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Enset Bacterial Wilt (*Xanthomonas campestris pv. Musacearum*): Effects and Management Strategies Deployed in Ethiopia

Tilahun Negash[1], Tamirat Wato[1], Atinafu Mengesha[2] and Abraham Alemu[2]*

[1]*Department of Plant Science, College of Agriculture and Natural Resource Management, Bonga University, Ethiopia*

[2]*Department of Horticulture, College of Agriculture and Natural Resource Management, Bonga University, Ethiopia*

Abstract

Enset wilt caused by *Xanthomonas campestris pv. Musacearum* is potentially destructive to enset crops, has a wide distribution, and limits the production of the crop in various parts of Ethiopia. Different disease management alternatives are being deployed to reduce its effect. Cultural disease management methods such as using healthy planting materials, optimum crop density, intercropping, rouging of the infected plant, host resistance, and Phyto-sanitation reduces the intensity of bacterial wilt by reducing available inoculum to initiate infection. The practice of using host plant resistance to control diseases stated as it is efficient and effective, long-lasting, easy to manage, and environment-friendly. Integrated management of enset bacterial wilt is possible because a combination of control strategies is applied in many parts of the world. Such an integrated approach does not depend on a sole method, which in the case of monogenic host resistance could not be long-lasting and should be more sustainable over time.

Keywords

Ensete ventricosum (Welw.) Cheesman, Effect, Enset Bacterial Wilt, Management

Introduction

Enset (*Ensete ventricosum* (Welw.) Cheesman) is used as a chief food for about 20% of the Ethiopian population, for more than twenty million people, mostly in the south and southwestern part of the country [1].

During 2019/2020 this banana resembling crop considerably contributes to food security issues and accounts 76% for household consumption, 16% for sale and 6% accounts for seed, wages, and others out of 92,960, 122.10 quintals total production at the country level [2]. The parts of the plant which are fit for human consumption include the underground stem (corm) and pseudo stem, which are pulverized and fermented into a starch-rich product traditionally known as “kocho” that would be stored for long being intact [3]. Products from enset are used in different forms in traditional medicine [4,5]. A starch for textile, adhesive, and paper industries is being produced [4]. However, due to inadequate research attention has been given to enset crop; its production system is still traditional and tedious. Different management practices starting from propagation to harvesting and processing demand high labor [5-7].

Enset was earlier cultivated only in the south and southwestern parts of Ethiopia, but the recurrent droughts have led to the expansion of enset cultivation to other parts of the country [8]. The crop is well known for its tolerance to drought and for the high productivity that makes it one of the priority crops for food security in Ethiopia. A wide adaptation within the species to altitude, soil, and climate has allowed widespread cultivation in western Bale, southwestern Oromia, including south and east Shewa, Jima, Illubabor, and Welega [7,9,10].

Enset is cultivated at an altitudinal range of 1200-3100 meters above sea level (masl), but scattered plants can also be found at lower altitudes [11]. However, it grows luxuriously in elevation between 2000 and 2750 masl [12]. For optimum growth, the plant requires an average rainfall of 1100-1500 mm per year and a mean temperature of 16-20 °C.

***Corresponding author:** Tilahun Negash, Department of Plant Science, College of Agriculture and Natural Resource, Bonga University, P.O. Box 334, Bonga, Ethiopia

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It resembles a banana plant, forming a single corm underground and a pseudo stem above the ground. Unlike domesticated bananas the seedy leathery fruits of the enset plant are inedible [13]. Almost all parts of Ensets are consumable and it is also considered as the major food source of the corm, Pseudo stem, and leaf petioles. Although wild species of enset are distributed throughout much of central, eastern, and southern Africa as well as Asia, its domestication and use as a food and fiber crop is restricted to Ethiopia [13,14]. Likewise, Taye, et al. [15]; Yemane & Fassil [16] noted that Enset has been cultivated as a food and fiber crop in Ethiopia for several years and over 80% of the production is concentrated in the south and south-western part of the country. Enset is the principal staple for the Southern Nation and Nationalities of people of Ethiopia particularly in the Bonga in-situ conservation site, Kaffa zone of southern, Ethiopia. It is cultivated as a staple along with cereals (tef, maize, sorghum, barley, and wheat), pulses (faba bean and field pea), and root and tuber crops (taro, yam, Oromo potato, and potato). It is well integrated into the culture of the people and is a typical multipurpose crop, of which every part is thoroughly utilized, not only for food but also for several cultural applications (including medicinal and ritual values) [16].

