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Status of Roots, Tuber and Corm Crops Research and Development in Ethiopia

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Abstract

Over the last four decades research priorities was given to a number of root, tuber and corm crops at both regional and national levels. Studies have shown that on food production impact simulation study indicated, root, tuber and corm crops will constitute more than 40% of food security of Sub Saharan Africa by the year 2020 provided combination of more productive technologies and enabling policy environment do prevail particularly to enhance the production and productivity of theses crops. New approaches such as breaking the "grain mentality" by promoting the root and tuber crops as an essential diet for human being must be given attention. The diverse agro-ecologies that exist in Ethiopia allow the production of root tuber and corm crops. Despite the suitable environment of the country, the cultivation and productivity of these crops are low as compared to most of the sub-Saharan countries. Expanded potato research and improvement since 1970 improved average yield from 5 to 8 tons per hectare. Low yields of potato are the consequence of multiple factors, including the use of unproductive, highly disease susceptible varieties subject to rapid degeneration by viruses, and limited use of sustainable integrated crop management (ICM) practices in potato cropping systems.

Introduction

Three decades ago Ethiopia's national potato area was estimated at 30,000 hectares reaching 160,000 hectares by 2001 (Gebre Medhin et al., 2001). These low yields are the consequence of multiple factors, including the use of unproductive, highly susceptible varieties subject to rapid degeneration by viruses, and limited use of sustainable integrated crop management (ICM) practices in potato cropping systems(Gebremedhin et al. 2006). Emphasis on the production of root, tuber and corm crops (potato, enset, sweet potato and cassava) will play a significant role in alleviating the recurrent food shortage in the country. Besides solving the food insecurity, the cash income of the poor farmers will be boosted through scaling up of improved cultivars of these crops. These crops, potato, enset, sweet potato and cassava are underutilized in Ethiopia with a high potential to contribute in alleviating food insecurity and improved nutrition (Table 1). Potato, traditionally an important food and cash crop in the highlands, is becoming an increasingly favored food in urban areas due mainly to the growing number of fast food industries and hotels. The potato is a balanced food with a high yielding potential of energy and high quality protein, whose biological value is next to that of eggs and has a high lysine content which is deficient in cereals. It is also rich in vitamin C and minerals. The Enset Farming System (EFS, here after) is among the backbone of Ethiopian agricultural economy. The crop accounts for the basic Livelihood from 16 to 18 % of Ethiopian Population.

As basic diet for millions people at various agro-ecologies, EFS has much influenced the development of rich and diversified cultures in the South and South-Western Ethiopia. The incidence of bacterial disease has threatened the enset agriculture to great extent (Daghachew et al. 1968, Dereje 1980). Fungus diseases such as *Fusarium oxysporum* that also threatened the enset agriculture in the 1970's has been the major occupation of research.

Over the last two decades, enset research has advanced in the identification of high food and fiber yielding enset cultivars. Research findings over five decades ago showed that enset and abaca fiber have similar strength and quality standard. The Philippines in particular used the abaca *(Musa teitalis)* fiber to expand its manufactured industrial product that also attracted export markets to Europe, North America and other countries. Regardless the research findings (five decades ago) that the enset fiber is of high quality and similar standard to that of abaca fiber, very limited industrial manufacturing did take place in Ethiopia due to lack of innovations by both the public and private sectors.

Table 1. Climatic Adaptation of Major Root, Tuber and Corm Crops in Ethiopia

Scientific Name	Common name	Altitude (M)	Annual Rainfall (MM)	Temperature. Range(0c)
Ensete ventricosum	Enset	1500—2850	700-1200-	16-26
Ipomoea batatas	Sweet Potato	1400-2000	550-800	18-27
Colocasia esculenta	Taro	1400-1900	600-850	20-27
Dioscorea abyssinica	Yam	1300-1900	500-800	22-27
Coccinia abyssinica	'Anchote'	1500-2000	700-1200	20-25
Solanum tuberosum	potato	1400-2000	550-800	18-35

Source: Westphal 1975

Technology Generation and Delivery

Potato *(Solanum tuberosum)*

Food insecurity is increasing in Ethiopia with 55% of the farmers reporting that their total annual harvest is insufficient to maintain the family for more than six months. At least seven million people require food aid per year. Efforts to address the problem through grain-led approach (cereals predominating) did not avert the problem. Underlying causes of food insecurity are the rapidly increasing population pressure, widespread environmental degradation, recurrent drought, low productivity of the agricultural sector and limited market access. Although the country has abundant resources and good potential for development, poverty is pandemic due to the above factors. New approaches such as breaking the "grain mentality" by promoting the root and tuber (RT) crops as an essential diet for human beings must be given attention. On top of this, the root and tuber crops can also serve as sources of cash income for low-income farm households and raw material for processing Food products for both rural and urban consumption.

