



**Ethnobotany and morphological trait analyses of Enset plant along  
with evaluation of farmers' propagation practice for the wild relative  
in Kaffa zone, Southwest Ethiopia**

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**June, 2019**

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with evaluation of farmers' propagation practice for the wild relative  
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A Thesis Submitted to

The Department of Plant Biology and Biodiversity Management

Presented in Partial Fulfillment of the Requirements for the Degree of  
Master of Science (Plant Biology and Biodiversity Management)

Addis Ababa University

Addis Ababa, Ethiopia

June, 2019

# Addis Ababa University

## Graduate Programmes

This is to certify that the thesis prepared by Asaminew Woldegebriel Gebre, entitled: *Ethnobotany and morphological trait analyses of Enset plant along with evaluation of farmers' propagation practice for the wild relative in Kaffa zone, Southwest Ethiopia* and submitted in partial fulfillment of the requirements for the Degree of Master of Science (Plant Biology and Biodiversity Management) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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## ABSTRACT

Ethnobotany and morphological trait analyses of Enset plant along with evaluation of farmers' propagation practice for the wild relative in Kaffa zone, Southwest Ethiopia

Asaminew Woldegebriel Gebre, M.Sc. Thesis

Addis Ababa University, June 2019

*Ensete ventricosum* ((Welw.) Cheesman, Musaceae) is a multipurpose plant cultivated in Ethiopia. This study was conducted in Decha, Chena and Gimbo districts (Kaffa zone) to document morphological diversity, qualities, threats, propagation and management practices along with testing the propagation performance of wild Enset relatives. Purposive and simple random sampling techniques were used to select study sites and the households, respectively. Data were collected from 120 Enset farms through interview, observation, and field experiment. Morphological traits were recorded for each landrace and wild relative. Twelve treatment combinations in three replicates were tested. Microsoft Excel 2010, R 3.4.3 and SAS programs were used for data analysis. Two wild Enset relatives and 52 cultivated Enset landraces were identified. Wild Enset relatives were inedible (bitter corm tastes and thought to have black kocho) and fast growing (mean maturity age = 4.34 years) on which the pest and disease attacks were not observed. However, over leaf utilization, deforestation, and lack of conservation interest might have contributed to the scarcity. They were uniquely observed with wider mean size ( $0.78 \pm 0.34$  to  $0.86 \pm 0.06$  meter) and deep green color of leaf. Cultivated Enset landraces were scaled as low, moderate and high for their uses and agromorphological qualities. Though poor performance was observed, the field experiment evidenced that the propagation practice of Enset growers is applicable to the wild relatives. Therefore, the previously reported wild Enset reproduction (via seed) can be assisted by asexual propagation. Adopting the best traits will contribute to the conservation of Enset plant.

**Key words:** Conservation, Enset morphology, Landrace, Propagation, Wild relative

## Acknowledgement

I would like to express my deepest gratitude to my almighty God. I would like to thank Mizan Tepi University for sponsoring me by covering education fee, and to the Department of Plant Biology and Biodiversity Management of Addis Ababa University for admitting me in the Department's MSc. program. I would also like to thank the GCR fund on "Modeling and Genomics Resource to Enhance Exploitation of the Sustainable and Diverse Ethiopian Starch Enset Crop and Support Livelihoods" for covering the research cost.

My profound gratitude goes to my advisors, Professor Sebsebe Demissew and Dr. Tigist Wondimu for their generous and unreserved guidance and assistance throughout the study period. All staff members and secretary of the Department of Plant Biology and Biodiversity Management are greatly acknowledged for their kind and positive service delivery. Special thanks to Professor Zemedu Asfaw, Professor Zerihun Woldu and Dr. Ermias Luelekal who had equipped me with the research methods and quantification of Ethnobotanical study. This also goes so do for Dr. James Borrell who also equipped me with methods of field data collection by involving me in field data collection in different areas. In addition, I am very grateful to Wege Abebe (staff of Herbarium in Addis Ababa University) for his contribution.

I would also like to thank administrative officers of Kaffa zone including Decha, Chena and Gimbo Woredas and their Kebeles. All the informants are highly acknowledged for their support time and unreserved willingness to share their knowledge. I thank field assistants. I am very grateful to Kochito Gebremikael (studying MSc. program in Plant Breeding in Jimma University), Tekalegn Gebreyesus (expert of Geo-informatics and remote sensing, and lecturer in Wollega University, Department of Earth Science), and Solomon Tamrat (studying Ph.D. in Plant Biology and Biodiversity Management) for their contributions. My classmates (Emebet Getachew and Meresa Gufuy) are equally acknowledged.

My great gratitude goes to my families who have been my backbones throughout my study, particularly my mother Zewditu Woldgebriel Gawo who encouraged me and energized me during difficult times. I extremely appreciate and thank my sister Neberet Woldegebriel for her continuous followup.

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## Acronyms

ANRKZ – Agriculture and Natural Resource officers of Kaffa Zone

BWD - Bacterial Wilting Disease,

DLNP - Deforestation and Lack of need for propagation

EWNHS – Ethiopian Wildlife and Natural History Society

HIEP – Harvesting immature Enset plant

NABU – Nature and Biodiversity Conservation Union

OUL – Over Utilization of Enset leaf for domestic uses

SNNPRS – Southern Nations Nationalities and Peoples Regional State

WBISPP – Woody Biomass Inventory and Strategic planning project

## CHAPTER ONE

### 1. INTRODUCTION

#### 1.1. Background of the study

Ethnobotanical study including local knowledge of taxonomy is crucial for biodiversity conservation in countries like Ethiopia. Among the several indigenous crops growing in Ethiopia, Enset (*Ensete ventricosum* ((Welw.) Cheesman, Musaceae)) is known to have diverse landraces with diverse vernacular names across different local languages and various management practices. These are the main challenges for applying a country-wide conservation system. It is important to narrow down the numbers of classification system (Mohammed Yesuf and Tariku Hunduma, 2012; Borrell *et al.*, 2019). It is poorly characterized starchy plant species (Borrell *et al.*, 2019). This is mainly due to the lumping (using single name while having different traits) and splitting (using different names while have similar trait) of landrace names which is amplified when it is identified by peoples having different training, languages and customs (Baraloto *et al.*, 2007).

*Ensete ventricosum* has diverse agromorphological traits and complex folk taxonomic classes in the Enset growing areas; it is a multipurpose crop dominantly cultivated by densely populated south and southwestern Ethiopians (Admasu Tsegaye, 2002; Mohammed Yesuf and Tariku Hunduma, 2012; Borell *et al.*, 2019). This is because each ethnic group has their own naming and folk classification system (Borrell *et al.*, 2019).

A number of cultivated Enset landraces are known as backyard plants including the wild relative. For example, Yemane Tsehaye and Fassil Kebebew (2006) recorded 42 landraces from Kaffa Zone (around Bonga), Temesgen Magule *et al.* (2014) 67 landraces from Wolaita, Awol Zeberga *et al.* (2014) a total of 312 landraces from

Wolaita, Kembata, Hadiya, Sidama, Gedeo, Silte, Gurage and Dawro, Admasu Tsegaye and Struik (2002) 166 landraces from Sidama, Wolaita and Hadiya (Sidama (52), Wolaita (55) and Hadiya (59)), Amare Seifu and Daniel Fitamo (2016) 61 landraces from Aleta Chuko district (Sidama Zone), Belachew Garedew *et al.* (2017) 68 landraces from Masha and Anderacha districts (Sheka Zone), Adanech Jarso (2017) 33 landraces from Gurage zone, and Ambachew Zerfu *et al.* (2018) 93 landraces from Yem special district.

*Ensete ventricosum* is a multipurpose plant species with a single underground corm and a pseudostem shoot that has long broad leaves and midribs (Yemane Tsehaye and Fassil Kebebew, 2006). It is a giant herbaceous flowering perennial plant (Family: Musaceae, Genus: Ensete, Species: *Ensete ventricosum*). It cannot produce suckers at its base when it is not damaged. It is monocarpic, i.e. whole plant dying after fruiting. Its bracts and flowers are not inserted independently on the axis, and it has large seeds usually more than 10 mm in diameter (Edwards *et al.*, 1997). Its farming system is mainly limited to homegarden management practices (Yemane Tsehaye and Fassil Kebebew, 2006), and its agronomic performance mainly depends on cultural practices (Mesele Gemu *et al.*, 2007).

It provides as sources of food (amicho, bulla and Kocho), animal feed, cultural materials, medicine, and serves as soil water conservation (Yemane Tsehaye and Fassil Kebebew, 2006; Tadessa Daba and Masayoshi Shigeta, 2016). Cultivated Enset landraces mainly serve as sources of food (amicho, bulla, porridge and kocho), traditional medicine, fiber, and spiritual services in Kaffa zone (Yemane Tsehaye and Fassil Kebebew, 2006).

Wild Enset relative, (non-edible by local people), grows in limited areas of Wolaita, Gamo-gofa, Kaffa zone, Sheko district and Sheka zone out of human

settlements, and it is regenerated naturally from its seed (Genet Birmeta *et al.*, 2004; Yemane Tsehaye and Fassil Kebebew, 2006; Hilderbrand, 2001; Belachew Garedew *et al.*, 2017; Temessgen Magule *et al.*, 2014).

## 1.2. Statement of problems

Cultivated Enset landraces grow in areas of diverse ethnic groups with diverse languages, customs and their naming systems, thus the Enset farming system is more complex (Brandt *et al.*, 1997; Admasu Tsegaye, 2002). It has various farming and management practices (Admasu Tsegaye, 2002; Genet Birmeta *et al.*, 2004; Mohammed Yesuf and Tariku Hunduma, 2012). In addition to taxonomic and management challenges, the production of Enset is declining due to local threats (diseases, corm and leaf pests). The traits of cultivated Enset landraces are different in yield provision and reaction against wilting disease (Admasu Tsegaye, 2002; Borrell *et al.*, 2019). Deforestation is becoming a critical problem in Kaffa zone, which can lead to habitat loss and degradation thereby to the loss of the restricted wild Enset relative (NABU, 2017). In addition to this, local people have no interest to conserve and propagate the wild Enset relative which may serve as gene pool for improvement of cultivated Enset landraces. Borrell *et al.* (2019) also discussed the wild Enset relative as it is more distinct from cultivated Enset landraces, and its data were not evidenced.

The difference in the mode of propagation between wild Enset relative and cultivated Enset landraces made them genetically distinct due to limited gene flow (Genet Birmeta *et al.*, 2004; Yemane Tsehaye and Fassil Kebebew, 2006). Ethiopian farmers propagate cultivated Enset landraces vegetatively using whole corms, half corms, and quarter corms, and the size of both whole corms and corm pieces has significant effects on percentage of regeneration, number of suckers per corm, but size has no effect on pseudostem circumference and emergence days (Taye Buke *et al.*,

2016). Vegetative propagation of Enset is important for conservation of the existing landraces with homogenous characteristics (Zippel, 2005). It is also important due to long duration of Enset to bear seed for sexual reproduction. It is also believed that local people know more about locally limited species, and indigenous knowledge has a great role for preservation and conservation of such species.

Therefore, it is wise to conduct and document ethnobotanical information together with different traits of both wild Enset relative and cultivated Enset landraces. This study was aimed to fill information gaps by identifying unique Enset names with its morphological traits, use values, threats and conservation practices of both wild Enset relative and cultivated Enset landraces. Also application of knowledge of Kaffecho people was interestingly applied on farmer's site to test the possibility of wild Enset relative viability from its corm so as to conserve it.

### 1.3. Research questions and objectives

#### 1.3.1. Research questions

- ❖ Do both wild Enset relative and cultivated Enset landraces have similar morphology?
- ❖ Do the morphological, agronomic, and end use qualities of Enset depend on types of local landraces?
- ❖ Are both wild Enset relative and cultivated Enset landraces affected by similar threats?
- ❖ Can the traditional Enset propagation practice be applied for wild relative?
- ❖ Are the performances of suckers of wild Enset relative and cultivated Enset landraces affected by corm partition into pieces?

### 1.3.2. Research objectives

#### General Objective

- ❖ To conduct ethnobotanical and morphological diversity studies of Enset plant along with an on-farm experiment on the performance of traditional Enset corm propagation practices of farmers (both on cultivated and wild).

#### Specific objectives

- ❖ To distinguish morphological diversity of wild Enset relative and cultivated Enset landraces along with the distinctive features of wild Enset relative.
- ❖ To compare the morphological, agronomic, and end use qualities of wild Enset relative and cultivated Enset landraces.
- ❖ To identify the major local threats on wild Enset relative and cultivated Enset landraces within their management practices.
- ❖ To document the propagation practices of cultivated Enset landraces in study area, and to test its application on the wild Enset relative.
- ❖ To compare the impact of Enset corm partition on sucker germination and performance for wild Enset relative and cultivated Enset landraces.

## CHAPTER TWO

### 2. LITERATURE REVIEW

#### 2.1. Definition of terminologies

Enset plant has landrace diversities based on their morphological heterogeneity on the farm. Landrace can be defined as the “crop populations that have not been bred as varieties by scientists but which farmers have adapted to local conditions through years of natural and artificial selection” (Melaku Wolde, 1991; also cited in Zippel, 2005, p. 427). It is also referred as ‘farmers’ variety’ which means a crop variety often harbouring some genetic variability yet with a certain genetic integrity that has evolved in cultivation, usually in a traditional agricultural system over long periods, and has adapted to a specific local environment or purpose (Bioversity International, 2017). Crop wild relatives are wild plant species that are genetically related to cultivated crops. Cultivar is a plant or grouping of plants selected for desirable characteristics that can be maintained by propagation. Most cultivars have arisen in cultivation, but a few are special selections from the wild. Variety is a plant or group of plants selected for desirable characteristics and maintained in cultivation. It may be traditional and maintained by farmers, or modern and developed as a result of deliberate breeding programs (Bioversity International, 2017). Lumping (Baraloto *et al.*, 2007) or homonyms (Borell *et al.*, 2019) is giving same name to different species or varieties. Synonyms (Borell *et al.*, 2019) and splitting (Baraloto *et al.*, 2007) is giving different names to same species or varieties.

In-situ conservation is the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings. In the case of domesticated or cultivated species, it refers to conservation in the surroundings where they have developed their distinctive properties.

Intercropping is a mixture of crop species in the same field at the same time, often with synergistic effects. On-farm conservation is a dynamic form of crop and animal genetic diversity population management in farmers' fields, which allows the processes of evolution under natural and human selection to continue. *Ensete ventricosum* is a plant species cultivated as staple food (bulla, amicho and kocho) in south and southwestern Ethiopia. Bulla is water insoluble starchy product obtained by squeezing the scrapped Enset leaf sheath and corm. Amicho is inner part of the Enset corm eaten boiled as other root crops. Kocho is fermented product of Enset obtained from a mixture of decorticated sheath and corm (Yemane Tsehaye and Fassil Kebebew, 2006).

## 2.2. Description of Enset plant

Enset is a giant herbaceous flowering perennial plant (Family: Musaceae, Genus: *Ensete*, Species: *Ensete ventricosum*). It can produce suckers at its bases when cut or damaged. It is monocarpic whose bracts and flowers are not inserted independently on the axis, and it has large seeds usually more than 10 mm in diameter (Edwards *et al.*, 1997).

*Ensete ventricosum* is a member of banana family, and it is a gigantic leafy monocarpic evergreen perennial root crop and main food source mostly for the southwestern part of Ethiopian highlands. The plant stores carbohydrate in its pseudostem during the vegetative stage in the leaf sheaths and the corm, which is used up at the flowering and fruiting stages, whose harvesting time is recommended to be ahead of flowering, and its seeds can stay viable for more than 25 years (Tadessa Daba and Masayoshi Shigeta, 2016). It has diverse morphological parts with sparse fibrous roots, corm, pseudostem (false stem), leave sheath, inflorescence, broad leaves and long midrib.

## 2.4. Ecology of Enset plant and its distribution

Wild Enset relatives are distributed throughout much of central, eastern and southern Africa as well as Asia (Brandt, 1996). Historically; Enset is commonly adapted to swampy and moist areas through central and eastern Africa (Bizuneh Taye *et al.*, 1967; Admasu Tsegaye, 2002). Admasu Tsegaye (2002) reviewed that there are wild Enset distributed in tropical Africa from Kenya and Uganda, south to Mozambique, and West to the Democratic Republic of Congo and Cameroon. He also discussed that *E. ventricosum* is native to south and south western highlands of Ethiopia with numerous farmers' varieties and its wild relatives in forests, river gorges and streams.

Enset grow in ecological condition where there is a recipient of annual rain fall between 1100 to 1500 milliliter per year, mean temperature 16 to 20<sup>0</sup>c and in elevation ranging 1500 to 3100 meter above sea level (Admasu Tsegaye, 2002). Some Enset landraces also recorded at lower altitudes (Tadessa Daba, and Masayoshi Shigeta, 2016). It also grows in different soil condition, but an ideal soils are moderately acidic to alkaline (pH 5.6 to 7.3) with 2-3% organic matter (Admasu Tsegaye, 2002).

However, wild Enset relative is also distributed in undisturbed limited areas of south and south western Ethiopia (Genet Birmeta *et al.*, 2004; Yemane Tsehaye and Fassil Kebebew, 2006). It occurs in the highlands (1100-3100 m. a. s. l.) of the southwestern part in very restricted distribution that grow mainly around the city of Bonga (Kaffa Zone) and round Omo river in habitats ranging from dense forests to open shrub land, or along riverbanks (Genet Birmeta *et al.*, 2004; Yemane Tsehaye and Fassil Kebebew, 2006). It is also reported that sparsely distributed Wild relative of Enset occurs in the forest of Sheko in Benchi Maji zone (Hilderbrand, 2001) and Masha and Andiracha districts of Sheka zone (Belachew Garedew *et al.*, 2017). This wild

Enset relative is inedible in Sheka zone locally called as Echo (Belachew Garedew *et al.*, 2017), and in Kaffa zone locally called as Eppo or Kocho seyitan (meaning devil's Enset) (Yemane Tsehaye and Fassil Kebebew, 2006).

## 2.5. Morphological diversity of Enset landraces and local identification

### methods

However, it seems very difficult to determine which belong to cultivated Enset landraces or wild Enset relatives for non-Enset growing farmers, the Enset growers can easily distinguish them based on color, shape, and many other characteristics. In addition to other morphological and end-use characters, midrib color and pseudostem color are the most important characters used by the farmers in classification (Yemane Tsehaye and Fassil Kebebew, 2006). The Wolayta farmers use folk classification systems for their Enset plant based on four criteria ((i) domestication status (ii) gender (iii) use value and (iv) eco-geographic adaptability) (Temesgen Magule *et al.*, 2014).

Irregardless of biologically related aspects of reproductive parts, farmers distinguish cultivated Enset landraces as female and male category based on the morphological traits, the end uses, qualities and characteristics in terms of desirability for harvesting, time of harvesting, fiber and food content, softness and hardness, palatability when immature, length of fermentation period required, size, growth rates, and resistance to disease and pests (Yemane Tsehaye and Fassil Kebebew, 2006; Temesgen Magule *et al.*, 2014). Cultivated Enset landraces under male category such as Nache Nobo (meaning white noobo), and Aa'i-noobo (meaning dark noobo) are locally identified as having poor quality bulla, amicho, fiber, fermentation qualities and are late maturing (Yemane Tsehaye and Fassil Kebebew, 2006). They are tolerant to bacterial wilting disease in Kaffa and Sheka Zones of south western Ethiopia (Yemane Tsehaye and Fassil Kebebew, 2006; Belachew Garedew *et al.*, 2017).

Based on indigenous use-value, farmers classified cultivated Enset landraces in two comprehensive use groups: food uses and non-food uses (fiber, fodder, firewood, medicinal, construction and water source). Although all cultivated Enset landraces can be used both for food and non-food uses, there are preferences for specific landrace among communities for particular purposes. Based on eco-geographic adaptability (altitude), cultivated Enset landraces are classified as low altitude and high altitude landraces (Temesgen Magule *et al.*, 2014).

Enset accessions can be also categorized through twelve distinguishing features that are grouped into three clusters are: (1) phenotypic characteristics: pseudostem, midrib, leaf, and petiole colors; (2) agronomic characteristics: disease resistance (susceptible, intermediate, tolerant); maturity (early, intermediate, late); plant vigor (poor, medium, high), and (3) use-value characteristics: bulla quality (not good, good); corm use (not used, used); Kocho yield (low, medium, high); medicinal value (not used, used); fiber quality (low, medium, high) (Almaz Negash and Niehof, 2004; Tadessa Daba and Masayoshi Shigeta, 2016).

New cultivated Enset landraces are obtained either by exchange and trade, or from seedlings and mutants. In Sidamo, traditional trading of Enset sprouts and a comparatively well-developed infrastructure may explain the immense increase in number of presently grown landraces (Zippel and Alemu Kefale, 1995; Bizuayehu Tesfaye, 2002). Several studies indicated that Enset plant is morphologically diverse that have many landraces with their own respective local names among farmers.

Table 1. Examples of the reported Enset morphological diversities in Ethiopia

NO.	Study area	Numbers of landraces	Citation
1	Bonga (Kaffa Zone)	42	Yemane Tsehaye and Fassil Kebebew, 2006
2	Wolaita	67	Temesgen Magule <i>et al.</i> , 2014
3	Wolaita, Kembata,	312	Awol Zeberga <i>et al.</i> , 2014

	Hadiya, Sidama, Gedeo, Silte, Gurage and Dawro		
4	Sidama, Wolaita and Hadiya	166 (Sidama (52), Wolaita (55) and Hadiya (59))	Admasu Tsegaye and Struik, 2002
5	Masha and Anderacha Districts (Sheka Zone)	68	Belachew Garedew <i>et al.</i> , 2017
6	Aleta Chuko District (Sidama Zone )	61	Amare Seifu and Daniel Fitamo, 2016
7	Yem Special district	93	Ambachew Zerfu <i>et al.</i> , 2018

## 2.6. Roles of Enset

### 2.6.1. Material culture and cultural role

Different parts of Enset plant have its own particular uses for local communities. For example, the leaves are the most widely used of all wrapping material, and as temporary ovens for baking special bread (Edwards *et al.*, 1997). All plant parts are used for various purposes in the household and agriculture, i.e. to make ropes, mats, towels, seats, fuel, manure, shade, umbrella and wrapping material for food products. Dried leaf sheaths are used for construction, and all plant parts for traditional medicinal treatments (Westphal, 1975; Huffnagel, 1961; Kefale Alemu and Sandford, 1991). Dried leaves and other pseudostem parts are also collected for making traditional seats and mattress. The dried and semi-dried long lamina is used for fastening harvests of grasses, crops, and firewood. The fiber of Enset is very strong (Temesgen Magule *et al.*, 2014).

The cultivation of Enset is also used as a cultural symbol for the communities and it is an expression of their identity. The communities indicate that Enset foods are traditionally incorporated into cultural events (births, deaths, weddings and festivals). Enset as a food crop is used for their consumption ranges from daily staple to specialty food in festive occasions and ceremonies in Wolaita (Temesgen Magule *et al.*, 2014).

#### 2.6.2. Food, feed and income source

Enset is cultivated for food products (flat bread kocho, or flour for gruel bulla) made from cultivated mainly for its edible pseudostem and corms (Edwards *et al.*, 1997). Leaf sheaths are scraped, and the corm is cut into pieces and pounded. Both provide a starchy porridge. Fermentation with lactic acid bacteria allows storage for more than one year. Farmers in Gurage, Sidamo and Arsi report storage of the fermented product for up to seven years, and the corm is also eaten boiled fresh. In addition, the different parts of Enset are used as animal fodder (Zippel, 2005).

Even though, the Enset plant is believed to be nutritionally poor (particularly in protein and vitamin), farmers are selecting cultivated landraces that contain relatively higher content of protein, fat and fiber. Almost all of the cultivated Enset landraces contain better amounts of total carbohydrate than the wild Enset relative. Wild Enset relative is characterized by having high fiber, nitrogen, crude protein, ash, large petiole and pseudostem length and low carbohydrate content (Yemane Tsehaye and Fasil Kebebew, 2006). The edible parts of Enset vary across places and farmers. The three most common Enset derived foods are kocho, bulla, and amicho (corm), and the pulp of the pseudostem, the young shoots, and the corm are also edible (Tadessa Daba and Masayoshi Shigeta, 2016).

Enset plant is grown for long time with minimum requirement of external inputs and labor, and the multipurpose nature of the plant and its valuable role in the

livelihood of the community differ it from the most cereals and root crops (Yemane Tsehaye and Fassil Kebebew, 2006). Its surplus products and planting materials are sold in local markets and generate income for the household (Temesgen Magule *et al.*, 2014). In Ethiopia, the fiber of the Enset plant is widely used for making bags and ropes and for basketry. Because of its resistant to sea water, however, its strength is less than that of *Musa textilis* or Agave (Edwards *et al.*, 1997).

