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Integrated Pest Management System of Enset (Ensete ventricosum (Welw.) Cheesman) in Ethiopia:A Review

Habtamu Gudisa Megersa[1]*, Dadi Tolessa Lemma[1] and Dejene Tadesse Banjaw[2]
1.Ethiopian Institute of Agricultural Research (EIAR), Wondo Genet Agricultural Research Centre
* Corresponding Author: Habtamu Gudisa Megersa; E-Mail: Habtegudisa21@gmail.com;
Telephone: +251912457986; P.O. Box 198, Shashemene, Ethiopia

Abstract
Enset is an important root crop widely used as a staple food for millions of peoples in Ethiopia. Despite its dominant production in southern and western parts of the county, diverse diseases and insect pests are challenging its production and productivity in Ethiopia. Hence this short review was aimed to discuss the IPM system developed to control the potential Enset pests in different production areas of Ethiopia. Hence, enset is a root crop that is highly susceptible to different microbial diseases and insect pest problems. Bacterial wilt 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 mealy bag is also an important insect pest found on the upper half of the corm and root parts of enset which can retard the plant growth and causes to dry outer parts of the leaf that might be leading to causes the plant death. However, most of the growers are practicing different controlling mechanisms against both the potential diseases and insect pests of the crop. Due to the chemical control methods needs the cost of purchase and usage on root mealybug has usually not effective, the growers are wide uses an integrated method of pest management systems with their indigenous knowledge to prevent the disease and insect introduction to the enset field and to control already infected plants. Hence, using host plant resistant method, cultural controlling method, biological controlling method, and finally uses of chemical controlling option are the IPM component practiced by enset growers in Ethiopia. The IPM system is not only an optional method but necessitates the management systems against the potential pest due to environmentally friend, cost-effective, and alternative options to various behaviors of pests. However, breeding of pest-resistant Enset genotype and adoption of successful IPM controlling methods to all enset growing areas need further work to alleviate the encountered challenges on enset growing sector in Ethiopia

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1. Introduction

Enset (*Ensete ventricosum* [Welw.] Cheesman) is a perennial herbaceous and monocarpic root crop with long broad leaves and bulky pseudo stem belongs to Musaceae family known to be originated in Ethiopia (Taye *et al*., 1967). 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 (Zippel *et al*., 1995). 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 into Ethiopia (Brandt, 1997). As a result, enset has been cultivated as 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 (Taye *et al*., 1967).

