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TRENDS AND GAPS IN ENSET (*ENSETE VENTRICOSUM* (WELW.) CHEESMAN RESEARCH

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ABSTRACT: Enset is a multipurpose crop that supports the livelihood of 20 million people. Enset starch is also used for paper, textile, adhesive industries and pharmaceuticals in tablet formulation as a binder and disintegrant. However research and extension on the crop was given attention recently. It was only in the 1970s that enset research, begun focusing on enset clone collection, evaluation for food, fiber, and maintenance of germplasm. This was followed by agronomic studies on the effect of traditional management methods such as transplanting, spacing and leaf pruning on dry matter production, food production and harvest indices. Some ecophysiological studies revealed that drought tolerance in enset was attributed to osmotic adjustment and improved water extraction through altered biomass partitioning. Currently, serious attention is given to the threat of enset bacterial wilt to enset cultivation. Consequently, research activities on the use of medicinal plant extracts and other bio-control agents and methods against bacterial wilt pathogens, and selection of disease resistance varieties have been initiated through coordinated multidisciplinary research to alleviate the problem of enset bacterial wilt. Despite the relatively better research attention given to enset in the past two decades, as compared to the previous ones, there are still several research gaps that need to be addressed. It is recommended that establishing a national database on enset research with periodic bibliographic publication; creating a clone collection centre; developing a prioritized enset research agenda and creating a National Enset Research Institute is of paramount importance. This will ensure the sustainable production of the crop for food security, income generation, agro-industry development and environment sustainability.

Key words/phrases: Agronomy, Ecophysiology, Enset bacterial wilt, Enset diversity, Osmotic adjustment.

INTRODUCTION

Enset is a multipurpose traditional crop widely cultivated in south and southwestern Ethiopia. The crop is embedded into the tradition of the people. It feeds approximately 20 million people in the country (Temesgen Magule *et al*., 2014). The crop has a number of desirable qualities which makes it superior to many other crops as a reliable crop in a population

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facing food insecurity. For instance, enset gives the highest yield per unit area and thus supports the densely populated areas in the south of the country (Admasu Tsegaye and Struik, 2001). Enset foods can be stored for long periods. The crop performs better than other crops even without the use of costly agricultural inputs. Furthermore, although the crop has long maturity time, it can be harvested before it attains maturity, allowing enset growers to surmount periods of food shortage (Admasu Tsegaye, 2002; Dereje Fekadu, 2009). Enset also grows in a wide range of altitudes extending from about 1200 to 3100 meters above sea level which means that farmers can expand the cultivation of the crop in all parts of the country including areas not suitable for cereal cultivation. Despite all these qualities, the crop received very little research attention in the past as compared to cereals. Nevertheless, significant advances have been made in recent times that are encouraging. The objective of this contribution is to review past and current research activities in enset agriculture and to explore areas that require immediate research attention.

PAST AND CURRENT RESEARCH TRENDS

Enset research started in the 1970s during which time clone collection, evaluation of the value of the crop for food and fiber, its agronomic traits and maintenance of germplasm were the main focuses (Seifu Gebremariam, 1996). During this period, 163 clones were collected, of which 103 and 60 were established at Holetta and Debre Zeit (Bishoftu), respectively. Clones with long pseudostem and large corms were found to be appropriate for fiber and food, respectively (Seifu Gebremariam, 1996). In 1976, enset clone collections were transferred to Wolaita Sodo with the establishment of Areka Enset Research Centre, in 1986 with the objective of collection, evaluation and germplasm maintenance research. However, this site was closed in 1981/82 (Terefe Belehu, 1996). Since then, research has been extended to address the other aspects of the crop with outstanding findings.

Several researches have been conducted about the influence of traditional crop management methods on dry matter and food production, and Kocho yield under different crop establishment methods were undertaken on limited enset clones (Admasu Tsegaye and Struik, 2001). Furthermore, Admasu Tsegaye (2002) made studies on characterization and diversity of enset, harvest indices, harvest and postharvest losses over the years. Admasu Tsegaye (2007) also showed that repetitive transplanting decreases total plant dry matter yield per unit area. This practice increases dry matter partitioning to harvestable parts such as pseudostem and corm. Unlike

transplanting, leaf pruning had insignificant effect on total dry matter production and partitioning.

Investigation into the nutrient status (Asnaketch Woldetensaye, 1997) of enset farming systems and nutrient balance therein (Tilahun Amede and Mulugeta Diro, 2005; Amare Haileselassie *et al*., 2006) showed that enset fields have a higher organic matter, nitrogen and phosphorus levels with significantly higher positive balances than cereal systems such as teff because of the possible use of enset litter as source of organic matter and mulch (Asnaketch Woldetensaye, 1997). These works implied that enset productivity can be sustained by implementing management practices that reduce nutrient loss from the system such as piling the manure and other household refuse between enset plants in an open air and applying at the surface. Cultivation of clones with higher nutrient use efficiency has also been recommended (Ferew Kebede, 2012).