### 2.6.3. Medicinal and ritual significance

Different cultivated Enset landraces are reported to have medicinal and religious (ritual) significance as preventive treatment, healing and other therapeutic purposes, and as protection against evil spirits. Some landraces (Taayo, Officho, Choro and Maaca dami) in Kaffa zone were reported to have selective medicinal roles (Yemane Tsehaye and Fassil Kebebew, 2006). Taayo is used to cure similar ailments in domesticated animals (dairy cows) when eaten with salt. The boiled corm amicho and starchy powder bulla are eaten with milk to cure ailments such as broken bones fractures, joint displacement and swelling with pus. Similarly, Officho is prepared as a dehydrated starch suspension bulla together with milk. This is used for a person who has health problems from broken bones, fractures and swelling in order to restore and heal the damaged part of the body. Choro and Maaca dami Enset landraces are similarly used as medicinal and ritual purposes. Their corm amicho is eaten with cheese particularly prepared with butter and milk by women who have just delivered babies and whose discharge of the placenta is delayed. It stimulates the placental discharge during delivery. For dairy cows, the amicho is given with salt for similar purposes, and farmers in both Decha and Chena districts of kafa zone plant them in front of their tikuls as a safe guard against devils' and all evil spirit attacks (Yemane Tsehaye and Fassil Kebebew, 2006; Tadessa Daba and Masayoshi Shigeta, 2016).

Only a few people use Enset for medicinal purpose; however, the Enset plant and its parts contribute to indigenous ethno-medicinal values in the Wolayta zone. Mostly, the traditional Enset medicines administered in the form of food products include (1) porridge made of Itima from Agino and Gefetanuwa landraces, for strengthening women after delivery, and healing bone fractures in humans respectively; (2) very highly fermented Uncca from Maziya and Halla landraces, for curing stomach cramps; and (3) boiled corm of Lochingia, for birth control and abortion in humans, and to feed cows to facilitate placental expulsion (Temesgen Magule *et al.*, 2014).

Farmers in the Kaffa zone maintain many cultivated Enset landraces along with associated myths, beliefs, songs/poems, and medicinal and ritual significance. Some of the people in Kaffa zone have interesting religious notion about spirits (adibaaro or qoolloo), mainly connected with the Enset plant. Enset in the form of chopped kocho (locally called Baaccuuro) is used as a sacrifice to enhance its fertility, production and a good harvest. When Enset is planted, some people perform religious rites to honor the adbar. Such ceremonies are usually conducted in sacred places and in the forest near to their farms (Yemane Tsehaye and Fassil Kebebew, 2006).

#### 2.6.4. Habitat role and ornamental uses

Enset agriculture fulfills an ecological role, because it is an organic farming system by using only farmyard manures, with no external chemical fertilizers, herbicides and insecticides. In Enset growing areas, animal husbandry is commonly practiced. Enset agriculture helps through a year-round supply of nutritious feed. Enset can be a safety-shield cattle feed because it is available during the drought seasons of the year, when most other feed sources dry out (Temesgen Magule *et al.*, 2014).

Enset plant is a flowering plant with male and female flower parts; the male flowers produce copious pollen and the female much nectar which attract large

numbers of honeybees (Edwards *et al.*, 1997). Enset plant species serves as the best preferred microhabitat for endemic species in Ethiopian highland amphibian species (Clarke's banana frog (*Afrivalus clarkeorum*)) (Largen, 1974; Largen and Spawls, 2010; NABU, 2017).

The Enset plantation in homegarden also serves as a wind break for Enset and other crop nurseries. At the same time, Enset farming is used as an aesthetic requirement for the homegarden through colorful ornamental landraces (Temesgen Magule *et al.*, 2014).

## 2.7. Threats on Enset farming and its prevention

Bacterial wilt disease (*Xanthomonas campestris* pv. *musacearum*) and recurrent drought, increasing population size and associated land shortages are threatening Enset agriculture, and they lead vulnerability of agricultural systems and agro-biodiversity in southern Ethiopia (Temesgen Magule *et al.*, 2014). The severe problems facing on the Enset cultivation are diseases that include sheath, corm, and dead heart leaf rots caused by an unknown bacterial pathogen and fungus as well as viral diseases, lesions, nematodes, and root-knot. There is also knowledge limitation in the implementation of preventing strategies on the severity of Enset plant diseases. Bacterial wilt, caused by the bacteria *Xanthomonas campestris* pv. *musacearum*, is the worst to the Enset farming system. It attacks the plant at any stages even after full maturity (Tadessa Daba and Masayoshi Shigeta, 2016).

Enset root mealy bug (*Cataenococcus ensete*) Williams and Matile-Ferrero (Homoptera: Pseudococcidae) is known to attack Enset in Gedeo, Sidama, Gurage, Kembata Tembaro, Hadya, Kaffa and Bench-Maji zones, and Amaro and Yem districts (Temesgen Addis *et al.*, 2008b). This pest can results a stunted growth and the damage appears more severe during the dry season (Ferdu Azerefegne *et al.*, 2009). The pest

attacks the crop at any age (Anonymous, 2001). It is easily dispersed by nymphs or crawlers, water, infected corms, ants, cultivation and transplanting (Ferdu Azerefege *et al.*, 2009). Botanically, mealy bug can be treated with the application of insecticidal plant extracts, *Millettia ferruginea* seed water suspension which was found to be more superior in terms of causing its mortality. However, it results in the suckers' mortality in early stage of Enset suckers, the temperature of the hot water greater than 55 °C can also treat with 100% mortality of the adult mealybugs in the soil system (Mesele Gemu *et al.*, 2010).

Selective propagation practices have its own impact on Enset plant sustainability. Different Ethnic groups frequently farm and grow some selective cultivated Enset landraces based on their specific references and required characteristics. Due to this reasons, some of the cultivated Enset landraces had disappeared, while new ones had emerged. Some cultivated Enset landraces that fulfilled these requirements used for very long periods were reported to have especially high value for human consumption (Zippel and Kefale Alemu, 1995; Kefale Alemu and Sandford, 1996; Bizuayehu Tesfaye, 2002; Zippel, 2005). New cultivated Enset landraces with selective characteristics replace older ones due to their characteristics. Highly esteemed Enset landraces are often cultivated despite unsuitable conditions requiring special cultivation measurements (i.e. frost protection or irrigation), and farmers always grow some less favoured landraces that tolerate extreme weather conditions, i.e. drought or frost, as well as diseases and pests to ensure permanent food supply (Zippel, 2005).

Porcupine and mole rats are the most threatening pests that lead to losses of root crops (Enset, sweet potato, yam, and potato) and grass species in highlands of Ethiopia. Some farmers attempted to control mole rats through fumigating their holes, pouring water into the holes and using traps. Traditionally, farmers protect their crops from

attack of porcupine through digging deep pits at outlets of Porcupine cave, wire trapping, and forming circular ditches around farm (Mohammed Yesuf and Tariku Hunduma, 2012).

## 2.8. Enset conservation practices

Many biogeographers and agronomists have described the center of origin for Enset agriculture to be the Ethiopian highlands (Vavilov, 1951; Harlan, 1969). Its domestication in Ethiopia had assumed as dated back more than 10,000 years (Brandt *et al.*, 1997; Tadessa Daba and Masayoshi Shigeta, 2016). It has not been yet reported about its cultivation for its multipurpose outside of Ethiopia; however, its distribution is frequently reported.

Enset crop is only cultivated by Ethiopians for its direct use values like food and fiber since beginning of Egyptian civilizations (Bizuneh Taye *et al.*, 1967; Admasu Tsegaye, 2002). The Enset farming system by densely populated south and southwestern Ethiopians are more complex which sustain the life of numerous people with several ethnic groups (Brandt *et al.*, 1997; Admasu Tsegaye, 2002). Since more than 10,000 years back, several researchers reported that Enset is grown mainly as homegarden with complex intercropping system in for staple or co-staple crop.

Currently, the south and southwest highlands of Ethiopia are the representative Enset growing areas with several cultivated Enset landraces for their multi – social, economic and cultural purposes (Brandt *et al.*, 1997; Edwards *et al.*, 1997; Zippel, 2005; Yemane Tsehaye and Fassil Kebebew, 2006; Awol Zeberga *et al.*, 2014; Tadessa Daba and Masayoshi Shigeta, 2016). Peoples of these areas grow Enset plants because of its multipurposes for direct and indirect uses in which intercropping systems are possible (Admasu Tsegaye, 2002; Belachew Garedew *et al.*, 2017). However, it is believed that Enset may have once played a much more important role in the

agricultural practices of central and northern Ethiopia (Awol Zeberga *et al.*, 2014). It is now becoming customary food in the southwest, central, towns, and cities with the Ethiopian delicious food as kitfo (Tadessa Daba and Masayoshi Shigeta, 2016).

Enset cultivation systems integrate animal husbandry and crop production (Westphal, 1975; Temesgen Magule *et al.*, 2014). In Wolayta, Sidama, Gurage and Ari ethno-linguistic community in southern Ethiopia, there are dynamic on-farm management of Enset landraces (Temesgen Magule *et al.*, 2014). Enset can be intercropped with sorghum, maize, and coffee, and Enset cultivation is suitable for sustainable agricultural systems due to its contribution to soil fertility, long storability, its multiple uses and accessibility at any time, and relatively high productivity depending on edaphic factors, altitude, cultural practices and varietal differences in Sheka zone (Belachew Garedew *et al.*, 2017). The Enset farming in Kaffa zone is complex practices and highly dependent on animal manure as a source of nutrient. Farmers managed complex gardens containing a number of plant species including cabbage, taro and crops other than Enset (Yemane Tsehaye and Fassil Kebebew, 2006).

## 2.9. Role of Enset based farming system as sustainable agriculture

The wild Enset relative and cultivated Enset landraces are genetically distinct from each other; this variability could potentially act as a source for useful or rare genes in the improvement of cultivated Enset (Genet Birmeta *et al.*, 2004; Yemane Tsehaye and Fassil Kebebew, 2006). Vegetative propagation of Enset is important for conservation of the existing traits because it provides homogenous plant material with known characteristics (Zippel, 2005). Enset plant cultivation is life saving crop for human including animals, and it has unique benefits over other crops. It has ability to be harvested any time of year at any growth stage, and can tolerate unexpected harsh environmental condition like drought (Abrham Shumbulo *et al.*, 2012).

Enset cultivation not only helps as direct use values, but also as ecological advantage with its broad leaved canopy covers. However, its cultivation methods vary across different ethnic groups based on their culture and socio-economic background (Admasu Tsegaye, 2002). It is mainly used as staple and/ or co-staple food. Enset plant has both end products uses (foods, fibre) and live use (ornamental and ecological function) (Admasu Tsegaye, 2002). Enset plays a key role for producing organic matter, creating a nutrient reservoir in the soil, controlling erosion. As a result, it contributes for the stability and continuity of farming (Asnaketch Woldetensae, 1997; Admasu Tsegaye, 2002).

Another basic important of Enset farming is that it requires low inputs having disproportional indigenous uses (Admasu Tsegaye, 2002), however, its function is not well known at nation and international levels in past decades. Even though utilization of wild Enset relative has not been reported yet, it is more distantly distinctive nutritional and morphological features from cultivated landraces in Kaffa zone. It contains only one variety which is propagated from seeds under natural condition. This wild Enset relative is characterized by having high fiber, nitrogen, crude protein, ash, large petiole and pseudostem length and low carbohydrate content. Breeding programs on Enset may be uses as a source of reliable resistant genes (Yemane Tsehaye and Fassil Kebebew, 2006).

## 2.10. Mode of Enset propagation and its propagule

Frequent reports indicated that there are two possibilities of Enset reproduction. These are sexual reproduction from its seed and/or asexual reproduction (vegetative propagation) from its corm of immature mother plant. There is different dominant mode of propagation practices on wild Enset relative and cultivated Enset landraces (Admasu Tsegaye, 2002; Yemane Tsehaye and Fassil Kebebew, 2006; Balachew

Garedew *et al.*, 2017). Cultivated Enset landraces are dominantly propagated asexually (Admasu Tsegaye, 2002; Yemane Tsehaye and Fassil Kebebew, 2006; Abrham Shumbulo *et al.*, 2012; Belachew Garedew *et al.*, 2017), whereas wild Enset relative is propagated sexually from its seed under natural condition (Yemane Tsehaye and Fassil Kebebew, 2006; Belachew Garedew *et al.*, 2017).

Ethiopian farmers propagate cultivated Enset landraces using whole corms, half corms, and quarter corms according to agroecology, cultural practice, farm size and living status of the farmers (Taye Buke *et al.*, 2016). Different studies reported that there were variation of corm pieces for sucker production (i.e. Majority farmers in Masha district in Sheka zone use quarter corm pieces; in Kucha district in Gamo Gofa zone use half corm; in Kambata-Hadiya and Chebo-Gurage use whole corm, and the farmers around Areka research center, Wolayta, use split corm for propagation and do not use whole corm for sucker production (Taye Buke *et al.*, 2016)).

Current report showed that the farmers in Wolayta zone uses equally halved corm pieces that they can produce between 20 to 150 suckers per 2 to 6 year aged single mother Enset plant, and on average of 30 to 50 suckers per 3 year aged Enset plant, but it is determined by edaphic, climatic, morphological and cultural practices (Abrham Shumbulo *et al.*, 2012). Size of both whole corms and corm pieces has significant effects on percentage of regeneration, number of suckers per corm, and size of corm pieces has effects on sucker height, pseudostem length, leaf width, leaf length and leaf number, but size has no effect on pseudostem circumference and emergence days (Taye Buke *et al.*, 2016). Maximum sucker numbers can be produced from half and quarter corm pieces than whole corm propagule (Bizuayehu Tesfaye, 2002; Taye Buke *et al.*, 2016), and the corms exposed on sun for only one day gives the highest

and economic propagation of Enset, and only the apical end of the corm has regeneration capacity (Taye Buke *et al.*, 2016).

Only one sucker is sprouted per corm when whole corm (Temesgen Mulugeta *et al.*, 2002), and corm pieces (Taye Buke *et al.*, 2016) is used for sucker production without removal of apical dominance, but multiple numbers germinate when corm and pieces planted after removal of the apical bud (Taye Buke *et al.*, 2016). Wounding (removing bud apex or central growing point) is necessary to propagate multiple numbers sucker formation as economical advantage and conservation of Enset (Taye Buke *et al.*, 2016).

## 2. 11. Procedures of Enset propagation and use of fertilizers

Conventional propagation of cultivated Enset landraces by farmers is sophisticated way and it takes numerous processes up to harvesting stage and maturity (Tadessa Daba and Masayoshi Shigeta, 2016). It varies across different Enset growing ethnic groups; however, use of corms of immature Enset plants for sucker production is the shared practices. Some indigenous cultivation methods (initiation of suckers, frequency of transplanting, leaf pruning and planting patterns) vary among regions (Admasu Tsegaye, 2002).

According to Abrham Shumbulo *et al.* (2012), Enset in Wolayta zone is planted plants in narrow spacing in their homesteads, however, it results in thinner pseudostem due to shortage of farm land. Admasu Tsegaye (2002) reported the vegetative propagation procedures of cultivated Enset landraces in Sidama, Wolayta and Hadiya people as follow:

1. Uprooting immature mother Enset plants (usually 3 – 5 years aged).
2. Cutting corm at pseudostem above junction (at 10-15 cm).

3. Removing (wounding) the central corm meristem (either full or splitted corm pieces).
4. Exposing it to sun (in Wolayta) or under shade (in Sidama) for 2-3 days.
5. Planting the corm with distributing of organic sources of fertilizers on it (mainly planted in December or January before beginning of rainfall).
6. Suckers produced after 2-3 months and then waited for one year.
7. After one year, suckers uproot within its mother corms and transplanted on other fields, but frequency of transplanting upto its maturity varies across ethnic groups.

Direct transplanting of Enset suckers to permanent field shorten the maturity period (Admasu Tsegaye, 2002). Enset growers in Ethiopia majorly use organic fertilizer locally available organic waste materials. These are animal manures, byproducts of crops, and domestic waste materials. They do not prefer synthetic fertilizer products for Enset farming. Enset farming in Wolayta peoples is reported as cultivation that donot need chemical inputs, but in small scale fields with disproportionated multipurposes for local peoples and more organic agricultural practices (Temesgen Magule *et al.*, 2014). They grow cultivated Enset landraces in their homesteads for accissability, application of organic sources of fertilizers from animal manures and domestic wastes with unspecified time and methods. Enset plants responds rapidly for better application and management practice so that it can mature in short time (Abrham Shumbulo *et al.*, 2012). Also Sheka peoples in south western Ethiopia use compost and organic sources of local byproducts without application of inorganic fertilizers due to its costiveness (Belachew Garedew *et al.*, 2017).

## CHAPTER THREE

### 3. MATERIALS AND METHODS

#### 3.1. Description of study area

##### 3.1.1. Location of study sites

This study was conducted in three districts of Kaffa zone (Decha, Gimbo and Chena) in south western Ethiopia. Ethnobotanical and morphological data of wild Enset relative and cultivated Enset landraces were collected from twelve sites (four sites from each district) (Figure 1). Totally, 120 Enset farms were surveyed (Appendix 5).

Enset corm propagation was employed in the farmers' site in Baha Gona Kebele in Decha district of Kaffa zone. The recorded geographical location of the site was located at  $07^{\circ}10'25.2''\text{N}$  and  $036^{\circ}13'19.8''\text{E}$  at altitude of 1911 m.a.s.l. It is 20 kilometer far from Bonga town (ANRKZ, 2017).

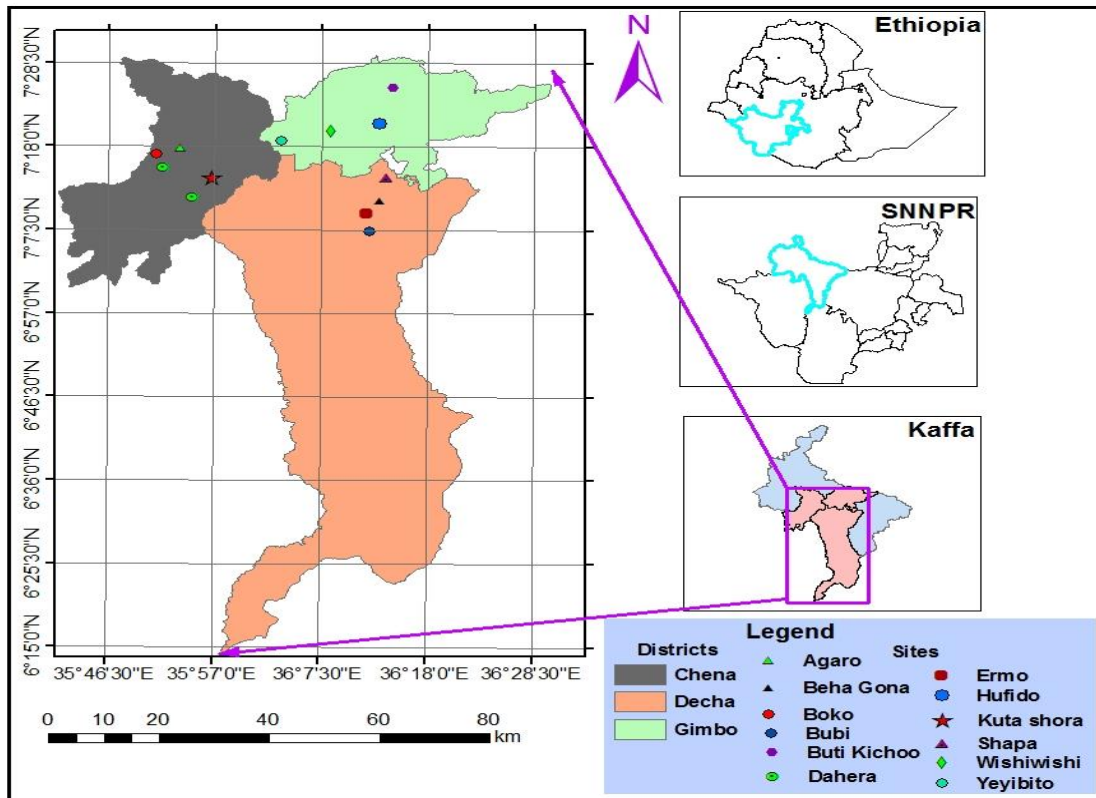


Figure 1. Map of the study area (three districts with their respective sites)

### 3.1.2. Topography, climate and farming system

The topography is characterized by slopping and rugged areas with very little plain land (Yemane Tsehaye and Fassil Kebebew, 2006). The altitude of the zone varies within the range between 500 m.a.s.l (the lowest in Decha woreda near Omo River) and 3348 m.a.s.l. (the highest point in Manjiyo and Tello woredas: Mount Shetra) (Tezera Chernet, 2008). It is characterized by moist Afromontane rain forests, which contain wild *Coffea arabica*, bamboo forests, grasslands and shrub lands. The Kaffa BR covers an area of more than 7500 km<sup>2</sup>, of which 47% is covered with forests (NABU, 2014; NABU, 2017). There are four zones of Kaffa Biosphere Reserve (core, candidates, buffer and transitional) zones with size (12172 (4%), 219130 (28%), 161351 (22%) and 336069 (46%)) hectares, and priority of biodiversity assessment (high, medium to high, medium and low) respectively (Dresen, 2011; NABU, 2017).

The climate of Kaffa Zone is characterized by a bimodal rainfall pattern, with the main rainy season between June and September and a short rainy period from February to April. It receives its rainfall from the Southwest monsoon, which reaches its maximum intensity during July and August with average annual rainfall ranges from 1500 mm in the lowlands up to 2000 mm at the highest elevations (EWNHS, 2008; NABU, 2017).

Kaffa Biosphere Reserve (KBR) is in the most humid part of the country, and annual temperatures vary between 15 and 24°C. Due to the high variety of landscapes and altitudes within the KBR, there are many microclimatic deviations from the usual rainfall patterns (NABU, 2017). According to the soil map produced by the WBISPP (2004), the dominant soils in the Kaffa Zone are dystric nitosols (EWNHS, 2008; NABU, 2017).

Subsistence farming plays a major role for local livelihoods which is traditional and rain fed practices. The people in the area mainly live from subsistence farming, the sale of wild coffee, the natural resources of their environment, and honey production. Over the centuries they have adapted the uses, traditions and customs to nature (Tezera Chernat, 2008; NABU, 2014). The most common livestock is cattle, followed by poultry, sheep and goats, and traditional honey production and coffee cultivation are the most important income sources (SNNPR, 2013).

### 3.1.3. Human population in study sites and administrative system

The Kaffa people (Omotic language speaking group) are found south of the Gojeb River with a population size of 1125145 (547162 males and 577983 female). The ethnic composition of the Kaffa Zone is dominated by Kaffecho (81%), followed by Bench (6%), Amhara (6%), Oromo (2%), and others (5%) (Tezera Chernet, 2008).

A zone has total coverage of 1056673 hectares including 46982 hectares of non-arable land. The zonal administrative center is situated at Bonga town under which ten districts (Adiyo, Bita, Chena, Cheta, Decha, Gesha, Gewata, Ginbo, Sayilem and Tello) are governed (Tezera Chernet, 2008; ANRKZ, 2017).

### 3.1.4. Enset and its farming system

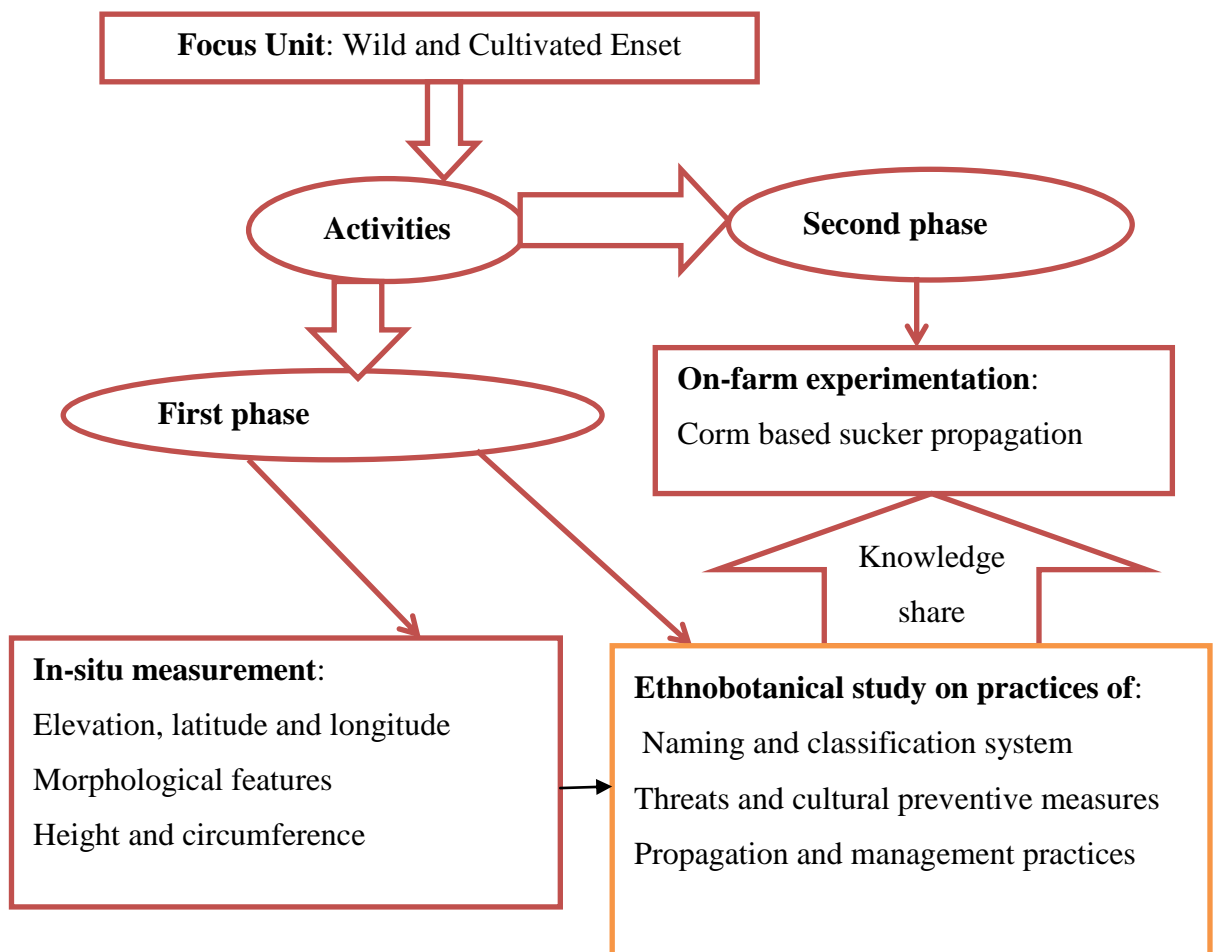
*Ensete ventricosum* is among the domesticated plants in Ethiopia growing both as wild relative and cultivated landraces in altitude ranging from 1,000 to 3,000 meter above sea level (Plant Genetic Resources Center, 1995). It is the primary staple food for the people in southern Ethiopia including the study area. The plant is usually grown around homesteads along with cereals, pulses, and root and tuber crops (Yemane Tsehaye and Fassil Kebebew, 2006; Tezera Cherenet, 2008; ANRKZ, 2017). It is a typical multipurpose crop having all its parts are utilized as food, medicine, material culture, with other cultural and ritual applications.