Enset is the most important crop in Ethiopia. However, its production is affected due to biotic and abiotic factors, such as diseases, insect pests, weeds, wild animals, and soil nutrient depletion, which contribute to low yield and low quality of Enset production [17]. Different fungal, bacterial, and nematode pathogens are constraints of Enset production worldwide. The diseases are jointly the greatest severe biotic factors for enset production. Among these, bacterial wilt of enset (BWE), which is caused by *Xanthomonas campestris* pv. *Musacearum* (Xcm) is the major destructive disease of Enset [8,18].

The disease was first reported in Ethiopia by Yirgou & Bradbury [19] and has since spread to all the enset growing regions in Ethiopia [8,17]. However, most of the studies showed in Ethiopia far focus on surveying the disease in some areas and characterizing the pathogen based on biochemical tests [6,20-24].

As high as 80% of enset farms in Ethiopia are infected with Xcm [25,26]. The disease causes a whole loss of yield for the infected plant that cannot be consumed by humans. The disease has forced farmers to abandon enset production resulting in critical food shortages in the densely populated areas of Southern Ethiopia [3,22,26,27]. At the country level, this disease straightly affects the livelihood of greater than a million enset producing farmers. Because the disease is more destructive, various management options are being used to minimize the consequence of Xcm to enset. Generally, controlling bacterial diseases of plants is very difficult. The strategy developed for Xcm management includes A) Cultural practices and sanitary control measures; B) Use of resistant/tolerant enset clones; C) Use of healthy and clean planting materials (suckers/transplants, corms). Cultural practices and sanitary control measures were efficient to significantly reduce the spread of the pathogen [27]. Experiences on the management of Xcm in enset and elsewhere in banana suggest that community mobilization and awareness creation for collective management of the disease is instrumental to effectively control the disease [27-29].

According to Zerihun, et al. [30] reported that sensitizing and mobilizing communities in various areas contributed to the significant decline of the incidence of the disease on the crop. Therefore, routine application of phytosanitary measures and agronomic practices to minimize spread by individual and community level is currently the most effective way of managing the disease caused by Xcm. This brief piece of work was, therefore, carried out intending to critically review the effect of Xcm on enset production, productivity, and management strategies deployed in Ethiopia.

Taxonomic Position of Xcm

Bacteria; Phylum Proteobacteria; Class Gammaproteobacteria; Order Xanthomonadales; Family Xanthomonadaceae; Genus Xanthomonas; currently classified as *Xanthomonas campestris pv. musacearum* (Xcm) [31].

Sign and Symptom of Enset Bacterial Wilt

The typical symptoms of EBW are known as wilting of the heart-leaf, followed by wilting of the adjacent overlying leaves [32]. When petioles and leaf sheaths are separated, pockets of yellow or cream-colored bacterial masses (oozes) are detected in the air pockets, and bacterial slime oozes out from cut vascular tissues (Figure 1) [3,33,34]. Eventually, infected plants wither, and the plant rots. Symptom development is rapid during the wet season and typically evident within 3 to 4 weeks under field conditions [35]. Entire leaves wilt, bend over and wither, bring about the death of the whole enset plant see in Figure 1 [19,31,34]. The different symptoms of bacterial wilt by Melese, et al. [34]; Blomme, et al. [36]; Borrell, et al. [37] & Uwamahoro, et al. [38] are clearly shown in Figure 1 and Figure 2.

