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Integrated Major Pest Management Systems of Enset (*Ensete ventricosum* (Welw.) Cheesman) in Ethiopia

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Abstract: Enset is an important root crop widely used as a staple food for millions of people in Ethiopia. Despite to enset is dominantly produced in southern and south western parts of the county, diverse diseases and insect pests are challenging its growth and productivity at these production areas. Hence, this review was aimed to discuss the integrated pest management (IPM) system that used to control the major enset pests (disease and inset) in different production areas of Ethiopia. Enset is a root crop that is highly susceptible to different kinds of diseases and insect pest problems. Enset Bacterial wilt (EBW) is a major devastating disease causing important economic losses and can lead up to killing the whole plant parts that are commonly observed around enset growing areas of the country. Enset root mealybug is also a major insect found on the upper half of the corm and root parts of enset which can retard the plant growth and causes to dry the outer parts of the leaf that might finally leading to the plant death. However, most of enset growers are practicing different controlling mechanisms against these major enset diseases and insect pests around the production areas. Due to the chemical controlling method needs the cost of purchase and usage on root mealybug has usually not effective, the producers are widely uses an IPM systems incorporating with their indigenous knowledges to prevent the major disease and insect introduction to the enset field and to control an already infected plant. Hence, the enset producers mainly uses the IPM components like the host plant resistance, the cultural controlling system, the biological controlling system, and the chemical controlling system as the last option to manage their enset farms in Ethiopia. These IPM components are not only an optional pest controlling methods but necessitate its practice against the major pest problems due to environmentally friend, cost-effective, and alternative options to various behaviors of pests. However, breeding for pest-resistant enset genotype and adoption of successful IPM controlling mechanisms to all enset growing areas need further work to alleviate the encountered challenges on the enset production areas in Ethiopia.

Keywords: Bacterial Wilt Disease, Biological Control Method, Chemical Control Method, Cultural Control Methods, Enset Root Mealy Bug, Pest Infestation

1. Introduction

Enset (*Ensete ventricosum* [Welw.] Cheesman) is a perennial herbaceous and monocarpic root crop with long broad leaves and bulky pseudostem that belongs to the Musaceae family known to be originated in Ethiopia [1]. It is widely distributed in eastern and southern africa but cultivated only in southern and southwestern parts of Ethiopia as a staple food for about 15 million peoples in mixed subsistence farming systems [2]. Although the wild species of enset are distributed throughout most of central, eastern, and southern africa, as well as asian countries, its domestication and uses as a food and fiber crop is restricted only to Ethiopia [3]. Thus, 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 southwestern part of the country [1].

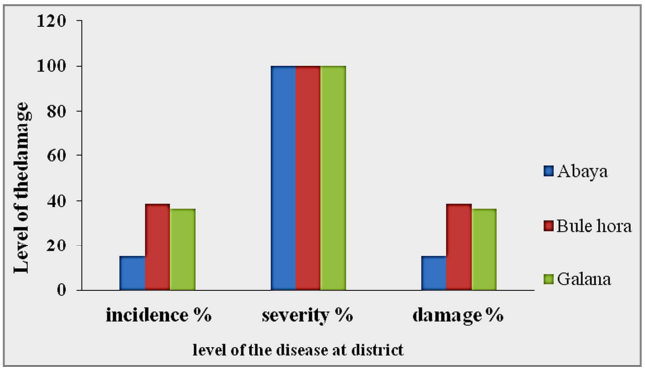
The root of enset, which is rich in carbohydrates, is the main edible portion as its fruit is not. It is an important multi-purpose and drought-tolerant crop, used for food (*kocho, bulla, and amicho*), fodder, fiber and traditional medicine [4].

The food obtained from the crop is rich in starch, a good source of calcium and iron, and has overall nutritive values similar to potato [5]. In terms of edible dry weight and energy, enset gives a higher yield than other crops cultivated in Ethiopia [4]. As a result, enset was appointed as "the tree against hunger" and is a straightforward way to facilitate people to achieve food and livelihood security in parts of Africa [3]. Also, enset has a positive contribution to the local environments by improving the nutrient balance and increasing the fraction of organic matter in the soil [6, 7]. In general, enset can be considered as part of farming systems with high biodiversity, which is the environmentally sustainable and drought-tolerant crop that contributes to the mitigation of climate changes [7].

