Review article – Thematic Issue

A review of enset [*Ensete ventricosum* (Welw.) Cheesman] diversity and its use in Ethiopia

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Summary

Introduction – **Enset is an indigenous crop in southern and southwestern Ethiopia, with a huge potential to provide year-round food production. Starch stored in the corm and pseudostem of the plant is the main source of energy provided by this crop. Enset was fully domesticated in Ethiopia between 10,000 and 5,000 years ago and initially farmed in a system of shifting cultivation. This long history of enset cultivation has contributed to the high within-species diversity.** *Materials and methods* – **This paper provides an overview of past research activities and knowledge linked to enset diversity and identifies critical research gaps, which should be addressed to improve the long-term conservation and use of this diversity.** *Results and discussion* – **Studies have identified numerous landraces across the vast enset-growing belt in Ethiopia, with genetic diversity in a particular area related to the extent of enset cultivation by different ethnic groups and the range of agro-ecologies to which the crop is adapted. Farmers' rich knowledge of enset, accumulated over many years, plays a significant role in the characterization and maintenance of the existing genetic diversity of this crop. Farmers differentiate landraces using morphological traits, such as plant height and pseudostem size, angle of leaf orientation, and pseudostem and leaf colour.** *Conclusion* – **Enset diversity provides resilience and food security despite challenging environmental conditions, diseases or changes in land use systems.**

Keywords
bacterial wilt, enset, Ethiopia, genetic resources, germplasm management

Résumé

Etat des lieux de la diversité de l'ensète [*Ensete ventricosum* (Welw.) Cheesman] et de son utilisation en Ethiopie.

Introduction – **L'ensète est une culture indigène du sud et du sud-ouest de l'Ethiopie, avec un potentiel énorme de production alimentaire tout au long de l'année. L'amidon stocké dans le corme et le pseudostème de la plante constitue la principale source d'énergie fournie par cette culture. L'ensète a été entièrement domestiqué en Ethiopie entre -10 000 et -5 000 ans et était initialement cultivé selon un système de culture itinérante. Cette longue histoire culturale de l'ensète a contribué à la grande diversité au sein de l'espèce.** *Matériels et methodes* – **Cet article fournit une vue d'ensemble des activités de recherche antérieures et des connaissances liées à la diversité des ensètes, et identifie les principales lacunes de la recherche qu'il conviendrait de combler pour améliorer la conservation et l'utilisation à long terme de cette diversité.** *Résultats et discussion* – **Des études ont identifié de nombreuses races locales à travers la vaste ceinture de cultures d'ensète en Éthiopie, avec une diversité génétique dans une zone particulière liée à l'étendue de la culture d'ensète par différents groupes ethniques et à la gamme des agro-écologies auxquelles la culture est adaptée. Les connaissances approfondies des paysans sur l'ensète, accumulées au fil des ans, jouent un rôle important dans la caractérisation et le maintien de**

Significance of this study

What is already known on this subject?

- Enset is characterized by a high genetic diversity due to farmer cultivation for thousands of years. Various studies have characterised enset landrace diversity.

What are the new findings?

- Several research gaps exist, *e.g.*, field gene banks need to be expanded; a taxonomic key and descriptor list to characterize enset diversity needs to be developed; in-depth varietal screening needs to be carried out for reaction to various biotic and abiotic constraints; improved exploitation of the industrial potential of enset-derived starch and fibre should be high on the agenda and expanded enset improvement/breeding efforts are needed.

What is the expected impact on horticulture?

- A more targeted and evidence-based use of enset landrace diversity will enhance system resilience, farm productivity and income.

la diversité génétique existante de cette plante. Les agriculteurs différencient les races locales en utilisant des caractéristiques morphologiques, telles que la hauteur de la plante et la taille du pseudostème, l'angle d'orientation des feuilles, et la couleur des feuilles et du pseudostème. *Conclusion* – **La diversité de l'ensète offre résilience et sécurité alimentaire malgré des conditions environnementales difficiles, des maladies ou des modifications des systèmes d'utilisation des terres.**

Mots-clés
ensète, Ethiopie, le flétrissement bactérien de l'ensète, gestion du germoplasme, ressources génétiques

Introduction

Enset [*Ensete ventricosum* (Welw.) Cheesman] is an important multipurpose indigenous crop for Ethiopia that ensures year-round food and feed security, traditional medicine and fiber (Bezuneh, 1984; Brandt *et al*., 1997). The enset cultivation system is economically viable and well adapted to Ethiopian agricultural systems (Bezuneh and Feleke, 1966). Cattle manure and household wastes are the predominant organic amendments in enset culture. Every part of the plant can be used in one way or another. Farmers often acknowledge that enset is their food, cloth, house, bed, cattle feed and plate (Brandt *et al*., 1997; Tsegaye, 2002).