Host Plant Ranges, Pathogen Survival and Mode of Transmission

Alternative host plants are important in the survival and perpetuation of several crop pathogens and have been suspected to play a role in the survival of Xcm and perpetuation of EXW disease of banana and enset [39,40]. Banana is the other common host of Xcm. Xcm is reported to survive for up to three months in the soil in the absence of a host [41] and more than four months on host stubbles and residues [33,35]. The disease persists on contaminated knives for 3 to 4 days [21]. Recently, the pathogen was recovered from the fermented enset plant after 105 days of fermentation [42]. Transmission of enset bacterial wilt from disease to healthy crop plants could occur through all possible means of contact, however, contaminated farm tools are major inoculants (Figure 3) [27,33,38,43]. Spread by animals browsing on infected leaves, use of infected plant materials, repeated transplanting which damage corms and roots, and possibly insects visiting bacterial oozes on enset foliage may also occur (Figure 3) [38,44-46]. Transmission by insect vector in enset was suggested (Figure 3) [45,46] but there is no clear information on insect and soil-borne pathogen mediated

Figure 1: Yellowing and wilting of enset leaves caused by bacterial wilt disease Photo captured by Sadessa K.) Source: Melese, et al. [34].

Source: Borrell, et al. 2020 [37].

Figure 1: (a&b) shows the symptoms in Banana plants [38].

Figure 2: Xanthomonas bacterial wilt of enset caused by *X. campestris* pv. *musacearum*. The photos depict leaf yellowing and wilting, and pockets of bacterial ooze in a leaf petiole. Photos were taken in Ethiopia by Guy Blomme [36].

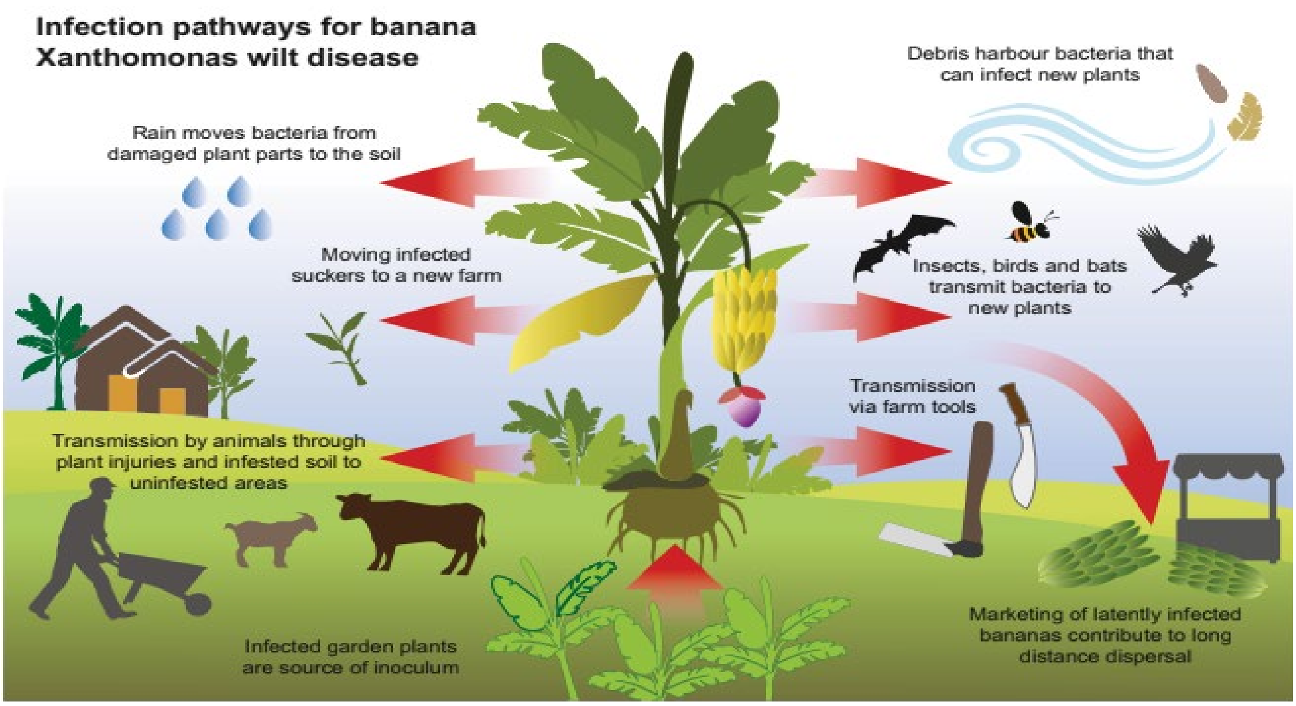

Figure 3: Transmission means of the bacterium *Xanthomonas campestris pv. musacearum* causing wilt. Source: Uwamahoro, et al. [38].