Even though the number of improved enset varieties were released by regional research institute, the Southern Agricultural Research Institute (SARI), at Areka Research Center in Ethiopia, the production and productivities of the crop have been challenged by different factors (biotic and abiotic). Most of the released varieties are non-resistant and widely susceptible to different diseases and insect pests. Those varieties are mostly affected by bacterial wilt diseases which currently becoming a great challenge in enset growing areas of the country [7]. In addition, inevitable insect pests are also becoming a great challenge for enset producers in the growing areas by limiting crop production and productivity. Integrated pest management (IPM) is the comprehensive and coordinated use of host plant resistant, cultural, biological, and chemical tactics to reduce a pest population below an acceptable threshold [8]. Therefore, this review was mainly aimed to discuss the potential disease and insect pests found in enset growing areas and their available integrated pest management systems in enset growing parts of Ethiopia.

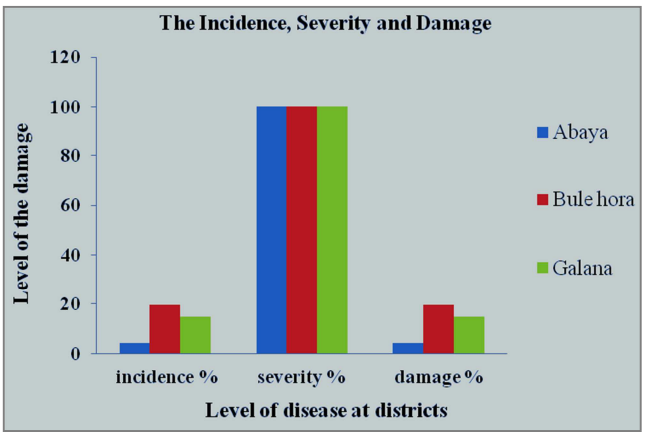
2. Major Enset Diseases in Ethiopia

Regardless of enset is used as a staple food by more than 15 million Ethiopian peoples, its sustainability has been threatening by different abiotic and biotic factors. Among the root crops produced in the country, enset is highly affected by biotic factors like diverse types of diseases, insect pests, nematodes, and termites [10]. The most devastating disease affecting the production and productivity of enset is the bacterial wilt (*Xanthomonas campestris* pv. *musacearum*) disease. Bacterial wilt (*Xanthomonas campestris* pv. *musacearum*) is originated in Ethiopia [11]. The bacteria wilt was first identified and reported by Yirgou and Bradbury [12] in Ethiopia and nowadays it has been distributed to the entire region of enset growing areas of the country and found on wild enset, which affects all the growth stages of plant parts at high land, midland, and low land areas. The natural epidemic of this disease was first reported from the banana cultivar Ducasse hybrid in Kafa province of the southwestern part of Ethiopia [12]. It was widely spread to different parts of the country, which could be through infected farm tools, infected planting materials, repeatedly transplanting the damaged root and corms, animal feeding of the infected plant, and possibly insects vector feeding on the foliage and male inflorescence [13]. Once the plant has been affected by this disease, it starts to show different and initial symptoms like bacterial ooze in the leaf petioles and leaf sheaths and progressive wilting of the leaves [14]. These critical effects lead to a gradual decline in the production and productivity of the crop. The different research studies showed that the infection rate of the disease in different parts of the country was higher. Hence, the survey reported from borena mid-altitude on bacterial wilt incidence in both 2014 and 2015 years by Desalegn and Addis [9] indicated that about 38% and 56% of enset farms were infected by this disease with a mean incidence of 29.46% and 12.89%, respectively. Also, the survey further showed that an average of 21.17% of enset stands was lost due to this disease (Figures 1 and 2). In addition, the assessed survey was noted that the extent of damage of enset is equal to the incidence percentages due to the plant certainly dies after infected by the diseases.



Source: Desalegn and Addis [9].

Figure 1. *Survey on bacterial wilt of enset in Borena mid-highlands in 2015.*

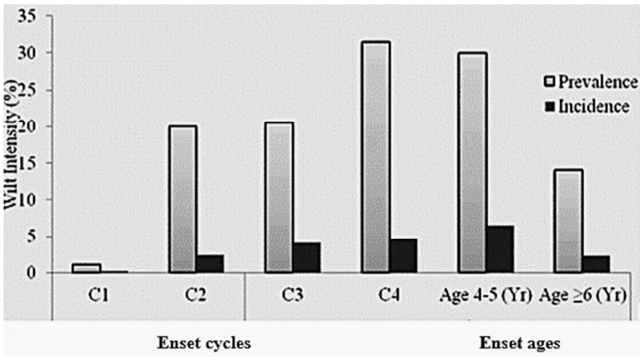


Source: Desalegn and Addis [9].

