Agricultural Research for
Ethiopian Renaissance

Challenges, Opportunities and Directions

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Root and Tuber Crops Research in Ethiopia: Achievements and Future Prospects

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Introduction

Root and tuber crops, including Enset *(Ensete ventricosum)*, potato (*Solanum tuberosum*), sweetpotato (*Ipomoea batatas* Lam.), taro (*Colocasia esculenta* Schott.), yam (*Dioscorea* spp.), anchote (*Coccinia abysinica*), 'Ethiopian dinich' (*Coleus edulis*), cassava (*Manihot esculanta*) and tannia (*Xanthsoma* spp.) are among the most important food crops for direct human consumption in Ethiopia (Gebremedihn *et al*., 2008). They are grown in diverse agro-ecologies and production systems ranging from densely populated highland regions to lowland drier areas prone to droughts or floods.

There are many compelling reasons for encouraging these humble root and tuber crops for sustainable food production in Ethiopia. They are versatile staples to address food and nutrition security for millions of people, as they produce more food per unit area of land than most other food crops. Potato and sweetpotato, short cycle crops with three to four months cropping cycle, are well suited to double cropping particularly in rain-fed systems and have significant advantage over grain crops which require relatively longer time to mature. Their short growing cycle allows for flexible planting and harvesting times and also permits quick production of foods to augment "hunger months "of October to December before grain harvests when people lack sufficient food to meet their basic caloric and nutritional requirements. Yam, taro and cassava, though with longer cropping cycles, are vital for annual cycle of food availability. Their broader agro-ecological adaptation including marginal environments, diverse maturity period and suitability for under-ground storage permit flexible harvesting periods which aids sustained food availability. These crops are also capable of efficiently converting natural resources into a more usable product, caloric energy in the growing season, which is the most productive of all major arable crops. Root and tuber crops are cheap but nutritionally rich staple foods that contribute protein, vitamin C, vitamin A, zinc, iron etc. towards the dietary demands of the country's fast-growing towns and cities. Another advantage of these crops is that they are largely traded locally and nationally, as opposed to internationally. They are far less susceptible to large-scale market shocks and price speculations experienced by more widely traded staples, such as grains, during international market crises. As such, they contribute to a more stable food system, maintain nutritional and food security, and are a predictable source of income (Nteranya Sanginga, 2015).

The Ethiopian Agricultural Research Institute (EIAR) through its implementing federal and regional research centers has been conducting several research activities since its establishment in 1966 under its former name Institute of Agricultural Research (IAR). Since then several technologies have been released, demonstrated and popularized for the larger farming community in the country. The objective of this paper is, therefore, to review research outputs obtained in the last four decades.

Historical background and trends in production, export and import

Historical background

Most root crops were introduced to Ethiopia. Potato (*Solanum. tuberosum* L.), originating in the highlands of the Andes in South America was brought to Europe in the 16th century. It was introduced to Ethiopia in 1859 by a German Botanist called Schimper (Horton 1987 and Pankrust 1964). For many years since its introduction, potato production was limited to homesteads as a garden crop. Cassava was introduced to the African continent by Portuguese traders in the late 16th century. It is grown on an estimated 80 million hectares in 34 African countries (AIC, 2002). The Democratic Republic of Congo is the largest consumer of cassava in Africa, followed by Nigeria. Although it was not very well documented when cassava was introduced to Ethiopia, some evidences indicated that it dated back to 100 years ago.

The exact date of introduction of sweetpotato to the continent of Africa is unknown. However, evidence indicates that slave traders brought it and since its introduction, it has been displacing true yam in tropical Africa (Low *et al*., 2009) given that it has been in the food system for several hundred years.

Little is known about its exact place of origin, production and distribution, the yam species D. *rotundata* and *D. cayenensis* are native to West Africa (Coursey 1976). Yam had limited eastward movement reaching only as far as East Africa including Ethiopia and the region is generally considered as 'an isolated center of yam cultivation' outside the 'yam belt' of West Africa (Norman *et al.*, 1995). It is widely believed that *D. abyssinica* Hochst. Ex Kunth is native to Ethiopia (Coursey 1967, and is currently distributed in the savanna regions of Africa. The other species were believed to be introduced before 1000 AD.