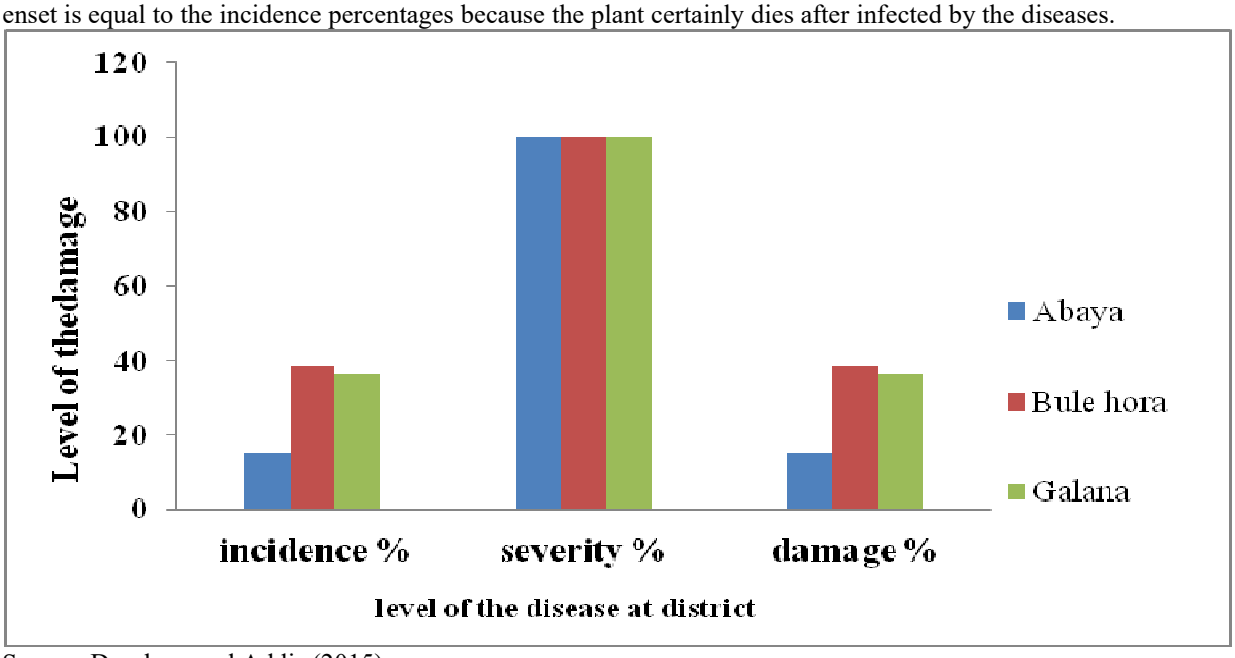
The root of enset, which is rich in carbohydrate, is the main edible portion as its fruit is not. It is an important multi-purpose and drought-tolerant crop, used for food (Kocho, Bulla, and Amicho), Fodder, Fibre, and traditional medicine (Tsegaye and Struik, 2001). The food obtained from the crop is rich in starch, a good source of Calcium and Iron, and has overall nutritive values similar to Potato (Mohammed *et al*., 2013). In terms of edible dry weight and energy, enset gives a higher yield than other crops cultivated in Ethiopia (Tsegaye and Struik, 2001). Hence, 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 (Brandt *et al*., 1997). Additionally, Enset has contributed positively to the local environments by improving the nutrient balance and increasing the fraction of organic matter in the soil (Elias *et al*., 1998; Tesfaye *et al*., 1998). Generally, it is a part of farming systems with high biodiversity, which is an environmentally sustainable and drought-tolerant crop that contributes to the mitigation of climate changes (Tesfaye, 2008).

Even though, the number of improved Enset varieties released by Southern Agricultural Research Institute, Areka research center in Ethiopia, the production and productivity of the crop have been challenged by different factors (biotic and abiotic). Most of the released varieties are susceptible to different diseases and insect pests.

The varieties are most affected by bacterial wilt diseases and currently the disease becoming a great challenge in enset growing areas of the country (Tesfaye, 2008). Also, inevitable insect pests are becoming a great problem for enset production in the growing areas by limiting crop productivity. Therefore, this review was aimed to discuss the major disease and insect pests found at enset growing areas and its available integrated management systems in Ethiopia.

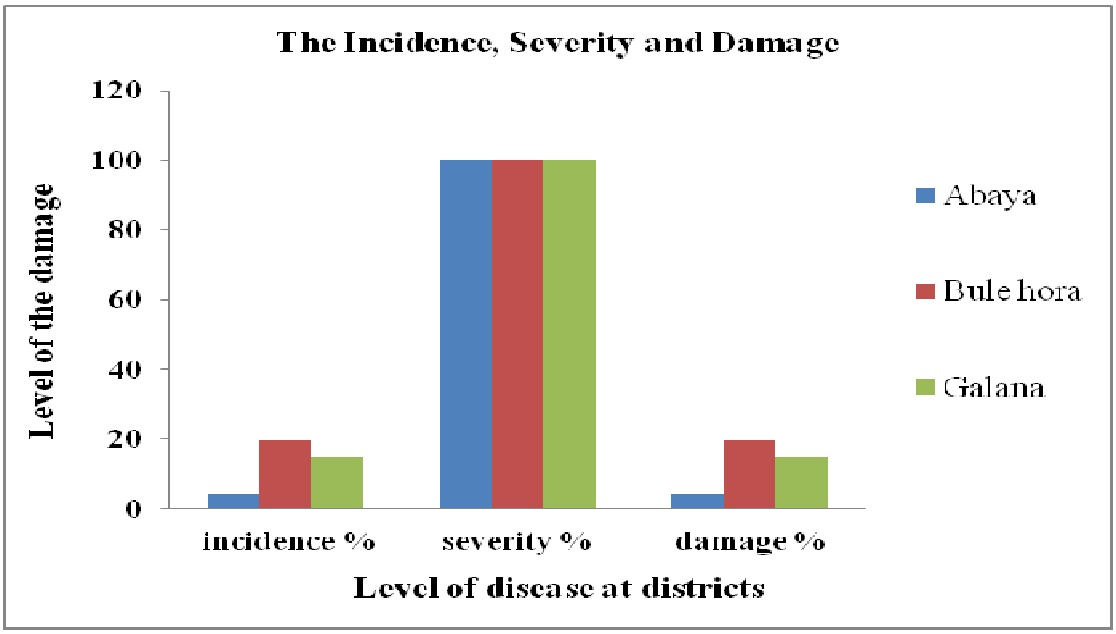
2. Potential diseases of Enset (*Ensete ventricosum* [Welw.] Cheesman)