Figure 2. *Survey on bacterial wilt of enset in Borena mid-highlands in 2015.*

Furthermore, the study of Wolde *et al.* [14] were assessed the distribution and incidence of enset bacterial wilt disease in relation to the plant age, altitudinal range, and clonal variation in major three enset growing zones (Gurage, Hadiya, and Sidama) of South Nation Nationalities and Peoples Regional State (SNNPRS). They pointed out that the

EBW disease is found in all enset growing agro-ecologies of Ethiopia to the varying extent based on plant growth stage, production cycle, and age of the plant at an altitudinal range of 2000-2500 m.a.s.l. They further elaborated that the disease incidence and prevalence were also varied based on the growth cycle and plant age in different enset growing areas of the country (Figure 3). According to the assessment report indicated that the highest mean disease prevalence (31.48%) and disease incidence (37.50%) were observed at the fourth production cycle of the crop at the age of 4-5 years old than at its early and late ages.



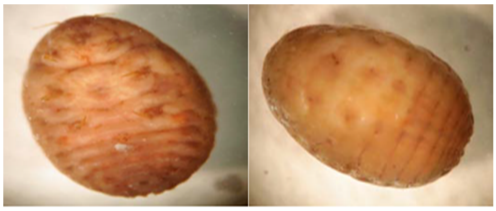
Source: Wolde *et al.* [14]

Figure 3. *Mean EBW prevalence and incidence at different production cycles and ages of enset in three zones (Gurage, Hadiya, and Sidama) of SNNPRS. C1 = Cycle 1; C2 = Cycle 2; C3 = Cycle 3 and C4 = Cycle 4.*

In general, currently, the enset bacterial wilt disease is a devastating and the most challenging pest of enset growing areas of the country which can kill the whole plant parts leading up to crop loss.

3. Major Enset Insect Pest in Ethiopia

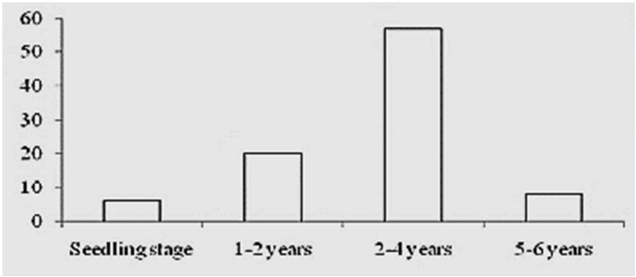
Even though the diverse biotic stresses are affecting enset production and productivities in the production areas of the country, enset root mealybug (*Cataenococcus ensete* [Williams and Matile-Ferrero, (Homoptera: Pseudococcidae)]) is the most important and major insect pest of enset growing areas in Ethiopia [15]. This root mealybug is a generic term for several *Pseudococcidae* feeding on underground plant parts. It has an elongate-oval body, which is covered with wax secretions on the dorsal and lateral side body parts (Figure 4). The wax secretion gives an appearance of cottony and spine-like projections. While these waxy secretions are not part of the mealybugs' body, they are lost with each molt. This insect pest was first reported in wonago, Ethiopia in 1988 [16]. It was known to attack Enset in Gedeo, Sidama, Gurage, Kembata Tembaro, Hadyia, Keffa and Bench zones, Amaro, and Yem special districts of enset growing areas of the country [17]. According to the study of Addis *et al*. [18], the insect pest can attack the crop at any growth stage, with infestations being most severe on two to four years old plants as shown in (Figure 5). Addis [13] was also further investigated the density and distribution of enset root mealybugs on enset and reported that most of the insect has found on the upper parts of the corm and the roots within a 20 cm radius of soil as shown in (Table 1 and Figure 6) bellow.



Source: Azerefegne [27].

Figure 4. *Adult enset root mealybug.*

According to the findings, the infestation of insect pests retards the normal growth of plants by causing losses of plant vigor, drying of lateral leaves but not green central shoot, and finally leading up to plant death at an area specially where the moisture stress is high. However, the finding on the extent of economic loss of the crop by mealybug attacks is little to found [15].



Source: Kefelegn [19].

Figure 5. *Frequent Enset root mealybug infestation was observed across different age categories of Enset plant by Dilla Zuria, Gedeb, and Wonago farmers.*

Table 1. *Distribution of Cataenococcus ensete population on corm and roots of enset plants (n=10).*

Plant parts	Number of mealybugs		SE
Corm (Total)	18.1[a]	-	10.99
Corm (Upper half)	-	10.7[a]	4.96
Corm (Lower half)	-	7.4[a]	6.42
Roots	68.6[b]	-	16.73
Total	86.7	18.1	20.43

Means followed by the same letter within a column are not significantly different according to the x^2 test at a 5% probability level.
Source: Addis *et al*. [17].

Source: Addis [28].