The corm and pseudostem of the enset plant are the most important sources of food, commonly harvested as *kocho* (fermented starch obtained from the decorticated (scraped) leaf sheaths and grated corm), *bulla* (a white powder produced by dehydrating squeezed sap from scraped leaf sheaths and grated corms), and *amicho* (boiled corm pieces of young enset plants, prepared and consumed in a similar manner to other root and tuber crops (Alemu and Sandford, 1991; Brandt *et al*., 1997). Enset plays a crucial economic role, providing a higher and more dependable yield compared to other crops in Ethiopia (Tsegaye, 2002). Enset provides important environmental and eco-systems services, such as the provision of organic matter to the soil through a continuous accumulation of litter (thus creating a nutrient reservoir in the soil which improves soil fertility and understory growth), protection of the soil from erosion, and provision of shade. It thus contributes to the overall sustainability of farming systems in enset-producing localities (Haile *et al*., 1996; Lee and Zawdie, 1997; Woldetensaye, 1997). Shortage of moisture can retard the growth but does not kill the plant. Enset has the capacity to accumulate moisture in its pseudostem, while the large corm or rhizome can be considered as a food-storage organ that enables the plant to survive. As a result, famine rarely occurs in areas where enset is widely grown.

Brandt *et al.* (1997) suggested that enset was initially farmed in a system of shifting cultivation and fully domesticated in Ethiopia between 10,000 and 5,000 years ago. By the mid-Holocene (4,000–5,000 years ago), domestication of livestock and the use of manure to maintain soil fertility enabled a more intensified farming system without the need for shifting cultivation (Brandt *et al*., 1997). This long history of enset cultivation has contributed to the high within-species diversity seen for this crop. Studies have identified numerous landraces across the vast enset-growing belt (Figure 1), with genetic diversity in a particular area related to the geographical extent of enset cultivation, the culture and distribution pattern of the different ethnic groups, and environmental regimes present in traditional farming systems (Wood and Lenne, 1999; Tsegaye, 2002; Birmeta, 2004). The high genetic diversity of enset warrants conservation, as it provides resilience to the enset farming system and thus food security for farming communities.

This desk review is based on publications, grey literature and reports on enset landrace diversity (written or published over the past four decades) which were compiled by the Southern Agricultural Research Institute (SARI) and Bioversity International. This review provides a structured overview of results and recommendations reported by the various authors, and discusses knowledge gaps linked to enset diversity and its use in the light of possible future research endeavours.

Enset taxonomy

Enset (also known as ensete, false banana, Ethiopian banana or Abyssinian banana) is a monocotyledon of the order *Scitamineae*, the family *Musaceae,* and the genus *Ensete.* Enset was first described by Bruce (1790) and later classified under the genus *Musa* by Gmelin in the 13th edition of Systema Naturae in 1791. Horaninow renamed the species *Ensete edule* in 1862 (Cheesman, 1947).

Studying specimens in the Botanical Garden of Kew, Cheesman (1947) reclassified 25 *Musa* spp. as *Ensete* with the reservation that some may prove to be synonymous following field study. Olango *et al.* (2015: citing Baker and Simmonds, 1953; Simmonds, 1962) stated that the genus *Ensete* consists of 5 or 6 species. Two wild enset species are found in Asia and four wild species in sub-Saharan Africa and Madagascar (Baker and Simmonds, 1953; Simmonds, 1958). *Ensete ventricosum* (Welw.) Cheesman is the only known wild species in Ethiopia, which is believed to be its center of origin (Vavilov, 1952).