Cultivation of enset has a long history with a strong cultural entrenchment with people of the different ethnic groups especially in south Ethiopia. An Ari ritual specialist explained the cultural entrenchment as: "We and enset have a long history of relatedness. We rely on it and it relies on us for survival. This means we cannot live without it and it cannot live without us either; we are created to support each other" (Gebre Yntiso, 1996). Each ethnic group has its own enset clone selection criteria, management practice and use preferences (Zippel and Ludder, 2005). It is also linked with a gender issue whereby men propagate plant and replant and women solely do harvesting by forming a small working group of friends and close relatives. Under the circumstances, efforts have been made to improve enset processing tools and minimize the labour burden of women. This shows that enset also strengthens the social interaction (Sandford and Helen Kassa, 1996; Spring, 1996). Moreover, hundreds of enset clones have been documented and characterized on the basis of phenotypic and molecular techniques (Endale Tabogie, 1997; Almaz Negash *et al*., 2002). According to Endale Tabogie (1997), enset clones have been grouped into 29 classes based on resemblance in colouration pattern (pseudostem, petiole and midrib) or presence of slight name variation suggesting that pseudostem, midrib, petiole and midrib are important parts that need to be exploited for diversity studies. A baseline survey by SARI (2013) enumerated a total of 440 cultivar names in eight enset growing administrative zones in Ethiopia. The number of cultivars in each zone was 75 (Dawro), 26 (Gedeo), 63 (Gurage), 51 (Hadiya), 66 (Kembata-Tembaro), 62 (Sidama), 69 (Silte) and 28 (Wolaita). However, this number was reduced to 312 after known

synonyms were replaced with distinct names.

Zerihun Yemataw *et al.* (2014) reported a total of 278 clones with distinct names from seven enset growing zones. Hadiya was the richest zone with a total of 59 clones followed by Kembata (43), Dawro (42), Wolaita (39), Gamo Gofa (34), Gurage (31) and Sidama (30). In a previous study, Admasu Tsegaye (2002) described 146 different enset clones from Sidama, Wolaita and Hadiya zones. Similarly, Almaz Negash (2001) recorded 146 different enset clones from four zones (65 from Kefa-Sheka, 30 clones from Sidama, 45 from Hadiya and 6 from Wolaita). In all the studies, duplication of names was reported in that the same enset clone was given different names in different areas and different enset clones were given the same name at different localities.

Despite the large variation in agro-ecological conditions among enset growing areas, amplified fragment length polymorphism (AFLPs) studies revealed that only 4.8% of the total genetic variation was found between regions and 95.2% within regions or populations (Almaz Negash *et al*., 2002). This may be explained by regular long distance exchange of clones and the existence of substantial levels of phenotypic plasticity in enset due to changing weather and soil conditions (Almaz Negash *et al*., 2002; Zippel and Ludder, 2005).

Genet Birmeta *et al*. (2004) studied 111 enset clones from nine enset growing areas of Ethiopia using Random Amplified Polymorphic DNA (RAPD) molecular methods, and suggested that the current cultivated enset clones had been introduced for domestication from a limited number of wild progenitors. They showed that the genetic diversity in cultivated enset in a particular area appeared to be related to the extent of enset cultivation, the culture and distribution pattern of the different ethnic groups than geographical distance. However, subsequent gene flow between wild and cultivated enset may have been inhibited by differences in modes of propagation and harvesting time. In cultivated enset, genetic diversity within populations was high (Dagmawit Chombe and Endashaw Bekele, 2011).

Enset has a genome size of approximately 547 megabases, similar to the 523-megabase genome of the closely related banana (*Musa acuminata*). Additionally, enset contains genes that are absent in banana. These include reverse transcriptases, virus-like sequences and a homolog of the RPP8-like resistance gene indicating the large gene pool in the species that could be utilized for improvement of the crop (Genet Birmeta *et al.*, 2004; Harrison *et al*., 2014). Although enset reproduces predominantly by vegetative

means, several investigations were carried out to develop alternative propagation techniques using modern biotechnological approaches (Tilahun Zeweldu and Ladders, 1998; Mulugeta Diro, 2003). Currently, protocols are in place for *in vitro* regeneration, micro-propagation (Almaz Negash *et al*., 2000) and *in vitro* conservation of enset under slow growth conditions (Almaz Negash *et al*., 2001). The micro-propagation of enset shoot tip culture rapidly produces large numbers of clonal plantlets that are free from pathogens (Almaz Negash, 2001). Tissue culture is also used to propagate new genotypes and/or specific pathogen-tolerant clones to deliver genes carrying desirable traits from another species to enset so as to develop tolerance in enset to different environmental factors including enset bacterial wilt.