Figure 6. *Root mealybugs on roots and corm of enset.*

4. Integrated Major Pest Management Systems of Enset in Ethiopia

4.1. Integrated Enset Bacterial Wilt Disease (Xanthomonas campestris Pv. Musacearum) Management Systems in Ethiopia

Bacterial wilt (*Xanthomonas campestris* pv. *musacearum*) is the most economically important disease putting the sustainability of enset farming systems in jeopardy comparing with all other constraints of crop production. Due to 80% of enset farms are reportedly infected by bacterial wilt disease, currently, the enset production and productivity are declining from time to time in the enset growing parts of Ethiopia [9]. This inevitable challenging enset production problem has been directly or indirectly affected the livelihood of more than 20 million enset growers in the country. This vividly observed problem needs strong attention and commitments to manage and conserve the available cultivars before the complete loss of the crop will occurs. Hence, the EBW disease hasn't a single management system to control the crop by this major pest. But different research findings have been reported the application of IPM systems can reduce the effect of EBW disease below an acceptable economic threshold level sustainably.

The Integrated Pest Management (IPM) system is an effective and environmentally sensitive approach to manage pests, which mainly relies on the combination of common-sense practices [20]. Thus, there was no clear-cut option has been reported to control enset wilt disease in the enset growing region of the country. But the growers in different enset production areas are practicing different IPM methods either alone or together apart from using the chemical treatment systems as the last options. This kind of management practice could be a system of controlling the EBW disease either by preventing their occurrences or by managing an already occurred disease under the economic threshold level in a sustainable manner known as "Integrated Pest Management Systems".

4.1.1. Using Host Plant Resistance

Developing the bacterial wilt disease-resistant enset varieties or using tolerant clones could be one of the best approaches to manage the enset bacterial wilt (EBW) disease. This approach is the best way to control the enset bacterial wilt disease, cheaper to the farmers, and safer to environmental areas [21]. Hence, Ethiopia was considered as the center of origin and sources of enset diversity which is widely distributed around the southern and southwestern parts of the country. It has been estimated that there are over 200 different enset clones described by their vernacular names in Ethiopia [14]. Currently, different research institutes, higher learning institutes, and government agricultural bureaus are also starting the collection of diverse enset clones from their potential growing areas for the future further multiple studies that includes screening for resistant genotypes against EBW disease. The study of Handoro and Said [22] was reported the startup of screening different enset clones for their resistance to enset wilt disease at Areka Research Center of SARI and some of the genotypes from the collected clones were showed promising resistance against EBW disease. Hunduma *et al*. [23] also reported similar findings on the startup of screening enset clones at Ambo Agricultural Research Center of Ethiopian Institute of Agricultural Research (EIAR), and found a promising resistant genotype against EBW disease. Thus, the presence of richest enset biodiversity in different parts of the country, the host and pathogen characterization, enset clone selection, and breeding for wilt resistance can be suggested as a long-term management system to control the widespread of the enset bacterial wilt disease in the future [9].

4.1.2. Using Cultural Control Method

This cultural controlling method of the IPM system mainly referring to the practices of indigenous knowledge of the growers to control the EBW disease from their enset farming areas. Uses of the cultural practices of disease control can disrupt the disease cycle, create unfavorable environmental conditions for the pathogen, reduce the pathogen population in the field and improve crop growth and vigor [24]. Hence, the enset growers from the southern and southwestern parts of Ethiopia have been practicing several cultural indigenous knowledges to control the EBW disease introduction into their healthier enset farming areas. Some of the common indigenous cultural control the growers' practicing are planting the healthier enset suckers, avoiding contact of healthier plants from the infected ones, avoiding uses and sharing of common farm tools with other growers, restriction of domestic animal movements in the enset farming areas and uprooting and burying of already infected plants and cleaning the left-over plants from their farm areas. However, most of the growers haven't similar awareness on the routes of EBW disease transmissions and uses of all available cultural controlling practices to protect the disease from their farming areas. In supporting these ideas, Mulualem and Walle [25] were identified and reported the main route of enset bacterial wilt disease transmission from the infected plant materials to healthier one was mainly by sharing an infected enset planting materials and using common farm equipment for enset farm managements. Thus, in order to prevent the disease transmission from the infected to the healthier plants, the growers are indigenously practicing certain controlling activities like keeping the farm hygiene [25], cleaning of the farming equipment, removing unwanted left over's and burning of the collected plant debris found in the fields and, uprooting and burying the infected plants from the farm. After uprooting and burying the infected enset plants, farmers fallow their land at least for six months until the pathogen will be eliminated from the soil by exposing the pathogen to the sun radiation. The growers also make a fence to protect the animal trafficking in the enset field to prevent the disease transmission to the healthier plants. In addition, when EBW causes severe damage to their enset plant, some of the growers also undertake a variety of traditional practices like smoking bones,