The diverse agro-ecologies that exist in Ethiopia are suitable to produce various root and tuber crops. Despite the suitable environment of the country, the cultivation and productivity of root and tuber crops are low as compared to most of the sub-Saharan countries. Ethiopia faces a huge food deficit, which may be due to drought that seems to occur every other two to four years. Much of the food deficit could be avoided if root and tuber crops were widely cultivated with adequate agronomic practices, as they have a high productivity potential. Most of the root and tuber crops have tolerance to drought. The present in-adequate use of root and tuber crops could be attributed to many factors, such as low investment in research, extension and training of farmers on the utilization of these crops. (Gebre Medhin *et al* 2008).

No country in sub-Saharan Africa has experienced a faster growth in potato production area than Ethiopia. The area under potato cultivation is increasing at an average annual rate of 15%. As in most developing countries, the growth in production of root and tuber crops was brought about by an expansion in acreage rather than productivity. Three decades ago Ethiopia's national potato area was estimated at 30,000 hectares, approaching 50,000 hectares by the mid 1980's, and 160,000 hectares by 2001 (Gebre Medhin *et al.*, 2001). Yet, during this same period average yields have only increased by 3 tons per hectare, from 5 tons per hectare in 1975 to 8 tons at present. These low yields are the consequence of multiple factors, including the use of unproductive, highly susceptible varieties subject to rapid degeneration by viruses, and limited use of sustainable integrated crop management (ICM) practices in potato cropping systems.

The potential of potato for improving smallholder livelihoods in Ethiopia is tremendous. The high potential of potato for improving food security, increasing household income and consequent poverty reduction is a result of:

a) The crop's high relative yield and output of carbohydrates, proteins and essential minerals (even under current inadequate management),
b) Increased urban demand for highly valued potato (for fresh consumption and processing),
c) Dynamic demographics including increased population size, subsequent decline in average farm size and consequent agricultural intensification for high per-area output.

The rapid increase in potato area, a trend that is autonomously fuelled by farmers without major outside incentives, reaffirms the promise of potato. Realizing the growing importance of the crop, the government of Ethiopia established a national potato research program in 1975 under the auspicious of the Ethiopian Institute of Agricultural Research (EIAR). Potato research has been promoted to a project level. Strategic plan has been developed and high thematic research areas were identified targeting the major potato production problems. A

Therefore, there is a strong need to improve existing seed systems to increase farmers' access to quality seed at affordable prices and in a timely manner.

The informal system exists in all potato growing areas of Ethiopia, and is the major seed potato system. According to Gildemacher et al. 2009b, informal seed system supplies 98.7% of the seed tubers required in Ethiopia. The seed tubers used for planting are sourced through an informal system and include planting materials derived from farmers' own fields, saved from previous harvest, local markets or neighbors. The seed tubers supplied by this system is known to be relatively poor in quality, in terms of seed size, sprouting, physiological age, varietal purity, disease and pest damage. This practice has contributed to the build-up of high level of viral and tuber-borne diseases in the locally grown cultivars. Farmers practice saving of potato tubers from previous season was one of the reasons for carry-over of devastating diseases like bacterial wilt, viral and other seed borne pathogens which contributed for low potato yield. A survey report by Gildemacher *et al*, 2009b indicated that half of the potato farmers in Ethiopia leave their produce in the soil that will later be used as seed. This apparently is the method some farmers prefer to store seed potatoes until the next season.

Agronomy and Crop Management Practices

The poor agronomic practices prevailing in most potato production areas are some of the factors that contribute to low average yields. For some time, agronomic aspects of potato production were studied. An enhanced yield gains have actually been a result of such research. Standards were set for seed-bed preparation, type of seed/planting material (Quality and size), planting methods, crop density and suitable planting dates. Fertilizer requirements and method of application for potato at different agro-ecologies were also recommended. However, the wide utilization of these crops at various locations and soil type, require different agronomic practices for their optimal production. Therefore efforts must continue to study and find agronomic recommendations for the new varieties that are being developed and to be developed. Agronomic practices like planting date, soil moisture, friability and fertility status remarkably influence crop emergence, the onset and area increase of leaves, canopy development and subsequent performance of the plant (Berga et al., 1994a, 1994b). The nature of the potato crop has to depend much on these factors that affect interception of radiation and efficiency of conversion of intercepted radiation to carbohydrate or dry matter.