In another development, enset growth, biomass accumulation and physiology have shown temporal variations which may be explained by the seasonal dynamics in precipitation, temperature and radiation. In relation to precipitation, drought stress induces accumulation of solutes (Solomon Zewdie *et al*., 2008) and alteration of biomass partitioning whereby more photosynthate is partitioned to belowground parts. These are adaptive responses to cope with the prevailing stress conditions. Moreover, Admasu Tsegaye and Struik (2003) reported yield differences between enset clones that were attributed to radiation use efficiency.

Several research activities were conducted on the nutritive value of enset products. Accordingly, the chemical composition of enset dry matter as whole plant was 90.87% organic matter and 9.13% ash. The organic matter was composed of 5.98% crude protein, 0.84% crude fat, 9.48% crude fibre and 74.57% carbohydrates (Mohammed *et al*., 2013). The unprocessed corm of enset was found to be rich in calcium (Ca), magnesium (Mg), potassium (K), zinc (Zn), and iron (Fe) (Ayalew Debebe *et al*., 2012; Sirawdink Fikreyesus *et al*., 2013). Processed forms such as Kocho and Bulla were rich in calcium (Ca) and zinc (Zn) compared to other similar food stuffs and contained comparable concentration of copper (Cu), iron (Fe) and manganese (Mn).

These products were free from heavy metal contaminants such as cadmium (Cd) and lead (Pb) (Minaleshewa Atlabachew, 2007). In addition, Amicho (boiled corm) had higher total phenolics content next to teff and corn (Sirawdink Fikreyesus *et al*., 2013). Moreover, Yewelsew Abebe *et al.* (2006) reported the presence of histidine (2.06), isoleucine (4.12), leucine (7.56), lysine (5.50), methionine+ (3.44), phenylalanine+ (6.78), threonine

(2.75), tryptophan (2.75) and valine (5.50) g/100 g of protein. Enset food products are generally poor in their protein content and thus enset dishes are always supplemented with animal products (Mohammed *et al*., 2013). Studies on genetic engineering to increase the protein content of enset to add value to the crop was minimal.

Industrially, enset starch is used for various applications. Several studies reveal that enset starch has amylose content with granule size, x-ray diffraction pattern and gelatinization temperature comparable to potato starch, which is commonly used in pharmaceutical applications (Abraham Wondimu *et al*., 2014). Tsige Gebre-Mariam and Nikolayev (1993) also reported that enset starch can be used both as a tablet binder and disintegrant possessing a better binding ability and less disintegrating power than potato starch. It is also used as gelling agent. The cross-linked and acetylated form of enset starch shows its potential use as a novel drug delivery system (Abraham Wondimu *et al*., 2014). Furthermore, the squeezed and dehydrated product of enset (Bulla) is used as a gelling agent substituting agar for *in vitro* propagation. According to Biruk Ayenew *et al*. (2012), dried Bulla could be used as a gelling agent to produce an equivalent number of shoots, roots, leaves, shoot height and associated fresh weight of pineapple plantlets compared to the use of agar as medium.

Of all environmental factors, enset bacterial wilt (EBW) caused by *Xanthomonas campestris* pv. *musacearum* (Xcm) (Dagnachew Yirgou and Bradbury, 1968; 1974), is the most important constraint to enset cultivation followed by drought (Solomon Zewdie *et al*., 2008). The pathogen also affects banana. Once established, the disease is difficult to control owing to the lack of an effective chemical or other curative treatments. Currently, a phytosanitary approach of the destruction of diseased plants has been suggested as the only option to control the disease (Biruma *et al*., 2007). The most attractive strategy for bacterial disease control in crops is to improve their natural defense mechanisms against a pathogen (Biruma *et al*., 2007). Related to this, research results have shown that induction of resistance can reduce disease incidence by 20-85% (Walters *et al*., 2013). In banana, researchers have been successful in producing bacterial wilt resistant banana varieties using transgenes encoding for plant ferredoxin-like protein (pflp) (Namukwaya *et al*., 2012) and hypersensitive response assisting protein (hrap) (Tripathi *et al*., 2010) isolated from sweet pepper (*Capsicum annum*). These are novel plant proteins that can intensify pathogen mediated hypersensitive response (Tripathi *et al*., 2010; Namukwaya *et al*., 2012).