### 3.2. Materials

The following materials and equipments were used for completion of this study:

- ❖ Global Positioning System (GPS) to collect geographical reference (latitude, longitude and elevation) of the study sites.
- ❖ Camera to pick photograph of some important research related pictures.
- ❖ Note book to record information, and questionnaire papers to fill all data.
- ❖ Color chart and color identifier software to distinguish color of Enset morphology.
- ❖ Corm propagule of cultivated Enset landraces and wild Enset relative for propagation experiment.
- ❖ Knives for partition of mother Enset corms into halved and quartered pieces.
- ❖ Field for corm propagation experiment.
- ❖ Labor (human and oxen power) to support field experimentation.
- ❖ Meter to measure diameter and length of individual Enset plant, suckers, and to design treatments in field experimentation.

### 3.3. Conceptual framework of research activities



### 3.4. Sampling technique and sample size

#### 3.4.1. Site selection for morphological and ethnobotanical study

Different sampling methods were used according to the objectives and nature of data. First, purposive sampling method was used to select three main districts of study area based on previous reports. The study sites were selected due to road access, distribution of Enset farm and its wild relative, and composition of more representative ethnic group for gathering sufficient ethnobotanical information and on-farm experimentation. Accordingly, Decha (58 kebeles), Chena (44 kebeles), and Gimbo (34 kebeles) districts were selected. The relevant information used in this selection was obtained from NABU (2017).

Those Chena and Decha districts have both cultivated landraces and the wild relatives of Enset around Bonga town in Kaffa Zone (Yemane Tsehaye and Fassil Kebebew, 2006). Among ten districts and Administrative Bonga town, Decha district has the highest numbers of female heads per households and majority of Kaffecho ethnic groups who can represent culture of Kaffecho people (Tezera Chernet, 2008; NABU, 2017). The third district (Gimbo) was mainly selected because it has also wild relative and cultivated landraces of Enset close to Bonga town (ANRKZ, 2017).

Simple random sampling technique was used to select Enset farms within each district so that equal chances of selection would be possible (Albuquerque *et al.*, 2014). The head of each selected farm was taken as a general informant. Once, the general informants were determined, snow ball method was used to select key informants that also included informants for their knowledge (without selection of their farms). A total of 120 farms (general informants) and 24 key informants (12 among the general and 12 as additional informants) had involved in this study (Table 2).

During preliminary survey in the districts, the more repeated information on objectives was obtained. Due to that reason, more emphasis was given for gathering detailed information than extending size of study sites. Then, four study sites per district with total of twelve study sites from three districts were conducted. Ten Enset farms with respective head as informants were investigated for general ethnobotanical and morphological study. Two key informants per study site (one from general informants and one new informant) were selected after collection of data from total farms so as to get sufficient information. Pair agreed responds (two key informants from nearer farms were allowed to discuss on requested information and gave their agreed responds) were taken in data analysis and presentation per site (total as 12 for

preference and direct matrix ranking), and independent responds for other data collection.

Table 2. Distribution and number of informants

No.	Region	Zone	District	Study sites	Number of informants			
					General	Key		Total
						From general	New	
1	SNNPR	Kaffa	Decha	Shapa	10	1	1	11
2				Baha Gona	10	1	1	11
3				Ermo	10	1	1	11
4				Bubi	10	1	1	11
5			Gimbo	Buti Kicho	10	1	1	11
6				Hufido	10	1	1	11
7				Wushiwishi	10	1	1	11
8				Yeyibito	10	1	1	11
9			Chena	Boko	10	1	1	11
10				Agaro	10	1	1	11
11				Kuta Shora	10	1	1	11
12				Dahera	10	1	1	11
Total respondents								<b>132</b>

### 3.4.2. Site selection for the field experiment

On farm experimentation was investigated after the sufficient data has been collected from total farms and key informants on selected site. Purposive sampling technique was used for site selection to have enough propagules of cultivated Enset landraces and its wild relative near the site to minimize ecological influence during transfer of mother Enset corms to the propagation site. It was cultivated four times in interval of two weeks through oxen power. Animal dung was distributed on sites and mixed well through cultivation. The site was fenced with wooden materials to protect from animal pests.

### 3.5. Experimental procedure

During conducting the field experimentation of vegetative Enset propagation from its corm, the following steps were followed:

1. Availability of the propagule of wild Enset relative and cultivated Enset landraces was assessed by considering minimal distance gaps from the site to minimize ecological influence during transfer.
2. All individuals of mother Enset propagule were uprooted and pruned at 15 centimeter above the junctions of corm and all were labeled with its name.
3. All of pruned full corms were parted in two halved pieces and one of respective halved corm piece was also parted into two equal pieces (quartered corms) then labeled as well.
4. All parted corm pieces were allowed to be dried on sun for twenty four hours.
5. All dried corm pieces were distributed on randomized and designed plots per block.
6. All distributed corms were buried by manual digging in 15 centimeter depth of soil and covered with soil followed with indigenous management practices.

### 3.6. Treatments, experimental design and replication

Two wild Enset relative groups and four cultivated landraces were selected to carry out on-farm experiment with having enough numbers of corm propagule. It was employed under Completely Randomized Block Design (CRBD) method with three replicates. Two levels of corm pieces (halved and quartered mother corm piece) with six Enset types (twelve treatment combinations) were employed in the site. Each plot (experimental unit) had nine single corm pieces for halved (Figure 2C) and nine paired corm pieces for quartered pieces (Figure 2D) all with removing apical buds.

Table 3. 2x6 factorial treatment combinations of Enset corm pieces and Enset types

Mother corm pieces	Two factorial treatment combinations (12 treatment combinations)					
	Six Enset types					
	Chele Eppo*	Nache Eppo*	Anaami noobo	Achecho	Chele Bocho	Shalako
Halved	Halved Chele Eppo	Halved Nache Eppo	Halved Anaami noobo	Halved Achecho	Halved Chele Bocho	Halved Shalako
Quartered	Quartered Chele Eppo	Quartered Nache Eppo	Quartered Anaami noobo	Quartered Achecho	Quartered Chele Bocho	Quartered Shalako

Note: the names (Enset types) with \* indicate wild Enset relative groups

### 3.7. Randomization, plantation of corm pieces and management of the site

All treatments were randomized and assigned in all plots through random table numbers independently per each replication. Each replication had twelve 3m x 3m plots (totally 36 plots). In order to get fair comparison for halved and quartered corm pieces, a pair quartered corm pieces were buried in clumped form as a single (Figure 2D). It was then planted one meter apart among corm propagule under similar environment and management practices.

Enset propagules were selected based on abundance (two wild and four cultivated) near site. Totally, 162 individual Enset mother corms (54 wild and 108 cultivated: 27 individual full corms per each) were used for burring. Therefore, 162 halved and 324 quartered corm pieces were planted.

All propagation practices and management were based on common practices in the study area after collection of sufficient data from all farms and key informants. The planted corms and their pieces were managed based on indigenous knowledge.

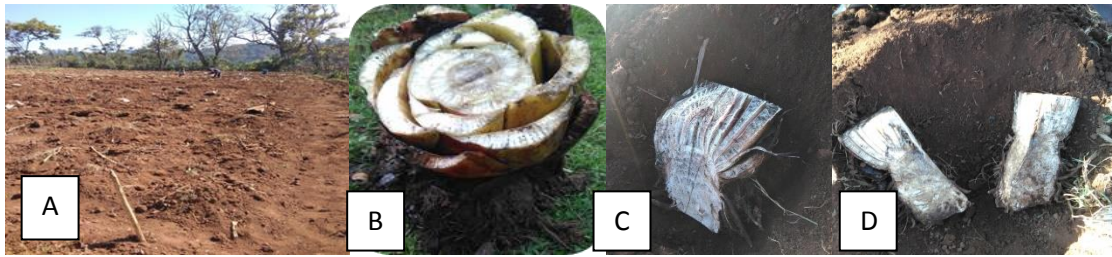


Figure 2. Propagation site (A), Full corm (B), Halved corm (C), & Quartered corm (D)

### 3.8. Methods of data collection

Both primary and secondary data were collected using different data collection methods. Ethnobotanical data were collected through semi-structured interview with face to face contact in 120 farms and in-situ observation of wild Enset relative and cultivated Enset landraces. Informants were allowed to list freely based on designed semi-structured interview. Two neighborhood key informants per site were allowed to discuss on selectively required information and gave their agreed information.

Morphological data were collected through counting, measuring and color identification. Direct measurement was conducted with indicative location of farms (altitude, latitude and longitude) and the quantitative traits of individual Enset plants (height, diameter and numbers of leaves). Mainly wild Enset relative groups occur in and out of farms, but its data were recorded within reference of its land owner. Therefore, its reference point (coordinate) was recorded from the Enset farm of landowner in which it present irregardless of its occurrence in and out of farm.

**Ethnobotanical data collection:** In study sites, local name with its meaning, sex class, growth rate, disease resistance, vigor (thickness of pseudostem), quality of bulla, amicho, kocho and fiber, edibility, current and maturity age of individuals of cultivated and wild Enset plants were evaluated from one hundred twenty (1 individual per unique name per 120 farms) farms. Other data like propagation and management practices, threats, and methods of wild Enset identifications were collected from one hundred thirty two (132) informants including eleven (11) new key informants.

**In-situ morphological data collection:** Besides counting leaf numbers, leaf size, total individual plant height, pseudostem height, and pseudostem circumference (basal, middle and top) were measured from in-situ cultivated landraces and wild relative of Enset from all six hundred eighty four individuals. The color of leaf, petiole, midrib and pseudostem of all individuals were identified through color identifier software in smart phone and color chart. Elevation, longitude and latitude points of farms were also recorded.

**Experimental data collection:** The dependent variables collected from field experiment were corm viability (all numbers of sprouted), numbers of suckers and leaves of per sprouted corm pieces, height (length of sucker) of suckers, and circumference of pseudostem. The data were recorded fully from the longest suckers per sucker clones at end of March, 2019 after suckers were performed well (at 3 months). The sample were taken from three sucker clones per plot whose halved and corresponding pairs of quartered corm pieces were sprouted to obtain pair comparison of corm partition effects. However, all sprouted wild Enset relative groups were taken for data collection because its quartered corm pieces were failed. In order to reduce edge effects, data were recorded from middle clones. Due to death of majority of corm pieces of wild Enset relative groups by shortage of rain, it was planted similarly again in Mid-March 2019 in rainy time to check its viability but its data were not included in this paper. Its data were used only to check its viability. After 2 months, all of corm pieces of wild Enset relatives planted in rainy time under similar management practices were sprouted.



Figure 3. Sprouted Enset suckers in the site (A), Data collection (B), Sucker from quartered corm pieces (C), and from halved pieces (D)

### 3.9. Characters of wild Enset relatives and cultivated Enset landraces used in the data analysis

All ethnobotanical and morphological data of different morphological traits and parameters were collected from all study sites. Fidelity Level (FL) was calculated by the ratio between the number of informants cited a scale (example: low, medium or high) for respective character (example disease resistance) and total number of informants who scaled for a single character multiplied by 100. Different descriptors of Enset plant were evaluated according to the IBPGR (1993) procedure used and useful traits obtained from study area (edibility, gender class and category).

Table 4. Features of Enset plant of the study area (Kaffa zone, south western Ethiopia) used in data analysis

NO	Character	Code	Classification & scaling for respective character
1	Category	Ct	1 = Cultivated, 2 = Wild
2	Gender class	Sc	1 = Male, 2 = Female, 3 = No sex class
3	Edibility	Ed	1 = Edible, 2 = Inedible
4	Growth rate	GR	1 = Fast, 2 = Medium, 3 = Slow
5	Vigor (pseudostem thickness)	Vr	1= Thick, 2= Medium, 3 = Thin
6	Disease resistance	DR	1 = High, 2 = Medium, 3 = Low 4 = Not used yet
7	Bulla quality	BQ	
8	Amicho quality	AQ	
9	Kocho quality	KQ	
10	Fiber quality	FQ	
11	Current age	CA	Year
12	Harvesting age	HA	Year
13	Total height of	TH	Meter

	Enset plant		
14	Pseudostem height	PsH	Meter
15	Basal circumference	BC	Meter
16	Middle circumference	MC	Meter
17	Top circumference	TC	Meter
18	Leaf number	LN	Meter
19	Mature leaf size	LS	Meter
20	Leaf color	LC	1 = Light green, 2 = Deep green, 3 = Whitish green, 4 = Entirely deep red, 5 = Entirely light red, 6 = Partly deep red around margin
21	Leaf midrib color	LMC	1 = Light green, 2 = Deep green, 3 = Whitish green, 4 = light red, 5 = Sectioned light red, 6 = Deep red, 7 = Light black, 8 = Yellow, 9 = Purple
22	Leaf petiole color	LPC	1 = Light green, 2 = Deep green, 3 = Dark red, 4 = Light red, 5 = Partly greenish and black around margin, 6 = Light red with many white spots, 7 = Light red with many black spots, 8 = light green with many black spots
23	Pseudostem color	PsC	1 = Light green, 2 = Deep green, 3 = Greenish black, 4 = Dark red, 5 = Light red, 6 = Purple, 7 = Partly greenish and black stripes, 8 = Light red with some white spots, 9 = Greenish yellow

### 3.10. Methods of data analysis

The obtained data through different methods were sequentially analyzed as per data gathering in the different phases of data collections. The preceding analyzed data were guided the following activities so that there was modification of objectives.

**Descriptive statistics:** Different descriptive statistics were used to analyze data obtained through interview, guided field walk observation and paired key informant by entering in to computer programs (Excel, R and SAS software ) to compute mean, standard deviation and range along with ANOVA, chi-square and Least significant difference tests to compare between wild Enset relatives and cultivated Enset landraces.

### 3.10.1. Morphological richness and frequency of wild Enset relative and cultivated Enset landraces

The richness of both wild Enset relatives and cultivated Enset landraces based on their morphological diversity per study site were analyzed. Richness was the counts of morphologically unique wild Enset relatives and cultivated Enset landraces recorded from the sites.

Ethnoecological data is used to know the interaction of local people with their natural environment, and it has vital role for decision making and sustainable resource management (Zemedede Asfaw and Tigist Wondimu, 2007). Frequency of species can be computed by measuring the proportion of samples within which that species is found, and its relative frequency is the ratio of frequency of species A and total frequency of all species multiplied by 100 (Kent and Coker, 1992). In this study, frequency was calculated for wild Enset relative and cultivated Enset landraces with morphologically unique character among Enset farms to determine their relative availability.

### 3.10.2. Threat analysis

Risk can be analyzed through calculation of risk incidence, severity index and total risk. Risk incidence (I) is the proportion of the respondents that identified a given risk source.  $I_j = n_r / n_j$ , where  $n_r$  is the number of times that the risk was cited, and  $n_j$  is the total number of respondents. The I values can range from 0 to 1; numbers close to 0 indicate a lower frequency of citations, and 1 indicates that the risk factor was cited by all the respondents. Severity index (S) is based on the number and rank of the risk factors cited by each respondent. The S values range from 1 to 2 and values close to 1 are considered more severe.  $S_j = 1 + ((r - 1)/(n - 1))$ , where  $r$  is the ranking based on the order indicated by the respondent, and  $n$  is the number of risk factors mentioned by the respondent. The average of the  $S_j$  values is calculated for the subgroup of people

that identified the problem (Albuquerque *et al.*, 2014). Therefore, it was found to be possible to identify the more abundant and the more severe local threats on Enset farm through ethnobotanical study. Hence, the threat incidence and threat index were computed following the method of risk analysis.

### 3.10.3. Analysis of information popularity

Fidelity level (FL) was described for the medicinal uses of plants in 1986 by Friedman *et al.* and considers only one use category. However, it can be adapted to any category. The technique relies on agreement among informant responses for a principal therapeutic indication.

$FL = (I_p / I_u) \times 100\%$ , where: FL = fidelity level;  $I_p$  = number of informants that cited the principal use of the species, and  $I_u$  = total number of informants that cited the species for any purpose. The calculation of this index demonstrates that relative importance considers informant consensus on two levels: (a) the distribution of the most important information in the social group and (b) the distribution of knowledge of the species in the social group (Albuquerque *et al.*, 2014).

However, this index was frequently used in ethnopharmacology; it was used for analysis of distribution and popularity of information on local Enset plant against bacterial wilting disease among 120 farms. Here,  $I_p$  = the number of informants who have a typical specific Enset names in their own land and cited its resistant level against wilting disease, and  $I_u$  = total number of informants who cited specific Enset names for any resistant level against wilting disease (low, medium or high). Secondly, it was also used to determine the relative popularity and distribution of knowledge of wild Enset relative identification methods among informants. Here,  $I_p$  = the number of informants who listed a specific wild Enset identification methods and  $I_u$  = total number of informants who were allowed to list wild Enset identification.

#### 3.10.4. Preference ranking and direct matrix ranking

Analysis using preference ranking technique is based on a single dimension, whereas direct matrix ranking is based on multiple dimensions (Cotton, 1996). Twenty four key informants were chosen to conduct both preference and direct matrix ranking. To show the simplified results, it was allowed that the two key informants per site to respondent pair agreed respond as per given criteria. Each pair of them was asked to rank based on domestic use frequency criteria (3= most common, 2= common, 1= least common, 0= not common) for each parts of wild Enset relative and cultivated Enset landraces independently. Average values of informants were calculated for direct matrix ranking. Therefore, the questions like which Enset type is best tolerant for which local threats and 2) which part of Enset is the most frequently affected were answered through direct matrix ranking.

#### 3.10.5. Experimental data analysis

Analysis of variance (ANOVA) was applied for analysis of field experiment in SAS software. Statistical tests were applied to test variation of between and among treatments on the characters of number of viable corm pieces, number of suckers per corm piece, total height and circumference of the longest sucker per suckers of Enset corm piece. Descriptive statistics like mean, standard deviation along with analysis of variance and Least Significance Difference (LSD) test were applied by referring book of Gomez and Gomez (1984).

## CHAPTER FOUR

### 4. RESULTS

#### 4.1. Distribution of morphological diversity of cultivated Enset landraces and wild Enset relatives in the study area

##### 4.1.1. Comparison between vernacular names and morphological analysis for the traits of cultivated Enset landraces and wild Enset relatives

The morphological trait analyses of the wild Enset relative, locally termed as Eppo (wild Enset in the literature), resulted in the recognition of two different groups. The two newly recognized wild Enset relatives due to the variation of its pseudostem and leaf midrib color from this study were termed as Nache Eppo (with green leaf midrib and pseudostem) and Chele Eppo (with light red leaf midrib and pseudostem). On the other hand, the cultivated Enset landrace known as Adelli bocho (Nache bocho) had two names used interchangeably while knowing its identical morphology in the study area. The local name or Nache bocho was found to be more explanatory than the other and used by many informants. Similarly, four local names (Gushiroo, Yudaafu, Goomijjo and Gooshindo) were found to be morphologically identical, but recorded by their local names used by different growers (Table 5). However, the vernacular names used in the study area for the majority of cultivated Enset landraces (47 of 52) were consistent with its uniqueness by morphological comparison of traits (Appendix 3).

Table 5. Inconsistent names of Enset recorded from comparison between vernacular names and morphological trait analysis in the study area

No.	Vernacular name of wild Enset relative and cultivated Enset landraces	Names used after morphological analysis in this report	Description for inconsistency between names and morphology
1	Eppo by local people (wild Enset in the literature)	Chele Eppo	Light red leaf midrib and pseudostem
		Nache Eppo	Green leaf midrib and

			pseudostem
2	Adelli bocho	Nache bocho	Two names were used by growers interchangeably
	Nache bocho		
3	Gushiroo	Gushiroo	They have identical morphology, but their names were different across the growers
	Yudaafo	Yudee aifo	
	Goomijjo	Goomijjo	
	Gooshindo	Gooshindo	

#### 4.1.2. Distribution of numbers of evaluated individuals and recorded Enset unique names in the study sites

Total of 54 Enset unique names (2 wild Enset relatives and 52 cultivated Enset landraces) were recorded from all 120 farms of three districts (Decha, Gimbo and Chena each having 37, 28 and 27, respectively) (Appendix 4 and Figure 5). The minimum and maximum numbers recorded were 12 (from Bubi, Buti Kicho and Kuta shora) and 24 (from Baha Gona), respectively among the twelve sites (Figure 4). Total of 684 individual Enset plants (251, 199 and 234 from Decha, Gimbo and Chena, respectively) were evaluated (Figure 5) for analysis of morphological traits and parameters. The minimum and maximum numbers evaluated were 49 (from Hufido and Buti Kicho) and 73 (from Ermo), respectively among the twelve sites (Figure 4).

Three cultivated Enset landraces (Chele bocho, Anaami noobo and Nache bocho) were grown by in the majority of surveyed Enset farms in the study area with calculated frequency of 89.2, 78.2 and 66.67, respectively. Then, they were also followed by three frequently distributed cultivated Enset landraces (Utiro, Bajjoo and Nache Arikoo) having frequency of 43.33, 33.3 and 31.67, respectively. In descending order of their occurrence frequency, Nache Eppo (wild), Goosheno, Chele Eppo (wild) and Kalloo were distributed in the study sites with frequency of 27.5, 22.5, 11.67, 11.67 respectively (Appendix 3 and Figure 6).

The significant variation ( $X^2 = 46.3$ ,  $DF = 1$  at  $\alpha = 0.05$  and  $0.01$ ) was observed for the richness between cultivated Enset landraces (52) and wild Enset relatives (2) (Table 6).