Regardless of enset is used as a staple food by more than 15 million of 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 (Zippel *et al*., 1995). The most devastating disease affecting the production and productivity of enset is the bacterial wilt (*Xanthomonas campestris* pv. *musacearum*). This bacteria wilt was first identified and reported by Yirgou and Bradbury (1974) 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 the disease was first reported from the banana cv. Ducasse hybrid in Kaffa province of the southwestern part of Ethiopia (Yirgou and Bradbury, 1974). Then, the disease 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 feeding on the foliage (Addis *et al*., 2004). The disease is also transmitted by male inflorescence of enset by various insect vectors. According to the study of Welde *et al*. (2008) reported that an infected enset has shown the initial symptom of a disease like bacterial ooze in the leaf petioles and leaf sheaths and progressive wilting of the leaves. These critical effects resulted in a gradual decline in the production and productivity of the crop. According to the survey report from borena mid-altitude on bacterial wilt incidence in both years of 2014 and 2015 by Desalegn and Addis, (2015) indicates that 38% and 56% of enset farms were infected by the disease with a mean incidence of 29.46% and 12.89%, respectively. From this survey, the average result of 21.17% enset stands was lost due to this disease (Fig. 1 and 2). Moreover, based on an assessed survey, the extent damage of enset is equal to the incidence percentages because the plant certainly dies after infected by the diseases.



Source: Desalegn and Addis (2015)

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



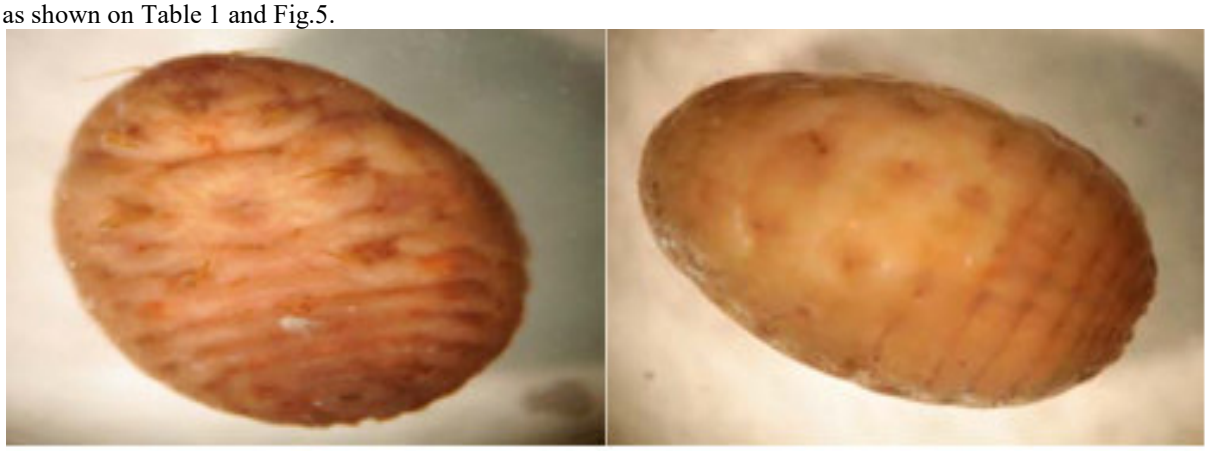
Source: Desalegn and Addis (2015)

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

Generally, Enset bacterial wilt disease is a devastating pest, which able to kill the whole plant that finally leads to crop loss, and currently, the problem is becoming the most challenging issue for enset growing areas of the country.