Various evidences suggest that taro originated in South Central Asia, probably in India or the Malay Peninsula and believed to arrive in the east coast of Africa around 100 BC (Purseglove, 1972). Conversely enset, anchote and Ethiopian Dinich are native to Ethiopia as evidenced by the presence of wild relatives and other facts.

Research establishment and Coordination: Research on various root and tuber crops has been going on since the establishment of IAR in 1966 under horticultural crops research division at different research centers and higher learning institutions (HLIs) in a fragmented manner. In 1997, after realization of the contribution of the root and tuber crops towards household food security, local industries and natural resources base conservation, research on root and tuber crops was reorganized as a program at the national level with projects on Enset, potato, sweet potato and other root crops. The projects were coordinated by different regional and federal research centers: Enset South Agricultural Research Institute, Hawassa Agricultural Research Center, potato and sweetpotato and other root crops by Areka, Holeta and Hawassa, respectively. Later, the potato project coordination has been transferred from Holeta to Adet since 2005 (Gebremedhin *et al., 2008*).

Importance

Root and tuber crops are most important in south, southwest, eastern and northwest parts of Ethiopia in terms of production area, distribution and consumption. They are also grown almost all over the nation. Small-scale subsistence farmers grow the crops, under resource-poor conditions. In general, root and tuber crops are part of traditional foods of Ethiopia. Their contribution to family food-self-sufficiency, income generation and soil-based resource conservation is indispensable. Currently, most root and tuber crops are grown as security crops against crop failures and/or to bridge the food deficit periods, as they are ready for harvest during "hunger months." These crops are also tolerant to termites, which might be attributed to their higher moisture content, and thrive well on poor soils and under moisture stress conditions. These crops can grow from extreme lowland to extreme highland agro climatic conditions of the country. Potato thrives well at mid to high altitudes whereas other root crops perform well at low mid altitudes. They are good source of food nutrients such as carbohydrate, protein, vitamins and minerals which alleviate the problem of malnutrition in subsistence farming areas. Root and tuber crops have attracted attention as industrial raw material. Starch extracted from root and tuber crops is used in many applications including pre-gummed papers, tapes, labels, stamps and envelopes. They have a great potential to substitute import in the textile, pharmaceutical, soft drink, beer and ethanol/alcohol industries (Tesfaye *et al.*, 2013).

Area, production and productivity

Root crops cover more than 1.42% of the area under all crops and contribute 6.15% to the total crop production in the country. Nevertheless, potatoes, sweet potatoes and Taro ('Godere') account for about 29.8%, 25.7% and 19.9%, respectively of the total area under root crops. The area coverage of these crops showed an increase compared to the 2012 figures of 28.45 %, 23.35 % and 18.87 %, respectively (CSA, 2012). Ten year "Meher" production data indicated that the area covered by major root and tuber crops in the country ranges from 111,434.00 to 175,450.00 ha with an average productivity of 7.2 to 29.8 t/ha (CSA, 2005-2015).

Production system

Root crops can be planted as standalone crops or cultivated alongside other crops like maize, vegetables and cover crops. They can be intercropped and rotated with different crops for different merits such as insect pest and disease management, maintenance of soil fertility, increase in land productivity and others. Compatible crops with root and tuber crops for intercropping and rotation purpose are pulses, cereals, oil crops, vegetables and coffee. Coffee is majorly intercropped with enset for which the latter provides shade for higher yield. It is noticed that root and tuber crops never follow other root and tuber crops and/or intercropped with them as they have almost similar nutrient requirements. Potatoes are often grown in rotation with other crops such as maize, linseed, rapeseed, faba beans, or haricot beans following the last cultivation of potato in May or June. A 1997 survey of 420 farmers in the Amhara region indicated that about half of the interviewed farmers intercropped potatoes with other crops. Factors affecting their decisions included late blight pressure, poor market outlets, insufficient seed availability, competition with other growers, and periodic food shortages (GebreMedhin *et. al*. 2001).