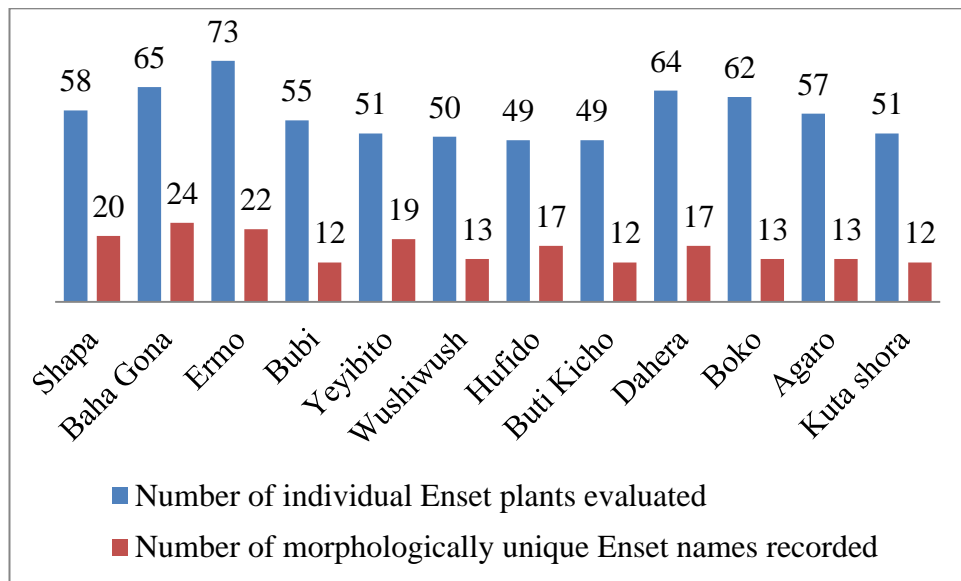


Figure 4. Number of individual Enset plants evaluated and the recorded morphologically unique Enset per site

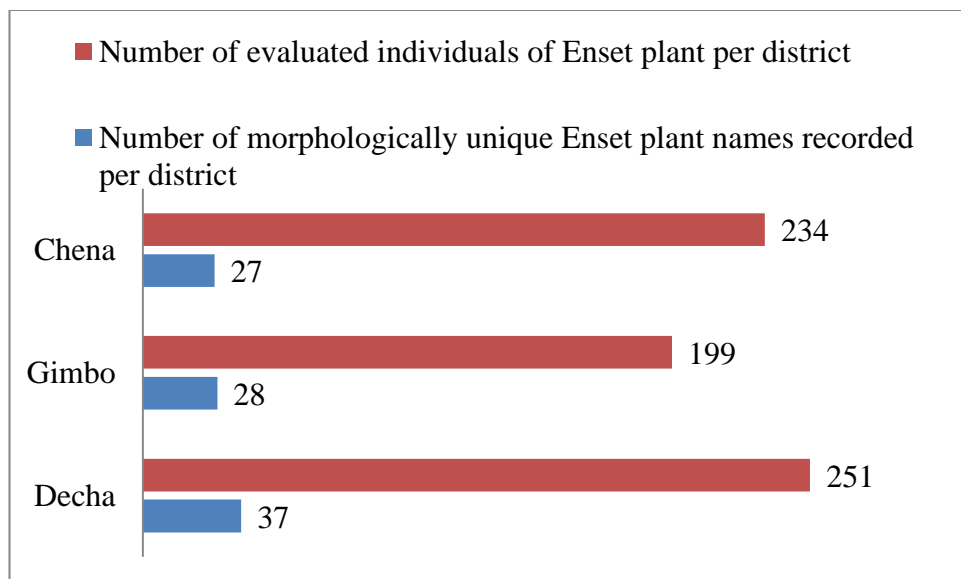


Figure 5. Number of individuals of Enset plant evaluated and the recorded morphologically unique Enset plant names per district

Table 6. Chi-Square ( $X^2$ ) test for richness of wild Enset relatives and cultivated Enset landraces in the study area

Observed richness value		Expected richness value	Calculated Chi-square ( $X^2$ ) value	Tabulated $X^2$ value	
Wild Enset relatives	Cultivated Enset landraces			$\alpha = 0.05$	$\alpha = 0.01$
2	52	27	46.3**	3.84	6.63

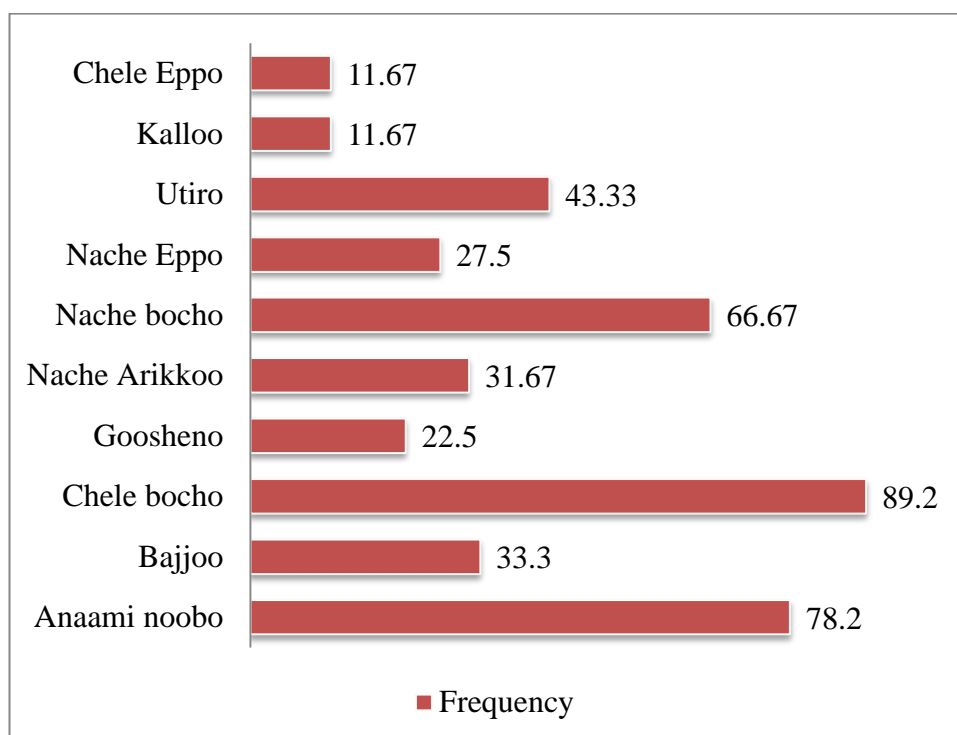


Figure 6. Record of top ten frequent cultivated Enset landraces and wild Enset relatives in the study area

#### 4.1.3. Popularity of information on unique features of wild Enset relatives and its identification methods in the study area

According to the informants (Table 7) and direct observation (Figure 7), the leaf morphology (smoother and wider deep green leaf blade both at ventral and abaxial) was the most shared identification and differentiation method of wild Enset relatives from diverse cultivated Enset landraces (97.7 % fidelity level). Other identification methods of wild Enset relatives with fidelity level of 87, 81.8, 56.1 and 55.3 percent,

respectively were easily breakable leaf midrib and pseudostem sheath, its occurrence out of farm land, harder and bigger corm, and blue greenish fluid in its sheath tissue.

Wild Enset relatives were mainly reported and observed with deep smoother leaves (with various color of midrib and pseudostem) in the study area. There was no conservation and propagation interest for wild Enset relatives (but germinate naturally from its seed which had no gender class as female and male unlike the cultivated Enset landraces). It was found to be inedible by people. Its corm was reported to be bitter, but local people were using its leaf extensively (Table 8).

Table 7. Fidelity level values for the identification methods of wild Enset relatives by informants

No.	Identification methods of wild Enset relatives	Ip	Iu	FL value (%)
1	Smoother and wider deep green leaf blade morphology	129	132	97.7
2	Easily breakable leaf midrib and pseudostem sheath	115	132	87
3	Its occurrence out of farm land	108	132	81.8
4	Harder and bigger corm	74	132	56.1
5	Blue greenish fluid in its shoot sheath tissue	73	132	55.3

**Ip** = the number of informants who listed a specific identification methods of wild Enset relatives, and **Iu** = total number of informants who were allowed to list the local identification methods of wild Enset relatives.

Table 8. Comparison between wild Enset relatives and cultivated Enset landraces in the study area

Character	Wild Enset relatives	Cultivated Enset landraces	Shared character
Common name	Eppo	Uuxo	-
Distribution	In and out of farm	In homegarden	Rarely in homegarden
Edibility	none	All edible	-
Corm	Bitter not attacked yet by pest	Selectively edible	Animal feed (Caammero has bitter corm)
Conservation	Not propagated	Multiplied yearly	-

Seed viability	Rapid naturally	Limited access	Used as sexual reproduction
Leaf color	Deep smoother green	Polycolored	-
Midrib, petiole, and pseudostem color	Various	Polycolored (mixed color)	-
Gender class	No	Male and Female	-
Disease attack	Not observed yet	Main threat	-
Main threats	Leaf pruning, lack of propagation and deforestation	Wilting disease, premature harvesting, corm and leaf pests	-
Dominant use	Leaf for domestic use	Multi-functional	Leaf and ornamental, Animal feed
Inner sheath tissue	Changed to blackish as soon as cut	No changes	-

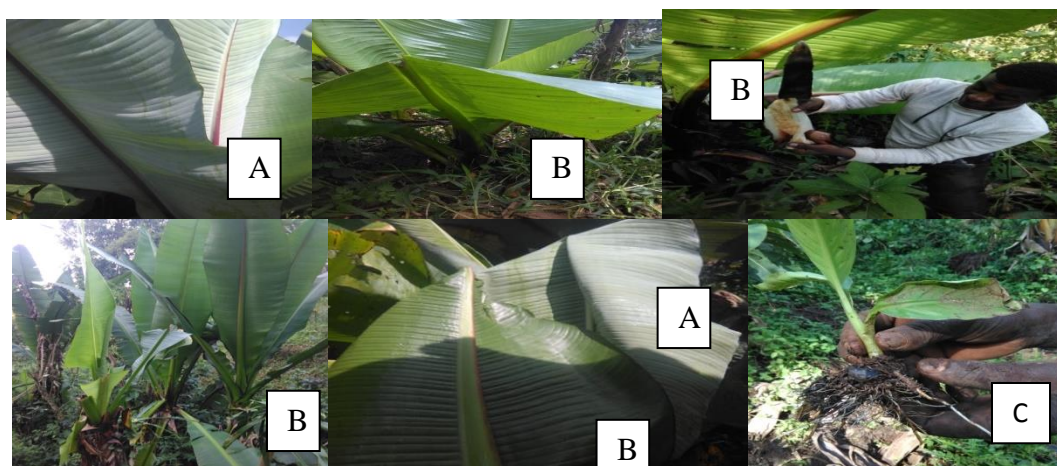


Figure 7. Morphology of cultivated Enset landrace (Chele bocho) (A), wild Enset relative (B) and seedling of wild Enset relative (C)

## 4.2. Characterization of wild Enset relatives and cultivated Enset landraces interms of end use qualities and agromorphological traits

### 4.2.1. Characterization of wild Enset relatives and cultivated Enset landraces based on numbers of individual evaluated

As shown in Table 9, 47 wild individual Enset relatives and 637 cultivated individual Enset landraces were evaluated from the study sites. All of the individuals

of wild Enset relatives (47 or 100 fidelity level) were found to be highly resistant against wilting disease, had no gender class, and were inedible and not used yet for kocho, amicho, bulla and fiber ( $X^2 = 47$ ). Majority of the individual of wild Enset relatives (39 of 47) were reported to be fast growing and grow with thicker diameter of pseudostem (37). The overall distribution and association of descriptive characters between individuals of wild Enset relatives and cultivated Enset landraces showed significant variations ( $X^2 = 9$  to  $X^2 = 637$ ,  $Pr < 0.01$ ).

The majority of individuals of cultivated Enset landraces (409 of 637) were low resistant against wilting disease, whereas a fewer individuals (90 of 637) were reported to be highly resistant. Among them, 316 individuals were male and 321 were female of all which (637) were edible. Also the majority of them grow with medium to thicker diameter of pseudostem. It was significant ( $pr < 0.01$ ) that the majority of individual cultivated Enset landraces were grouped under medium to high quality level for amicho, bulla, kocho and fiber quality (Table 9).

Table 9. Chi-square test for association of Enset quality descriptors between wild Enset relatives and cultivated Enset landraces per individual evaluated

Descriptors of Enset	Quality status by informants	Numbers of individual Enset plants assigned under each quality status		Mean value	Chi-square at $\alpha = 0.01$
		Wild Enset relatives	Cultivated Enset landraces		
Disease resistance	High	47	90	68.5	13.5*
	Medium	0	138	69	138*
	Low	0	409	204.5	409*
Growth rate	Fast	39	295	167	196*
	Medium	6	328	167	310*
	Slow	2	14	8	9*
Gender class	Male	0	316	158	316*
	Female	0	321	184	204*

	No class	47	0	23.5	47*
Pseudostem circumference	Thicker	34	303	168.5	214.7*
	Medium	10	180	95	152*
	Thinner	3	154	78.5	145*
Edibility by people	Edible	0	637	318.5	637*
	Inedible	47	0	23.5	47*
Amicho (Uchi wuxoo) quality	High	0	199	99.5	199*
	Medium	0	82	41	82*
	Low	0	356	178	356*
	Inedible	47	0	23.5	47*
Bulla (Ettino) quality	High	0	292	146	292*
	Medium	0	300	150	300*
	Low	0	45	22.5	45*
	Inedible	47	0	23.5	47*
Kocho (Qoccoo) quality	High	0	371	185.5	371*
	Medium	0	250	125	250*
	Low	0	16	8	16*
	Inedible	47	0	23.5	47*
Fiber (Yi'o) quality	High	0	218	109	218*
	Medium	0	312	56	312*
	Low	0	107	53.5	10*
	Not used	47	0	23.5	47*

#### 4.2.2. Characterization of wild Enset relatives and cultivated Enset

landraces based on main use categories

The significant variations were observed on all tested quality level of main use categories by growers of the study area (amicho;  $X^2 = 16.93$ , Kocho;  $X^2 = 46.96$ ; bulla;  $X^2 = 42.08$ ; fiber;  $X^2 = 80.73$ , and medicine;  $X^2 = 48.6$ ). Among 52 cultivated Enset landraces, the number of highly selective landraces for amicho, bulla, kocho, fiber, and traditional medicine were 16, 28, 18, 6 and 3, respectively. The majority of cultivated

Enset landraces in study area were found to be under medium quality level for local uses (Appendix 2 and Table 10).

Wild Enset relatives were commonly inedible by local people. The best 16 selective lists with high quality level for amicho (with 100 fidelity level) were Agene, Chele Arikoo, Qupho, Boongo, Gayoo, Otino, Tuutto, Bumbo, Kalloo, Shuuri, Utiro, Kekero, Nache Arikoo, Qophirii, Korimmoo, and Waango. Whereas those reported as the best for fiber strength were Anaami noobo, Bumbo, Gobii noobo, Congo, Gudicho and Shallaako. On the other hand, only three cultivated Enset landraces (Choro, Maaca dami and Taayo) were identified as highly useful for traditional medicine (Appendix 2 and Table 11).

Table 10. Composition of wild Enset relatives and cultivated Enset landraces based on level of qualities for common local use categories in the study area

N O .	Use category	Level of quality	Observed No. of wild Enset relatives and cultivated Enset landraces	Expected mean (Hypothesis: Ratio of 1:1:1:1): no variation	Computed Chi-square ( $X^2$ )
1	<b>Amicho (Uuchi wuxoo)</b>	High	16	13.5	16.93**
		Moderate	23		
		Low	13		
		Not used*	2		
2	<b>Kocho (Qoccoo)</b>	High	28	13.5	46.96**
		Moderate	24		
		Low	0		
		Not used*	2		
3	<b>Bulla (Ettino)</b>	High	18	13.5	42.08**
		Moderate	31		
		Low	3		
		Not used*	2		
4	<b>Fiber (Yi'o)</b>	High	6	13.5	80.73**
		Moderate	42		
		Low	4		
		Not used*	2		
5	<b>Medicine (Atto)</b>	High	3	13.5	48.6**

Where, \* - Indicated wild Enset relative, and \*\* - significant mean variations at 0.01(Degree of freedom = number of level of quality minus 1), and the bolded terms in the bracket were used in Kaffecho language.

Table 11. List of cultivated Enset landraces with high quality for amicho, fiber and medicinal uses in the study area

Uses	List of cultivated Enset landraces (Names in language of Kaffecho people)							
Amicho	Agene	Boongo	Bumbo	Chele Arikkoo	Gayoo	Kalloo	Kekero	Korimmoo
	Nache Arikkoo	Otino	Qophirii	Qupho	Shuuri	Tuutto	Utiro	Waango
Fiber	Anaami noobo		Bumbo	Congo	Gobii noobo		Gudicho	Shallaako
Medicine	Chooro	Maaca damii		Taayo				

#### 4.2.3. Enset characterization based on analysis of morphological traits and parameters

As shown in Appendix 3, the color evaluation of Enset morphology showed that the naming system of 47 cultivated Enset landraces was consistent with color. However, there was no unicolor distinction of individual Enset plants, except cultivated landrace called Choro that is dark red plants (Figure 8F). All wild Enset relatives were found to be unique over cultivated landraces with having wider and deep green leaf blade, but the leaf blade of majority of cultivated Enset landraces were observed with having light green. But, few landraces had whitish green leaf blade (Wu'iro and Anaami noobo) and dark to light red (Choro, Shuuri, Ganji bocho, and Qupho with curved leaf margin). Pseudostem color could not be used alone to make Enset unique among other, except two cultivated landraces in the field (Agene: light red with many white spots, and Anaami noobo: partly greenish with vertically oriented black stripes) (Figure 8A and 8B).

Two important indicative colors that were used for Enset naming system were color of leaf midrib and petiole. Majority of Enset landraces in the study area were light to dark red colored leaf midrib and petiole. But, homogeneous color of both Enset leaf midrib and petiole was observed on some landraces (light black on Cikii meaning black; Yellow on Goomijjo, Yudaafu, Gooshindo and Gushiroo) (Appendix, 3).



Figure 8. Distinctive traits of Enset morphology by color: A - Agene, B - Anaami noobo, C - Yaaho, D - Cikii, E - Goomijjo, Gushiroo, Gooshindo and Yudaafu, F - Choro, G - Kalloo, H - Qophirii, I - Qupho, J - Ganji bocho, K - Shuuri, L - Nache Eppo (wild)

At 0.05 level of probability, insignificant variation was resulted on mean current age of Enset plants (cultivated Enset landraces = 4.18 years and wild Enset relative = 3.81 years,  $X^2 = 0.02$ ). However, there was significant variation ( $X^2 = 5.3$ ) observed on the mean maturity age between cultivated Enset landraces (4.34 years) and wild Enset relatives (5.99 years). Total height, pseudostem height and pseudostem diameter of the cultivated Enset landraces (6.68, 1.68 and 1.43 meter, respectively) were insignificantly smaller ( $X^2 = 0.01, 0.01$  and  $0.03$ , respectively) than of the wild Enset relatives (6.99, 1.75 and 1.68 meter, respectively). The mean leaf number of cultivated Enset landraces (11.49) was a little bit smaller than wild Enset relatives (11.68) with insignificant

variation ( $X^2 = 0.01$ ). The mean leaf size of wild Enset relatives (0.82 meter) was greater than cultivated Enset landraces (0.54 meter) (Table 12).

Table 12. Quantitative comparison between wild relatives and cultivated Enset landraces

Character of Enset plant	Observed mean scores		Hypothesis (Expected)	Values of Chi-square ( $X^2$ )	
	Cultivated Enset landraces	Wild Enset relatives	No mean variation	Computed	Tabular
Current age (year)	4.18	3.81	1:1 = 3.99	0.02ns	$\alpha = 0.05$ (3.84) and $\alpha = 0.01$ (6.63)
Maturity age (year)	5.99	4.34	1:1 = 10.33	5.3*	
Total Enset height (m)	6.68	6.99	1:1 = 6.84	0.01ns	
Pseudostem height (m)	1.68	1.75	1:1 = 1.72	0.01ns	
Pseudostem diameter (m)	1.43	1.68	1:1 = 1.56	0.03ns	
Leaf number (count)	11.49	11.68	1:1 = 11.58	0.01ns	
Leaf size (m)	0.54	0.82	1:1 = 0.68	0.06ns	


\* - Indicated significant mean variation at 0.05 and ns – non-significant mean variation

#### 4.2.4. Direct matrix ranking on domestic use frequency of Enset parts

Direct matrix ranking analyses to determine the use diversity of Enset plant parts indicated that the leaf as the most frequently used parts for both cultivated Enset landraces and wild Enset relatives. This is followed by pseudostem and midrib, respectively. The result indicated that corm of wild Enset relative is not used by local people in the study area, but they use the corm of cultivated Enset landraces selectively.

Daily basis of leaf utilization of Enset was reported while pseudostem and midrib of cultivated Enset landraces were ranked first for its weekly based uses followed by end life cycle utilization. Pseudostem, leaf and midrib of wild Enset relatives were ranked first for its monthly based uses (Table 13).

Table 13. Average direct matrix rank scores on domestic use frequency of cultivated and wild Enset parts in study sites

A. Cultivated Enset landraces								B. Wild Enset relatives						
Rank	Total	Once in a life	Yearly	Month ly	Week ly	Daily	Use frequency of Enset parts	Daily	Week ly	Month ly	Year ly	Once in a life	Total	Rank
4 <sup>th</sup>	3	3	0	0	0	0	Corm	0	0	0	0	0	0	4 <sup>th</sup>
<b>2<sup>nd</sup></b>	<b>9</b>	2	1	2	3	1	Pseudostem	0	2	3	1	0	<b>6</b>	<b>2<sup>nd</sup></b>
<b>1<sup>st</sup></b>	<b>11</b>	1	2	2	3	3	Leaf	3	2	2	1	1	<b>9</b>	<b>1<sup>st</sup></b>
3 <sup>rd</sup>	7	1	1	1	2	2	Midrib	0	0	1	0	0	1	3 <sup>rd</sup>
		7	4	5	8	6	Total	3	<b>4</b>	<b>6</b>	2	1		
		<b>2<sup>nd</sup></b>	5 <sup>th</sup>	4 <sup>th</sup>	<b>1<sup>st</sup></b>	3 <sup>rd</sup>	Rank	3 <sup>rd</sup>	<b>2<sup>nd</sup></b>	<b>1<sup>st</sup></b>	4 <sup>th</sup>	5 <sup>th</sup>		

Use frequency criteria (3 = the most common, 2 = common, 1= the least common, 0 = not common)

### 4.3. Threats on wild Enset relatives and cultivated Enset landraces

#### 4.3.1. Frequently observed and listed threats on wild Enset relatives and cultivated Enset landraces

**Enset pests:** It was directly observed and frequently listed that animal and insect pests were affecting Enset plant in different study sites, however, its distribution differs locally. They affected Enset leaf and corm. The most frequent identified pests were leaf hopper that feeds the leaves of cultivated Enset landraces and mole rat (locally called “Ecece”) that destructs whole individual of Enset plant because it feeds underground corm the cultivated Enset landraces (Figure 9).



Figure 9. Cultivated Enset landraces affected by mole rat (A) and leaf hopper (B)

**Enset wilting disease (*Xanthomonas campestris* pv. *musacearum*):** Enset wilting disease (locally called as “Nuushoo”) was the most frequently observed threat of cultivated Enset landraces in Chena district. It was recognized by comparison of its in-situ symptom on affected plant with previously reported photos and knowledge of local peoples. It affected the majority of cultivated Enset landraces, but it was not observed on wild Enset relatives (Figure 10).



Figure 10. Cultivated Enset landraces affected by wilting disease

**Over utilization of leaf part:** All most all the informants in the study sites informed that they use leaves of both cultivated Enset landraces and wild Enset relatives daily for numerous domestic purposes like for baking of kocho bread. Majority of the informants reported that they choose to use the leaf of wild Enset relative for fear of transfer of bacterial wilting disease during cutting by knives. It was observed that there were many leaf pruned wild Enset relatives present in managed forest with use right (Figure 11), river banks and in home garden (unintentionally grown) within cultivated Enset landraces.



Figure 11. Leaf pruned wild Enset relatives observed in managed forest with use right

**Poor management practices:** Most of the informants reported that due to its long duration of Enset plant in addition to narrow field to cultivate other crops like sorghum (they told that if sorghum is sowed near Enset farm, it calls mole rat so they did not need to grow it as intercrop with Enset), Enset is planted as more clumped distribution as homestead with diverse intercrops. On the other hand, informants did not need and interest of conserving and propagating wild Enset relatives; however, it has potential of regeneration from its seeds naturally. It was frequently observed that wild Enset seed was germinated at short period of time under burned plant species (Figure 7C, 13F and Appendix 6).

#### 4.3.2. Threat Severity Index ( $S_t$ ) and Incidence ( $I_t$ ) calculation for the threats Enset plant

The major threats on cultivated Enset landraces were bacterial wilting disease (*Xanthomonas campestris* pv. *musacearum*), corm pests (mole rat and porcupine), leaf pest (leaf hopper), and harvesting immature Enset plant (HIEP). Whereas over utilization of leaf for domestic use (OUL), and deforestation and lack of need for conservation and propagation (DLNP) were reported as common threats on wild Enset relatives (Table 14 and 15).

Of all, BWD, porcupine, OUL and HIEP were common abundant threats on cultivated Enset landraces in three districts, while mole rat was the 1<sup>st</sup> ranked in Decha district as severe threat of cultivated Enset landraces. Leaf hopper occurred in Chena district ranked as the least severe (6<sup>th</sup>, its severity index = 2) (Table 14 and 15).

Similarly, BWD, porcupine, LPDU and HIEP were the most abundant threats on cultivated Enset landraces (threat incidence = 1); mole rat occurred in two districts (Decha and Chena, threat incidence = 0.67), but the least abundantly distributed threats (0.33) was leaf hopper in Chena. Bacterial wilting disease (BWD), mole rat, HIEP, DLNP and OUL were the top five severe threats on cultivated Enset landraces in the study area (1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> severe threats with severity indices of 1.08, 1.2, 1.32, 1.5 and 1.7, respectively). On the other hand, OUL, and DLNP for conservation were the two most abundant threats (threat incidence = 1) where former was more severe (mean severity index = 1.33) than latter (1.67).


