2). Similarly, *Pratylenchus goodeyi* was found in al1 enset samples, while *A. ensete* was found in 87% of the samples and the *Meloidogyne* spp. (second stage juveniles) in 60% of the samples.

Table 2. Population density and frequency of enset common nematodes in Ethiopia (extracted from Mesfin Bogale *et al*., 2004).

Nematode species	Prominence value Nematode number per 100 g fresh wt	Percent of samples with nematode
Pratylenchus goodeyi	5640	100
Aphelenchoides ensete	137	87
Melodogyne spp	26	60

Other parasitic nematode species reported on enset are *Helcotylenchus dhystera, H. multicinctus, Hoplolaimus* spp., *Pratylenchus coffeae, Rodopholus similis, Scutellonema bradys* and *Tylenchus* spp. (Peregrine and Bridge, 1992). These species are encountered at lesser frequency and relatively smaller density. Nematode diseases of enset are economically important in many growing areas causing moderate damage at national level, sometimes causing severe loss in specific localities. However, little research efforts have been made to develop options for their management. Future research should focus on quantifying yield loss and developing feasible control measures.

Currently, nematode diseases collectively cause significant damage to enset which can be considered of moderate economic importance although this varies from one location to the other (Mesfin Bogale *et al*., 2004). However, the possibility remains that the population of nematodes can increase more in the absence of any control measures thereby threatening enset production in the future.

Viral diseases

Viruses are very small pathogens causing diseases in plants, animals and microorganisms. There is little information on viruses or viral diseases affecting members of genus *Ensete* in the literature. The only available report in Ethiopia is that of viral chlorotic streak disease causing severe stunting affecting cultivated enset plants reported in 1990's (Quimio and Mesfin Tessera, 1996). The association of bacilliform virus particles has been confirmed with the disease (Mesfin Tessera *et al*., 1996; Adane Abraham *et al*., 2018). Subsequent surveys indicated that the disease is widely distributed in different parts of Ethiopia (Quimio and Mesfin Tessera, 1996; Williams and Matile-Ferrero, 1999; Mesfin Tessera *et al.*, 2009). Preliminary assessment of yield loss in two enset clones in natural stands (Table 3) indicated that there was very high reduction in the fresh yield, pseudostem circumference and height (Mesfin Tessera *et al*., 2009).

Table 3. The effect of enset virus on yield and yield parameters in two clones in natural stands (Source: Mesfin Tessera *et al*., 2009).

Enset Clones	**Age**	**Parameters**	**Reduction due to virus (%)**
Midesho-HS	6	Fresh yield (kg)	93
		Circumference (m)	74
		Pseud. height (m)	73
Pena-AK	4	Fresh yield (kg)	98
		Circumference (m)	77
		Pseud. height (m)	64

Recently, a virus with bacilliform particles associated with enset leaf streak disease was characterized using serological and molecular methods (Adane Abraham *et al*., 2018). The virus particles decorated at medium level using Banana streak OL virus antibodies indicating its serological relatedness to this common banana virus. Sequence analysis indicated that its circular dsDNA genome has 7163 nucleotide base pairs encoding three open reading frames (ORFs) with predicted proteins of 21.5 kDa, 14.5 kDa and 202.5 kDa arranged in a manner typical of badnaviruses (Fig. 1). The virus was shown to be genetically most closely related to Sugarcane bacilliform Guadaloupe D virus earlier reported from sugarcane (Muller *et al.*, 2011) with 73.6% overall nucleotide identity. Based on the current species demarcation criteria of the genus *Badnavirus* (King *et al.*, 2012), the virus is sufficiently distinct that it should be considered a new species for which the name Enset leaf streak virus (ELSV) is suggested. Using specific primers designed from its sequence, the badnavirus was also detected in 6 out of 40 randomly collected enset samples using virus specific primers in PCR suggesting that ELSV is fairly widely distributed on enset.