transmission of Xcm in enset. According to Uwamahoro, et al. [38] illustrated the Xcm transmission mechanism at the field condition (Figure 3).

Geographical Distribution and Economic Importance of *Xcm*

Xanthomonas campestris pv. musacearum has only been found in African countries, specifically Ethiopia, Burundi, the Democratic Republic of the Congo, Kenya, Rwanda, Uganda, and Tanzania [31]. The damage due to bacterial wilt disease could range from 70% to 100% yield loss with huge economic impact if the damage occurs to mature enset plants after years of field management [47,48]. Up to 30% bacterial wilt incidence was recorded on 4-5-year enset plants in some districts [17,35]. Such late-emerging infections could be a big loss considering the amount of time and labor farmers have invested during growing seasons [3,48]. The disease has received a lot of attention, following the epidemics of bacterial wilt on banana in 2001 [35,49] and its subsequent dissemination in the East and Central African countries [48,50,51]. This loss was estimated to a monetary value of US$ 2-8 billion over 10 years [48,50].

Management Options

Use of healthy planting materials

Infected plant material is one the most important source of inoculum. With this regard, Getachew, et al. [52] reported that the presence of the strong association of source of planting material and the wilt epidemics. However, suckers from own field and other farmers were the only means of obtaining the planting materials in the inspected fields [3]. Hence, various planting materials like suckers are the principal means of spread for systemic microbial diseases. For enset suckers are used for planting material and infected suckers are a source of inoculum in addition to infested soil, sucker and soil treatment methods have to be developed in addition to clone resistance to control the disease [3].

Using clean farm tool (phytosanitary measures)

Farming materials used during field management are the main transmission methods for bacterial wilt disease in enset, implying the importance of cleansing as a means of reducing the adverse effect of the disease [53]. Slashing by machete of weeds might result in cross inoculation in so doing increasing the incidence and severity of EBW in enset fields [3]. This author stated that the lowest disease incidence was recorded from fields managed by the clean use of farming material and rouging out and throwing of infected enset plants. Moreover, the other studies also showed that wilt management through the cutting of wilted plants and on spot burning or burying, careful utilization of farm tools, and restricted movement of infected plant parts lowered wilt epidemics close to 100% [54,55]. Such practices are supposed to reduce inoculum build-up, disease development, and farm tool transmission of plant disease [3,52,54].

Weeding

For different host-pathogen systems, high weed infestation could reduce crop strength and promote disease development through competition for available resources that increase crops susceptibility to diseases [3,53]. Managing weed properly and removing alternate hosts, along with others, from infected fields highly reduces and checks the spread of the pathogen [52,56].

Intercropping

Intercropping delayed disease epidemic onset, lowered disease incidence, and severity, and reduced the disease progress rate [57] by altering wind, rain, and vector dispersal; modifying the microclimate particularly temperature and moisture; altering host morphology and physiology; and directly constraining the pathogen [58]. The type of cropping system and planting pattern affected disease incidence and severity at initial, final, and overall assessments and affected the rate of disease development [57,59]. In the intercropping system component crops might have increased spatial distance between enset plants and act as a physical barrier between infected and healthy enset [3]. Intercropping might also reduce and minimize enset population and adjust microclimate that might disfavor the wilt causing pathogen. In this regard, component crops reduced host population, increased spatial distance between hosts to impede the transfer of diseases carrying propagules from infected plants to healthy plants [3,17,52].