3. Potential insect pest of Enset (*Ensete ventricosum* [Welw.] Cheesman)

Even though the diverse biotic stresses are affecting enset production and productivities in the country, Enset root mealybug (*Cataenococcus ensete* [Williams and Matile-Ferrero, (Homoptera: Pseudococcidae)]) is the most important insect pest of Enset (Lemawork *et al*., 2011). The *Cataenococcus ensete* is a major insect pest of enset growing areas of Ethiopia. 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 (Fig.3). The wax secretion gives an appearance of cottony and spine-like projections. While these waxy secretions are not part of the mealybugs' body, they lost with each molt. This insect pest was first reported at wonago, Ethiopia in 1988 (Abate, 1988). It was known to attack Enset in Gedeo, Sidama, Gurage, Kembata Tembaro, Hadyia, Keffa and Bench zones, Amaro, and Yem districts of enset growing areas of the country (Addis *et al.,* 2008). According to Addis *et al*. (2010) were elaborated, the pest can attack the crop at any growth stage, with infestations being most severe on two to four years old plants as shown in (Fig.4). Addis, (2005) also further investigated the density and distribution of enset root mealybugs on enset in Ethiopia and reported that most of the insect has found on the upper parts of the corm and the roots within 20 cm radius of soil as shown on Table 1 and Fig.5.

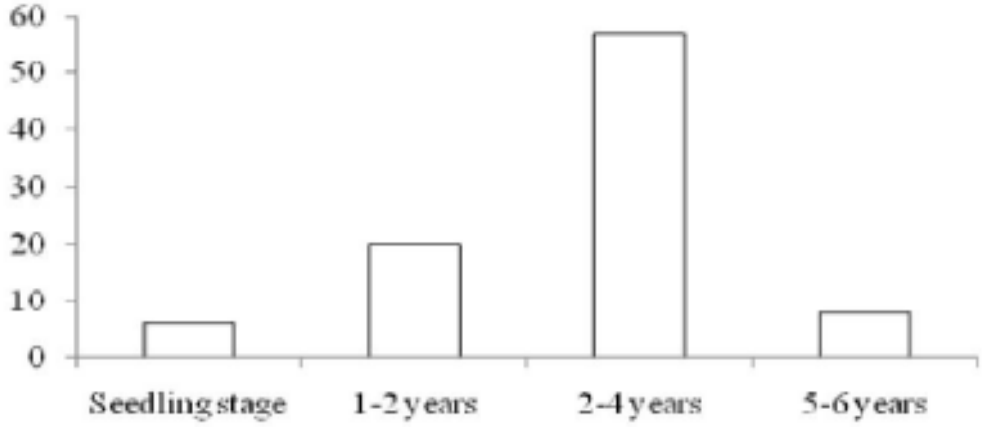


Source: Azerefegne (2009)

Figure 3. Adult enset root mealybug

According to the findings, the infestation of insect pests retards the normal growth of plants, causes in losses of plant vigor, dry lateral leaves but not green central shoot, and finally may lead to death at an area where

the moisture stress is high. However, the finding on the extent of economic loss of the crop by mealybug attacks little to found (Lemawork *et al.,* 2011).



Source: Kefelegn, (2014)

Figure 4. Frequent Enset root mealybug infestation 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 5% probability level.

Source: Addis *et al*. (2008)

Source: Addis, (2010)

Figure 5. Root mealybugs on roots and corm of enset

4. Integrated Enset (*Ensete ventricosum* (Welw.) Chees man.) Bacterial wilt disease (*Xanthomonas campestris* pv. *musacearum*) management system

Bacterial wilt disease is the most economically important, putting the sustainability of enset farming systems in jeopardy comparing with all other constraints of the crop production. Due to 80% of Enset farm 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 (Desalegn and Addis, 2015). This inevitable problem of enset production in the country has been directly or indirectly affected the livelihood of more than 20 million of enset

growers. This boldly observed problem needs strong attention and commitments to manage and conserve the available cultivars before the complete loss of the crop occur. The most important and sustainable way of enset bacterial wilt disease management is using the integrated disease management systems.