Table 14. Severity Index ( $S_t$ ) calculation for Enset threats in the study area per district

Districts	Threat factors listed per district	Ranking		No. of threat (n)		St	
		CEL	WER	CEL	WER	CEL	WER
Decha	BWD	2	-			1.25	-
	Mole rat	1	-			1	-
	Porcupine	5	-			2	-

	OUL	4	1	5	2	1.75	1
	DLNP	-	2			-	2
	HIEP	3	-			1.5	-
Chena	BWD	1	-			1	-
	OUL	4	2			1.6	2
	DLNP	-	1			-	1
	HIEP	2	-	6	2	1.2	-
	Mole rat	3	-			1.4	-
	Porcupine	5	-			1.8	-
	Leaf hopper	6	-			2	-
Gimbo	BWD	1	-			1	-
	DLNP	3	2			1.5	2
	OUL	4	1	5	2	1.75	1
	HIEP	2	-			1.25	-
	Porcupine	5	-			2	-

Where: CEL – stands for cultivated Enset landraces, and WER – wild Enset relative

Table 15. Mean Threat Severity Index and Incidence on Enset in the study area by key informants per district

Threats on cultivated Enset landraces			Threats on wild Enset relative	
Threat Incidence	Mean Severity Index		Threat Incidence	Mean Severity Index
		Enset constraints in three districts of the study area		
1	1.08	Enset wilting disease ( <b>Nuushoo</b> in Kaffecho)	-	-
0.67	1.2	Mole rat ( <b>Eccee</b> in Kaffecho)	-	-
1	1.93	Porcupine ( <b>Caayo</b> in Kaffecho)	-	-
0.33	2	Leaf hopper	-	-
1	1.7	Over utilization of Enset leaf parts	1	1.33
1	1.32	Harvesting of immature Enset plants	-	-
0.33	1.5	Deforestation and lack of need for conservation and propagation	1	1.67

#### 4.3.3. Relative potential of Enset to resist against bacterial wilting disease

As shown in Table 16, Anaami noobo, Nache Eppo and Chele Eppo were three most popularly known as highly resistant against wilting disease (100 percent of fidelity level). They were occurred in and out of 89, 33 and 14 informants' farm land.

Chele bocho was also the most popularly known as moderately resistant cultivated Enset landrace against wilting disease, and it was the most frequently distributed among Enset growers in the study sites that anyone can found with the highest probability in farms of Kaffa Zone (occurred 107 of 120 farms).

Eventhough they occurred less frequently (5, 5, 13, 13, 39 and 5 from 120 farms, respectively), Gobi noobo, Congo, Bumbo, Ganji bocho, Bajjoo and Gudicho had moderate (80, 80, 38.5, 84.6, 2.6 and 20 percent of fidelity level) to low (20, 20, 61.5, 25.4, 97.4 and 80 percent of fidelity level) level of resistance to wilting disease. Gepe taato, Shallaako and Aai bocho were the least frequently distributed cultivated Enset landraces (each occurred in one farm among 120 farms), and they were reported as moderately resistant against Enset wilting diseases. The majority of cultivated Enset landraces (41 landraces) in the study area were low resistant (Table 16).

Table 16. Fidelity level values (FL) of Enset plant against bacterial wilting disease (BWD) as reported by informants

Enset varieties	Level of resistance against BWD	IP	IU	FL (%)
Anaami noobo	High	89	89	100
Nache Eppo (Wild)	High	33	33	100
Chele Eppo (Wild)	High	14	14	100
Chele bocho	Medium	107	107	100
Gobi noobo	Medium	4	5	80
Congo	Medium	4	5	80
Bumbo	Medium	5	13	38.5
Ganji bocho	Medium	11	13	84.6
Bajjoo	Medium	1	39	2.6
Gepe taato	Medium	1	1	100
Shallaako	Medium	1	1	100
Aai bocbo	Medium	1	1	100
Gudicho	Medium	1	5	20
Other 41 landraces	All are low resistant	Vary	Vary	Vary

Ip = the number of informants who had a typical Enset names in their own field and cited its resistant level against wilting disease, and Iu = total number of informants that cited Enset names for any resistant level against wilting disease (low, medium or high).

#### 4.3.4. Direct matrix ranking on Enset exposing to local threats

Cultivated Enset landraces those grouped as low resistant against wilting disease (Table 16) were ranked the 1<sup>st</sup> due to their exposing for cumulative effects of Enset threats in the study area. It was followed (2<sup>nd</sup> and 3<sup>rd</sup>) by cultivated Enset landraces with medium and high level of resistant against wilting disease, respectively. Cumulative effects of Enset threats had low impact on wild Enset relative (ranked 4<sup>th</sup>). The effect of mole rat, BWD, porcupine, HIEP, and leaf hoper on wild Enset relative was not observed (Table 17).

Among them, OUL was ranked the 1<sup>st</sup> as a threat on all cultivated Enset landraces and its wild relatives. Both porcupine and mole rat were ranked 2<sup>nd</sup> as threats on all cultivated Enset landraces followed by HIEP (ranked 4<sup>th</sup>). Besides OUL, DLNP was ranked 5<sup>th</sup> that was a threat on both cultivated Enset landraces and wild Enset relatives. Finally, leaf hoper and EWD were ranked 5<sup>th</sup> and 6<sup>th</sup>, respectively as threats on cultivated Enset landraces.

Table 17. Average direct matrix rank scores on cultivated Enset landraces and wild Enset relatives based on level of exposing to local threats in study sites

Local Enset threats	High resistant CEL to BWD	Medium resistant CEL to BWD	Low resistant CEL to BWD	WER	Total	Rank
BWD	1.14	2.06	3	0.08	<b>6.28</b>	<b>6<sup>th</sup></b>
Mole rats	3	3	3	0	<b>9</b>	<b>2<sup>nd</sup></b>
Porcupine	3	3	3	0	<b>9</b>	<b>2<sup>nd</sup></b>
OUL	3	3	3	3	<b>12</b>	<b>1<sup>st</sup></b>
DLNP	1.82	1.96	1.92	2.96	<b>8.66</b>	<b>4<sup>th</sup></b>
HIEP	2.94	2.98	3	0	<b>8.92</b>	<b>3<sup>rd</sup></b>
Leaf hoper	1.98	2.83	2.68	0	<b>7.49</b>	<b>5<sup>th</sup></b>
<b>Total</b>	<b>16.88</b>	<b>18.83</b>	<b>19.6</b>	<b>6.04</b>		
Rank	<b>3<sup>rd</sup></b>	<b>2<sup>nd</sup></b>	<b>1<sup>st</sup></b>	<b>4<sup>th</sup></b>		

Criteria (3= High, 2= Medium, 1= Low, 0= Not observed yet), CEL – cultivated Enset landraces, and WER – Wild Enset relatives

#### 4.3.5. Preventive practices against Enset threats in the study area

There was no any means of preventive practice reported for leaf hopper, but they took a lethal measures and digging of its holes against mole rat. Those all effects were observed on cultivated Enset landraces, none on wild Enset relatives. Growers believe that it was might be due to hard and bitter nature of corm of the wild Enset relatives. They were taking measures against wilting disease by removing and burring the affected Enset plant, planting “Yee’ero” plant species (*Pycnostachys abyssinica*) near the affected corm of Enset plant, and multiplying more numbers of highly and moderately resistant Enset landraces.

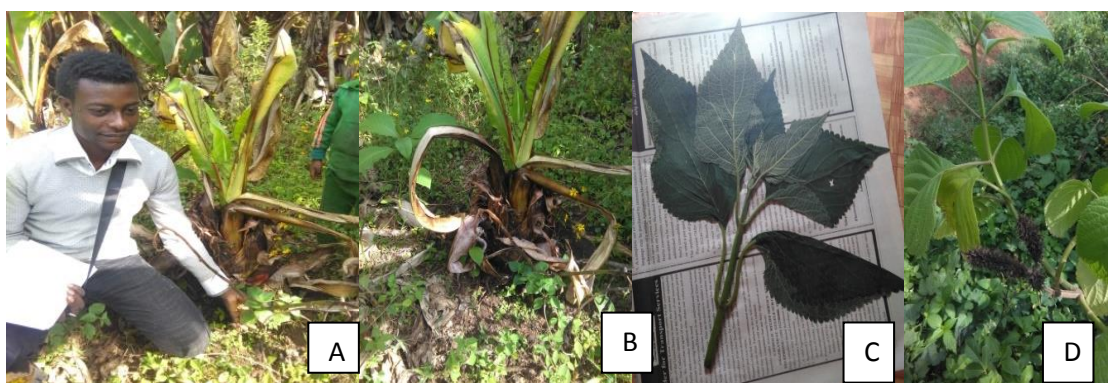


Figure 12. *Pycnostachys abyssinica* planted under corm of the cultivated Enset landraces as protection against wilting disease (A & B), and voucher specimen collection of *P. abyssinica* (C &D)


#### 4.4. Enset management and propagation practices in the study area

##### 4.4.1. Preference ranking on Enset propagule corm pieces and local inputs for sucker maximization

The results of preference ranking analysis on the Enset propagule corm pieces (A) and local inputs for sucker maximization (B) by 24 key informants (shown as 12 paired informants in the Table 18) showed that halved corm pieces of Enset plant was ranked first as a propagule of vegetative Enset propagation followed by quartered, one-third parted and full corm pieces in descending order. Organic waste was ranked first as

preferred local inputs for Enset sucker maximization followed by with no application use, combined and synthetic fertilizer application as the least preferred.

Table 18. Preference ranking on Enset propagule corm pieces (A) and local inputs for sucker maximization (B) (1: for the least used and 4: for the most used)

A. Preference for the use of corm pieces for Enset propagation				Paired key informants per site	B. Preference for application of local inputs for Enset propagation			
Full corm	Halved corm	1/3 corm	Quartered corm		Synthetic Fertilizers	Organic wastes	Synthetic and organic	Without application
2	4	1	3		1	4	2	3
1	4	2	3	Shapa	1	4	3	2
1	4	2	3	Baha gona	1	4	2	3
1	4	2	3	Ermo	2	3	1	4
1	4	2	3	Bubi	1	4	2	3
1	4	2	3	Dahera	1	4	2	3
1	4	2	3	Boko	1	4	2	3
2	4	1	3	Agaro	1	4	2	3
1	4	2	3	Kuta shora	1	3	2	4
1	4	2	3	Yayibito	1	4	2	3
1	4	2	3	Wushiwush	1	4	2	3
2	4	1	3	Hufido	3	2	1	4
1	4	2	3	Buti Kicho	1	3	2	4
<b>15</b>	<b>48</b>	<b>21</b>	<b>36</b>	Total	<b>15</b>	<b>43</b>	<b>23</b>	<b>39</b>
<b>4<sup>th</sup></b>	<b>1<sup>st</sup></b>	<b>3<sup>rd</sup></b>	<b>2<sup>nd</sup></b>	Rank	<b>4<sup>th</sup></b>	<b>1<sup>st</sup></b>	<b>3<sup>rd</sup></b>	<b>2<sup>nd</sup></b>

Note: Paired key informants – indicated that the two nearer Enset growers per site (12 paired or total of 24 informants from 12 sites) were allowed to discuss and respond their shared preferences and common practices.

#### 4.4.2. Enset conservation practices and mode of propagation in the study area

Besides the information obtained from informants, it was also observed that cultivated Enset landraces grow in clumped and densely distributed around their house along with other diverse plant species in it. There were multilayer canopy of Enset landraces in their homesteads because they plant and replace Enset suckers for the

harvested individuals for its sustenance. They reported that other plants which grow in Enset farms affect Enset plantation indirectly because their root support as a fixed refuge for mole rat that made them hard to protect cultivated Enset landraces against its corm attack. However, these plant species have great role for growth of Enset plants.

Traditionally, people in the study area propagate diverse cultivated Enset landraces from vegetative propagule of corm, and they produce suckers of all types of landraces annually for its sustainability. They also reported that the best date to plant a corm for sucker production is around December (they call it as “**Gannee Uukko**” in Kafi noonoo meaning sucker of Christ Mas because it is related to the date around holiday of Christ Mas). All of the informants were using equally halved corm pieces for sucker production, but none of informants know about the potential of whole and quartered pieces of Enset corm to produce suckers. They were growing Enset and suckers under rain fed condition by using only organic animal and domestic wastes. When unusually mature Enset is left without harvested within its mature fruits, its seed can produce a morphologically diverse landraces from single mother Enset plant.

Wild Enset relatives (which were observed in 47 growers’ field a fewer within cultivated Enset landraces and many from managed forest with use right) cannot be propagated in almost all Enset growers. However, they reported that it can be regenerated itself from its seed easily. It was also observed that wild Enset relatives were easily germinated in growers’ farms and in managed forest with use right mainly along swampy areas and streams. They did not know and practice its sucker germination from corm. During field survey, wild Enset relatives were distributed sparsely and as a single individual both in homegarden and in managed forest with use right (Figure 13).



Figure 13. Wild Enset relatives grow in homegarden (A & B), in managed forest with use right (C & D), fruit and seed of wild Enset relatives (E), seedling of wild Enset relatives under burned tree (F), and cultivated Enset landraces grow in clumped distribution in homegarden (G)

#### 4.4.3. Enset sucker production and transplanting practices in the study area

Cultivated Enset landraces were reported to be propagated from the corm of immature mother Enset plant. Enset growers in the study area had common shared procedures in production of Enset suckers. They had also common preferred date of corm planting (mainly around December around Christ Mas holiday) so as to produce more number of suckers per corm piece. Their sucker production steps involved:

1. Uprooting of immature Enset mother plants whose ages depend on the growth rate of landraces.
2. They prune an uprooted plant at the basal pseudostem at the short length above corm junction.
3. Grower then split the pruned whole corm into two equal parts longitudinally (halved corm pieces) and remove apical meristems to initiate more suckers unless “**Baaddo**” (meaning single sucker per corm piece) will emerge.

4. They allow the parted corm pieces to be dried by sunlight for a day or more but determined by intensity of the sun.
5. They then plant it in pit by digging manually in clumped distribution around their home and they cover soil mixed with different organic byproducts.
6. Then suckers (“**Uukko**”) can be fully emerged after two to three months and allowed to grow for one year.
7. Finally, they transfer to permanent field (either in sparsely distributed Enset plants since after harvest or in new area) by pruning leaves of suckers.

They plant leaf pruned suckers as singly when enough grow or more suckers as clumped when they are thinner. This determines frequency of their transplanting. When they planted single sucker, then they do not need to transfer to other field unless incase for special management. A sucker planted more than one sucker is also thinned after a year. However, common shared transplanting of Enset sucker upto harvesting (either immature or matured) was found to be once directly to the permanent field. Most of the Enset growers in the study area were reported that they produce their own Enset suckers per annual in their fields. Some growers buy sucker clones upto fifty Ethiopian birr per single clone of halved corm piece.

#### 4.5. Vegetative propagation test for the wild Enset relatives and cultivated Enset landraces

##### 4.5.1. Sprouted percentage of the tested wild Enset relatives and cultivated Enset landraces

The highest percentage of Enset sprout for halved corm pieces was observed on CB (92.6%) followed by three other cultivated Enset landraces (A, N and S) with equal percentage of sprout (88.9%). Two wild Enset relatives (CE and NE) for halved corm pieces showed relatively lower percentage of sprout (3.7% and 7.4%, respectively).

Similarly, the highest percentage of sprout for the quartered corm pieces was also observed on CB (79.6%) followed by N, A and S (72.2%, 68.5% and 63%, respectively). Both wild Enset relatives were failed for quartered corm pieces. Among the tested cultivated Enset landraces, CB (Chele bocho) sprouted with the highest percentage for both halved (92.6%) and quartered (79.6%) corm pieces. More percentage of sprouts was observed for the halved corm peices (61.7%) than for quartered corm pieces (47.2%) (Table 19).

Table 19. Sprouted percentage of the tested wild Enset relatives and cultivated Enset landraces

Percentage of sprouted Enset corm pieces	Percentage of sprouted WER and CEL per halved and quartered corms											
	Halved corms of WER & CEL						Quartered corms of WER & CEL					
	A	CB	CE	N	NE	S	A	CB	CE	N	NE	S
Sprouted	24	25	1	24	2	24	37	43	0	39	0	34
Total	27	27	27	27	27	27	54	54	54	54	54	54
Percent (%)	88.9	92.6	3.7	88.9	7.4	88.9	68.5	79.6	0	72.2	0	63
Sprouted	100						153					
Total	162						324					
Percent (%)	61.7						47.2					

A – Achecho, CB – Chele bocho, CE – Chele Eppo (Wild), N – Anaami nobo, NE – Nache Eppo (Wild), S – Shallaako; WER & CEL – Wild Enset relatives and Cultivated Enset landraces, respectively

#### 4.5.2. Analysis of variance of mean squares for the main and interactional effects on the performance of Enset propagation

Analysis of variance revealed very significant effects on all of studied traits due to the differences in wild Enset relatives and cultivated Enset landraces with  $R^2$  values ranging from 80 percent to 99 percent. Interactional effects of both the differences in wild Enset relatives and cultivated Enset landraces, and corm partition into halved and quartered pieces showed significant variation only on the maximization of sucker numbers. Corm partition of the mother Enset plant into halved and quartered pieces showed significant variation ( $P < 0.01$ ) for the number of sprouted corm pieces and maximization and production of sucker numbers per the tested corm piece (Table 20).

Table 20. Mean squares for agromorphological traits of the tested wild Enset relatives and cultivated Enset landraces

Source of variations	DF	Sucker number	Leaf number	Total height	Leaf height	Pseudostem height	Pseudostem circumference	Sprouted corm pieces
Replication	2	84.78 ns	10.78 ns	315.09 ns	28.36 ns	56.19 ns	12.55 ns	0.69 ns
Corm partition (CP)	1	10336.11**	11.11 ns	354.69 ns	21.01 ns	79.51 ns	19.51 ns	32.11 **
Differences in WER and CEL (DWER & CEL)	5	10057.38 **	62.04 **	3588.09 **	854.72 **	658.49 **	121.64 **	69.11 **
CP x (DWER & CEL)	5	1526.44 **	2.84 ns	125.49 ns	32.42 ns	18.89 ns	5.11 ns	2.04 ns
Error	22	30.87	3.99	148.66	30.76	22.23	7.20	1.42
Total	35							
R <sup>2</sup>		0.99	0.80	0.86	0.87	0.88	0.81	0.92
Coefficient of variance (%)		9.91	36.69	30.38	29.56	28.84	35.84	25.86

\*\* and ns – indicated the significant and non-significant mean variation, respectively (at 0.01 significant level), and DF – Degree of freedom

#### 4.5.3. Least Significant Difference (LSD) test for comparison of mean pairs on the effect due to the differences in wild Enset relatives and cultivated Enset landraces

As shown in Table 21, there were significant (at 0.05 level of probability) mean variations on their performances between four cultivated Enset landraces (Chele bocho, Anaami noobo, Achecho and Shallaako) and two wild Enset relatives (Nache Eppo and Chele Eppo). This was because all of the possible paired mean differences between them were greater than respective least significant difference values for all of the studied morphological traits. There were greater mean values of all agro morphological traits of cultivated Enset landraces than wild Enset relatives. Means of all studied morphological traits among wild Enset relatives were not significantly different (Table 21).

All possible pairs of means (A) of sucker leaf numbers, total height, basal pseudostem circumference, and number of sprouted corms were not significantly varied within all tested cultivated Enset landraces; however, all showed significant mean differences from wild Enset relatives.

Chele bocho produced the highest sucker numbers (averagely 90.17 suckers per corm) with significant mean differences ( $LSD = 6.65$ , at 0.05 level of probability). It was followed by Anaami noobo, Achecho and Shallaako with average sucker numbers of 82.33, 79.50 and 77.33, respectively and two wild Enset relatives. Similarly, the highest numbers of corm sprout was showed from Chele bocho with average of 7.3 per 9 corm piece ( $LSD = 1.43$ ) (Table 21).

Table 21. LSD test for all possible pairs of mean comparisons due to the differences in wild Enset relatives and cultivated Enset landraces on the performance of propagation

The tested cultivated Enset landraces and wild Enset relatives	LSD test for the counted parameters from experiment						LSD test for the measured traits from experiment (in cm)			
	Number of sprouted corm pieces (LSD = 1.43)		Number of suckers per corm piece (LSD = 6.65)		Number of leaves per sucker (LSD = 2.39)		Total height of sucker (LSD = 14.6)		Circumference of sucker pseudostem (LSD = 3.21)	
	Mean value	Group	Mean	Group	Mean	Group	Mean	Group	Mean	Group
Chele bocho	7.33	A	90.17	A	8.33	A	60.67	A	10.25	A
Anaami noobo	6.83	A	82.33	B	7.33	A	57.58	A	9.58	A
Achecho	6.67	A	79.50	B	7.00	A	50.42	A	10.58	A
Shalaako	6.33	A	77.33	B	7.33	A	54.42	A	11.08	A
Nache Eppo	0.33	B	4.00	C	1.33	B	9.00	B	1.83	B
Chele bocho	0.17	B	3.00	C	1.33	B	8.75	B	1.58	B

Note: Means with the same letters were not significantly different for respective traits at  $\alpha = 0.05$  level of probability (Critical value of  $t = 2.07387$ , Error degrees of freedom = 22); LSD = Least Significant Difference

#### 4.5.4. Least Significant Difference (LSD) test for comparison of mean pairs on effect of Enset corm partition on the performance of propagation practices

At 0.05 level of probability (as shown in Table 22), Enset corm partition into halved and quartered pieces resulted in significant mean differences for maximization of sucker numbers (LSD = 1.38), number of sprouted corm pieces (LSD = 0.82). Quartered corm pieces of the tested wild Enset relatives and cultivated Enset landraces produced more average sucker numbers (mean = 73) than halved corm pieces (mean = 39.11). More average numbers of corm pieces were sprouted from halved Enset corm pieces (mean = 5.56) than quartered Enset corm pieces (mean = 3.67) (Table 22).

Table 22. LSD test for all possible pairs of mean comparisons of Enset corm partition effects on the performance of Enset propagation

The tested Enset corm partition	LSD test for the counted parameters from experiment						LSD test for the measured traits from experiment (in cm)			
	Number of sprouted corm pieces (LSD = 0.82)		Number of suckers per corm piece (LSD = 1.38)		Number of leaves per sucker (LSD = 1.38)		Total height of sucker (LSD = 8.43)		Circumference of sucker pseudostem (LSD = 1.85)	
	Mean value	Group	Mean	Group	Mean	Group	Mean	Group	Mean	Group
Halved corm pieces	5.56	B	39.11	B	4.89	A	43.28	A	8.22	A
Quartered corm pieces	3.67	A	73	A	6	A	37	A	6.75	A

Note: Means with the same letters were not significantly different for respective traits at  $\alpha = 0.05$  level of probability (Critical value of  $t = 2.07387$ , Error degrees of freedom = 22); LSD = Least Significant Difference

## CHAPTER FIVE

### 5. DISCUSSION, CONCLUSION AND RECOMMENDATION

#### 5.1. Discussion

##### 5.1.1. Morphological diversity of Enset

Both wild Enset relatives and cultivated Enset landraces were recorded though their distribution varies across the growers. Wild Enset relative was still named as single (locally “Eppo” only in Kafecho people) in Kaffa zone, and it was also reported and discussed as a single variety (called as Wild Enset) in previous study and reports (Admasu Tsegaye, 2002; Genet Birmeta, 2004; Yemane Tsehaye and Fasil Kebebew, 2006; Borell *et al.*, 2019). As a result of the morphological data analyses, however, two groups of wild Enset relatives (named as Nache Eppo and Chele Eppo) were identified. These were due to color variations on their leaf midrib and pseudostem; however, they had similar color of leaf blade (wide smoother deep green). This naming system was derived from the naming system of Kafecho people for two cultivated Enset landraces (Nache bocho and Chele bocho) which have similar leaf blade, but different morphology on other traits.

On other hand, a single cultivated Enset landrace had two vernacular names (Adelli bocho or Nache bocho) which were interchangeably used by growers while knowing its similar morphology. It was then recorded as Nache bocho because it was listed by majority of informants and more indicative with its morphology. Similarly, four cultivated Enset landraces (Gushiroo, Yudaafu, Goomijjo and Gooshindo) had similar color morphology; however, they were named differently among different sites. They were recorded with their vernacular names because it needs molecular analysis. The naming system of Enset had still problem in different Enset growing areas of Ethiopia (Mohammed Yesuf and Tariku Hunduma, 2012; Borrell *et al.*,

2019). This problem might be due to involvement of new Enset growers of local immigrants with different language speaking people in Kaffa zone and/or diminishing of local indigenous knowledge on naming system. Such problem can be amplified when naming system is used by peoples having different training, languages and customs (Baraloto *et al.*, 2007). However, the naming mechanism that they were using was not different from the naming system of Wolayta, Sidama and Gurage people (Temesgen Magule *et al.*, 2014; Amare Seifu *et al.*, 2016; Adanech Jarso, 2017).