There is considerable room for improvement agronomic practices in most of the potato growing areas of Ethiopia. The agro-ecologies where farmers thrive to grow potato are characterized by diverse conditions. They vary considerably in soil type, moisture and temperature regimes, fertility conditions, and in the on-set, intensity and duration of rain. Therefore, crop management operations have to take into account all these differences to ensure high yield levels. In general, the poor crop management practices observed in most farmers' fields include the use of too low or too high plant density, absence of row planting, poor quality seed material, inappropriate land preparation, time of planting, fertilizer application, depth of planting, ridging, harvesting techniques and crop rotation.

Time of Planting

Along with the development of improved varieties, studies were also candidate to determine the optimum planting date at different parts of the country. Based on the studies the studies it was recommended that early June is the optimum planting time for Holeta/ Emdibir and other similar areas. At Adet, planting date was determined using two varieties with different reactions to late blight. Planting from 1 to 15 May and from 15 May to 1st June are recommended as optimum dates, respectively, for planting late blight susceptible and moderately resistant potato cultivars. At Ankober planting at the end of May to early June gave better mean tuber yield.

Key Biotic Stresses and their Management

Potato is prone to many diseases caused either by bacteria, fungi, viruses or mycoplasma and many insect pests like cutworms (*Agrotis* spp. and *Euxoa* spp.), red ants (*Dorylus* spp.), green peach aphid *(Myzus persicae)* and the potato tuber moth, *Phthorimaea operculella* (Zeller) among which the potato tuber moth received more attention.

Viruses are the major constraints in potato seed production worldwide occurring wherever the potato crop is grown. They received particular attention in seed certification schemes because they cause degeneration whereby they accumulate in successive generation via seed tubers and result in diseased plants that produce progressively smaller tuber yield. When farm saved seed potatoes are used for several cropping cycles, without renewing the seed, seed-borne diseases cause severe yield and quality losses. This process of yield loss over seasons of seed recycling is generally called degeneration, and can be attributed to the accumulation of seed borne diseases.

Integrated disease management (IDM) procedures had been recommended for late blight disease of potato. The key point in this approach is the integration of reduced fungicide usage with disease resistant varieties. The other components include adjusting planting date, sanitation measures, adoption of suitable rotation with non-host crops for pests and use of clean seed. Considerable research has been done on bacterial wilt management at Ambo and Holetta research centers in collaboration with the International Potato Center. Reaction of various clones to bacterial wilt has been studied; and no source of resistance appears to be available so far. Other aspects of IDM for bacterial wilt had also been studied including effect of rotation and soil fertility on occurrence and seventy of the disease.

Current Level of Technology Transfer and Scaling up of Successful Technologies on Potato

Much has not been done to extend the available technologies to end-users. However, there are on farm trials and pre-scaling up activities in collaboration with MOA, NGOs and farmers, mainly on potato and sweet potato, the main objectives of these activates are (i) to disseminate the technologies closer to farmers (ii) to involve farmers in evaluating research results for easier adoption and (iii) to bring together the different stakeholders. For example the potato varieties such as, Jalene, and Gudenie were widely distributed through participatory evaluation.

The farmer field school (FFS) was implemented from 2000–2007 in collaboration with CIP. It was found to be an appropriate method for participatory training, research and dissemination of technologies. This approach had increased knowledge of farmers' and promoted un understanding of particularly potato diseases and pests and their management practices.

Potato has the potential to produce far greater amounts of food per unit area and time than grain crops and this to making it an ideal crop for food security interventions. Furthermore, urban demand for table and processing potato varieties is increasing rapidly, providing new opportunities for farmers to increase their incomes through potato sales. The demand for quality potato seed is also very high, but still unattended. The potential of potato for improving smallholder livelihoods in Ethiopia is tremendous, but largely ignored by the development community. Yet, the Ethiopian government, recognizing this potential, has put favorable policies in place towards decentralized and intensified dissemination of potato technology. Realizing the growing importance of the crop, the government of Ethiopia established a national potato research program in 1975 under the auspicious of then Institute of Agricultural Research (EIAR) and the Alemaya college of Agriculture. Potato research has been promoted to a program level. Strategic plan has been developed and high thematic research areas were identified targeting the major potato production problems. A considerable amount of budget has been allocated annually for its research and development.

Packages of new technologies that include high yielding and resistant varieties, agronomic and disease best management practices and post harvest technologies were developed. Moreover, trainings were given to potato growers and development workers in the major potato growing areas.