Although there had been early efforts to find alternative methods of controlling the bacterial wilt of enset, most of them were focused on characterization of the virulence of the pathogen and screening for enset clone resistance against Xcm (Kidist Bobosha, 2003; Gizachew Wolde-Michael *et al*., 2008; Tariku Hunduma *et al*., 2015; Mekuria Wolde *et al*., 2016). These researchers identified several resistant and susceptible enset clones to Xcm in different areas. Moreover, some studies also showed the antibacterial activity of medicinal plant extracts against Xcm (Kidist Bobosha, 2003; Daniel Kasa and Getaneh Woldeab, 2015; Getahun Yemata, 2016) and some promising *in vitro* effect on the pathogen (Getahun Yemata and Masresha Fetene, 2016).

In enset, inducing plants of a susceptible clone with the crude leaf extract of a medicinal plant reduced disease incidence by 33% showing the prospect of the technique to control the disease. Induction of resistance was inferred from the higher activity of phenylalanine ammonia lyase, peroxidase, polyphenol oxidase and increased concentration of total phenolics in extract induced enset plant (Getahun Yemata and Masresha Fetene, 2016).

RESEARCH GAPS

Although enormous research efforts have been exerted on different aspects of enset, a lot remains to be done to maintain its sustainability. Despite the large variation in agro-ecological conditions among enset growing areas, molecular studies revealed that only 4.8% of the total genetic variation was found between zones and 95.2% within zones or populations (Almaz Negash, 2001; Almaz Negash *et al*., 2002). Thus, the cultural, social and economic basis of this variation, as well as advantages and disadvantages of the different traditional practices of each ethnic group need to be investigated (Admasu Tsegaye, 2002).

To that end, research should be conducted on the selection criteria, management practices and use preferences of enset by different ethnic groups in order to conserve enset diversity for sustainable utilization of the crop. It was found out that the net rate of manure mineralization was rapid at the initial period of incubation, application of manure close to transplanting and immediate incorporation into the soil was highly recommended (Ferew Kebede, 2012). Since the rate of mineralization depends on climate, soil and the enset clone, studies should be undertaken in specific areas. There is also a dearth of information on the nutrient use efficiency of enset clones that require compulsory screening studies (Ferew Kebede, 2012). Furthermore, enset clones showed variations in their growth and yield performance under

different environmental conditions. Consequently, there is need for studies on growth requirements and yield determining factors of the clones under different agro-ecologies to single out promising clones (Solomon Zewdie *et al*., 2008).

Drought tolerance in enset has been reported to be due to osmotic adjustment and improved water extraction through altered biomass partitioning. However, due to the high enset clonal diversity, many more screening studies are required to search for more physiological traits of the clones that confer their tolerance to low moisture stress and water use efficiency. Moreover, studies on the interactive effects of multiple environmental factors on the growth and yield of enset, and intercropping with diverse crop species as well as landrace mixtures are all the more important in order to advance the production system and increase productivity per unit area (Admasu Tsegaye, 2002; Solomon Zewdie *et al.*, 2008).

In spite of the achievements in micropropagation, *in vitro* regeneration and *in vitro* conservation of enset (Almaz Negash, 2001), many more studies should be conducted on optimization of the protocol and hardening of the plantlets under glasshouse and field condition (Almaz Negash, 2001). With respect to the industrial application of enset products, there have been good beginnings to see the potential use of enset starch in tablet formulation as a binder and disintegrant (Tsige Gebre-Mariam and Nikolayev, 1993; Abraham Wondimu *et al.,* 2014). However, more remains to be done to exploit the huge starch (60%) content of the crop and the strong enset fiber for a variety of purposes.

Several trials have been made by different research groups to improve labour intensive and unhygienic enset processing tools. Not much success has been achieved in this respect as women still use traditional processing tools. The problem might be lack of awareness among enset farmers about the few available tools, low accessibility of the improved tools and inadequate research on the subject. Therefore, researches should be conducted that are geared towards producing affordable and easy to manipulate tools with the active involvement of women.

Currently, the most critical problem in enset cultivation is enset bacterial wilt. Thus, organized researches need to be carried out on screening of medicinal plant extracts, evaluation of application methods and integrated management strategies. Moreover, the role of other biocontrol agents such as arbuscular mycorrhizal and Trichodermal fungi should also be evaluated.

Researchers have been successful in producing bacterial wilt resistant banana varieties using transgenes. Since the pathogen is the same, genetic engineering studies to develop enset clones resistant to Xcm should be conducted at a large scale.

Despite the relatively better research attention given to enset in the past two decades, as compared to the previous ones, there are still several research gaps that need to be addressed. It is recommended that establishing a national database on enset research with periodic bibliographic publication; creating a clone collection centre; developing a prioritized Enset research agenda and creating a National Enset Research Institute is an urgent requirement. This will ensure the contribution of enset production to food security, income generation, agro-industry development and environment sustainability.

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