This study found 54 types of Enset vernacular names (52 cultivated Enset landraces landraces and 2 wild Enset relative groups). Among these, Chele bocho, Nache bocho and Anaami noobo were the top most frequently distributed landraces among study sites. Cultivated Enset landraces were significantly richer than wild ( $X^2 = 46.3$ ,  $DF = 1$  both at  $\alpha = 0.05$  and  $0.01$ ). Unique names of cultivated Enset landraces and wild Enset relatives with different morphological traits were the richest in Baha Gona site (24) and lower in Bubi, Buti Kicho and Kuta Shora sites (12). Richness of cultivated Enset landraces per study sites were done similarly like study, and variations among sites were observed in Gurage Zone and 33 cultivated Enset landraces were identified (Adanech Jarso, 2017).

### 5.1.2. Unique features of wild Enset relatives based on indigenous knowledge of informants and participant observation

It was popular that all most all informants (97.7 % fidelity level) had common knowledge to identify and differentiate wild Enset relatives from cultivated landraces by visual observation of its leaf morphology regardless of its distribution in and out of farmland. Its leaf blade is smoother and wider deep green both at ventral and abaxial parts. It was also observed that it was more unique over cultivated Enset landraces.

This was consistent with the past reports of its isolate separation from diverse cultivated Enset landraces in dendrogram (Genet Birmeta, 2004; Yemane Tsehaye and Fassil Kebebew, 2006). However, it was also true that Enset growing in managed forest (out of settlement) can be more probably wild relatives because they grow cultivated Enset landraces in their farmland majorly in homegarden. More experienced growers reported that wild Enset relatives can be also identified by other methods (easily breakable leaf midrib and pseudostem sheath, its occurrence out of farm land, harder and bigger corm, and blue greenish fluid in its sheath tissue). These were directly tested in the field and it was surprisingly true that it was unique having those traits.

Wild Enset relatives were mainly reported and observed having deep green and smoother leaves with various color of petiole, midrib and pseudostem. But, it was reported as having green (glaucous) leaf color, and green midrib, petiole and pseudostem color (Borrell *et al.*, 2019). This was might be due to lack of clear report of prior studies. It was sparsely distributed from single isolated individual to some finger countable groups. It was not conserved and propagated, but it rapidly germinates naturally and has no gender class. It is inedible, but its leaf is used extensively by people, and its corm is reported as bitter. This indicated that there might be historical possibility of its edibility by people, and this also created the question on the mind of researcher that may be the reason why it was escaped from corm pests (mole rat and porcupine) and leaf hopper. The non-palatability (non-edibility) of wild Enset relatives was reported (Belachew Garedew *et al.*, 2017, and Borrell *et al.*, 2019), and its corm bitter test was similarly reported recently in this year (Borrell *et al.*, 2019).

However, bitter test of wild Enset relatives might not lead to inedibility by people because one edible cultivated Enset landrace was reported (Caammero) with bitter corm. This further needs scientific testing of bitter taste of wild Enset corm.

As reported by more experienced growers and tested by researcher, the inner whitish sheath tissue of wild Enset relatives was quickly turned to blackish color when cut and exposed to air (showed immediately color change of inner sheath tissue). This might be due to the reaction of its nutritional contents with atmospheric air. Some experienced informants reported that it was the main reason why people escaped from using its Kocho product (probably dark blackish Kocho). It was not observed and reported that the prevalence of bacterial wilting disease, corm pests and leaf hopper on wild Enset relatives in study sites. This was comfirmly reported recently (Borrell *et al.*, 2019).

### 5.1.3. Distinctive traits on end uses, morphological, and agronomic qualities between wild Enset relatives and cultivated Enset landraces

Both wild Enset relatives and cultivated Enset landraces had no single distinctive morphological traits. The levels of qualitative descriptors of Enset plant showed high significant variation ( $X^2 = 9$  to 637) in their distribution per study sites between wild Enset relatives and cultivated Enset landraces. These significant variations were observed for disease resistance, growth rate, sex class, pseudostem thickness, edibility (amicho, bulla and kocho), and fiber. Wild Enset relatives were found to be inedible by local people (not used for amicho, bulla, kocho and fiber), and it had no gender class. Inedibility of wild Enset relatives was truly reported (Belachew Garedew *et al.*, 2018; Borrell *et al.*, 2019). Cultivated Enset landraces were classified as female and male regardless of biological relation, but due to its quality of agromorphological traits and cultural use values. This was similarly reported from

Kaffa zone (Yemane Tsehaye and Fassil Kebebew, 2006), but not reported for wild (Eppo) clearly.

On other hand, all cultivated Enset landraces were reported to be edible. However, there were variations on qualities per landrace for main use categories (amicho;  $X^2 = 16.93$ , Kocho;  $X^2 = 46.96$ ; bulla;  $X^2 = 42.08$ ;  $X^2 = 16.93$ , fiber;  $X^2 = 80.73$ , and medicine;  $X^2 = 48.6$ ). Among 54 identified the number of landraces with high quality level (as scaled by informants) for amicho, bulla, kocho, fiber, and traditional medicine were 16, 28, 18, 6 and 3, respectively. The variation of Enset quality for cultural use was frequently reported to be dependent of type of landraces from other growers (Admasu Tsegaye, 2002; Yemane Tsehaye and Fassil Kebebew, 2006; Abrham Shumbulo *et al.*, 2012; Temesgen Magule *et al.*, 2014; Belachew Garedew *et al.*, 2017).

Among identified cultivated Enset landraces , the 16 best selective list for amicho (with 100 fidelity level) were Agene, Chele Arikko, Qupho, Boongo, Gayoo, Otino, Tuutto, Bumbo, Kalloo, Shuuri, Utiro, Kekero, Nache Arikko, Qophirii, Korimmoo, and Waango. Whereas those report as the best for fiber strength were Anaami noobo, Bumbo, Gobii noobo, Congo, Gudicho and Shallaako, but only three cultivated Enset landraces were identified as highly useful for traditional medicine in study area (Choro, Maaca dami and Taayo). The use of these medicinal Enset landraces and their applications were clearly reported in past study from Kaffa zone, and they reported four medicinal cultivated Enset landraces of which one (officho) was not found during this study. Besides, they also reported as their uses as spiritual purposes (Yemane Tsehaye and Fassil Kebebew, 2006). The current reports were similarly informed so that its all description was not included.

There was no unicolor distinction of individual Enset plants, except one cultivated Enset landrace called Choro (entirely dark red landrace). All wild Enset relatives were found to be unique over cultivated Enset landraces having deep green leaf blade. The leaf blade of majority of cultivated Enset landraces was observed having light green. However, few cultivated Enset landraces had whitish green leaf blade (Wu'iro and Anaami noobo) and dark to light red (Choro, Shuuri, Ganji bocho, and Qupho with curved leaf margin). Pseudostem color could not be used alone to make Enset unique among other, except two cultivated landraces in the field (Agene: light red with many white spots, and Anaami noobo: partly greenish with vertically oriented black stripes). Two important indicative colors which were consistent with vernacular names of the majority of cultivated Enset landraces were color of leaf midrib and petiole.

Majority of Enset landraces in study area had light to dark red colored leaf midrib and petiole. However, homogeneous color of both Enset leaf midrib and petiole was observed on some cultivated Enset landraces (light black on Cikii meaning black; Yellow on Goomijjo, Yudaafu, Gooshindo and Gushiroo). This confirms with the knowledge of local Enset growers and the past reports that there was use of multiple color combination for cultivated Enset identification in different areas (Admasu Tsegaye, 2002; Yemane Tsehaye and Fassil Kebebew, 2006; Abraham Shumbulo *et al.*, 2012; Temesgen Magule *et al.*, 2014; Borrell *et al.*, 2019).

At 0.05 level of probability and 1 degree of freedom, insignificant variation was resulted on mean current age (cultivated Enset landraces = 4.18 years, wild Enset relatives = 3.81 years,  $X^2 = 0.02$ ). Wild Enset relatives had short mean maturity age (4.34 years) with significant variation ( $X^2 = 5.3$ ) from cultivated Enset landraces (5.99 years). The overall mean leaf size of wild Enset relatives was greater (0.82 meter)

than cultivated Enset landraces (0.54 meter). This indicated that wild Enset relatives had faster growth rate and wider leaves than cultivated Enset landraces which is advantageous for conservation. However, there was no significant variations observed on other measured Enset traits and parameters. The leaf parts of Enset plant was found to be utilized daily for domestic purposes. Corm utilization was also destructive use of cultivated Enset landraces. This indicated that Enset plant is frequently affected by daily leaf use, and corm harvesting is also destructive.

#### 5.1.4. Abundance and severity of Enset threats and management practices in the study area

There were different local threats reported and observed during the study in the study sites, however, level of their impact and distribution were different. There was significant variation ( $p < 0.01$ ) observed between threats of cultivated Enset landraces and of wild Enset relatives. An identified threats of cultivated Enset landraces from the study area were bacterial Enset wilting disease (BWD) or *Xanthomonas campestris* pv. *musacearum* (locally Called “Nuushoo”), corm pests (mole rat and porcupine), leaf pest (leaf hopper), harvesting immature Enset plants (HIEP), and poor management practices. On the other hand, extensive leaf utilization for daily domestic uses, deforestation (habitat loss), and lack of need for conservation and propagation were the main threats on the wild Enset relatives. This filled the information gaps because the threats of wild Enset relatives were not clearly reported and had no detailed information (Borrell *et al.*, 2019). However, the presence of many constraints on production the cultivated Enset landraces were frequently reported (Brandt *et al.*, 1997; Admassu Tsegaye, 2002; Temesgen Magule *et al.*, 2014; Adanech Jarso, 2017; Ambachew Zerfu *et al.*, 2018; Borrell *et al.*, 2019).

Of all, BWD, porcupine, DLNP and HIEP were abundant threats on cultivated Enset landraces in three districts of the area. Bacterial wilting disease (BWD), mole rat, HIEP, LPD and LPDU were the five top severe threats on cultivated Enset landraces in the study area (1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> severe threats with severity indices of 1.08, 1.2, 1.32, 1.5 and 1.7, respectively). This result confirmed with past reports that indicated BWD was the top constraint in Yem special district (Ambachew Zerfu *et al.*, 2018) and other Enset growing areas (Borrell *et al.*, 2019).

On the other hand, OUL, and DLNP for conservation were the two most abundant threats (threat incidence = 1) on wild Enset relatives. The former was more severe (mean severity index = 1.33) than latter (1.67). This will play great role for conservation plan because there was no clear report on constraints of wild Enset relative (Borrell *et al.*, 2019). Those all pest effects were observed and reported on cultivated Enset landraces, but none on wild Enset relatives. Farmers believe that it might be due to the hard and bitter nature of wild Enset corm in addition to its major distribution in semi-forest that made wild Enset relatives not be easily exposed to corm and leaf pests. However, this knowledge of local people needs scientific verification. Porcupine and mole rat were also reported as the most vertebrate burrowing pests that lead to loss of root crops (Mohammed Yesuf and Tariku Hunduma, 2012). The presence of these pests can easily amplify incidence of BWD if once occur in Enset farm because the bacteria can be easily move by vectors and tools wich can be transfered through direct contact (Brandt *et al.*, 1997; Admassu Tsegaye, 2002, Ambachew Zerfu *et al.*, 2018; Borrell *et al.*, 2019).

Enset wilting disease (*Xanthomonas campestris* pv. *musacearum*) was the most frequent threat observed in Chena district. This bacteria disease was reported first in Kaffa zone in 1960s then distributed to Enset growing areas of Ethiopia

(Ambachew Zerfu *et al.*, 2018). It was also reported that occurrence of pathogen (bacteria) was first observed in 1930s in Ethiopia then distinguished as *Xanthomonas campestris* pv. *musacearum* on Enset in 1968, and it is currently reported in Uganda and Eastern Democratic Republic of Congo in 2001 and highland banana growing areas of East and Central Africa (Blomme *et al.*, 2017; Borrell *et al.*, 2019).

Over exploitation of leave part (leaf pruning) for daily domestic use was found to be the first severe threat on wild Enset relatives. It was also observed that there were leaf pruned wild Enset relative present in managed forest, river banks and in home garden. Poor management practices of Enset plant was also reported as one of the constraint in the study area. Most of informants reported that due to its long duration of Enset plant in addition to narrow field to cultivate other crops like sorghum (they told that if sorghum is sowed near Enset farm, it calls mole rat so they do not need to grow it as intercrop with Enset), Enset is planted as a more clumped homestead with diverse intercrops. On other hand, farmers do not need to conserve and propagate wild Enset relatives; however, it has potential of regeneration from seeds naturally. Premature harvesting was also the challenge on the production of Enset in the study area which was similarly reported as threat on cultivated Enset landraces (Genet Birmeta, 2004; Yemane Tsehaye and Fassil Kebebew, 2006; Borell *et al.*, 2019).

Majority of cultivated Enset landraces (41 landraces) were reported as low resistant against wilting disease which were ranked 1<sup>st</sup> due to their exposing for cumulative effects of local Enset threats. Cumulative effects of Enset threats in the study area had low impacts on wild Enset relative (ranked 4<sup>th</sup>). This is important for conservationist because the numbers of threats on wild Enset relatives were fewer and easily manageable.

There were different traditional prevention and management practices of Enset threats. Enset growers were taking measures against bacterial wilting disease of cultivated Enset landraces by removing and burring the affected Enset plant, controlling tool sharing and leaf pruning, planting “Yee’ero” plant species (*Pycnostachys abyssinica*) near affected Enset corm, and multiplying more numbers of highly and moderately resistant Enset landraces. The direct practice of using plant species locally called “yee’ero” (*Pycnostachys abyssinica*) against Enset wilting disease was observed in Chena district. It is believed that it can increase the tolerance of infected Enset plant (it makes die and come back) when planted near Enset corm. Majority informants had similar knowledge on such uses of the species; however, the practice was limited. It may have anti-bacterial character that should be evaluated. It has a smell feature which is under the family of major medicinal plants (Lamiaceae). There was no effective means of protection reported on leaf hopper, but they took a lethal measure and digging of its holes against mole rats.

#### 5.1.5. Traditional Enset propagation and management practices in the study area

Vegetative propagation mode of cultivated Enset landraces and regeneration of wild Enset relatives from seed was common in the study area. This was consistent with the past reports that there was a different mode of propagation between cultivated Enset landraces and wild Enset relatives (Admasu Tsegaye, 2002; Genet Birmeta, 2004; Yemane Tsehaye and Fasil Kebebew, 2006, Belachew Garedew *et al.*, 2017; Borell *et al.*, 2019).

Enset growers in the study area ranked that the halved corm pieces and organic byproducts as their most (first) choice and practice for Enset propagation propagule and inputs for sucker propagation and growth in the field, respectively.

Using of halved corm pieces in the study area shared with practice of people in Kucha district in Gamo Gofa zone, but created variation from practices of majority of people in Masha district in Sheka Zone (uses quarter corm pieces) and in Kambata-Hadiya and Chebo-Gurage (use whole corm) as reviewed by Taye Buke *et al.* (2016). Also the consistency was made in practices of using organic byproducts of domestic animals, crops and wastes in the study area with other Enset growers in south and southwestern Ethiopia (Admasu Tsegaye, 2002; Abrham Shumbulo *et al.*, 2012; Temesgen Magule *et al.*, 2014; Belachew Garedew *et al.*, 2017). This indicated that Enset farming practices by different ethnic groups is more organic farming system that can sustain soil dwelling biodiversity.

Growers in the study area planted the cultivated Enset landraces in the clumped and densely distributed system around their house along with diverse plant species in it. There were multilayer canopy of Enset landraces in their homesteads because they plant and replace Enset suckers for the harvested individuals for its sustenance. This result is shared with other Enset growing areas where intercropping in it is possible (Admassu Tsegaye, 2002; Belachew Garedew *et al.*, 2017). They reported that other plants which grow in Enset farms were affecting Enset plantation indirectly because its root make fixed refuge for mole rat that was making them a challenge to protect Enset landraces against corm attack. However, these plant species have great role for growth of Enset plants. But, it calls investigation of other means for their interaction.

The current practices of leaf use from wild Enset relatives will open the mind of local people for sustained conservation and domestication because or unintentionally introduced individuals of wild Enset relatives were observed. It was observed in swampy areas, near streams in managed forest with use rights and

sparsely in homegarden. However, the reports indicated that wild Enset relative was distributed only in forest (Admasu Tsegaye, 2002; Genet Birmeta, 2004; Yemane Tsehaye and Fassil Kebebew, 2006; Belachew Garede *et al.*, 2017; Borrell *et al.*, 2019) whose occurrence in homegarden was not reported. This indicated that the awareness of local Enset growers is developing from their frequent observation on nature because they allowed wild Enset relatives to grow removing from their farms. It was observed and reported that there is no difficulty in its seed germination, but still need of local people to conserve it is one challenge. This confirmed with the recent predict and report that showed its seed can be stored from 1 to 2 years in commercial storage and it has orthodox nature, and embryo of Enset is not extend within seed that indicated there is no morphological dormancy (Borrell *et al.*, 2019).

Enset growers in the study area produce sucker continuously per annual near their homegarden. Even though there is a slight difference, their propagation procedure was more and less similar with vegetative propagation procedures of Enset in Sidama, Wolayta and Hadiya (Admasu Tsegaye, 2002) and with the procedure followed by Taye Buke *et al.* (2016) in the field. They were producing suckers for continuous plantation, and surplus suckers are also marketable. Majorly, local grower transfer produced suckers after a year directly to its permanent growing field either under matured plants or new field. This is advantageous practices as reported by Admasu Tsegaye (2002) because transplanting sucker directly to permanent field shorten the maturity date.

### 5.1.6. Effects of the differences in the wild Enset relatives and cultivated Enset landraces, and corm partition on the performance of propagation practices

The differences in wild Enset relatives and cultivated Enset landraces (due to diverse character effect) have had a pronounced effect ( $p < 0.01$ ) on corm viability, maximization of sucker number, and all other studied suckers. Corm partition into pieces significantly affected only the corm and production of suckers. Their interactional effect was significant on production of suckers.

The means of all studied morphological traits among wild Enset relatives were not significantly different at 0.05 significant level of probability. This was agreed with the past results reported by Genet Birmeta (2004) through biotechnological genetic analysis in which there was low differentiation (low diversity) in wild Enset relative and there was non-correlation between its genetic and geographical distances among wild Enset relatives. This low diversity (more similarity) might make near similar response of agro morphological traits for traditional Enset propagation.

Least Significant Difference test (LSD test at 0.05 level of probability) showed that there were significant differences in all possible pairs of means among tested cultivated Enset landraces. This is true according to the result reported by Genet Birmeta (2004); there was high genetic diversity in cultivated Enset landraces. Also cultivated Enset landraces were frequently reported having diverse morphological traits that were clustered in different groups by biotechnological (Genet Birmeta, 2004) and ethnobotanical studies (Yemane Tsehaye and Fasil Kebebew, 2006; Adanech Jarso, 2017).

However, there were significant variations (at 0.05 level of probability) between wild Enset relatives and cultivated Enset landraces on the performance of

morphological traits. This result was also in agreement with past reports of clustering analysis in which wild Enset relative was clustered separately through ethnobotanical studies with several unique agro morphological traits (Hilderbrand, 2001;, and Yemane Tsehaye and Fassil Kebebew, 2006), and it was thought that the current cultivated Enset landraces in Kaffa zone were originated from few wild progenitors (Hilderbrand, 2001; Genet Birmeta, 2004).

**Viability of Enset corm pieces:** There were significant variations between four cultivated Enset landraces (Chele bocho, Anaami noobo, Achecho and Shallaako) and two wild Enset relatives (Nache Eppo and Chele Eppo) on sprouting under similar management practices. This was because all possible paired mean differences within and among them was greater than respective least significant difference value (at 0.05 significant level of probability). This result agreed with several ethnobotanical studies conducted on Enset that were repeatedly reported that there were diverse Enset landraces having diverse respective quality of traits (Admasu Tsegaye, 2002; Yemane Tsehaye and Fassil Kebebew, 2006; Adanech Jarso, 2017).

The highest number of corm sprouts were resulted from Chele bocho with average of 7.3 per 9 corm pieces (LSD = 1.43, at 0.05). It was followed by Anaami noobo, Achecho and Shallaako with average sucker numbers of 6.83, 6.67 and 6.33, respectively and two wild Enset relatives.

At 0.05 level of probability, Enset corm partition into halved and quartered pieces showed significant mean difference for number of sprouting (LSD = 0.82). The highest percentage of Enset sprouting for halved corm pieces was observed on CB (92.6%) followed by three other cultivated Enset landraces (A, N and S) with equal percentage (88.9%). Two wild Enset relatives (CE and NE) for halved corm pieces performed relatively lower (3.7% and 7.4%, respectively).

High variation on performance of wild Enset relative from cultivated Enset landraces was resulted might be due to its response to shortage of rain fall. There was one month extended shortage of rain fed since after two weeks of corm plantation. However, that gap of failed wild Enset corm under similar management practice with cultivated Enset landraces from same date of corm plantation to data collection showed that there was high variation between them. Due to the death of majority of corm pieces of wild Enset relatives by shortage of rain fed, it was planted again in Mid-March 2019 in rainy time to check its viability, but its data were not included in this paper because the main intention was to identify its corm sprouting. Its data were used only to check its viability. After 2 months, all of corm pieces of wild Enset relatives planted in rainy time under similar management practices were sprouted. This indicated that it needs more attention and unique management to propagate and adapt wild Enset relatives under traditional practices.

**Multiplication of sucker and leaf number:** Entirely, independent effects of each factor of both Enset morphological differences and corm partition into halved and quartered pieces, and their interactional effect were highly significant ( $P < 0.01$ ) on production and maximization of suckers per mother corm. Enset corm partition had significant variations (at 0.05 level of probability) on production of mean sucker numbers, but insignificant variation ( $P > 0.05$ ) on production of mean sucker leaf numbers. Similarly, Taye Buke *et al.* (2016) reported that there was significant variation among treatments in the mean number of suckers per whole corm and several parted corm pieces with the mean score of 28.4 suckers from whole corms and 38.1 suckers from corm pieces. Also they concluded that more sucker numbers regenerated from parted corm pieces than whole Enset corms. However, the mean numbers of 39.11 suckers from halved corm pieces and 73 suckers from quartered

corm pieces were recorded from this study. This deviation from results of Taye Buke *et al.* (2016) might be due to variation of Enset tested because they used only one cultivated Enset landrace. This indicated that the size of corm pieces can affect the numbers of sucker production.

Based on the result of experiment, halved corms Enset corm can produce suckers numbers from 50 to 61, whereas two quartered pairs of corresponding mother corm for cultivated Enset varieties from 102 to 109 suckers. However, wild Enset relatives need more attention on management practices and other study. Therefore, growers can produce from 100 to 122 suckers per a single mother plants when two equal halved corm pieces and from 204 to 218 when four equal quartered corm pieces are used for these tested cultivated Enset landraces. This result agreed with the result of Taye Buke *et al.* (2016) that was reported as more suckers numbers produced from corm pieces than whole corm propagation. Also it was reported that local farmers in Sheka zone were producing between 20 to 200 suckers per corm pieces (Belachew Garedew *et al.*, 2017) by using quartered corm pieces (Taye Buke *et al.*, 2016) .

Regardless of corm partition, Chele bocho produced the highest sucker numbers (averagely 90.17 suckers per corm) with significant differences (LSD = 6.65, at 0.05 level of probability). It was followed by Anaami noobo, Achecho and Shallaako with average sucker numbers of 82.33, 79.50 and 77.33, respectively and two wild Enset relatives. Mean values of suckers produced from wild Enset relatives were highly varied from cultivated Enset landraces.

Mean values of sucker leaf numbers was showed insignificant variation at LSD = 1.38 at 0.05 level of probability. This indicates that each of suckers had nearly between six to eight leaves in three months of corm planted. Also it was similarly

affected significantly due to effect of corm size and corm pieces as reported by Taye Buke *et al.* (2016).

**Height of sucker:** There was a significant effect from varietal differences on the length (growth) of suckers. However, there were no significant effects from corm partition as on the growth suckers. However, it was conducted by using single Enset landrace in past study, it was reported that the size of corm had significant effect. They were negatively correlated with numbers of sucker regenerated (Taye Buke *et al.*, 2016). But, there were differences in sizes of corm pieces (between halved and quartered) with minimum (insignificant) effect on growth of sucker.

The mean length of suckers regenerated from cultivated Enset landraces ranges between 50.42 centimeter (for Achecho, the shortest) and 60.67 centimeter (for Chele bocho, the longest) without significant variation (LSD = 14.60) among them. Similarly, there was no significant variation within mean length of suckers from wild Enset relatives that ranges between 8.75 and 9.00 centimeter. But, there was high significant variation observed between mean length of suckers from cultivated Enset landraces and wild Enset relatives (LSD = 14.60). Although there was insignificant effects of corm partition on length of suckers, the longer suckers were observed from halved corm pieces (43.28 centimeter) than quartered corm pieces (37 centimeter) without significant variation (LSD = 8.43). This is truly agreed with report of Taye Buke *et al.* (2016) that number of sucker was negatively correlated the increment of sucker length so that higher number of suckers regenerated in quartered corm pieces shorten the height of suckers. But, this was surprisingly not implied for wild Enset relatives because they produced fewer suckers with shorter length of suckers. This incase might be due to late in regeneration.