Significant achievements have been attained in the past mainly in variety development, integrated pest management, generation and dissemination of information on production of healthy seed tubers using the informal seed system. Not all the technologies indicated have been widely distributed and implemented by farmers due to the very limited current capacity of the seed system in Ethiopia. Nevertheless, through consistent on-farm technology demonstration that was integrated with training of farmers and seed growers, several improved varieties have been disseminated in different potato growing zones of the country. From the use of these improved technologies, farmers have been able to get considerable economic benefit and impacts in their lives and livelihoods. The most important benefit from these technologies, as indicated by the farmers themselves, has been the possibility of growing the potato crop during the main rainy season, which was a key challenge to production due to the detrimental effect of the late blight disease.

Post-Harvest Handling, Storage, and Marketing

Post-harvest management in potato or any other crop is a set of operations and functions between crop production and consumption. Potato is inherently perishable crop. During the process of harvesting, storage, distribution and marketing, substantial losses are incurred which range from a slight loss of quality to substantial spoilage. Post-harvest losses may occur at any point in the marketing process, from the initial harvest through assembly and distribution to the consumer. The causes of losses are many: physical damage during handling and transport, physiological decay, water loss, or sometimes simply because there is a surplus in the marketplace and potatoes are kept longer under inconvenient condition for some time (Endale et al, 2008). In Ethiopia, it is estimated that there is very high post-harvest losses for fruits, vegetables, roots and tuber crops that sometimes reaches as high as 50% (Solomon 1987).

Estimates of the production losses in developing countries are hard to judge; but some estimate the losses of potatoes, sweet potatoes, plantain, tomatoes, bananas and citrus to be very high. About 30–50% of the total produce (1.3 million tons) is lost after harvest. Globally, horticultural crops postharvest losses have been reported at 19% for the USA which is equivalent to an estimated annual loss of $18 billion. Higher losses have been reported for African countries ranging between 15%–30% of the harvested product.

Post-harvest losses are mainly caused by different physical, environmental and biological factors which include mechanical injuries, extreme temperatures and pathogens. The causal factors promote post-harvest losses through changes in the chemical composition and physical properties of the tuber in the process of respiration, loss of moisture from the tuber, sprouting, and spread of diseases. In the light of the little information generated on the major factors of post-harvest losses in Ethiopia, some of the principles in post-harvest management and the basic environmental and physiological causes of post-harvest loss are discussed as below.

In Ethiopia potatoes are basically stored for two reasons: ware and seed. Farmers use different traditional potato storage system depending on the use. However, these storage facilities are not proper to keep the quality of tuber for more than 1–2 months. As a result, farmers are forced to sell their potatoes at low prices during harvest. They buy seed potatoes at a very high price at planting. Some farmers store seed potatoes either in burlap sacks or in dark rooms, which result in the formation of long and etiolated sprouts that break easily while handling and during planting. Storing seed potatoes in diffused light stores (DLS) results in the formation of shorter and sturdier sprouts than storing in the traditional dark storage method or in burlap sacks. Potato seeds stored in DLS have better emergence, more uniform growth and better plant establishment, resulting in higher tuber yield than seed stored in the traditional storage.

The effect of direct sun and radiant heat on the storage interior should be avoided by including resistance to these effects so that the desired cool condition is maintained. This is because consumption potatoes (ware potatoes) must be kept in dark to prevent greening of tubers.

Crop Utilization Including Processing and Value Addition

In Ethiopia most of the potato produced is consumed as boiled potato and frequently prepared in local dishes sauced or mixed with other vegetables and spices. The per capital consumption of potato in Ethiopia is probably the lowest in Africa (Endale *et al*, 2008).The main reasons for the low consumption of potato may be due to insufficient supply of consumption potatoes throughout the year poor post-harvest handling and supply, unavailability of processing industries, lack of improved varieties with appropriate processing quality (chips, crisps, dehydrated potatoes and several potato-based snack food products), and lack of awareness of the different uses of the crop. In recent years, the demand for potato chips and crisps is increasing very rapidly in urban areas.

Conclusions and Recommendations

In the light of the various factors discussed above, the following major researchable problems should be considered towards the improvement of the potato industry in the country.

Continue the development of better varieties that are adaptable to different AEZ, resistant to late blight, early maturing with good eating quality and suitable for processing.

Scale up the technology for the production healthy and quality seed tuber Intensity the improvement of the informal seed tuber production system in farmer's fields.

Disease and insect pest management techniques that will reduce reliance on use of chemicals should be intensified at farmers fields.

Research and Development should continue on post harvest technology for both ware potato and seed tuber.

Man power development and an effective technology disseminate on mechanism must be promoted to capture the benefits of the research results.