Ensete ventricosum is the only species of the genus that has been domesticated. It is of particular significance for Ethiopian farming systems in the south and southwestern regions as source of food and feed. It is also found in the central and northern highlands of Ethiopia around Lake Tana, the Simien Mountains, and as far north as Adigrat and into southern Eritrea (Simoons, 1960, 1965; Brandt *et al*., 1997). It is locally known by its vernacular names *enset* or *koba* (by the ethnic group Amhara), *asat* (Gurage), *weise* (Kambata), *werke* (Oromia) and *wassa* (Sidama). From here on, any mention of the word "enset" refers to *E. ventricosum* plants unless otherwise specified.

Most wild and a few cultivated plants are produced from seed, and have more than one parent (Alemu and Sandford, 1991). Most domesticated enset plants, however, are propagated from suckers, and are clones derived from a single parent. Therefore, in the literature, enset landraces/cultivars are often referred to as clones. In this review, we have used the term landrace, as defined by Melaku (1991), to designate between 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.

Enset diversity: vernacular names, phenotypic plasticity and genotypic differentiation

Farmers' rich knowledge of enset, accumulated over many years, plays a significant role in the characterization and maintenance of the existing genetic diversity of this crop.

Figure 1. Small-scale enset farm in the vicinity of Shashemene, Southern Ethiopia, with various enset landraces grown in the backyard (Source: Guy Blomme).

Farmers differentiate landraces based on phenotypic characteristics, such as colour of the petiole, midrib and leaf sheath, angle of leaf orientation, size and colour of leaves, and circumference and length of the pseudostem (Shambulo *et al.*, 2012; Yemataw *et al.*, 2014a). Elderly members of households are generally the best informed about enset diversity, and this knowledge is transferred through oral tradition (Negash, 2001). Vernacular names are often descriptive and reflect variation of landraces in places of origin, morphology, as well as agronomic and cooking characteristics (Olango *et al.*, 2014). Characterization of enset germplasm using morphological traits shows much variability in quantitative and qualitative morphological, growth and yield traits among enset accessions, including maturation rate, plant height, colour and susceptibility to disease (Tabogie, 1997; Yeshitla and Diro, 2009; Yemataw *et al.*, 2012).

The number of landraces grown is closely linked to the importance of enset for a certain ethnic group (Zippel, 2005). At farmers' level, the same landraces may have different vernacular names depending on the ethnic or linguistic groups and agro-ecological zones. For example, the names 'Choro' and 'Ketano' are used by farmers in two districts of Kaffa province for the same enset landrace (Negash, 2001). In addition, the same name can be given to different clones across ethnical groups and agro-ecologies. For example, the landrace 'Mazia' from Dawro and Wolaita represents different landraces (Yemataw *et al.*, 2018). Such nomenclatural duplication is mostly due to different uses of the same landrace.

Exchange of planting materials is common between farmers of the same or different ethnic groups, and vernacular names may be altered after long-term adaptation of the exchanged clone, corresponding to the farmer's own preferences and language. For instance, landraces with similar vernacular names are often identical, *e.g.*, 'Katino' is identical with 'Ketano', 'Chele bocho' with 'Ganji bocho', and so forth. In other instances, genotypes may be exchanged across largely varying agro-ecological systems and geographical distances, resulting in very different vernacular names for the same landrace. Several authors have reported on the difficulty of evaluating enset diversity due to such duplication of names for the same landrace (Tabogie, 1997; Negash, 2001; Tsegaye, 2002; Yemataw *et al.*, 2014a).

Women (*vs*. men) and elderly (*vs*. younger) farmers are generally more knowledgeable about the different attributes of enset landraces and able to recall more landraces than men during group discussions (Negash, 2001). Farmers' own taxonomic knowledge categorizes enset landraces into either male or female, based on particular morphological or phenological properties (Negash, 2001; Tsehay and Kebebew, 2006; Yemataw *et al.*, 2014a). For example, male farmers generally prefer male enset landraces, which are late maturing and disease resistant, but with a lower quality of *amicho* and *kocho*. By contrast, female farmers prefer female enset landraces, which mature earlier and have a tastier *kocho* and *amicho*, but are less vigorous and more susceptible to disease (Table 1).

Table 1. Characteristics of "male" and "female" enset landraces in Wolaita, Gamo Goffa and Dawro zones of Southern Ethiopia. Source: Yemataw *et al.*, 2014a.