**Pseudostem circumference of suckers:** The differences in wild Enset relatives and cultivated Enset landraces had significant effect on increment of sucker pseudostem in diameter with insignificant mean variations within cultivated Enset landraces (ranges from 9.58 – 11.08 centimeter) and within wild Enset relatives (LSD = 3.21, at 0.05 level of probability).

Enset corm partition showed insignificant effect ( $p > 0.05$ , at LSD = 1.85) on growth performance on diameter of sucker pseudostem. This result agreed with the report of Taye Buke *et al.* (2016) that the size of whole and parted several corm pieces had no significant differences in circumferences of sucker pseudostem. This was because the sizes of halved corm pieces were greater than quartered pieces for all tested Enset.

## 5.2. Conclusion

This study found 52 cultivated Enset landraces and 2 wild Enset relative groups based on morphological analysis and information gained from informants in the study sites. Wild Enset relative was locally known as “Eppo”, but two main groups were identified (Nache Eppo and Chele Eppo) due to color variations on their leaf midrib and pseudostem. The new group called as Nache Eppo has deep green leaf midrib and pseudostem. Whereas, those called as Chele Eppo has light red leaf midrib and pseudostem. All wild Enset relatives have similar smoother, wider and deep green leaves. Chele bocho, Nache bocho and Anaami noobo were the top most frequently distributed cultivated Enset landraces among study sites.

Wild Enset relative can be easily distinguished by color of its leaf blade irregardless of whether it occurs in or out of cultivated Enset landraces. Its leaf blade is wider, smoother and deep green both at ventral and abaxial parts (97.7 % fidelity

level). It has partly green and black at margin of leaf petiole color. But, there was variation in color of midrib and pseudostem. More experienced growers were identifying by other methods (easily breakable leaf midrib and pseudostem sheath, its occurrence out of farm land, harder and bigger corm, and blue greenish fluid in its sheath tissue). It is not conserved well and propagated asexually by local Enset growers, but its seed rapidly germinates naturally. It has no gender class. Its leaf is used by peoples, and its corm is reported as bitter and harder which was thought as the main reason for inedibility by pests and human.

The quality level of Enset plant was different for disease resistance and use values. Anaami noobo, Nache Eppo and Chele Eppo were the most popularly resistant against wilting disease (100 percent of Fidelity level), and they were present in and out of 89, 33 and 14 informants' farm land, respectively. Chele bocho (occurred 107 of 120 farms), Gobi noobo, Congo, Bumbo, Ganji bocho, Bajjoo, Aa'i bocho, Gudicho, Gepe taato and Shallaako were moderately resistance. Most of cultivated Enset landraces (41 landraces) in study area were low resistant which were ranked 1<sup>st</sup> due to their exposing for cumulative effects of local Enset threats. However, the growers reported that the high and moderate resistant landraces cannot completely escape from death, but they tolerate for extended time than low resistant landraces.

Both wild Enset relatives and cultivated Enset landraces had no single distinctive agromorphological traits. The levels of qualitative descriptors of Enset plant showed variations between wild Enset relatives and cultivated Enset landraces for disease resistance, growth rate, gender class, edibility, amicho, bulla, kocho and fiber. Wild Enset relative was found to be inedible by local people, which is not used for amicho, bulla, kocho, fiber, and it has no gender class (100 percent fidelity level, and  $X^2 = 47$ ). Cultivated Enset landraces had female and male groups due to their

quality of agromorphological traits and cultural use values. Among quantitative determinants of traits between wild Enset relatives and cultivated Enset landraces (current and maturity age, height of plant and pseudostem, diameter of pseudostem, and leaf number and size), the significant variation was observed only on maturity age. Wild Enset relatives had short mean maturity age (4.34 years) with significant variation ( $X^2 = 5.3$ ) from cultivated Enset landraces (5.99 years). Overall mean leaf size of wild Enset relatives (0.82 meter) was wider than cultivated Enset landraces (0.54 meter). There was no unicolor distinction of individual Enset plants. All wild Enset relatives were found to be unique over cultivated Enset landraces having deep green leaf blade. Majority of cultivated Enset landraces were classified with color of leaf midrib and petiole. The Enset naming system for the majority of cultivated Enset landraces (47 of 52 landraces) was consistent with morphological analysis based on the color of different traits in the study area.

Majority of cultivated Enset landraces had medium quality level for amicho, bulla, kocho, and fiber quality. Among 52 cultivated Enset landraces, the number of highly selective landraces for amicho, bulla, kocho, fiber, and traditional medicine were 16, 28, 18, 6 and 3, respectively with 100 fidelity level. The leaf part of both cultivated Enset landraces and wild Enset relatives was ranked first for its frequent domestic use throughout its life.

There was significant variation ( $p < 0.01$ ) observed between threats of cultivated Enset landraces and of wild Enset relatives. The threats of cultivated Enset landraces in the study area were bacterial Enset wilting disease or *Xanthomonas campestris* pv. *musacearum* (locally Called “Nuushoo”), corm pests (mole rat and porcupine), leaf hopper, and harvesting immature Enset plants (HIEP). On the other hand, extensive leaf utilization for domestic uses, and lack of interest for conservation

and propagation, and deforestation (loss of its habitat) were the main threats on wild Enset relatives.

Eventhough there was poor management on wild Enset relatives; diverse cultivated Enset landraces grow in clumped and multilayer canopy cover in home garden with annual production of suckers from halved corm pieces. The Enset farming system in the study area was a practice of organic farming system with single transplant. Growers were taking the measures agaist Enset wilting disease by removing and burring the affected Enset, controlling tool sharing and leaf cutting, planting “Yee’ero” plant species (*Pycnostachys abyssinica*) near affected Enset corm, and multiplying more numbers of highly and moderately resistant cultivated Enset landraces. Lethal measures were reported as a means of Enset protection from pests. The density of Enset plantation system in the study area may open a door for expansion of Enset pathogens once it affected. Also growers reported that tree roots in Enset farm acts as refuge for mole rat which was the second serious Enset threat on Enset farm. On the other hand, lethal measures have been taken on mole rat wrongly by local peoples. It was also reported that crops like sorghum is not needed to be intercropped with Enset because it increases mole rat. Local growers transplant their annually produced suckers directly into its permanent field either under matured Enset plant or new fields. The surplus suckers are sold for income gain as local exchange.

Field experiment result evidenced that there is possibility that the conservation of wild Enset relatives can be assisted by asexual reproduction with common propagation practice of Kaffecho people. It’s halved corm pieces were produced suckers. Kaffecho people use only equally halved corm pieces to produce suckers from cultivated Enset landraces. Use of quartered corm pieces and propagation of wild Enset relative from its corm was new for Kaffecho because it regenerates itself in

managed forest and in their farm (unintentionally) from its seed. They did not know about the potential of whole and quartered corm pieces to produce the suckers.

Eventhough there was potential of sprouting of corm pieces of the wild Enset relatives, its performance compared to cultivated Enset landraces showed poorer under similar management practices. This was might be due to the shortage of rain fed occurred for one extended month since after two weeks of corm plantation. However, the majority of the tested cultivated Enset landraces were sprouted well. Due to that reason, the corms of wild Enset relatives were replanted in rainy time (of which all were sprouted).

All possible mean pairs tested by Least Significant difference (at 0.05 level of probability) significantly showed that all individuals of four cultivated Enset landraces performed with high mean values of all traits than all individuals of wild Enset relatives. Enset corm partition into halved and quartered pieces has had a pronounced significant effects ( $P < 0.01$ ) on corm viability and maximization of sucker numbers, but insignificant effects on all other traits tested. More number of sprouted corm pieces were observed from halved partitions than quartered ( $LSD = 0.82$ ). More number suckers were observed from sum of the paired quartered corm pieces (73) than its corresponding halved corm pieces (39.11) with significant variation at 0.05 level of probability ( $LSD = 1.38$ ).

Wild Enset relatives with both halved corm pieces and quartered corm pieces produced lower sucker numbers than all tested cultivated Enset landraces. However, the highest sucker numbers were produced from both halved and quartered corm pieces of Chele bocho (the most frequent cultivated Enset landrace which was occurred in 107 of 120 farms in the study area) at 0.05 level of probability.

### 5.3. Recommendation and future direction

- Conservation plan should consider morphological variations of wild Enset relatives which were reported as single variety, and the use of traditional identification methods in the study area can be used for the further studies.
- The majority of cultivated Enset landraces in the study area were low resistant to wilting disease and had moderate qualities for end uses, whereas fewer were highly resistant and had high quality for end uses. Therefore, cross breeding can improve genotype while maintaining sustainability of the extant traits.
- The potential of botanical control practices for cultivated Enset landraces against wilting disease by *Pycnostachys abyssinica* should be examined.
- Wild Enset relatives should be conserved both in-situ and ex-situ conservation methods, and local people can use the leaf of wild Enset relative by propagating it vegetatively (with common practices so as to increase awareness and interest for conservation) while conserving its habitat.
- It was believed that the hardness and bitter nature of the corm of wild Enset relatives might make it to be escaped from attack of pests. Therefore, this should be tested in field with mixed plantation of cultivated Enset landraces and wild Enset relatives in pest attacking areas. This is because it might be due to less probability of exposing to the pests.
- The bitter taste of the corm of wild Enset relatives along with its reason should be chemically demonstrated.
- Enset growers in the study area should use quartered corm partition to maximize the suckers from the tested cultivated Enset landraces per corm which also needs immediate trainings.

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## APPENDICES

### Appendix 1. Semi-structured questionnaire

**Leading questions for Interview:** For Informants      Date: \_\_\_\_\_

Sex \_\_\_\_\_ Age \_\_\_\_\_

Location: Zone \_\_\_\_\_ Woreda \_\_\_\_\_ Kebele \_\_\_\_\_ Village \_\_\_\_\_  
Code: \_\_\_\_\_ Sex of house head \_\_\_\_\_ marital status \_\_\_\_\_

#### A. Ethnobotanical data

Lists of entire cultivated Enset landraces and wild Enset relative, and capital letters used in filling the columns given below (where: Ma – Male, F – Female, NGC – No gender class, F- Fast, M- Moderate, S - Slow, H - High, and L - Low, E – Edible by local people, NE – Not edible, C – Cultivated and W - Wild)

NO.	Landrace name	Gender class: Ma, Fe, NGC	Meaning of local name	Growth rate: Fa, M, S	Disease resistance: H, M, L	Yield: H, M, L	Quality: H, M, L				Edibility: E, NE	Type: C, W	Current Age	Harvesting Age
							Bulla	Amicho	Kocho	Fiber				
1														
2														

The most dominant landrace \_\_\_\_\_ ; the least dominant \_\_\_\_\_

Unique feature of wild Enset relative: \_\_\_\_\_

**Lost Landraces:** List of the locally lost Enset names and all possible responds in the given table (Not limited).

No.	Name of lost landraces	Meaning of local name	Estimate time of lost	What was (were) cause (s)?
1				
2				

#### B. Local threats on Enset farming:

List the most local threats on Enset plant and rank them according to their severity on your Enset farm for wild relative and cultivated landraces (table is not limited). For general and key informants

NO.	Threats on Enset farm	Rank based on their severity		Your Management Practices
		On cultivated	On wild	
1				
2				

The most serious threat: \_\_\_\_\_

**C. Uses of Enset:** List of local use values for respective parts.

No.	Name of landraces	Parts of landraces	List local uses (for cultivated Enset landraces)
1		Corm	
2		Pseudostem	
3		Leaf	
4		Leaf mid rib	
5		Whole part	
			List any local uses (for wild Enset relative )
1		Corm	
2		Pseudostem	
3		Leaf	
4		Leaf mid rib	
5		Whole part	

**D. Local use frequency on different parts of Enset to identify multipurpose parts** (assign by using “X” sign). For Key informants

No.	Part of Enset	How often you use the parts of Enset plant					Notes
		Daily	Weekly	Monthly	Yearly	Once	
1	Corm						
2	Pseudostem						
3	Leaf						
4	Leaf mid rib						
5	Whole part						

**E. General Yes or No questions:** Responds from the experiences of Enset growers.

No.	Questions	Yes or No?
1	Do you know wild Enset relative growing in your area?	
2	Have the wild Enset relative ever been affected by local disease and pests as cultivated Enset landraces?	
3	Do you perceive that conservation of wild Enset is necessary?	
4	Have you practiced propagation of wild Enset relatives with corm?	
5	Have you used seed of cultivated Enset landraces for propagation?	
6	Are you still propagating Enset with corm only?	
7	Can you differentiate cultivated Enset landraces and its wild relative with morphology assuming when both are growing in same field?	

8	Did you domesticate wild Enset relative in your farm?	
9	Is there any variation in germination rate of corm suckers among types of Enset landraces?	

**E. Propagation and Management practices**

What corm pieces you use for Enset sucker multiplication: \_\_\_\_\_

When you plant Enset corm: \_\_\_\_\_

What inputs you apply? \_\_\_\_\_

Frequency of transplanting: \_\_\_\_\_

Steps of Enset sucker production (propagation): \_\_\_\_\_

\_\_\_\_\_

**F. Morphological measurement and evaluation:**

Farm location: LAT \_\_\_\_\_ LONG \_\_\_\_\_ Altitude (m): \_\_\_\_\_

Serial number	Local names of Enset (wild relatives and cultivated landraces)	Leaf number	Leaf size	Total height	Pseudostem height	Pseudostem circumference (widest)	Pseudostem circumference (midpoint)	Pseudostem circumference (top)	Leaf color	Leaf petiole color	Leaf midrib color	Pseudo stem color
1												
2												

**I. Any suggestions and notes on Enset plant by general and key informants**


\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**J. Preference ranking format: For key informants**

Rank in table below based on you own preference for choices of corm pieces for Enset propagation and inputs you use for propagation

A. Corm pieces for Enset propagation				Pair key informants per site	B. Local inputs for Enset propagation			
Full corm	Halved corm	1/3 corm	Quartered corm		Synthetic Fertilizers	Organic wastes	Synthetic and organic	Without application
				Shapa				
				Baha Gona				
				Ermo				
				Bubi				
				Dahera				
				Boko				
				Agaro				
				Kuta shora				
				Yeyibito				
				Wushiwishi				
				Hufido				
				Buti Kicho				

**K. Any notes from field observation: For researcher**

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Thank You!

Appendix 2. Ethnobotanical information of cultivated Enset landraces and wild Enset relatives in the study area

**Note:** SD = Standard deviation; Fe= Female for gender class and Fast for growth rate; S= Slow; L= Low; M= Male for gender class and Medium for other traits; H= High; E= Locally Edible; NE= locally non edible; C= Cultivated Enset landrace, and W= Wild relative

NO.	Cultivated Enset landraces and wild relatives used in this report	Correct writing system in Kaficho Language	Gender Class	Meaning	Growth rate	Disease resistance	Vigor (Thickness)	Bulla quality	Amicho quality	Kocho quality	Fiber quality	Edibility	Type	Mean current age	SD	Mean maturity age	SD
1	Aai bocho	Aa'i bocho	M		M	M	M	M	L	M	M	E	C	3	0	6	0
2	Achecho	Aachecho	F	watered	M	L	M	M	M	M	M	E	C	4.33	0.87	5.67	0.48
3	Agene	Agene	F	Moon	M	L	L	H	H	H	M	E	C	5	0.94	5.9	0.99
4	Anami noobo	Anaami noobo	M		M	<b>H</b>	H	M	M	H	H	E	C	4.63	1.1	6.09	0.85
5	Badado	Badadoo	M		M	L	M	M	M	H	M	E	C	5	0	6	0
6	Bajjoo	Bajjoo	M		M	L	H	M	L	M	M	E	C	4.43	1.06	5.95	0.88
7	Boongo	Boongo	F		M	L	L	M	H	H	M	E	C	5	0.82	5.6	0.7
8	Bumbo	Bumbo	M		M	L	<b>H</b>	M	H	M	H	E	C	4.7	0.86	5.38	0.65
9	Butecho	Butecho	M		M	L	M	H	L	M	M	E	C	5	0	7	0
10	Cammero	Caammero	F	Bitter	M	L	M	M	M	M	M	E	C	4	1.22	6	1
11	Chele Arikoo	Celle Arikoo	F		M	L	L	H	H	H	M	E	C	5.5	0.7	6.5	0.7
12	Chele bocho	Celle bocho	M		M	<b>M</b>	<b>H</b>	M	L	M	M	E	C	4.47	0.99	6.14	0.75
13	Chele	Celle Eppo	M		F	<b>H</b>	H	-	-	-	-	NE	W	3.93	0.62	4.71	1.07

	Eppo																
14	Choro	Cooro	F		M	L	L	L	L	M	L	E	C	4.33	0.71	6.33	0.87
15	Cikii	Cikii	F	Blackish	M	L	M	M	M	H	M	E	C	4.33	0.58	6	1.17
16	Congo	Congo	M		M	M	H	M	L	M	H	E	C	4.4	1.67	6.6	0.89
17	Gaddo	Gaddoo	M		M	L	M	M	L	M	M	E	C	5	0	7	0
18	Ganji bocho	Ganji bocho	M		M	M	M	M	L	M	M	E	C	4.39	1.12	6.15	0.55
19	Gayoo	Gayoo	F		M	L	M	M	H	H	M	E	C	4	1	5.6	0.55
20	Geno	Genoo	F		M	L	M	H	M	H	M	E	C	4.25	0.5	6.75	1.5
21	Gepe tato	Geppee taatoo	M	King of mountain	F	M	H	H	M	H	M	E	C	4	0	7	0
22	Gobi noobo	Gobii noobo	M		M	M	M	M	L	H	H	E	C	4.25	0.5	5.5	1.29
23	Gomijo	Goomijjo	M		H	L	L	H	M	H	M	E	C	3	0	6	0
24	Goosheno	Goosheno	F		M	L	M	H	M	H	M	E	C	3.5	0.96	5.95	0.09
25	Goshindo	Gooshindo	F		M	L	M	M	M	H	M	E	C	4	0.32	5.64	0.62
26	Gudicho	Gudicho	M	Looks pig	H	M	H	H	M	H	H	E	C	4.25	0.71	5.38	0.04
27	Gushiro	Gushiroo	F		H	L	M	H	M	H	M	E	C	3.5	0.58	7.25	0.03
28	Kaloo	Kaloo	F		H	L	M	H	H	H	M	E	C	4.33	1.63	6	1.67
29	Keci bocho	Kecii bocho	M		M	L	M	M	L	M	M	E	C	5	0	6.7	0
30	Kekero	Qeqero	M		M	L	M	M	H	M	M	E	C	4	0	6	0
31	Koche Taatoo	Qoccee taatoo	M	King of Kocho	F	L	M	H	M	H	M	E	C	3	0.09	5.92	0.09
32	Korimmoo	Korimmoo	F		M	L	M	M	H	M	M	E	C	3.5	0.34	5.65	0.66
33	Maca dami	Maaca dami	F	Bleed when cut	F	L	M	L	M	M	M	E	C	4	0.35	5.38	0.54

34	Mishiqoo	Mishiqoo	F		M	L	M	M	L	H	M	E	C	4	0	5	0
35	Moocho	Moocho	M		F	L	M	M	M	M	M	E	C	3	0	6.4	0
36	Nache Ariko	Naccee Arikoo	F		F	L	L	H	H	H	M	E	C	4.23	0.33	6.14	0.06
37	Nache bocho	Naccee bocho	F		F	L	H	M	L	M	M	E	C	3.94	0.003	5.85	0.004
38	Nache Eppo	Naccee Eppo	-		F	<b>H</b>	H	-	-	-	-	NE	W	3.68	0.08	3.97	0.002
39	Otino	Otino	F		M	L	L	H	H	H	M	E	C	5	0	6	0
40	Qophiri	Qophirii	F		F	L	L	H	H	H	M	E	C	4.5	0.08	5.88	0.07
41	Qupho	Qupho	F	Comma	M	L	L	H	H	H	L	E	C	3.25	1.06	4.46	0.66
42	Shalako	Shallaako	M		F	M	H	L	L	H	H	E	C	3	0	5	0
43	Shimmo	Shimmoo	F		M	L	L	M	M	M	M	E	C	4.33	0.93	5.38	0.99
44	Shuri	Shuuri	F		M	L	L	M	H	H	M	E	C	4.33	0.33	6.25	0.62
45	Taayo	Taayo	M		M	L	L	H	M	H	M	E	C	4.4	0.64	6.53	0.71
46	Taralo	Taraallo	F		F	L	H	M	M	M	M	E	C	5	0.07	6.7	0.58
47	Tuusho	Tuushoo	F		M	L	L	H	M	H	L	E	C	3	0	5	0
48	Tuutto	Tuutto	F	Peestle	F	L	M	M	H	M	L	E	C	4	0.07	5.35	1.5
49	Utiro	Utiro	F		F	L	M	M	H	H	M	E	C	5.51	0.62	7.25	0.64
50	Waango	Waango	F		F	L	L	H	H	H	M	E	C	4.47	0.71	6.06	1.29
51	Wuiro	Wu'iroo	F		M	L	M	M	M	M	M	E	C	3.93	0.58	6.7	0.53
52	Yaahoo	Yaahoo	F	Looks Woyera	M	L	L	M	M	M	M	E	C	4.35	1.67	6.16	0.09
53	Yeebeno	Yeebeno	M	Looks Zembaba	M	L	L	M	M	M	M	E	C	4.33	0.26	5.92	0.62
54	Yudaaf	Yudee aaf	M	Fruit of its flower	F	L	L	M	M	M	M	E	C	3	0	6	0

Appendix 3. In-situ morphological data of cultivated Enset landraces and wild Enset relatives in the study area

**Note: Leaf color** (1 = Light green, 2 = Deep green, 3 = Whitish green, 4 = Entirely deep red, 5 = Entirely light red, 6 = Partly deep red around margin); **Leaf midrib color** (1 = Light green, 2 = Deep green, 3 = Whitish green, 4 = light red, 5 = Sectioned light red, 6 = Deep red, 7 = Light black, 8 = Yellow, 9 = Purple ); **Leaf petiole color** (1 = Light green, 2 = Deep green, 3 = Dark red, 4 = Light red, 5 = Partly greenish and black around margin, 6= Light red with many white spots, 7 =Light red with many black spots, 8 = light green with many black spots ), and **Pseudostem color** (1 = Light green, 2 = Deep green, 3 Greenish black, 4 = Dark red, 5 = Light red, 6 = Purple, 7 = Partly greenish and black stripes, 8= Light red with some white spots, 9 = Greenish yellow)

NO.	Varieties	Frequency distribution, measurements (in meter) with in standard deviation											Color of Enset morphologies			
		Frequency per farms	Leaf No.	SD	Leaf size	SD	Total height	SD	Pseudo stem height	SD	Pseudostem diameter	SD	Leaf	Midrib	Petiole	Pseudostem
1	Aai bocho	0.83	16	0	0.53	0	4.98	0	1.63	0	1.15	0.14	1	4	5	3
2	Achecho	7.5	12.33	2.06	0.54	0.07	6.94	0.73	1.74	0.05	1.64	0.41	1	4	4	5
3	Agene	4.2	10.6	2.46	0.53	0.03	6.47	0.85	1.76	0.44	1.42	0.26	1	4	6	8
4	Anaami noobo	<b>74.2</b>	11.78	2.15	0.53	0.07	6.93	1.12	1.91	0.16	1.46	0.34	3	3	5	7
5	Badado	0.83	12	0	0.53	0	6.4	0	1.88	0	1.3	0.15	1	5	5	1
6	Bajjoo	<b>33.3</b>	11.15	1.98	0.52	0.06	6.74	1.12	1.75	0.73	1.36	0.29	1	2	1	1
7	Boongo	8.3	12.5	1.9	0.52	0.04	7.31	0.83	1.59	0.86	1.39	0.25	1	6	3	4
8	Bumbo	10.8	12.15	1.57	0.53	0.06	6.94	1.27	1.61	0.003	1.4	0.36	1	1	5	1
9	Butecho	0.83	11	0	0.39	0	7.3	0	1.43	0	1.3	0.15	1	4	7	6
10	Caammero	4.2	12	2	0.54	0.03	7.21	0.67	1.60	0.24	1.39	0.24	1	4	4	6
11	Chele Arikoo	1.7	12.5	2.12	0.59	0.05	4.57	0.52	1.23	0.66	1.08	0.16	1	9	3	6