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to manage pests, which mainly relies on the combination of common-sense practices (Dent, 2000). There was no clear-cut option is reported to control enset wilt disease in the enset growing region of the country. However, the growers are practicing different integrated management options apart from the chemical treatment systems. This option of management practices could be a method of the controlling system either by preventing the disease occurrences or by managing the disease under the economic threshold level in a sustainable manner 'integrated management systems.

4.1 Using host plant resistance

Developing the bacterial wilt disease-resistant varieties or using of tolerant enset clones could be one of the best approaches to the management of enset bacterial wilt disease. This method of a management system is the best approach to the control of EBW, cheaper to farmers, and safer to environments (Fikre & Gizachew 2007). It has been estimated that there are over 200 different enset clones described by their vernacular names in Ethiopia (Wolde *et al*., 2016). According to the finding of Handoro and Said (2016) reported that the screening of different enset clones for their resistance to enset wilt disease at Areka research center have been made and from the collected genotypes some of them were found promising to be resistant to bacterial wilt disease. Also, Hunduma *et al.* (2015) were reported a similar finding on the screening of enset clones resistant to bacterial wilt disease at Ambo Agricultural Research Center and they have got a promising resistant enset genotype against bacterial wilt diseases from the collection. Hence, due to the presence of rich enset biodiversity in different parts of the country, the host and pathogen characterization, Enset selection and breeding for wilt resistance can be suggested as a long-term management system to control the widespread of the crop disease in the future (Desalegn and Addis, 2015).

4.2 Using cultural control method

This method of bacterial wilt disease control system mainly referring to the uses of indigenous knowledge of the growers. To identify this management system against to EBW, Mulualem and Walle (2014) were first assessed the main route of Enset bacterial wilt disease transmission from the infected plant materials to healthier one and, they found that cutting knife, sharing of infected planting materials and using of common farm equipment was the main route of the disease transmission. Then they reported that to prevent transmission of the disease through the stated ways, the growers indigenously practiced certain controlling activities like uprooting and burying of the infected plants, cleaning of the farming equipment, removing of unwanted left over's and burning of the collected plant debris found in the fields. After uprooting and burying of the infected enset plants, farmers fallow the land at least for six months until the pathogen will be eliminated from the soil by exposing the pathogen to the sun radiation They also make a fence to protect the animal traffic in the growing enset field to prevent the disease transmission to the healthy plants. Furthermore, due to EBW causes severe damage to enset plant, some of the growers 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…etc. (Wolde *et al*., 2016). Hence, the best way of practicing cultural methods against EBW disease control is by creating awareness 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.