Characteristics	Male enset	Female enset
Plant vigour	Vigorous	Less vigorous
Disease reaction	Tolerant	Susceptible
Kocho quality	Less quality	More quality
Maturity	Late maturing	Early maturing
Amicho palatability	Not preferred	Edible and tasty
Fibre quality	High strength	Low strength
Productivity (plant^{-1} yr^{-1})	Highly productive	Less productive

Field experiments have demonstrated that landraces differ in their environmental requirements (Zippel, 2005). Yemataw *et al.* (2016b) found strong crossover genotype × environment interaction with a significant change of rank for mean yield performance from one environment to the other. The large variation in agro-ecologies suitable for enset cultivation systems, combined with low regional differentiation of enset genotypes, suggests phenotypic plasticity (Negash, 2001). Phenotypic plasticity is the capacity of a single genotype to exhibit a range of phenotypes in response to variation in the environment (Fordyce, 2006), thus enabling the adaptation of enset genotypes to different agro-ecological conditions with elevations ranging from 1,400 to 3,100 meters above sea level (Taboge *et al.*, 1996). This also complicates enset landrace identification based on morphological and physiological characteristics.

The analysis of molecular markers is a useful tool to analyse genetic diversity and evolutionary relationships among enset landraces. Found in the whole genome, molecular markers are independent of plant tissue, influence of environmental and management practices, and thus particularly suited to crops such as enset (Manifesto *et al.*, 2001; Altintas *et al.*, 2008). Molecular genetic marker techniques, such as Amplified Fragment Length Polymorphism (AFLP), Random Amplified Polymorphic DNA (RAPD), Inter Simple Sequence Repeats (ISSR) and Simple Sequence Repeat (SSR), have been used to evaluate the germplasm of cultivated enset from several enset-growing regions of Ethiopia (Negash, 2001; Tsegaye, 2002; Birmeta, 2004; Tobiaw and Bekele, 2011; Olango *et al.*, 2015). However, molecular techniques used in these studies were not always in agreement with field-level plant morphological observations. For example, the landraces 'Choro' and 'Ketano' showed no molecular differentiation despite easy distinction by farmers based on morphological characteristics, possibly indicating an environmental effect on the cultivar's appearance (Negash, 2001).). Recent molecular studies using SNPs provided a clear distinction between enset landraces (Yemataw *et al.*, 2018). For example, the landrace 'Arkia' from Dawro and Wolaita showed extensive genetic differences.

Table 2. Number of farmer-grown landraces recorded by different authors in major enset-producing areas of Ethiopia.

Study sites	N° of landraces	References
Arsi	6	Birmeta (2004)
Dawro	42	Yemataw (2014b)
	75	Yemataw (2016a)
Gamo Goffa	34	Yemataw (2014b)
	44	Alemu and Sandford (1991)
	25	Birmeta (2004)
Gedeo	26	Yemataw (2016a)
Gurage	63	Yemataw (2016a)
	31	Yemataw (2014b)
	20	Birmeta (2004)
Hadiya	51	Yemataw (2016a)
	45	Negash (2001)
	59	Tsegaye (2002)
	9	Birmeta (2004)
	59	Yemataw (2014b)
Kaffa	65	Negash (2001)
	20	Birmeta (2004)
	42	Tsehay and Kebebew (2006)
Kembata-Tembaro	43	Yemataw (2014b)
	66	Yemataw (2016a)
Segen Peoples	17	Alemu and Sandford (1991)
Sheka	43	Abadura (2017)
Sidama	30	Negash (2001)
	79	Tesfaye (2002)
	12	Birmeta (2004)
	62	Yemataw (2016a)
	52	Tsegaye (2002)
	29	Yemataw (2014b)
Silte	8	Birmeta (2004)
	69	Yemataw (2016a)
South Omo (Ari)	76	Shigeta (1990)
Wolaita	111	Alemu and Sandford (1991)
	6	Negash (2001)
	55	Tsegaye (2002)
	11	Birmeta (2004)
	67	Olango (2014)
	28	Yemataw (2016a)
	39	Yemataw (2014b)

Diversity management of enset landraces *in situ* and *ex situ*

On-farm maintenance of agro-biodiversity minimizes risks linked to biotic (pests and diseases) or abiotic (*e.g.*, low soil fertility stress and drought stress) factors, stabilizes production and yields, promotes dietary diversity and maximizes returns using low levels of technology and limited resources (Altieri, 2004). Farmers are the main curators of enset diversity, and hundreds of varieties (Table 2) have been reported by various authors (Shigeta, 1990; Alemu and Sandford, 1991; Negash, 2001; Tsegaye, 2002; Birmeta, 2004; Tsehay and Kebebew, 2006; Yemataw, 2014b, 2016a; Olango, 2014; Abadura, 2017). The diversity of landraces is not spread evenly, with a small number of highly abundant landraces grown over larger areas and a larger number of moderately common or rare landraces (Yemataw *et al.*, 2014a).