Sweet Potato *(Ipomoea batatas)*

Among the root and tuber crops, sweet potato is one of the world's major crops especially in developing countries, where it ranks third in value of production and fifth in calorie contribution to human. Sweet potato is a member of the family *Convolvulaceae,* in which there are over 400 *Ipomoea* species distributed throughout the tropics. Large number of sweet potato cultivars are known to exist. They differ in tuber skin (usually white, brown, yellow or reddish purple); color of the tuber flesh (usually white or yellow); shape of the tuber and weight of the tuber. On the basis of tuber texture after cooking, sweet potato cultivars can be classified generally into three groups:

- Those with firm dry, mealy flesh;
- Those with soft, moist, gelatinous flesh and
- Those with very coarse tubers which are suitable only for animal feed or industrial use (Onwueme, 1978).

In many parts of Ethiopia as population growth, fertile arable land available per head diminishes. This tends to create a shift to the use of marginal land in those densely populated areas where low incomes allow only modest investment in land improvement and crop production. Therefore, crops like sweet potato which yield greatest amount of food per unit area per unit of time, and which are capable of yielding evening marginal conditions will have to be accorded their rightful place in the Ethiopian food production system. The crop also provides significant amount of energy and protein. Its production efficiency of edible energy and protein are outstanding in the developing world (Assefa *et al* .2008).

Sweet potato does best in areas with 750-1000 mm of rainfall per annum; with about 500 mm falling during the growing season at altitudes of 750-2500 m and in areas where average temperature is 24oC. Sweet potato is essentially a warm weather crop. Growth is best at temperatures above 24oC; when temperature falls below 100c, growth is severely affected. A soil pH of 6 is most favorable for optimum growth. Though sweet potato is vegetative propagated, it is a short day plant and photoperiod of less than 11 hours induces flowering.

Sweet potato, renowned in Sub-Saharan Africa as the "classic" food security crop, is a staple or co-staple food for the majority of the people in the Southern Nations, Nationalities and Peoples Region (SNNPR) of Ethiopia and in eastern Ethiopia around Harar. In area coverage and production, it is the third important root and tuber crop next to enset (false banana) and potato. In 1999, 63% of the estimated 52,022 hectares of sweet potato cultivated in Ethiopia was in SNNPR, with Oromia being the second region of importance with 34% of cultivated area. Similar to potato, sweet potato can generate large amounts of food/unit time/unit area (194 MJ/ha/day) during relatively short rainy periods, tolerates occasional dry spells, provides excellent ground cover once established that reduces erosion and yields even on less fertile soils. Furthermore, sweet potato roots and leaves are excellent sources of many B vitamins and other important micro-nutrients. Orange-fleshed sweet potato varieties (OFSP) are rich in beta-carotene, the pre-cursor to vitamin A. One-half cup of boiled and mashed OFSP contains the recommended daily allowance of vitamin A for a young child.

The quick-growing, drought tolerant, rustic nature of the sweet potato crop also renders it suited to marginal conditions that characterize rain fed agriculture, and some areas dominated by the pastoral cultures. A wide range of sweet potato types exist, ranging from varieties that produce predominantly roots to those that produce predominantly vines. The roots (circa 28% dry matter) are mainly starch and a good source of energy, whilst the foliage is high in protein (15% dry matter (DM) and >23% crude protein (CP)) and vitamins and minerals. Separately or combined, they can be manipulated to enhance the rations and total available energy of other locally-available fodders or forages. Given that Ethiopia has area remained low in the country. This is partly because; these varieties are not yet been available to many farmers. The need to test adaptability of the promising clones in diverse agro-ecologies, especially in response to emerging constraints such as pests and diseases, declining soil fertility, and also market preferences mainly for the orange-fleshed varieties is an urgent issue. Cultivars of sweet potato with an orange flesh (OFSP) contain high β-carotene contents (the precursor of vitamin A). As little as 100g per day of these cultivars is sufficient to provide the vitamin A requirement of the at-risk groups for growing children and the youth.

In the past few years, several organizations have used OFSP materials released by national agricultural research institutes (NARIs). However, most of these initiatives have not been accompanied by awareness and educational campaigns necessary to ensure uptake. In sweet potato, like in all other crops, agronomic factors and indeed the management practices used are among the crucial factors that highly influence crop yield and quality. However, sweet potato farmers in Ethiopia usually use traditional management practices. In most cases, the farmers' practices cannot effectively and efficiently address the different agronomic challenges and problems by growers. The production and productivity of the crop has thus remained low due to poor management, among other major reasons. The sweet potato improvement research program undertakes different works that can help to alleviate the existing production and productivity barriers of the crop through the use of not only improved varieties but also appropriate management practices (Girma et al, 2008).