Host resistant

Breeding for genetic resistance is one of the best methods to handle plant diseases, as it is the most economical and environment-friendly control method. In Ethiopia, various enset landraces show different responses to *Xcm*. This could have resulted from the differential response of local enset clones to enset bacterial wilt as testified by Mengistu, et al. [54] & Tushemereirwe, et al. [60], for several plantations could possess different levels of disease resistance. But completely immune enset cultivars to Xcm have not been found yet [61]. More research is, however, needed considering the vast wealth of enset genetic resources in the different enset-growing regions [62]. Breeding for resistance to EBW should be given high priority and should be supported with good agronomic management practices that do not favor EBW epidemics [3].

Rouging

Because of the giant nature of the enset, some farmers in the surveyed region cut infected enset into pieces and leave them in the field [3]. This practice might disseminate the causal pathogen within and across the whole field while wind and rain splash move through it. The overflow of water from infected to uninfected fields spreads the enset bacterial wilt thereby increasing disease incidence [26]. Other studies also indicated that pathogen spread is thought to happen through the soil, planting materials, wind, rain, surface run-off, and contaminated irrigation water [63].

Integrated disease management

To reduce yield loss of enset due to Xcm integrating all components-cultural practices (rouging, using healthy planting material, Phyto-sanitation, optimum crop density, weeding), host resistance, and into a disease management scheme that are environmentally compatible, economically feasible, and socially acceptable to reduce damage caused by disease to tolerable levels [64]. Integrated disease management is not a sole method of management which means an amalgamation of various disease methods like cultural, biological, and host resistance that are environmentally compatible and sound able, economically feasible, and socially acceptable to decrease injury triggered by disease to acceptable and tolerable levels. The effect of Xcm on enset can be minimized by the integrated use of different control measures.

Future Perspectives

In Ethiopia where enset is a place where only cultivated most of the research on EBW focused on cultural control and landrace screening as disease management tactics. For having an understanding of the biology, ecology, and management of the disease, there is a need for more research to great extents. The development of disease-resistant enset cultivars should be given main concern for farmers who are exposed to deploy labor-intensive disease management strategies. This however requires a clear understanding of the molecular basis of interaction between *Xcm* and enset, and an analysis of the intermediate products produced by both the pathogen and plant following infection. Additionally, determination of the population structure of the pathogen from a wider geographic area is required to develop a database on *Xcm* isolates and consequently determine the best strategy for deployment of resistance and or to incorporate the non-matching resistance genes to the existing pathogen. The use of biotechnological approaches may be one of the best strategies in managing this disease.

References

1. Borrell JS, Biswas MK, Goodwin M, et al. (2018) Enset in Ethiopia: A poorly characterised but resilient starch.
2. Central Statistical Agency (2020) The federal democratic republic of Ethiopia central statistical agency agricultural sample survey (Meher season, private peasant holding), Statistical Bulletin, Number, 588. Addis Ababa, Ethiopia.
3. Befekadu H, Chemeda F, Habtamu T, et al. (2020) Spatial distribution of Enset bacterial wilt (Xanthomonas campestris Pv. musacearum) and its association with biophysical factors in Southwestern Ethiopia. Ethiop J Agric Sci 30: 33-55.
4. Diro M, Van Staden J (2005) The type of explant plays a determining role in the micropropagation of Ensete ventricosum. S Afr J Bot 71: 154-159.
5. Dagmawit C (2008) Analysis of genetic diversity among cultivated enset (Ensete ventricosum) populations from Essera and Kefficho, southwestern part of Ethiopia Using ISSR Marker. A Thesis Submitted to School of Graduate Studies of Addis Ababa. 1-61.
6. Bobosha K (2003) Characterization of Xanthomonas campestris Pv. musacearum Isolates: Causal Agent of Enset Bacterial Wilt Disease. Addis Ababa University, Ethiopia.
7. Dagmawit CT, Endashaw B (2011) Analysis of genetic diversity among cultivated Enset (Ensete ventricosum) populations from Essera and Kefficho, southwestern part of Ethiopia using inter simple sequence repeats (ISSRs) marker. Afr J Biotechnol 10: 15697-15709.
8. Brandt SA, Spring A, Hiebsch C, et al. (1997) "The tree against hunger". Enset based agricultural systems in Ethiopia. Am Ass Adv Sci.