An extensive comparison of previous reports on enset diversity showed considerable changes over a 50-year period, with increasing number of enset landraces in Sidama, but decreasing diversity of landraces in other regions (Zippel, 2005). Some enset landraces disappeared over time in certain regions, while new ones also emerged (Zippel, 2005). Gebremariam (1997) stated that many valuable landraces have been lost due to various human and environmental factors. A recent survey carried out by Yemataw *et al.* (2017a) at Hadiya, Kembata Tembaro and Wolaita reported a decreasing enset production and a reduction in enset landrace diversity. The majority of farmers believe pests and diseases, especially Enset Xanthomonas wilt, and climate change to be a major cause for the declining production and productivity of enset in the region. Farmers have also lost landraces to changes in land use systems, especially in proximity to markets and road axes (*e.g.*, due to an expansion in highly marketable Khat and annual crops like maize) (Abebe, 2013). Overall, across the enset-growing belt, there is a reduction in enset production per farm and landrace diversity.

Ex situ conservation of enset is done either *in vitro* or in field gene banks (Negash, 2001). Enset germplasm collections are important for their contribution to conservation, enset breeding programs and as a place where farmers can access better-performing landraces to diversify their enset stock or retrieve previously lost landraces.

The Areka Agricultural Research Center (AARC) started its enset research programme in 1986, focusing on agronomy, conservation and socio-economy of enset farming systems (Yeshitila and Yemataw, 2012). To date, enset germplasm at AARC has not been systematically evaluated. A non-exhaustive collection of 623 landraces from 12 enset growing areas of Ethiopia is conserved in a field gene bank at AARC. Olango *et al.* (2014) noted that the AARC collection sourced from Wolaita represented only 40% of the landraces known to the Wolaita farming communities, suggesting that true diversity is not yet represented.

Building on previous endeavours by Bezuneh (1984) and Negash *et al.* (2000), Birmeta and Welander (2004) developed a three-step protocol for *in vitro* propagation of enset, including initiation, bud proliferation and shoot elongation and rooting stages. Diro and Van Staden (2005) noted that the apical meristem should preferably be split or wounded (hence removing the apical dominance of the tip) in order to release lateral buds during micropropagation.

Conservation of enset genetic resources *ex situ* as seed in cold storage is difficult or even impossible. Guzzon and Müller (2016) surveyed plant genetic resource databases, gene and seed banks, research centres and interviewed individual researchers, but found a seed accession of only one of the enset species (*E. ventricosum*), in the Millennium Seed Bank of the Royal Botanic Garden, Kew, UK. Seeds of enset landraces cannot be obtained easily and if so, they are difficult to store because of their bulky size, and are hard to germinate. Moreover, conservation of seeds has limited value for utilisation in view of the preferred clonal propagation of the crop. Nevertheless, the existence of stored seed material is important, particularly in the context of crop improvement programs. Birmeta *et al.* (2004) demonstrated that wild enset populations show higher genetic variability with potentially useful traits for cultivated/domesticated enset, making them prime candidates for an enset breeding program. Enset landrace and wild enset germplasm collection and characterization started in 1986, while pre-breeding efforts started in 1997 at the SARI Areka research station. Wild enset diversity will be used for breeding enset genotypes that are vigorous, stress tolerant, high yielding and highly marketable (Zerihun Yemataw, 2017, pers. commun.).

Evaluation of enset varieties for different uses

Different agronomic, culinary and morphologic properties of enset landraces have been evaluated either *ad hoc* during on-farm surveys or in randomized controlled field trials.