The major agronomic factors affecting the production of the Sweet potato includes seed bed preparation, spacing, soil fertility management, vine management, vine clipping, vine Storage and planting date.

Seed bed preparation: Different seed bed preparation methods are used in sweet potato production at different localities based on the soil type, moisture holding capacity, depth and workability. However, the most common methods are mounds, ridges and planting on the flat.

Spacing: Spacing may vary depending on soil condition and crop variety. In root and tuber crops, spacing directly affects the root size grades for domestic as well as for market. From the experiments conducted at Bako, Jima and Tepi the combination of spacing's of 60x35 cm between rows and plants respectively was recommended for the areas and others with similar environments (Girma et al, 2008).

Soil Fertility Management: The fertilizer rate recommendations can differ based on several environmental conditions. Experimental results indicated that the use of fertilizer trials conducted at Bako, Loko and Nedjo over three years (1998-2001) revealed the application of nitrogen as having significant impact on marketable and total root yield. But extreme yield differences were observed over the locations probably due to the differences in the inherent soil macro and micro nutrients and other agro-ecological conditions which influence the nutrient release of the soils and its uptake by the crop. Considering the high costs, the lower but affordable and profitable rate 50/20 N/P kg/ha were recommended as optimum for sweet potato production at Bako area (Girma et al, 2008).

Planting Date: Plating date can be area specific based on the set of rainfall, altitude variation and disease pressure. Planting dates were investigated at Bako for two consecutive years using white star variety of sweet potato and the whole month of June was found optimum for the area and other similar agro-ecologies provided reliable rainfall exists during and after planting.

Biotic Stresses Including Insects, Diseases, and Weeds and their Management/Control

Over a dozen of insect pests are recorded on sweet potato in Ethiopia. Among these the sweet potato weevil is the major one and it attacks leaves, stems and tubers. Tuber damage and to a lesser extent stem damage cause economic loss brought forth by larvae tunnelling into the tuber in association with the excrements of the larvae causes disagreeable taste and would result in unmarketable tubers. In Ethiopia, losses due to the insect pest range from 20-75%. So far the method commonly practiced by growers to minimize sweet potato weevil attack is only crop rotation.

The second most important insect pest of sweet potato is the sweet potato butterfly *(Acrea acerata)* which was reported to cause over 60% defoliation (Temesgen et al.) 2008). Other insects such as tortoise beetle *(Aspidomorpha tecta)*, potato tuber moth *(Phthorimaea operculella)*, metallic leaf beetle *(Lagria villosa)*, green sting bug *(Nezara virdula)*, and flea beetle *(Podagrica Spp.)* were recorded as minor insect pests. Armyworm *(Spodoptera exempta)* is considered as a sporadic pest of sweet potato.

Crop Utilization Including Processing and Value Addition

The tuberous roots are boiled or steamed and consumed directly. Even though it is not accustomed eating its leaf part at green stage in Ethiopia, it has high protein, vitamins and mineral content. They are used as vegetable food in many parts of the tropics. The leaves are also feed for livestock. Recently, yellow fleshed sweet potatoes are becoming recognized for their high beta-carotene (precursor of vitamin A) content. Sweet potato roots and leaves are excellent sources of many B vitamins and other important micro-nutrients. Orange-fleshed sweet potato varieties (OFSP) are rich in beta-carotene, the pre-cursor to vitamin A. One-half cup of boiled and mashed OFSP contains the recommended daily allowance of vitamin A for a young child.

Enset *(Ensete ventricosum)*

Systematic farm level survey is required to quantify the area of cultivation occupied by the enset crop. The main challenges for sustainable enset Farming System (EFS here after) is to attain food security in particular, and to sustain the livelihood for at least 16% of the population in general. The main focus of research and improvement has been to develop productive and sustainable EFS at different agro-ecologies with main thrust to avoid fragmentation of traditional farms from generation to generation as consequence of increase of family size. Sustainable EFS requires sustenance of soil fertility in order to minimize land degradation, and to develop bacterial wilt diseases resistance cultivars so as to minimize threats to enset agriculture. EFS should be perceived as a dynamic concept that promotes environment friendly sustainable agricultural practices based on the recycling of renewable resources and economic complementarily between sub-systems of production (i.e. crops, livestock, horticultural, stimulant crops etc).