9. Shank R (1994) The Enset culture, technical report on enset or the false banana. United Nations-Emergencies Unit for Ethiopia.
10. Genet B (2004) Genetic variability and biotechnological studies for the conservation and improvement of Ensete ventricosum. Doctoral thesis Swedish University of Agricultural Sciences Alnarp. Acta Universitatis Agriculturae Sueciae Agraria 502: 1-38.
11. Haile B, Diro M, Tabogie E (1996) Agronomy research on Enset. In: Abate T, Hiebsch C, Brandt S, Geberemariam S, Enset-based sustainable agriculture in Ethiopia. Institute of Agricultural Research, Addis Ababa, 235-241.
12. Diro M, Tabogie E (1994) Preliminary investigation on enset culture. In: Herath E, Dessalegn L, Proceedings of the second national horticultural workshop of Ethiopia. Institute of Agricultural Research, Addis Ababa, 120-131.
13. Yemane T, Fassil K (2018) Diversity and cultural use of Enset (Enset ventricosum) and spices such as Aframomum corrorima, Zingiber in Bonga Insitu Conservation Site, Ethiopia.
14. Brandt AS (1996) A model for the origins and evolution of Enset food production. In: Proceedings from international workshop on Enset. Enset-Based Sustainable Agriculture in Ethiopia. Institute of Agricultural Research, Addis Ababa, 172-187.
15. Taye B, Asrat F, Regassa B (1967) The cultivation of the genus Enset in Ethiopia. Soil and Crop Science Society of Florida 27: 133-141.
16. Yemane T, Fassil K (2006) Diversity and cultural use of Enset (Enset ventricosum (Welw.) Cheesman) in Bonga in situ Conservation Site, Ethiopia. Ethnobot Res Appl 4: 147-157.
17. Mekuria W, Amare A, Alemayehu C (2016) Assessment of bacterial wilt (Xanthomonas campestris pv. musacearum) of enset in Southern Ethiopia. Afr J Agric Res 11: 1724-1733.
18. Misganaw A, Befekadu H (2020) Distribution and management of bacterial wilt (Xanthomonas Campestris pv. Musacearum) of Enset (Ensete Ventricosum) in Ethiopia: A Review. Int J Res Agric for 7: 40-53.
19. Yirgou D, Bradbury JF, Yemataw Z, et al. (1968) Bacterial wilt of Enset (Ensete ventricosum) incited by Xanthomonas musacearum sp. Phytopathology 58: 111-112.
20. Wondimagagne E (1981) The role of Poecilocarda Nigrineruis, Pentanolia nigronervousa and Planonococcus ficus in the transmission of enset wilt pathogen Xanthomonas musacearum sp. In: Wolyita, Ethiopia. Addis Ababa, Ethiopia, Addis Ababa University, MSc. Thesis.
21. Ashagari D (1985) Studies on the bacterial wilt of enset (Ensete ventricosum) and prospects for its control. Ethiop J Agric Sci 7: 1-14.
22. Spring A, Hiebsch C, Tabogie E, et al. (1996) Enset needs assessment project phase I Report. Awasa, Ethiopia.
23. Addis T, Handoro F, Blomme G (2004) Bacterial wilt (Xanthomonas campestris pv. musacearum) on Enset and banana in Ethiopia. InfoMusa 13: 44-45.
24. Alemayehu C, Tadesse K, Guy B (2016) Natural occurrence and pathogenicity of Xanthomonas bacteria on selected plants. Afr J Biotechnol 15: 2146-2155.
25. McKnight CCRP (2013) Integrated management of bacterial wilt of enset (Ensete ventricosum (Welw.) Cheesman) caused by Xanthomonas campestris pv. musacearum in Ethiopia. Annual Report 11: 1-73.