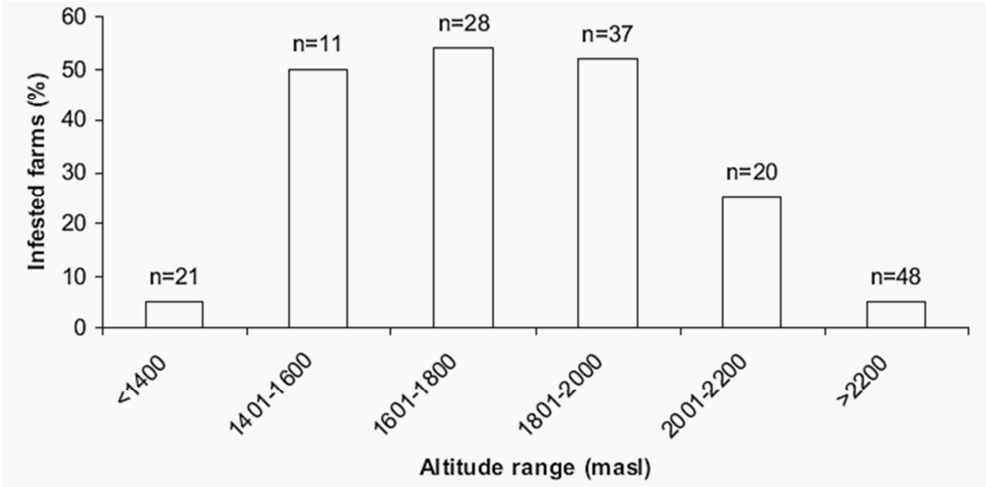
tires, burning porcupine body, doing local spiritual beliefs such as prayer ceremony ('*Dua* on khat chewing'), and slaughtering a black goat [14]. Above all, the best way of practicing cultural methods against EBW disease control is creating awareness to the growers about the potential effects of the disease and its prevalence and advising them strictly to practices the locally available cultural control options to the growers.

4.1.3. Using Chemical Control Method

Chemical applications are often used to control pathogens and can be an important component of the overall disease management plan [24]. However, the chemical controlling methods are the last recommendation option in the IPM system. Even if various efforts were made by scholars at different times, there was a scientific report that hardly showed the effectiveness of a single chemical control method against the enset bacterial wilt diseases in the country. However, the study of Kasa *et al*. [26] were reported the presence of a trial by using different botanical plant extracts and other materials against Bacterial Wilt (*Xanthomonas campestris PV Musacearum*) disease. They found the results based on the invetro test which a combination of botanical plant extracts of Etecha + Kabericho as well as, a single botanical extract of Etecha and a combination of Solle + Hidafite + Tembosuse were showed a better antibacterial effect against *Xanthomonas campestris pv. musacearum* isolates, next to standard check (penicillin). Currently, an investigation on the effectiveness of the chemical control method is in progress in different areas and a promising result will be expected.

4.2. Integrated Enset Root Mealybug (Cataenococcus ensete) Management Systems in Ethiopia

The root mealybug *(Cataenococcus ensete*) is the major insect pest of enset (*Ensete ventricosum*) growing area of southern Ethiopia. The adults and nymphs of insects are overlapping generations, which feed on corms and roots of enset and are difficult to control once it has been established [15]. Hence, it is very difficult to control enset root mealybugs with a single management method once it has been infested the root of enset due to their cryptic habit, waxy body cover, and formation of dense colonies of multiple and overlapping generations [27]. However, finding the alternate solution against the insect pest is very crucial to control an insect in an environmentally and economically sustainable manner 'Integrated Pest Management (IPM)'. The first resort to enset root mealybug control is the use/production of clean enset planting material. This insect is greatly intense only at an altitude between 1400-2200 m.a.s.l (Figure 7). Therefore, as the planting materials moved from one place to another area of these altitude ranges, care should be given due to their invasiveness at these suitable altitudinal ranges. Because of great difficulties to control insect pests by a single mechanism, different IPM components have been used to control the problem aroused by insect pests in different enset growing areas of the country.



Source: Addis *et al*. [28].

Figure 7. *Effect of altitudinal ranges on enset root mealybug infestation.*

4.2.1. Use of Host Plant Resistance

Growing mealybug free enset is very important for the enset producers. Planting the insect free sucker can resistrict the mealybug introduction to the new production areas. On the other hand, uses of host plant resistance are a very important method to reduce the mealybug effects. The study of [19] was reported as the growers uses indigenously a locally well-known resistant genotype of enset called 'genetica' which was one of the dominant enset clones against to the root mealybug in the area (Table 2). In addition, some of enset growers prefers the suckers comes from high land areas where the prevalence of enset mealybug is low [19]. Hence, an attention on the collection of different enset genotypes for screening the resistant clone against enset root mealybug has been started to alleviate the overall losses of the plant.