The Genus Ensete

The basic botanical differences between the two genera, i.e. Musa and Ensete, has been established based on taxonomic and morphological characteristics (Cheesman 1947 and Moore 1957). This study which was based on cytological differences (chromosome number, pseudo-stem, seed, embryo size, morphology and propagation differences etc.) led to the transfer of about 20 species from the genus Musa to Ensete. *Ensete ventricosum* is of economic importance in Ethiopia; *Ensete gilletttie* is largely adapted to drier areas in West and Central Africa from Sierra Leon, Nigeria, Cameroon, to Angola; *Ensete perrieri* is largely distributed on the island of Madagascar. Most species of Ensete are widely distributed across Africa except for *Ensete glaucum* and *E. superbum* which are of Asian origin. Furthermore, *Ensete calospermum* is widely distributed in the Pacific, Fijii and in New Guinea. Another species, *E. facundum*, is largely distributed in Eastern Africa for example, in Uganda; *Ensete amoldianum* is largely distributed in tropical Africa. Although Ethiopia is the center of diversity of *Ensete ventricosum* there is need to narrow down or to re-group several clones types based on taxonomic morphological characteristics as well as on food and fiber yield traits.

Enset Farming System (EFS) as Backbone of Ethiopian Agriculture

The Enset Farming System is among the backbone of Ethiopian agricultural economy based on the following salient analysis:

a) Livelihood: The EFS supports the basic diet or co-staple food and income of at least 16 to 18% of the Ethiopian Population;
b) As a backbone of Ethiopian Agriculture: Unlike other crops, enset integrates or associates the cultivation of cereals, root, tuber, stimulant crops, spices and even livestock production to sustain livelihoods at different agro-ecological zones;
c) As sustainable food production system: The EFS has *Integrated livestock and crop production practices of EFS also included* the basic components such as conservation of soil fertility through the use of manure and intercropping legumes;

d) Socio cultural diversification: The enset food as basic or co staple diet for large number of ethnic groups has much influenced the development of rich and diversified cultures;
e) Population Carrying Capacity: Regions where Enset crop is used as major staple food are among the most densely populated in Ethiopia. For example, 150 to 200 inhabitants per square kilometer in the Guraghe area to over 300 inhabitants per square kilometer in Kembata, North Omo and Weliata regions;
f) Food security perspectives: It has been established that only 15 to 25 plants could provide the yearly supply of food per family and;
g) The **bio-dynamism of Enset Farming System** incorporates diversified cropping systems at different ecologies There could be 6-12 harvests for vegetables, cereals; 1 to 3 harvests for fruits and 3 to 5 harvests, for papaya; 4 to 5 harvests for established coffee before the completion of the growth cycle of the Enset plant (i.e. harvesting)

Research for Improving Production and Productivity of Enset Crop

Enset research and improvement to a limited extent started five decades ago. However, the Enset was recognized as priority crop at national level since 1990. This coincided with the concurrent evolution of the Federal and Regional Research Systems that also led to establishment of Areka Agricultural Research Center (AARC) which gave more emphasis and thrust to Enset research and improvement. Advanced agronomic research by Atnafua et al. (2008) accrued to the following encouraging research outputs (particularly at AARC):

Grouping of the enset clones/land races (based on growth cycle, yield of kocho and fiber):

a) **Early Set:** Reported superior clones with kocho yield ranging from 310 to 600 quintal/ha/yr and boula yield from 30 to 60q/ha/yr;
b) **The intermediate Set:** Identified 6 clones that gave kocho yield from 350 to 510 q/ha/yr; also reported 5 clones that gave boula yield from 31 to 45 quintal/ha/yr;
c) **Late Set:**It is likely this group of enset clones mature 2 to 3 years later than earliest set. Reported kocho yield varied 200 to 350q/ha/yr and reported boula yield varied from 15 to 23q/ha/yr.

The assessment of several clones from above three sets of enset groupings identified 14 and 6 high yielding kocho and boula clones respectively as well as 7 high fiber yielding enset cultivars. The best fiber and boula yielders have been obtained from early set of enset clones. Furthermore, enset clones that gave high yield of kocho were also observed as good yielders of fiber (Atnafua et al. 2008). This research progress that grouped enset clones based on maturity , yield of kocho, fiber and boula could save considerable time and resources in the agronomic evaluation to a great extent, and to identify genetic variation among clones to some extent. Mulugeta et al (2008) have extensively reviewed the propagation research work undertaken on enset. Tissue culture has been used to propagate large number of plants both at Areka and Holleta research centers. This system of propagation will reduce the 2 to 3 times transplanting of seedlings, but also reduce years for harvesting.