12	Chele bocho	<b>89.2</b>	11.52	1.95	0.54	0.07	6.83	1.09	1.67	0.005	1.5	0.37	1	4	4	4
13	Chele Eppo	<b>11.67</b>	11.86	2.03	0.86	0.06	7.01	0.81	1.71	0.02	1.56	0.33	2	4	5	5
14	Choro	7.5	11.11	2.03	0.54	0.13	7.01	0.63	1.8.6	0.08	1.38	0.43	4	6	3	4
15	Cikii	2.5	11.67	2.08	0.51	1.1	6.97	1.23	1.65	0.55	1.24	0.22	1	7	5	3
16	Congo	4.2	10.8	2.59	0.54	0.04	7.53	1.67	1.68	0	1.45	0.34	1	2	4	1
17	Gaddo	0.83	12	0	0.53	0	8.1	0	1.74	0.001	1.05	0.1	1	2	5	1
18	Ganji bocho	10.83	11.31	1.12	0.53	0.06	6.74	1.12	1.84	0.45	1.4	0.28	5	2	4	5
19	Gayoo	4.2	12	1	0.53	0.04	6.53	0.57	1.64	0.24	1.45	0.37	1	9	4	6
20	Geno	3.33	13.25	0.5	0.55	0.02	7.19	0.98	1.73	0.64	1.93	1.26	1	2	2	2
21	Geppee taatoo	0.83	9	0	0.53	0	8.08	0	1.89	0	1.15	0.14	1	1	4	5
22	Gobi noobo	3.33	13	2.16	0.52	0.09	6.68	1.17	1.56	0.24	1.32	0.29	3	3	5	7
23	Goomijjo	0.83	10	0	0.66	0	4.97	0	1.44	0	1.2	0.02	1	8	1	9
24	Goosheno	<b>22.5</b>	11.85	0.17	0.54	0.16	6.62	0.27	1.77	0.05	1.7	0.15	1	6	2	4
25	Gooshindo	1.67	10	0.38	0.49	0.37	6.85	0.34	1.79	0.07	1.4	0.44	1	8	1	7
26	Gudicho	4.2	11.4	0.09	0.63	0.22	6.55	0.15	1.60	0.06	1.57	0.16	1	3	5	3
27	Gushiroo	1.67	13	0.86	0.54	0.34	7.63	0.09	1.62	0.13	1.43	0.37	1	6	1	7
28	Kaloo	<b>11.67</b>	12.3	0.003	0.55	0.15	6.68	0.25	1.80	1.13	1.4	0.33	5	8	3	6
29	Keci bocho	0.83	12	0	0.58	0.29	7.2	0.06	1.77	0	1.8	0.86	1	4	1	5
30	Kekero	0.83	11	0	0.57	0.05	6	0.41	1.25	0	1.2	0.003	1	4	1	5
31	Koche Taatoo	0.83	12	0.08	0.53	0.16	4.47	0.32	1.34	0.06	1.3	0.15	1	4	1	5
32	Korimmo	2.5	9.67	0.37	0.49	0.37	6.67	0.06	1.81	0.64	1.4	0.24	1	4	4	5
33	Maca dami	3.33	10.75	0.74	56	0.22	6.86	0.34	1.7	0.02	1.3	0.16	1	2	2	1
34	Mishiqoo	0.83	11	0	0.53	0	7.2	0	1.78	0	1.1	0.005	1	1	2	1
35	Moocho	1.67	13	0.08	0.61	0.16	6.74	0.21	1.6	0	1.6	0.02	1	2	5	1
36	Nache Arikoo	<b>31.67</b>	11	0.07	0.53	0.37	6.4	0.05	1.71	0.03	1.7	0.08	1	3	4	5
37	Nache bocho	<b>66.67</b>	11.7	0.66	0.55	0.22	6.82	0.38	1.75	0.05	2.36	0.07	1	2	5	1

38	Nache Eppo	<b>27.5</b>	11.5	0.001	0.78	0.34	6.98	0.41	1.79	0.07	1.8	0.74	2	2	5	1
39	Otino	0.83	9	0	0.50	0.15	6.16	0	1.41	0	1	0.001	1	4	4	5
40	Qophiri	5	11.3	0.41	0.53	0.29	7.22	0.34	1.68	0.13	1.7	0.15	5	6	3	6
41	Qupho	6.67	10.75	0.26	0.52	0.05	6.98	0.15	1.7	1.47	1.3	0.24	5	6	3	4
42	Shallaako	0.83	9	0	0.45	0	9.17	0	2.1	0	1.4	0.64	1	1	5	1
43	Shimmo	3.33	11.5	0.15	0.49	0.16	7.85	0.35	1.68	0.89	1.68	0.15	1	9	7	6
44	Shuri	6.67	10.75	0.29	0.55	0.37	7.03	0.04	1.71	0.06	1.53	0.24	5	6	3	4
45	Taayo	8.33	10.8	0.25	0.49	0.22	6.18	0.12	1.61	0.04	1.3	0.16	1	4	7	6
46	Taralo	1.67	10.5	0.36	0.51	0.34	5.71	0.33	1.78	0.02	1.37	0.37	1	1	5	1
47	Tuusho	0.83	15	0	0.51	0	6.23	0	1.66	0	1.53	0.22	1	4	4	1
48	Tuutto	1.67	10	0.15	0.50	0.07	4.18	0.03	1.35	0.54	1.4	0.34	1	4	4	1
49	Utiro	<b>43.33</b>	11.93	0.22	0.51	0.08	6.67	0.35	1.81	0.46	1.47	0.15	1	3	1	9
50	Waango	5.83	11.47	0.16	0.49	0.07	6.77	0.67	1.73	0.03	1.56	0.29	1	6	3	4
51	Wuiro	6.67	11.13	0.37	0.52	0.84	5.67	0.46	1.79	0.05	1.37	0.05	3	3	1	1
52	Yaahoo	2.5	12.67	0.24	0.48	0.001	6.1	0.17	1.69	0.07	1.33	0.36	1	3	8	7
53	Yeebeno	3.33	11	0.47	0.51	0.06	7.55	0.42	1.81	1.78	1.44	0.15	1	4	7	6
54	Yudaafo	3.33	10.25	0.04	0.63	0.18	6.40	0.06	1.64	1.41	1.38	0.24	1	8	1	9

Appendix 4. Distribution records of cultivated Enset landraces and wild Enset relatives per district

District	List of recorded cultivated Enset landraces and wild Enset relatives							
Decha	Aai bocho	Achecho	Agene	Anaami noobo	Bajjoo	Boongo	Bumbo	Butecho
	Caammero	Chele Arikko	Chele Eppo	Chele bocho	Choro	Congo	Ganji bocho	Gayoo
	Geno	Goosheno	Kalloo	Koche taatoo	Korimmo	Mishiqoo	Nache Arikko	Nache bocho
	Nache Eppo	Otino	Qupho	Shalako	Shimmo	Taralo	Tuusho	Tuutto
	Utiro	Waango	Wuiro	Yaahoo	Yeebeno			
Gimbo	Agene	Anaami noobo	Bajjoo	Bumbo	Cammero	Chele bocho	Chele Eppo	Choro
	Gaddo	Gayoo	Geno	Goosheno	Goshindo	Gudicho	Gushiro	Kalloo
	Moocho	Nache Arikko	Nache bocho	Nache Eppo	Qupho	Shuri	Taayo	Utiro
	Waango	Wuiro	Yeebeno	Yudaafu				
Chena	Agene	Anaami noobo	Badado	Bajjoo	Chele Arikko	Chele bocho	Chele Eppo	Cikii
	Ganji bocho	Geppee taato	Gobii noobo	Gomijo	Goosheno	Gudicho	Kalloo	Kecii bocho
	Kekero	Maaca dami	Nache Arikko	Nache bocho	Nache Eppo	Qophiri	Shimmo	Taayo
	Utiro	Waango	Yudaafu					

## Appendix 5. Record of coordinate points of Enset farms in the study sites

Country: **Ethiopia**, Region: **SNNPR**, and Zone: **Kaffa zone**

**Note:** \*\* - indicated the Enset grower's farm where there were occurrence of both cultivated Enset landraces and wild Enset relatives.

No.	Site codes	District (Woreda)	Kebele (sites)	Latitude (N)	Longitude (E)	Elevation (m)
1	DS01	Decha	Shapa	07°14'27.7"	036°13'36.5"	1873
2	DS02**	Decha	Shapa	07°14'26.7"	036°13'4.6"	1885
3	DS03	Decha	Shapa	07°14'05.2"	036°13'37.7 "	1890
4	DS04	Decha	Shapa	07°13'33.8"	036°13'14.4"	1969
5	DS05**	Decha	Shapa	07°14'04.3"	036°13'39.0"	1900
6	DS06**	Decha	Shapa	07°14'01.4"	036°13'39.7"	1896
7	DS07**	Decha	Shapa	07°13'35.0"	036°13'10.2"	1969
8	DS08	Decha	Shapa	07°13'55.2"	036°13'25.3"	1950
9	DS09	Decha	Shapa	07°13'48.8"	036°13'32.1"	1950
10	DS10	Decha	Shapa	07°13'35.9"	036°13'30.4"	1949
11	DBe01**	Decha	Baha Gona	07°12'31.2"	036°13'43.2"	2048
12	DBe02	Decha	Baha Gona	07°12'38.7"	036°13'34.2"	2057
13	DBe03**	Decha	Baha Gona	07°12'26.2"	036°13'43.6"	2035
14	DBe04	Decha	Baha Gona	07°11'40.0"	036°14'05.5"	2026
15	DBe05	Decha	Baha Gona	07°10'28.4"	036°13'45.7"	1955
16	DBe06**	Decha	Baha Gona	07°10'17.0"	036°13'36.8"	1917
17	DBe07**	Decha	Baha Gona	07°10'17.5"	036°13'31.6 "	1888
18	DBe08	Decha	Baha Gona	07°11'15.5"	036°14'09.5"	2048
19	DBe09**	Decha	Baha Gona	07°10'51.1"	036°14'20.6"	1901
20	DBe10	Decha	Baha Gona	07°10'26.0"	036°13'17.6"	1912
21	DE01	Decha	Ermo	07°09'24.8"	036°12'22.8"	1953
22	DE02	Decha	Ermo	07°09'20.8"	036°12'22.3"	1952
23	DE03**	Decha	Ermo	07°09'13.3"	036°12'12.7"	1948
24	DE04	Decha	Ermo	07°09'05.0"	036°11'56.3"	1953
25	DE05**	Decha	Ermo	07°09'06.5"	036°11'54.4"	1958
26	DE06**	Decha	Ermo	07°09'35.2"	036°11'44.7"	1956
27	DE07**	Decha	Ermo	07°09'25.7"	036°11'42.9"	1946
28	DE08**	Decha	Ermo	07°09'20.6"	036°11'43.7"	1951
29	DE09**	Decha	Ermo	07°09'38.9"	036°11'22.2"	1961
30	DE10	Decha	Ermo	07°09'36.3"	036°11'18.8"	1977
31	DBu01	Decha	Bubi	07°07'37.1"	036°11'45.2"	2011
32	DBu02	Decha	Bubi	07°07'36.2"	036°11'48.2"	2000
33	DBu03	Decha	Bubi	07°07'38.0"	036°11'51.4"	1991
34	DBu04	Decha	Bubi	07°07'41.1"	036°11'54.9"	1982
35	DBu05	Decha	Bubi	07°07'43.6"	036°11'58.5"	1970
36	DBu06	Decha	Bubi	07°07'42.8"	036°11'59.3"	1971
37	DBu07**	Decha	Bubi	07°07'41.2"	036°12'01.6"	1944
38	DBu08	Decha	Bubi	07°07'47.1"	036°12'11.0"	1886
39	DBu09**	Decha	Bubi	07°07'51.3"	036°12'15.5"	1856
40	DBu10**	Decha	Bubi	07°07'52.3"	036°12'17.7"	1843
41	GYB01	Gimbo	Yeyibito	07°19'11.8"	036°01'38.5"	1786

42	GYB02**	Gimbo	Yeyibito	07 <sup>0</sup> 19'14.6"	036 <sup>0</sup> 01'27.7"	1812
43	GYB03	Gimbo	Yeyibito	07 <sup>0</sup> 19'05.8"	036 <sup>0</sup> 01'47.5"	1812
44	GYB04**	Gimbo	Yeyibito	07 <sup>0</sup> 19'02.8"	036 <sup>0</sup> 02'00.9"	1800
45	GYB05**	Gimbo	Yeyibito	07 <sup>0</sup> 19'11.4"	036 <sup>0</sup> 02'22.3"	1821
46	GYB06**	Gimbo	Yeyibito	07 <sup>0</sup> 19'29.1"	036 <sup>0</sup> 02'37.0"	1827
47	GYB07	Gimbo	Yeyibito	07 <sup>0</sup> 19'28.3"	036 <sup>0</sup> 02'41.4"	1835
48	GYB08	Gimbo	Yeyibito	07 <sup>0</sup> 19'30.9"	036 <sup>0</sup> 02'45.9"	1838
49	GYB09	Gimbo	Yeyibito	07 <sup>0</sup> 19'14.0"	036 <sup>0</sup> 02'58.2"	1825
50	GYB10	Gimbo	Yeyibito	07 <sup>0</sup> 19'05.4"	036 <sup>0</sup> 03'04.8"	1827
51	GW01**	Gimbo	Wushiwishi	07 <sup>0</sup> 18'40.0"	036 <sup>0</sup> 07'13.9"	1895
52	GW02**	Gimbo	Wushiwishi	07 <sup>0</sup> 18'45.8"	036 <sup>0</sup> 07'12.7"	1890
53	GW03	Gimbo	Wushiwishi	07 <sup>0</sup> 18'51.0"	036 <sup>0</sup> 07'11.1"	1897
54	GW04	Gimbo	Wushiwishi	07 <sup>0</sup> 18'25.8"	036 <sup>0</sup> 07'28.6"	1919
55	GW05**	Gimbo	Wushiwishi	07 <sup>0</sup> 18'30.5"	036 <sup>0</sup> 07'38.3"	1940
56	GW06**	Gimbo	Wushiwishi	07 <sup>0</sup> 17'58.7"	036 <sup>0</sup> 08'18.5"	1954
57	GW07**	Gimbo	Wushiwishi	07 <sup>0</sup> 17'55.2"	036 <sup>0</sup> 08'18.6"	1939
58	GW08	Gimbo	Wushiwishi	07 <sup>0</sup> 17'59.0"	036 <sup>0</sup> 08'37.7"	1924
59	GW09	Gimbo	Wushiwishi	07 <sup>0</sup> 17'53.4"	036 <sup>0</sup> 08'44.9"	1932
60	GW10**	Gimbo	Wushiwishi	07 <sup>0</sup> 17'50.2"	036 <sup>0</sup> 08'47.1"	1933
61	GU01	Gimbo	Hufido	07 <sup>0</sup> 21'35.3"	036 <sup>0</sup> 13'02.3"	1758
62	GU02**	Gimbo	Hufido	07 <sup>0</sup> 21'05.6"	036 <sup>0</sup> 13'07.5"	1760
63	GU03	Gimbo	Hufido	07 <sup>0</sup> 22'06.8"	036 <sup>0</sup> 13'09.1"	1754
64	GU04	Gimbo	Hufido	07 <sup>0</sup> 22'19.7"	036 <sup>0</sup> 13'08.4"	1764
65	GU05	Gimbo	Hufido	07 <sup>0</sup> 22'35.0"	036 <sup>0</sup> 12'43.5"	1746
66	GU06	Gimbo	Hufido	07 <sup>0</sup> 22'37.2"	036 <sup>0</sup> 12'38.3"	1743
67	GU07**	Gimbo	Hufido	07 <sup>0</sup> 22'17.0"	036 <sup>0</sup> 12'30.3"	1747
68	GU08	Gimbo	Hufido	07 <sup>0</sup> 22'08.6"	036 <sup>0</sup> 12'23.1"	1736
69	GU09	Gimbo	Hufido	07 <sup>0</sup> 22'06.6"	036 <sup>0</sup> 12'18.9"	1712
70	GU10	Gimbo	Hufido	07 <sup>0</sup> 22'06.1"	036 <sup>0</sup> 12'14.9"	1702
71	GK01**	Gimbo	Buti Kicho	07 <sup>0</sup> 14'02.3"	036 <sup>0</sup> 24'39.5"	1794
72	GK02	Gimbo	Buti Kicho	07 <sup>0</sup> 14'08.4"	036 <sup>0</sup> 24'40.6"	1790
73	GK03	Gimbo	Buti Kicho	07 <sup>0</sup> 14'13.4"	036 <sup>0</sup> 24'40.3"	1794
74	GK04	Gimbo	Buti Kicho	07 <sup>0</sup> 14'14.2"	036 <sup>0</sup> 24'41.1"	1795
75	GK05**	Gimbo	Buti Kicho	07 <sup>0</sup> 14'18.0"	036 <sup>0</sup> 24'42.2"	1792
76	GK06**	Gimbo	Buti Kicho	07 <sup>0</sup> 14'36.5"	036 <sup>0</sup> 24'50.1"	1775
77	GK07	Gimbo	Buti Kicho	07 <sup>0</sup> 14'43.8"	036 <sup>0</sup> 24'58.3"	1774
78	GK08	Gimbo	Buti Kicho	07 <sup>0</sup> 14'44.4"	036 <sup>0</sup> 24'58.9"	1769
79	GK09	Gimbo	Buti Kicho	07 <sup>0</sup> 14'51.7"	036 <sup>0</sup> 25'06.5"	1760
80	GK10	Gimbo	Buti Kicho	07 <sup>0</sup> 14'52.6"	036 <sup>0</sup> 25'06.8"	1754
81	CD01**	Chena	Dahera	07 <sup>0</sup> 13'55.5"	035 <sup>0</sup> 52'21.2"	2004
82	CD02**	Chena	Dahera	07 <sup>0</sup> 13'31.9"	035 <sup>0</sup> 52'24.3"	2002
83	CD03	Chena	Dahera	07 <sup>0</sup> 12'30.9"	035 <sup>0</sup> 52'15.1"	1993
84	CD04**	Chena	Dahera	07 <sup>0</sup> 12'23.0"	035 <sup>0</sup> 52'09.6"	1988
85	CD05	Chena	Dahera	07 <sup>0</sup> 12'15.4"	035 <sup>0</sup> 51'59.1"	1959
86	CD06**	Chena	Dahera	07 <sup>0</sup> 12'02.0"	035 <sup>0</sup> 51'41.5"	1902
87	CD07	Chena	Dahera	07 <sup>0</sup> 13'11.0"	035 <sup>0</sup> 52'12.4"	2002
88	CD08	Chena	Dahera	07 <sup>0</sup> 13'12.5"	035 <sup>0</sup> 52'01.8"	2011
89	CD09	Chena	Dahera	07 <sup>0</sup> 13'13.9"	035 <sup>0</sup> 51'58.8"	2012

90	CD10	Chena	Dahera	07 <sup>0</sup> 13'32.4"	035 <sup>0</sup> 52'22.1"	1996
91	CB01	Chena	Boko	07 <sup>0</sup> 16'44.3"	035 <sup>0</sup> 51'19.9"	1932
92	CB02	Chena	Boko	07 <sup>0</sup> 16'40.3"	035 <sup>0</sup> 51'16.6"	1924
93	CB03	Chena	Boko	07 <sup>0</sup> 16'35.8"	035 <sup>0</sup> 51'10.8"	1930
94	CB04	Chena	Boko	07 <sup>0</sup> 16'34.4"	035 <sup>0</sup> 51'02.6"	1926
95	CB05	Chena	Boko	07 <sup>0</sup> 16'58.8"	035 <sup>0</sup> 51'15.5"	1897
96	CB06**	Chena	Boko	07 <sup>0</sup> 16'15.8"	035 <sup>0</sup> 51'06.3"	1891
97	CB07**	Chena	Boko	07 <sup>0</sup> 16'16.5"	035 <sup>0</sup> 51'19.5"	1889
98	CB08	Chena	Boko	07 <sup>0</sup> 17'01.9"	035 <sup>0</sup> 51'08.7"	1893
99	CB09	Chena	Boko	07 <sup>0</sup> 16'41.5"	035 <sup>0</sup> 51'32.1"	1918
100	CB10**	Chena	Boko	07 <sup>0</sup> 16'40.0"	035 <sup>0</sup> 51'42.5"	1880
101	CA01	Chena	Agaro	07 <sup>0</sup> 16'04.8"	035 <sup>0</sup> 54'05.4"	2008
102	CA02	Chena	Agaro	07 <sup>0</sup> 16'05.3"	035 <sup>0</sup> 54'01.8"	2012
103	CA03	Chena	Agaro	07 <sup>0</sup> 16'18.6"	035 <sup>0</sup> 54'22.9"	1992
104	CA04	Chena	Agaro	07 <sup>0</sup> 16'49.8"	035 <sup>0</sup> 54'17.8"	1986
105	CA05	Chena	Agaro	07 <sup>0</sup> 16'56.2"	035 <sup>0</sup> 54'20.6"	1982
106	CA06	Chena	Agaro	07 <sup>0</sup> 15'54.5"	035 <sup>0</sup> 54'13.3"	2028
107	CA07	Chena	Agaro	07 <sup>0</sup> 15'59.0"	035 <sup>0</sup> 54'13.1"	2027
108	CA08	Chena	Agaro	07 <sup>0</sup> 15'54.4"	035 <sup>0</sup> 54'08.8"	2020
109	CA09	Chena	Agaro	07 <sup>0</sup> 16'11.5"	035 <sup>0</sup> 54'37.5"	1993
110	CA010	Chena	Agaro	07 <sup>0</sup> 16'10.6"	035 <sup>0</sup> 54'35.9"	2004
111	CKS01**	Chena	Kuta shora	07 <sup>0</sup> 15'53.1"	035 <sup>0</sup> 54'32.5"	2031
112	CKS02	Chena	Kuta shora	07 <sup>0</sup> 15'49.6"	035 <sup>0</sup> 54'33.2"	2026
113	CKS03	Chena	Kuta shora	07 <sup>0</sup> 16'22.0"	035 <sup>0</sup> 55'04.5"	1925
114	CKS04	Chena	Kuta shora	07 <sup>0</sup> 16'20.5"	035 <sup>0</sup> 55'13.6"	1922
115	CKS05	Chena	Kuta shora	07 <sup>0</sup> 16'21.5"	035 <sup>0</sup> 55'29.4"	1924
116	CKS06	Chena	Kuta shora	07 <sup>0</sup> 16'30.4"	035 <sup>0</sup> 55'30.7"	1911
117	CKS07	Chena	Kuta shora	07 <sup>0</sup> 16'31.9"	035 <sup>0</sup> 55'43.3"	1908
118	CKS08	Chena	Kuta shora	07 <sup>0</sup> 16'29.4"	035 <sup>0</sup> 55'43.1"	1922
119	CKS09	Chena	Kuta shora	07 <sup>0</sup> 16'18.6"	035 <sup>0</sup> 55'46.2"	1911
120	CKS10	Chena	Kuta shora	07 <sup>0</sup> 16'05.0"	035 <sup>0</sup> 55'52.3"	1902

Appendix 6. Some recorded photos from the study area



## Appendix 7. Mean values of traits and parameters collected from the experimental field of Enset propagation

ECP – Enset corm partition ( H & Q – Halved & Quartered Enset corm pieces, respectively), NoR – Number of replication, A, CB, CE, N, NE & S – Achecho, Chele bocho, Chele Eppo (wild), Anaami nobo, Nache Eppo (wild) and Shalaako, respectively, and SD – Standard deviation.

ECP	Tested Enset	NoR	Sucker number per corm piece		Leaf number per sucker		Total height (cm)		Leaf height (cm)		Pseudostem height (cm)		Pseudostem diameter (cm)		sprouted corm pieces		Failed corm pieces	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
H	A	3	53.0	4.0	6.7	1.2	50.5	1.3	26.2	1.8	20.5	2.8	11.8	1.3	8.0	1.0	1.0	1.0
H	CB	3	60.7	3.1	8.7	1.2	62.3	2.5	30.2	2.3	25.8	2.3	10	1	8.3	0.6	0.7	0.6
H	CE	3	6.0	10.4	2.7	4.6	18.0	31.2	7.2	12.4	6.3	10.9	3.2	5.5	0.3	0.6	8.7	0.6
H	N	3	56.3	4.5	7.3	1.2	56	2	22.2	1.1	25.5	0.9	9.5	1.5	8.0	1.0	1.0	1.0
H	NE	3	8.0	13.9	2.7	4.6	17.5	30.3	7.8	13.6	6.8	11.8	3.7	6.4	0.7	1.2	8.3	1.2
H	S	3	50.7	3.1	8	0	55.3	0.8	23.7	1.2	22.0	1.3	11.2	0.8	8.0	1.7	1.0	1.7
Q	A	3	101.7	3.5	7.3	1.2	50.3	2.5	28.2	1.8	15.8	3.3	9.3	1.5	5.3	0.6	3.7	0.6
Q	CB	3	119.7	2.1	8.0	2.0	59	4.4	31.2	1.8	23.7	3.1	10.5	1.5	6.3	1.5	2.7	1.5
Q	CE	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0
Q	N	3	108.3	4.1	7.3	1.2	59.2	4.1	23.2	1.8	27.0	1.5	9.7	2.1	5.7	1.2	3.3	1.2
Q	NE	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0
Q	S	3	108.3	6.1	6.7	1.2	53.5	2.3	25.5	2.8	22.7	1.5	11.0	2.6	4.7	2.3	4.3	2.3

## DECLARATION

I, the undersigned declare that this Thesis is my original work and it has not been presented in other universities, colleges or institutes for a degree or other purpose. All sources of the materials used have been duly acknowledged.

Name: Asaminew Woldegebriel Gebriel Signature: \_\_\_\_\_ Date: \_\_\_\_\_

This paper work has been done under our supervision.

Name: \_\_\_\_\_ Signature: \_\_\_\_\_ Date: \_\_\_\_\_

\_\_\_\_\_ Signature: \_\_\_\_\_ Date: \_\_\_\_\_