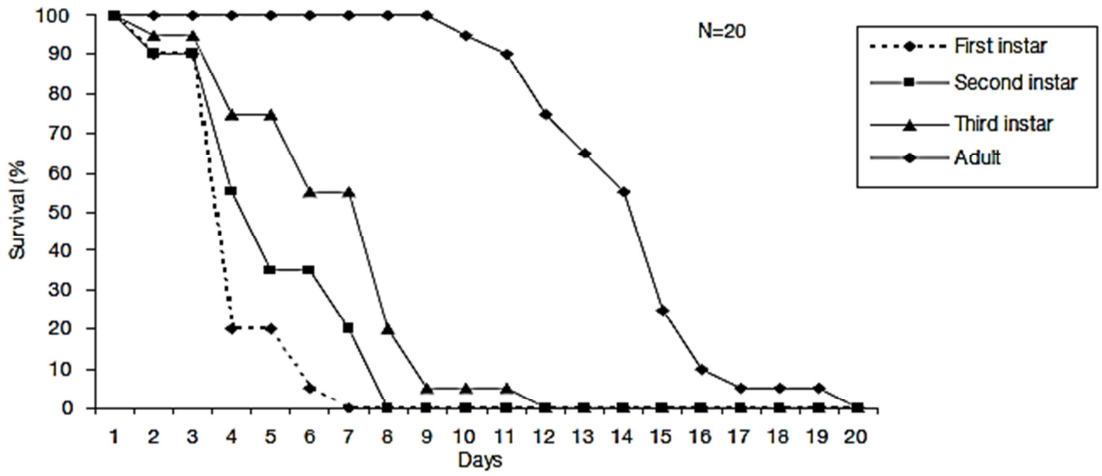
Table 2. *Rating of frequently cultivated enset varieties by farmers concerning plant productivity, quick maturation, tolerance of root mealybug in Gedeb, Wonago, and Dilla Zuria districts.*

No	Enset cultivars (frequently used by the farmers)	Productivity of enset varieties (Rank)	Quick maturation (Rank)	Tolerance for Root mealybug infestation	Frequently cultivated by the farmers
1	Genetica	1	3	Mild	1
2	Torecha	2	2	-	2
3	Dembele	3	2	-	3
4	Ado	4	3	-	4
5	Qerese	5	2	-	5
6	Nifo	6	1	-	6
7	Astara	7	1	-	7

Source: Kefelegn *et al*. [19].

4.2.2. Uses of Cultural Practices

The cultural methods used to control the root mealybug insect are very common and could have practiced by many growers. Addis *et al*. [19] and Kefelegn *et al.* [19] were reported in their studies that different cultural prevention methods of enset root mealybug are widely available in different parts of the country. The finding stated that the cultural method commonly practiced to control the root mealybug by addition of farmyard manure and ash to the field, disinfection of enset plant by using hot water treatments, keeping the farm hygiene by repeatedly plowing and removing of weeds and grasses in the fields (makes the insect starve) (Figure 8), fallowing of the lands, cleaning of the seedlings (planting materials) before planting, increasing the soil moisture, uprooting an infested plants and burning in the hole, site selection and removal of host plants are the main activities that have been widely practiced to prevent insect infestation. For these practices, most of the farmers use the presence of ants for inspection purposes because the ant is the vector of mealybug and indicatomealy bug availability in the areas.



Source: Azerefegne et al. [27].

Figure 8. *Effect of food deprivation on the survival of the different stages of Cataenococcus ensete in the soil.*

4.2.3. Uses of Biological Control

The biological mealybug control system is one component of IPM, which is an environmentally friend to manage the enset root mealy bug. Lemawork *et al.* [15] investigated the biological control of mealybug insects by using entomopathogenic fungi. They reported as the tested entomopathogenic fungal species and isolates showed 72e100%, 83e97%, and 19e51% and 25e54% mortalities of enset root mealybugs. Hence, they recommended that the fungal isolates have the potential to kill the insect and can be integrated for the management of enset root mealybugs with other methods.

4.2.4. Uses of Chemical Control

Using chemical insecticide is very difficult to control root mealybug due to their cryptic, waxy coat, and lifestyle of forming dense colonies of multiple and overlapping generations [29]. However, different findings have been reported as some effective chemicals can be controlled mealy infestation despite its purchasing costs. According to the study of Azerefegne *et al*. [27] were report on the selection of effective insecticide against root mealybug in southern Ethiopia, the significant results had got which can control the root mealybug and they have been recommended a single application of Diazinion or Chlorpyrios for the insect pest control. The effect of some botanical extracts against root mealybug was also reported by Tadesse *et al*. [30]. The finding noted that, drenching the seed water suspension of 10% *Millettia ferruginoea* in the root zone of infested enset in the field was found to be effective against the enset root mealy

bugs. Also, dipping of the young enset seedlings into the solution to the root zone of infested plants can be used for the management of the insect pest.