26. Yemataw Z, Mekonen A, Chala A, et al. (2017) Farmers' knowledge and perception of enset Xanthomonas wilt in southern Ethiopia. Agric & Food Secur 6: 62.
27. Tadesse M, Kidist B, Gizachew WM (2003) Enset bacterial wilt sanitary control in Gurage Zone. Research Report No. 53: 1-23.
28. Eshetu A, Mohammed Y (2010) Experience on bacterial wilt management in eastern Africa: The case of banana. In: Mohammed Yesuf and Tariku Hunduma, Proceedings of Enset National Workshop, Wolkite, 74-86.
29. Tesfahun F, Karamura E (2012) Regional strategy for banana/enset bacterial wilt management in east Africa: The road map for the national action plan. In: Mohammed Yesuf and Tariku Hunduma, Proceedings of Enset National Workshop. Wolkite, 74-86.
30. Zerihun Y, Tesfaye K, Zeberga A, et al. (2016) Exploiting indigenous knowledge of subsistence farmers'for the management and conservation of Enset (Ensete ventricosum (Welw.) Cheesman) (musaceae family) diversity on-farm. J Ethnobiol Ethnomed 12: 1-25.
31. Nakato V, Mahuku G, Coutinho A (2018) Xanthomonas campestris pv. musacearum: A major constraint to banana, plantain and enset production in central and east Africa over the past decade. Mol Plant Pathol 19: 525-536.
32. Welde Michael G, Bobosha K, Addis T, et al. (2008) Mechanical transmission and survival of bacterial wilt on Enset. Afr Crop Sci J 16: 97-102.
33. Gizachew W, Kidist B, Blomme G, et al. (2008) Evaluation of enset clones against enset bacterial wilt. Afr Crop Sci J 16: 89-95.
34. Melese H, Yifru HG, Leulseged M (2014) Controlling bacterial wilt of enset using cultural methods. Factsheets for Farmers, Plantwise is a global initiative led by CABI.
35. Tripathi L, Merga IF, Hvoslef-Eide AK, et al. (2019) Application of genetic engineering for control of bacterial wilt disease of enset, Ethiopia's Sustainability Crop. Front Plant Sci 10.
36. Blomme G, Dita M, Jacobsen KS, et al. (2017) Bacterial diseases of bananas and enset: Current state of knowledge and integrated approaches toward sustainable management. Front Plant Sci 8.
37. Borrell JS, Zerihun Y, Manosh KB, et al. (2020) The distribution of enset pests and pathogens and a genomic survey of enset Xanthomonas Wilt. 1-38.
38. Uwamahoro F, Berlin A, Bylund H, et al. (2019) Management strategies for banana Xanthomonas wilt in Rwanda include mixing indigenous and improved cultivars. Agron Sustain Dev 39: 1-11.
39. Thwaites R, Eden Green S, Black R (2000) Diseases caused by bacteria. In: Jones, D.R. ed, Diseases of Banana, Abaca and Enset Wallingford, Oxfordshire: CABI.213-240.
40. Ocimati W, Were E, Jeroen J, et al. (2018) Risks posed by intercrops and weeds as alternative hosts to Xanthomonas campestris pv. musacearum in banana fields. Front Plant Sci 9: 1471.
41. Mwebaze JM, Tusiime G, Tushemereirwe WK, et al. (2006) The survival of Xanthomonas campestris Musacearum in soil and plant debris. Afr Crop Sci J 14: 121-127.
42. Fikre H (2014) Study the existence of EBW pathogen in Kocho: Plays role in bacterial wilt disease transmission. IJSIT 3: 292-297.
43. Dereje A (1985) Studies on the bacterial wilt of enset (Ensete ventricosum) and prospects for its control. Ethiop J Agric Sci 7: 1-14.