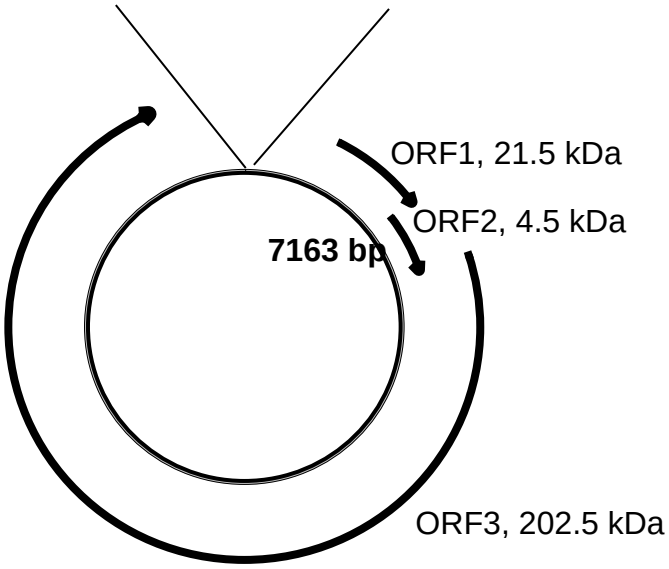

Fig. 1. Organisation of the circular dsDNA genome of Enset leaf streak virus. Circle at the center depicts the dsDNA genome whereas the arrows indicate the deduced open reading frames (ORFs) with indicated encoding capacity of +sense strand. The tRNA binding site sequences are indicated (Source: Adane Abraham *et al*., 2018).

The most serious viral disease of banana worldwide is leaf streak and mosaic caused by a group of viruses collectively called *Banana streak viruses* (BSVs) (in the genus *Badnavirus*, family Caulimoviridae). The most common of BSVs in Africa is Banana streak OL virus (BSOLV). PCR tests were done to detect BSOLV using specific primers (5'-CATGCCATGGAGTATACAGCAGAATATGA-3') and 5'-CAGACTCGAGGCCGACTGAGATAACGTC-3') on dozens of enset and banana samples originating from farmers field and germplasm accessions from research centers in Ethiopia. Results indicated the absence of BSOLV in any of enset samples while several banana samples were positive with expected 720 bp product amplified (Fig. 2). Hence, only ELSV was so far identified as associated with enset leaf streak disease on enset in Ethiopia in the samples tested. On the other hand, BSOLV is reported from banana for the first time in Ethiopia in this work. Further research is needed to establish whether BSOLV does not affect enset at all or it escaped detection due to small number of enset samples tested.

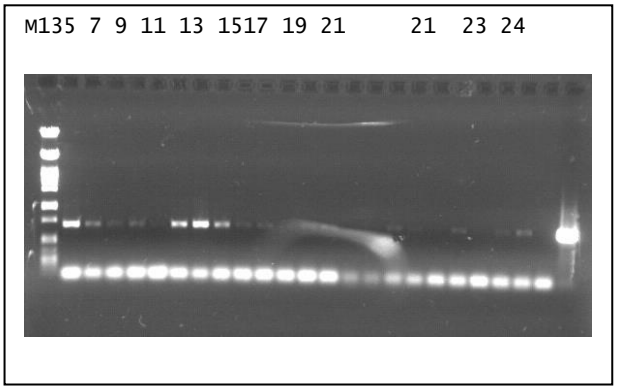

Fig. 2. Agarose gel electrophoresis showing PCR products of 720 bp obtained by PCR using BSOLV specific primers on dried banana leaf samples. M is size marker, 1-23 samples from Ethiopia, 24 is positive controls (Source: Adane Abraham *et al*., 2018).

Since enset is vegetatively propagated, one of the practical control measures to minimize possible loss due to viruses is to use virus-free plants which can be obtained by eliminating virus by tissue culture. It should also be noted however that, mealy bugs which are known to be main vectors of badnaviruses (King *et al*., 2012), may also contribute to the field spread of viruses from infected to healthy plant. In Ethiopia, two species of mealy bugs, *Cateanococcus ensete* and *Planaococcus ficus* are reported to be associated with enset (Temesgen Addis *et al*., 2008; Williams and Matile-Ferrero, 1999). *C. ensete* is very widely distributed and is one of the most important pests of enset in the country. It is also reported on enset plants suspected to be infected by a badnavirus (Williams and Matile-Ferrero, 1999). Hence, the potential of these mealy bugs in transmitting ELSV should be investigated.

Other potential viruses

Cucumber mosaic virus and *Banana bunchy top virus* are the other two common viruses of banana that may affect enset. In addition, enset could harbour any of the several of banana viruses recently reported from East Africa given the close genetic relatedness of banana. It is possible that some of these viruses or their strains or other new viruses can infect enset. Future research on enset should focus on further identification of viruses using conventional and molecular methods including sequence-independent technologies such as next generation sequencing and rolling circle amplification.