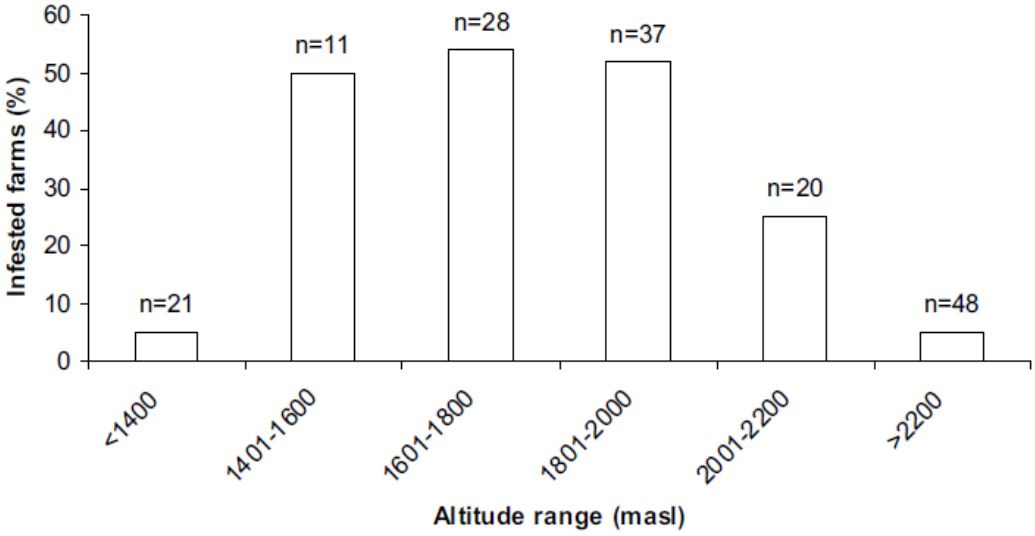
4.3 Using chemical control method

Even though the chemical methods of pest control system are recommended as the last option in IPM, till now there was no scientific report showed the effectiveness of single chemical control against to enset bacterial wilt diseases in the country. However, Kasa *et al*. (2013) were reported the presence of trial by using different botanical plant extracts and other materials against Bacterial Wilt (*Xanthomonas campestris PV Musacearum*) disease. They found based on the invetro test result that combination of botanical plant extracts of Etecha + Kabericho as well as, a single botanical extract of Etecha and 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 the promising result will be expected.

5. Integrated management of Enset (*Ensete ventricosum* [Welw.] Chees man.) Root mealybug

The enset root mealybug *(Cataenococcus ensete*) is becoming the most important and devastating 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 is difficult to control once it has been established

(Lemawork *et al*., 2011). Hence, it is very difficult to control Enset root mealybugs with a single method of the controlling system once it has infested the root of enset due to their cryptic habit, waxy body cover, and formation of dense colonies of multiple and overlapping generations (Azerefegne *et al*., 2009). However, finding the alternate solution against the insect pest is very crucial to control Enset root mealybug in environmentally and economically sustainable manner 'Integrated Pest Management [IPM]'. The first resort to 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 (Fig 6). Therefore, as the planting materials moved from one area to another area of this altitude ranges, care should be given due to their invasiveness at this 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's pest in different Enset growing areas of the country.



Source: Addis *et al*. (2010)
Figure 6. Effect of altitude on enset root mealybug infestation

5.1 Using host plant resistance

Using host plant resistance is a very important method of mealybug control. According to the study of Kefelegn *et al.* (2014) reported that on indigenous management of enset root mealybug (*Cataenococcus Ensete*) Williams and Matile - Ferrero (Homoptera: Pseudococcidae) in Gedeo Zone, Ethiopia by using locally well-known resistant genotype of enset called 'genetica' which was one of the dominant enset clones against to the mealybug in the area (Table 2). Furthermore, attention on the collection of different enset genotypes for screening the resistant clone against to enset root mealybug is underway 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

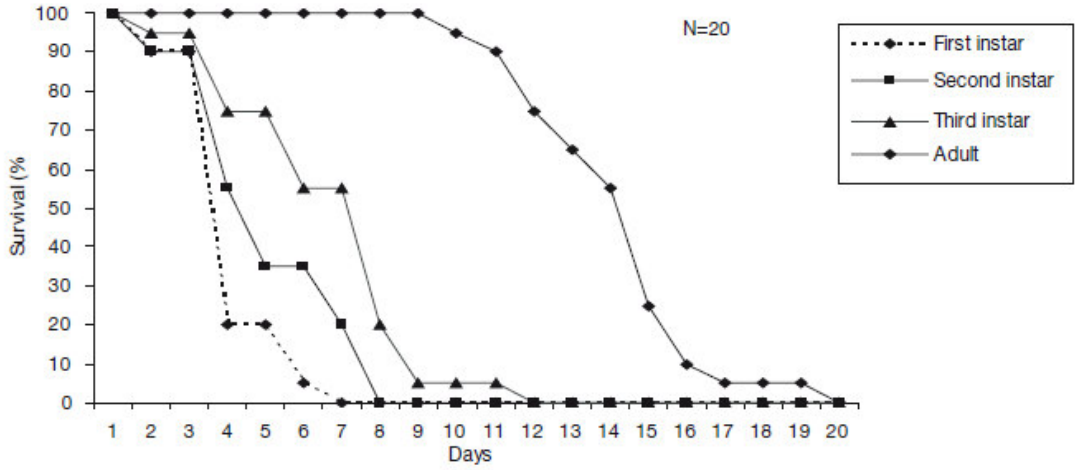
S. No	Enset cultivars (frequently used by the farmers)	Productivity of Enset varieties (Rank)	Quick maturation (Rank)	Tolerance for mealybug infestation	frequently cultivated by the farmers
1	Genetica	1	3	Mild	1
2	Torecha	2	2	-	2
3	Dembele	3	2	-	3
4	Ado	4	3	-	4
5	Qerese	5	2	-	5
6	Nifo	6	1	-	6
7	Astara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