44. Dagnachew Y, Bradbury JF (1974) A note on wilt of banana caused by the enset wilt organism Xanthomonas musacearum. East Afr Agric For J 40: 111-114.
45. Eshetu W (1981) The role of poecilocarda nigrinervis, pentanoia nigronervosa and planococcus ficus in the transmission of enset wilt pathogen Xanthomonas musacearum sp.n. In: Wolayita. M.Sc. Thesis, Addis Ababa University, Addis Ababa.
46. Fikre H, Tariku H, Endale H (2012) Research achievements, experience and future direction on Bacterial Wilt of Enset. In: Mohammed Yesuf, Tariku Hunduma, Proceedings of Enset National Workshop, Wolkite, 88-96.
47. Tariku H, Kassahun S, Endale H, et al. (2015) Evaluation of enset clones resistance against enset bacterial wilt disease (Xanthomonas campestris pv. musacearum). J Vet Sci Technol 6: 1-7.
48. Merga IF, Tripathi L, Hvoslef-Eide AK, et al. (2019) Application of genetic engineering for control of bacterial wilt disease of enset, Ethiopia's Sustainability Crop. Front Plant Sci 10: 133.
49. Tushemereirwe W, Kangire A, Smith J, et al. (2003) An outbreak of bacterial wilt on banana in Uganda. InfoMusa 12: 6-8.
50. Abele S, Pillay M (2007) Bacterial wilt and drought stresses in banana production and their impact on economic welfare in Uganda. J Crop Improv 19: 173-191.
51. Biruma M, Pillay M, Tripathi L, et al. (2007) Banana Xanthomonas wilt: A review of the disease, management strategies and future research directions. Afr J Biotechnol 6: 953-962.
52. Getachew G, Habtamu T, Asela K (2018) Spatial distribution and association of banana (Musa spp.) Fusarium wilt (Fusarium oxysporum f.sp. cubense) epidemics with biophysical factors in southwestern Ethiopia. Arch Phytopathol Plant Prot 51: 575-601.
53. Addis T, Turyagyenda L, Alemu T, et al. (2010) Garden tool transmission of Xanthomonas campestris pv. musacearum on banana (Musa spp.) and enset in Ethiopia.
54. Selvaraj T, Mengistu O, Kassahun SB, et al. (2014) Assessment of disease intensity and evaluation of enset clones against bacterial wilt (Xanthomonas campestris pv. musacearum) in Tikur Inchini and Jibat districts of west Shewa, Ethiopia. ScieXplore: Int J Res Sci 1: 83-97.
55. Habtamu T, Befekadu H, Chemeda F, et al. (2020) Spatial distribution of enset bacterial wilt (Xanthomonas campestris Pv. musacearum) and its association with biophysical factors in southwestern Ethiopia. Ethiop J Agric Sci 30: 33-55.
56. Hennessy C, Walduck G, Daly A, et al. (2005) Weed hosts of Fusarium oxysporum f.sp. cubense tropical race 4 in northern Australia. Australas Plant Pathol 34: 115-117.
57. Fininsa C, Yuen J (2002) Temporal progression of bean common bacterial blight (Xanthomonas Campestris pv. phaseoli) in sole and intercropping systems. Eur J Plant Pathol 108: 485-495.
58. Boudreau MA (2013) Diseases in intercropping systems. Annu Rev Phytopathol 51: 499-519.
59. Tamado T, Fininsa C, Worku W (2007) Agronomic performance and productivity of common beans (Phaseous Vulgaris L.) varieties in double intercropping with maize (Zea mays L.) in Eastern Ethiopia. Asian J Plant Sci 6: 749-756.
60. Tushemereirwe W, Sekiwoko F, Taligoola HK (2006) Xanthomonas campestris pv. musacearum host range in Uganda. Afr Crop Sci J 14: 111-120.
61. Girma A, Befekadu H, Fikre H (2014) Physiological characteristics and pathogenicity of Xanthomonas campestris pv. musacearum strains collected from enset and banana in Southwest Ethiopia. African J Biotechnol 13: 2425-2434.
62. Yemataw Z, Muzemil S, Ambachew D, et al. (2018) Genome sequence data from 17 accessions of Ensete ventricosum, a staple food crop for millions in Ethiopia. Data in Brief 18: 285-293.
63. Ghag SB, Upendra KS, Ganapathi TR (2015) Fusarium wilt of banana: Biology, epidemiology and management. Int J Pest Manag 61: 250-263.
64. Tilahun N, Hassen S (2018) Garlic Rust (Puccinia Allii): Effect and management options- A review. Advances in Life Science and Technology 69: 25-30.

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