Fungal diseases

Fungal foliar diseases of enset are numerous and include leaf spot diseases caused by *Phyllostica* sp., *Pyricularia* sp., and *Drechslera* sp. which commonly affect suckers, seedlings and young plants. In older plants, leaf spots are caused by *Cladosporium* sp. and *Deightoniella* sp., *Mycosphaerella musicola*, which causes sigatoka in banana, is also known to cause destructive leaf spot on enset. Sclerotium wilt and root rot, caused by *Sclerotium rolfsii* is also encountered but rare. While some of these fungal diseases can be destructive on suckers, seedlings, young transplants and rapidly growing plants up to two years old, infected enset plants normally tolerate these diseases and recover as they grow older. Hence, mature enset plants do not have serious foliar fungal disease problems.

Some of the fungal taxa reported as causing enset diseases are known to be pathogens of banana. These include *Mycosphaerella musicola* that causes the devastating sigatoka disease in banana and *Fusarium oxysporum fs cubense* causes involved in panama wilt disease. Similarly, the genus *Cladosporium* is also known as important disease of banana in countries like Kenya (Reddy *et al*., 1999). However, for many of the fungi listed in literature as causing enset diseases, there is no information as to their pathogenic potential or the fulfilment of Koch's postulate. This raises a question as to whether they are pathogens that have intimate genetic interactions with enset or saprophytes which simply colonize enset surface. For example, many fungi that belong to the genera *Drechslera, Cladosporium, Phylosticta* or *Fusarium* are also known to be common saprophytes colonizing surfaces of many plant species. Thus, investigations are needed to unequivocally establish the pathogenic potential of many fungal microbes reported on enset as their mere isolation from plants does not necessarily indicate they are pathogenic. Finally, since many of the fungal genera reported on enset are identified only to genus level, efforts should be made to accurately identify to species level employing both traditional and molecular methods.

GAPS AND CHALLENGES IN ENSET PATHOLOGY RESEARCH

A close look at previous research in enset pathology reveals a number of gaps and challenges of which the major ones are presented below.

- Despite the considerable investment in research on bacterial wilt, technology packages for its management are not yet available.
- No enset variety with disease resistance, yield, early maturity and

culinary quality has yet been developed.

- Key epidemiological information such as biological vectors enhancing field transmission of BW pathogen is not available. It is also not clear as to whether the pathogen is disseminated during the processing of enset products for food.
- Research on enset diseases in general lacks continuity from problem identification to developing management options. This is often due to student research projects culminating after thesis defense, staff turnover in various institutions, donor-driven project lacking sustainability, and fragmented nationally funded projects with poor coordination.
- Researchers focus on "easier to do" research activities (surveys, pathogen characterization, *in vitro* assays, etc.) at the expense of long-term but more demanding and problem-solving ones (e.g. resistance breeding or crossing experiments, field trials with biocontrol agents, integrated various disease management options).
- Research on management of nematodes, viral and fungal diseases has been given little attention.
- Lack of knowledge and skills to exploit available genomic sequence data. For example, the complete genomes of both enset and bacterial wilt pathogen were sequenced but no effort was made to exploit these resources using bioinformatic tools.
- There is a lack of national coordination on enset research and development. This has resulted in duplication of efforts, fragmentation of results and wastage of resources.

CONCLUSION AND RECOMMENDATIONS

BW remains the major production constraint of enset. Apart from sanitary measures, more efficient management options do not yet exist to mitigate the enormous losses it incurs. Significant progress has been made on understanding the geographical distribution of the disease, biochemical, physiological and biological properties of the pathogen, the genetic resistance of the host and management options based on sanitary measures. This can be aided by a clear understanding of the molecular basis of interaction between the bacterium and the host plant. Hence, an integrated and multidisciplinary national effort for bacterial wilt management that include diverse approaches ranging from creating conducive environment

for researchers to engaging in conventional resistance breeding and crossing activities to capacity building for transgenic research and biosafety assessment and exploitation of available genomic and biotechnological tools should be in place.

It is also evident that enset diseases other than BW have been given little attention generally despite their actual and potential importance in production. For example, the population of the lesion nematode recorded in huge numbers under each enset plant indicates the need for due attention as severe root damage could contribute to easy toppling, and the role of the nematodes as disease vector might further complicate the problem. Similarly, the widespread occurrence and considerable reduction in yield and yield parameters of ELSV indicates that it should be given due attention. It is also very likely that more viruses including those infecting banana in other countries could cause latent but significant effect on enset due to its vegetative propagation. Hence, research efforts should be made to further understand the etiology and biology of these diseases, assess their impact on yield and develop management option of diseases as they may become more important in the near future due to factors like climate change. Overall, integration of the various available management practices and development and effective dissemination of new improved technologies such as the disease-free planting materials and resistant varieties are the best options to manage bacterial wilt and stop other diseases before they become threatening. This calls for a nationally coordinated research on enset diseases and their management.

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