Generally, promoting the cultural indigenous insect controlling practices integrating with other IPM components are very essential to control enset root mealy bug to the enset production areas.

5. Conclusion

Enset is one of the root crops, which has been used as a staple food for millions of Ethiopian peoples. Despite its largest production status in the southern and south western parts of the country, the production and productivities of enset have been challenged by different biotic and abiotic factors. Bacterial wilt disease, insect pests, nematodes, and termites are the most important production constraints of enset growing areas. Enset bacterial wilt is the major enset disease causing stunted growth, which delays the maturity and affecting productivity and even leads up to crop loss in Ethiopia. Also, the root mealybug is a major insect pest that affects the enset growth and productivity especially in the southern parts of Ethiopia. However, the enset producers are managing their farms from EBW disease and enset root mealy bug through practicing the 'integrated pest management systems' which includes planting a resistant enset genotypes, practicing the cultural pest management system, using biological control method and using the chemical controlling methods as final management options. In general, the combinations of IPM components are found to be a succesfull practicing method against to major enset pest in the enset farming areas of the country. However, further study on enset breeding for pest resistance and adoption of a successful IPM controlling method to all enset growing areas should be addressed to alleviate the challenges encountered in the enset growing sector in Ethiopia.

References

[1] Taye, B., F. Asrat & B. Regassa. 1967. The Cultivation of The Genus *Enset* in Ethiopia. *Soil and Crop Science Society of Florida.* 27: 133-141.

[2] Zippel K. and Kefale A., 1995. A field guide to enset landraces of North Omo, Ethiopia. FRP Technical Pamphlet No. 9, iv+208 pp., FARM Africa, Addis Ababa.

[3] Brandt, S. A., 1997. The 'Tree against hunger' Enset-Based Agricultural Systems in Ethiopia. In: *American Association for the advancement of science*. 7 (1): 21-22.

[4] Tsegaye A. and Struik P. C. 2001. Enset (*Ensete ventricosum* (Welw.) Cheesman) Kocho Yield Under Different Crop Establishment Methods as Compared to Yields of Other Carbohydrate-Rich Food Crops. *Netherlands Journal of Agricultural Science*. 49: 81–94.

[5] Mohammed B., Gabel M., and Karlsson L. M., 2013. Nutritive Values of Drought-Tolerant Food and Fodder Crop Enset. *African Journal of Agricultural Research*. 8: 2326–2333.

[6] Elias E., Morse S., and Belshaw D. G. R. 1998. Nitrogen and Phosphorus Balance of Kindo Koisha Farms in Southern Ethiopia. *Agriculture, Ecosystems and Environment*. 71: 93–113.

[7] Tesfaye B. 2008. The Enset (*Ensete ventricosum*) Gardens of Sidama: Composition, Structure, and Dynamics of a Traditional Poly-Variety System. *Genetic Resources and Crop Evolution*. 55: 1347–1358.

[8] Riyaz, S. M. and Kathiravan, K., 2019. Integrated Pest Management Approaches. *Geminiviruses*, Pp. 219-235. Doi.org/10.1007/978-3-030-18248-9_12.

[9] Desalegn R, Addis S., 2015. Enset (*Ensete ventricosum* [Welw]) Bacterial Wilt Survey in Borena Mid-Altitude. *International Inv. Journal of Agricultural Soil Science*. 3 (2): 9-12.

[10] Zipper K. 2005. Diversity Over Time and Space in Enset Landraces (*Ensete ventricosum*) in Ethiopia. In: Huber, B. A., Sinclair, B. J. and Lampe, K.-H. (eds.). African Biodiversity Molecules, Organisms, Ecosystems. Pp: 423–438. *Springer Science, New York.*

[11] Blomme, G., Ploetz, R., Jones, D., De Langhe, E., Price, N., Gold, C., Geering, A., Viljoen, A., Karamura, D., Pillay, M. and Tinzaara, W., 2013. A Historical Overview of The Appearance and Spread of Musa Pests and Pathogens on the African Continent: Highlighting the Importance of Clean Musa Planting Materials and Quarantine Measures. *Annals of Applied Biology*. *162* (1): 4-26.

[12] Yirgou, D. and Bradbury, J. F. 1974. A Note Wilt of Banana Caused by the Enset Wilt Organism *Xanthomonas musacearum. East African Agricultural and Forestry Journal*. 40: 111-114.

[13] Addis, T., 2005. Biology of Enset Root Mealybug (*Cataenococcus ensete*) Williams and Matileferrero (Homoptera: Pseudococcidae) and Its Geographical Distribution in Southern Ethiopia (Doctoral Dissertation, MSc. Thesis, Haramaya University, Haramaya, Ethiopia. Pp: 81).