Yields of *Kocho* (the primary product of enset) are variable across different agro-ecological zones (Shambulo *et al.*, 2012) and between landraces. The average yield of *kocho* ranges from 7 to 12 tonnes ha^{-1} year^{-1}, although yields as high as 43 tonnes ha^{-1} year^{-1} have been reported (Bekele and Taboge, 2008). The cultivar 'Halla' showed very high Kocho yields, but it is more preferable in the highlands than in mid-altitude areas, whereas 'Tuzuma' is equally accepted. *Kocho* from other landraces such as 'Falakia', 'Gena' and 'Maziya', is preferred in the highlands whereas 'Nakaka' and 'Kekeruwa' are more common in mid-altitude areas (Shambulo *et al.*, 2012). Yeshitla and Yemataw (2012) reported on the wide-scale (>500,000 suckers to >25,000 households) dissemination of selected landraces for better *kocho* yield and quality: 'Yanbule', 'Gewada' and 'Endale' (early maturing: 3 to 4 years) and 'Kelisa', 'Zerita' and 'Mesena' (late maturing: 4 to 5 years). The average squeezed *kocho* yield of the early maturing landraces was 17 to 21 tonnes ha^{-1} year^{-1}, while it ranged from 13 to 16 tonnes ha^{-1} year^{-1} for the late maturing landraces (Yeshitla and Yemataw, 2012). A negative correlation has been observed between maturity time and squeezed *kocho* yield (Yemataw *et al.*, 2017b).

Similarly, landraces differ in quantity and quality of *amicho* produced, whereby a landrace that is good for *kocho* is not necessarily also preferred for *amicho*. Yemataw *et al.* (2016b) found a superior rhizome *amicho* yield for the landraces 'Chohot', 'Ashakit', 'Bose' and 'Gazner' across different locations. In contrast, the enset landraces 'Niffo', 'Zinke' and 'Bukuniya' gave the lowest *amicho* rhizome yield across the studied regions.

However, it is important to note that desirable sensory and utilization characteristics equally contribute in farmer decision-making (Yemataw *et al.*, 2016b). Enset is also processed for non-edible products, such as the fibre, a by-product after *kocho* and *bulla* have been extracted. Small quantities of *bulla,* a high quality starch, are obtained per processed plant and can be sold for premium prices. Yemataw *et al.* (2012) reported differences in *bulla* yield across enset landraces, ranging from 0.01 to 7.08 tonnes ha^{-1} year^{-1}. *Bulla*, which is edible, may also have other applications, such as starch for textile, paper, adhesive components and many other industrial products. Moreover, *bulla* can be used as an alternative starch in pharmaceutical industries (Wondimu and Gebremariam, 2014).

Enset fibre is a by-product of enset leaf sheath processing. Bekele *et al.* (2008) reported enset fibre yields ranging from 350 to 600 kg fresh weight ha^{-1} year^{-1}, while Yemataw *et al.* (2012) reported an average fibre dry weight of 0.16 tonnes ha^{-1} year^{-1}. Enset and Abaca (*Musa textilis*) fibres were reported to have a similar strength and quality (Bezuneh,

TABLE 3. Mean disease incidence of Xanthomonas wilt-tolerant enset landraces collected from different enset growing areas.

Collection zone	Name of landrace	Mean disease incidence (%)	Reference
Dawro	Maziya	19.31	Hunduma *et al.*, 2015
Dawro	Halaa	22.50	McKnight, 2013, Annual report
Gurage	Nechuwe	11.00	Welde-Michael *et al.*, 2008
Gurage	Dere	11.00	Welde-Michael *et al.*, 2008
Gurage	Bezeriyet	11.00	Welde-Michael *et al.*, 2008
Gurage	Lemat	22.00	Welde-Michael *et al.*, 2008
Gurage	Anikefiye	33.00	Welde-Michael *et al.*, 2008
Kembata-Tembaro	Hiniba	33.00	Welde-Michael *et al.*, 2008
Kembata-Tembaro	Sorpie	33.00	Welde-Michael *et al.*, 2008
Kembata-Tembaro	Dirbo	35.00	McKnight, 2013, Annual report
Kembata-Tembaro	Onjamo	18.75	McKnight, 2013, Annual report
Sheka	Nobo	6.70	Haile *et al.*, 2014
West & Southwest Shewa	Badadiat	34.26	Hunduma *et al.*, 2015
West & Southwest Shewa	Hiniba	30.18	Hunduma *et al.*, 2015
Wolaita	Halla	33.00	Welde-Michael *et al.*, 2008