Biotechnology

The molecular characterization research work started by Almaz (2008) is good beginning to streamline the genetic relationship and variation among *Ensete ventricosum* clones. This research work can become complex process due to the occurrence of genome size variation similar to its relative genus Musa diploids which DNA markers can be employed to identify clones resistance to bacterial wilt disease. Such research work of the employment of DNA markers should be supported (fund and lab. equipments) to strengthen biotechnology research on the genus not only to enhance the identification of genes resistance to bacterial wilt disease, but also to establish the genetic variability among high food and fiber yielding superior enset clones (such as Digomerza , Godera, Henuwa , Zerbo, Ado, Astarae, etc). It must be noted that tissue culture research work could advance significantly the biotechnology research on Enset. The ARC botanical collections including other spp. of the genus from other countries is the way forward for developing cultivars not only resistance to bacterial wilt , but also to improve yield of food and fiber of the crop.

Production of Enset Food and Fiber

The total area covered with the enset crop has grown from 65,000 ha to about 300,000 ha (CSO 2009/2010). The Southern and Oromia Regions produce close to 80% of the crop. Over the last three decades more than 200 Enset clones have been evaluated. However, there has been limited systematic trials to assess for food and fiber production. Based on actual randomized trials during four and half years at Debre Zeit Agricultural Research Center (Taye 1973), showed variation of fresh yield from 150 ton/ha for Tuzuma clone; 160 and 175 tons/ha for Ferezea and Adow Clones respectively. The actual fermented product weight for the clones mentioned above and of several others varied from 350 to 500q/ha. The kocho and boula yield of enset clones seem to vary considerably. Table 2 below has compared the yield of four clones previously studied that gave yield at level 190 to 300 q/ha/yr kocho and less than 30 q/ha/yr boula (Taye 1973). Between 1986-2010) (or since the establishment of AARC) several superior food and fiber yielding cultivars (such as Digomerza , Godera, Henuwa and Zerbo) that gave yield over 430 q/ha/yr kocho and at least 40 q/ha/yr boula were identified (Atnafua et al. 2008,) Systematic planting or inter-cropping of these new cultivars at their respective agro-ecology, and concurrent improvement of enset harvesting and processing implements /devices could easily triple the volume of enset production.

Enset propagation practices and its planting system (involving traditional stages of nurseries) have been reviewed extensively (Mulugetta et al. 2008). Series of enset propagating studies including tissue culture has established the pathway for rapid and large scale multiplication of enset planting materials that should be explored. The production of enset foods i.e kocho, amicho and bulla seem to considerably vary among clones and the agro-ecology of cultivation. The food yield particularly of kocho varies from 18 to 40kg/plant (Table 2).

Table2. Kocho, boula and fiber production of some Enset clones

Vernacular Names	Kocho q/ha/yr	Boula q/ha/yr	Fiber kg/ha/yr
Ferezae +	247	33	389
Godera ++	520	NA	424
Henuwa	440	43	317
Ado+	192	29	460
Zerbo ++	420	47	362
Midasho +	304	27	559
Djgomerza++	550	57	406
Tuzuma +	386	26	380
Gena ++	410	NA	554

Sources: +Taye Bezuneh 1973; ++Atnafua et al. 2008; NA (Not Available)

Nutrition

The production of Enset foods i.e kocho, amicho and bulla seem to considerably vary among clones and the agro-ecology of cultivation. The food yield particularly of kocho varies from 18 to 40kg/plant. The carbohydrate content of the clones evaluated, therefore, varied from 17.8t/ha to 29.3t/ha in a 4-5 year growth cycle. (Taye 1966, 1973). Study of the effect of length of fermentation on carbohydrate and Ca content of enset products showed that very little change occurs. It was observed that the carbohydrate content decreased in the 5-9 week period of fermentation and then maintained uniform level thereafter. The cause of the slight decrease in carbohydrate content during the early phase of the fermentation period will need to be further investigated. The 'Kocho' yield as fermented product has 44 to 50% moisture. Decrease of protein content in fermented products accompanying length of fermentation period has been reported (Taye 1973). The analysis by Abraham et al., (1979) showed that the Enset Protein content changed from 3.60% before fermentation to 3.35% after fermentation. The length of fermentation also improves the quality of protein. Furthermore, it was reported that the Enset protein is generally higher in lysine than most cereals.

Industrial Utilization of the Enset Crop

Slight improvement of current practices of the harvesting, decortications and pulverizing due to improvement of tools/machines not only improve the quality of the enset fiber and the kocho, but also minimize waste of both fresh harvest and fermented products. The fiber of Enset and the abaca fiber (from *Musa texitalis*) have similar strength and quality (Taye et al 1973). While the Philippines used the abaca *(Musa texitalis)* fiber to expand its manufactured industrial product that also attracted export markets to Europe, North America and other countries, very limited industrial manufacturing did take place in Ethiopia using En-

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