[14] Wolde, M., Ayalew, A. and Chala, A., 2016. Assessment Of Bacterial Wilt (*Xanthomonas campestris Pv. Musacearum*) of Enset in Southern Ethiopia. *African Journal of Agricultural Research*, *11* (19): 1724-1733.

[15] Lemawork, S., Azerefegne, F., Alemu, T., Addis, T., and Blomme, G., 2011. Evaluation Of Entomopathogenic Fungi Against *Cataenococcus ensete* [Williams and Matile-Ferrero, (Homoptera: Pseudococcidae)] on Enset. *Crop Protection*. 30 (4): 401-404.

[16] Abate, T., 1988. Insect And Mite Pests of Horticultural and Miscellaneous Plants in Ethiopia.

[17] Addis, T., Azerefegne, F., and Blomme, G., 2008. Density and Distribution on Enset Root Mealybugs on Enset. *African Crop Science Journal*. *16* (1).

[18] Addis, T., Azerefegne, F., Alemu, T., Lemawork, S., Tadesse, E., Gemu, M., and Blomme, G., 2010. Biology, Geographical Distribution, Prevention, and Control of the Enset Root mealybug, *Cataenococcus ensete* (Homoptera: Pseudococcidae) in Ethiopia. Special Issue: Bananas, Plantains, And Ensete II.). *A tree for Science and Biotechnology*. 4 (1): 39-46.

[19] Kefelegn, H., Tilahun, B., and Girma, F., 2014. Indigenous Management of Enset Root Mealybug (*Cataenococcus ensete*) Williams and Matile-Ferrero (Homoptera: Pseudococcidae) in Gedeo Zone, Ethiopia. *International Journal of Life Sciences*. 3 (4): 131-136.

[20] Dent, D., 2000. Insect Pest Management. Cabi.

[21] Fikre H. & Gizachew W. 2007. Evaluation of Enset Clone Media Against Enset Bacterial Wilt. *African Crop Science Conference Proceedings*. 8: 887-890.

[22] Handoro F., and Said A., 2016. Enset Clones' Responses to Bacterial Wilt Disease (*Xanthomonas campestris* pv. *Musacearum)*. *IJAPSA*. 2 (9): 45-53.

[23] Hunduma T., Kassahun S., Endale H., and Mengistu O. 2015. Evaluation of Enset Clones Resistance Against Enset Bacterial Wilt Disease (*Xanthomonas campestris* pv. *musacearum*).

[24] Jenkins E. and Hines R., 2007. Horticulture Pest Management. A Guide for Commercial Applicators Category 2b.

[25] Mulualem, T., and Walle, T., 2014. Farmer's Indigenous Knowledge and Assessment of Enset (*Ensete ventricosum* [Welw.] Cheesman) Cultivars for Major Insect Pests in Ojojia Water Shade Kembata-Tembaro Zone, South Ethiopia. *Sky Journal of Agriculture Research*. 3 (6): 112-119.

[26] Kasa, D., Getaneh, W., and Tesfahun, F., 2013. Evaluation of Different Botanical Plant Extracts and Other Material Against Enset Bacterial Wilt Disease in Oromia Regional State, Ethiopia. 11th African Crop Science Proceedings. Sowing Innovations for Sustainable Food and Nutrition Security in Africa. Entebbe, Uganda, 14-17 October 2013. Pp: 389-393.

[27] Azerefegne, F., Addis, T., Alemu, T., Lemawork, S., Tadesse, E., Gemu, M., and Blomme, G., 2009. An IPM Guide for Enset Root Mealybug (*Cataenococcus ensete*) in Enset Production. *Biodiversity International, Uganda, and France offices*.

[28] Addis T, Azerefegne F, Blomme G, and K Kanaujia. 2008a. Biology of the Enset Root Mealybug, *Cataenococcus ensete,* and its Geographical Distribution in Southern Ethiopia. *Journal of Applied Biosciences*. 8 (1): 251–260.

[29] Blumberg, D., and Van Driesche, R. G., 2001. Encapsulation Rates of Three Encrypted Parasitoids by Three Mealybug Species (Homoptera: Pseudococcidae) Found Commonly as Pests in Commercial Greenhouses. *Biological Control.* 22 (2): 191-199.

[30] Tadesse, E., Azerefegne, F., Alemu, T., Addis, T., and Blomme, G., 2010. Studies on the Efficacy of Some Selected Botanicals Against Ensete Root Mealybug (*Cataenococcus ensete*) Williams and Matile-Ferrero (Homoptera: Pseudococcidae) (Special Issue: Bananas, Plantains and Ensete II.). *Tree and Forestry Science and Biotechnology*. 4 (2): 91-94.