2012). Bezuneh and Feleke (1966) suggested variations in fibre quality, depending on the landrace. Enset fibre is used for different social and cultural purposes (Bezuneh, 2012), including the fabrication of ropes (*e.g.*, for house construction and tethering domestic animals), house mats and woven sacks. The importance of fibre was demonstrated during a recent farming system study of eight ethnic groups where more than 40 landraces were identified for fibre use (Yemataw *et al.*, 2016a). Farmers also ranked the production of high-quality fibre as a very important cultivar selection criteria (Olango *et al.*, 2014).

Evaluation of enset landraces for host reaction to pests and diseases

Enset is plagued by a number of disease threats, including several bacteria, nematodes, fungi, and viruses. The most serious of these constraints is bacterial wilt disease, caused by *Xanthomonas campestris* pv. *musacearum* (Yirgou and Bradbury, 1968; Ashagari, 1985; Quimio, 1991; Quimio and Tessera, 1996; Welde-Michael, 2000). Ashagari (1985) reported that none of the landraces screened showed complete resistance to Xanthomonas wilt. Table 3 depicts the variable levels of response to Xanthomonas wilt depending on the landraces under farmers' field conditions and using artificial inoculation in on-station trials (Spring *et al.*, 1996; Welde-Michael, 2000; Welde-Michael *et al.*, 2008; McKnight, 2013; Haile *et al.*, 2014; Hunduma *et al.*, 2015). For example, disease symptoms have been shown to develop with variable intensity on a large number of landraces tested by Welde-Michael *et al.* (2008). Some landraces, such as 'Maziya', showed a relative tolerance to the disease (Handoro and Welde-Michael, 2007; Welde-Michael *et al.,* 2008). Yemataw *et al.* (2014b) reported that farmers preferred 'Maziya' and 'Gena' because of their perceived resistance to Xanthomonas wilt.

Mulualem and Walle (2014) carried out household surveys in the Doyogena district of the Kambata Tembaro zone of south Ethiopia and obtained farmers' feedback on 29 enset landraces regarding susceptibility or tolerance to the enset root mealy bug (*Cataenococcus ensete*). Scores ranged from 1 to 3 which indicated variation in susceptibility/tolerance across the landraces. Kefelegn *et al.* (2014) assessed the variability in host reaction to the enset root mealybug for 7 enset landraces and reported that only the farmer-preferred enset landrace 'Genticha' had a mild tolerance to the enset root mealy bug. Additional trials are needed to assess, on station or on farm, the level of susceptibility/tolerance of a wide range of enset landraces to this soil-borne pest.

Few other studies have examined response of enset landraces to pests and diseases. Bogale *et al.* (2004) observed large differences in the densities of *Pratylenchus goodeyi* extracted from roots of different landraces sampled in farmers' fields, suggesting that there may be inherent differences in susceptibility among them.

Research and knowledge gaps, and future directions

Enset is characterized by a high genetic diversity, due to farmer cultivation/management for thousands of years. Enset landrace diversity provides resilience and food security despite challenging environmental conditions. Management of enset landrace diversity is a dynamic process, with much exchange between regions due to changing food preferences, climate, pests and diseases, cultivation systems, and infrastructure. However, farmers have also lost landraces to diseases, abiotic selection pressures, or changes in land use systems.

Several research gaps need to be addressed in order to improve the long-term conservation of this diversity: 1) development of a taxonomic key and descriptor list to characterize enset diversity; 2) seed collection, research on seed morphology, germination and survival/storage methods of seed, and *ex situ* conservation of enset seeds from domesticated and wild relatives; 3) expansion of the existing field gene bank at AARC, in combination with appropriate biotechnological approaches, such as the use of improved tissue culture methods, rapid propagation and distribution of planting material; 4) varietal screening programs to identify possible sources of resistance or tolerance to the most common biotic (*e.g.*, Xanthomonas wilt of enset and the enset root mealy bug) and abiotic (*e.g.*, drought stress and low soil fertility stress) constraints; 5) improved exploitation of the industrial potential of enset-derived starch and fibre; and 6) expanded enset improvement/breeding efforts at AARC, using the vast diversity in cultivated and wild enset genotypes.

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