Source: Kefelegn *et al*. (2014)

5.2 Using cultural methods

The cultural methods used to control the mealybug insect are very common and could be practiced by many growers. Addis *et al*. (2010) and Kefelegn *et al. (*2011) were stated that different cultural prevention methods of the enset root mealybug are widely available in different parts of the country. According to the finding, the cultural practices including uses of farmyard manure and ash, disinfection of enset plant by using hot water treatments, keeping the hygiene of farming area by repeatedly plowing and removing of weeds and grasses in the

fields (makes the insect starve) (Fig.7), 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 as inspection purposes because the ant is the vector of mealybug and indicatomealy bug availability in the areas.



Source: Azerefegne *et al*. (2009)
Figure 7. Effect of food deprivation on the survival of the different stages of Cataenococcus Ensete in the soil.

5.3 Using biological methods

The biological methods of mealybug control are one component of IPM, which is an environmentally friendly way of controlling methods. Lemawork *et al., (*2011) investigated the biological control of mealybug insect by using of Entomopathogenic fungi. They reported that the tested entomopathogenic fungal species and isolates showed 72e100%, 83e97%, and 19e51% and 25e54% mortalities of enset root Mealybugs. Therefore, they recommended the fungal isolates have the potential to kill the insect and can be integrated for the management of enset root Mealybugs with other methods.

5.4 Using chemical methods

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 (Blumberg and van driesche, 2001). However, different findings were reported that some effective chemicals that can control mealy infestation despite its purchasing cost. According to Azerefegne *et al*. (2009) finding on selecting effective insecticide against root mealybug in southern Ethiopia, they recommended a single application of Diazinion or Chlorpyrios for root mealybug control. The effect of some botanical extracts against to root mealy bug was also investigated. Tadesse *et al*., (2010) were reported that drenching 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 mealy bugs. Also dipping of the young seedling into the solution to the root zone of infested enset plants can be used for the management of the insect pest.

6. Summary and prospects

Enset is one of the root crops, which has been used as a staple food for many Ethiopian peoples. Despite its largest production status in the southern and western parts of our country, the production and productivities of enset are challenged by different biotic and abiotic factors. Bacterial wilt disease, insect pests, nematodes, and termites are the most important challenge production constraints around enset growing regions. Enset bacterial wilt is the devastating disease known by reducing crop production and productivity, which affects directly or indirectly the lives of most Ethiopian peoples. Enset root mealybug also an insect pest that causes a huge loss of Enset crop. It reduces the yield of the crop by causing stunted growth, which delays crop maturity. However, these important pests are not only controlled by a single management option but it can be alleviated by applying different controlling methods ‘integrated pest management systems’ including the grower's indigenous knowledge. Using resistant genotypes, practicing of cultural management system like uprooting and burring of the infected crop, cleaning, and burning of plant debris in the field of enset, cultivating the infected soil and fallowing for a certain period, disinfecting of the farm tools, treating the enset crop by hot water and excluding of animals from the enset farming are applied to control the insect pest problem from the crop. Also, biological control and using botanical extracts are identified as effective ways against the pests. Finally, using the chemical

controlling method is found to be the last option for enset pest control in the IPM system. Generally, all of the combinations are found to be a useful method of important Enset pest control in 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 on the enset growing sector in Ethiopia.

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