Export status of root and tuber crops

Export of root and tuber crops is either non-existent or very negligible. The potential of export markets within east and central African region is not fully exploited. Despite the presence of different opportunities to export row and processed root and tuber crops products to different African, Asia, European and other countries, only Irish potato is being exported to the neighboring countries such as Somalia, Sudan, United Arab Emirates and the like. Fig.1 shows three years (2009-2011) export data for potato.

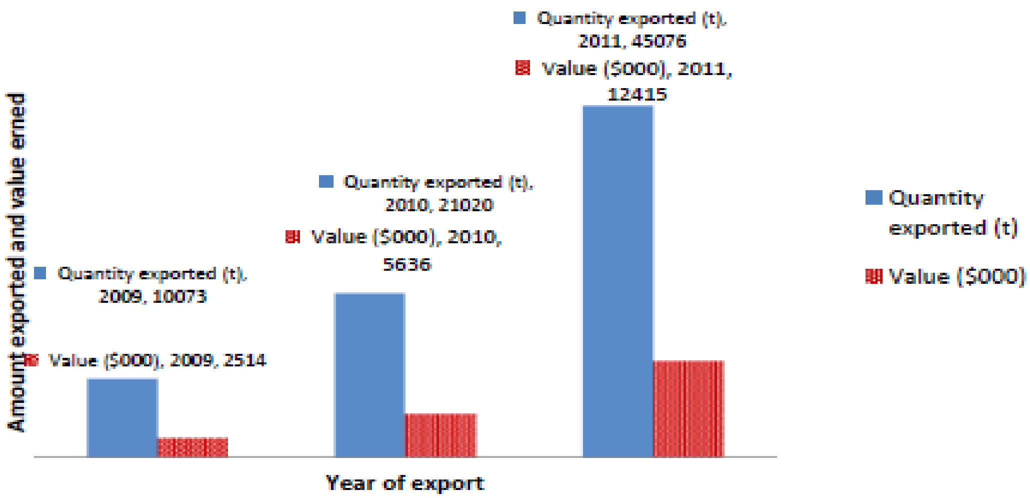

Fig. 1 potato Export quantity and value obtained

Achievements

A number of technologies have been selected, developed, released, adopted, and popularized since the establishment of research system in the country. Among which variety development for different agro ecologies, crop pest management technologies, crop husbandry, post harvest management and food quality appraisals are the major ones.

Potato

Ethiopia is among the top potato (*Solanum tuberosum* L.) producers in Africa, with 70% of its arable land in the high altitude areas above 1500m being suitable for potato production (FAOSTAT, 2008). Currently, potato is produced mainly in the north western, central and eastern highlands of Ethiopia (Berhanu *et al*., 2011). Its production is constrained by a wide range of factors that result in low yields. These include shortage of high yielding varieties tolerant to late blight, marginal soils, inadequate seeds, deficient cultural practices, storage problems, high cost of farm inputs, and insect pests and diseases (Gebremedhin, 2013).

Varieties developed: The local varieties introduced earlier may be of the same parentage (Haile-michael, 1979). This intensely shows that the genetic base of the local varieties are narrow; making any progress in improving the productivity of the crop unsatisfactory. To make such a progress possible by widening the genetic base of potato, a selection program with a large number of seedling populations started in 1973 at the College of Agriculture in Alemaya in cooperation with IAR and International Potato Center (CIP). A more coordinated improvement work on potato started in 1975. National potato research programs in sub-Saharan Africa have continuously focused on selection of high-yielding varieties with resistance to late blight (LB) disease (El-Bedewy *et al*., 2001).

Introduction and evaluation of broader germplasm and commercial varieties, and generation of local population and recently introduction of advanced materials are some of the strategies that have been followed to develop varieties wide adaptability, resistant/tolerant to different pests and stresses (Berga *et al*., 1994a). Accordingly a number of variety trials have been conducted in different corners of the country to address different agro-ecologies of the potato growing areas. From these experiments widely adaptable, late blight resistant and high yielding (25-40 tons/ha) potato varieties were released and are under production. So-far, about 33 improved potato varieties have been released and recommended by the National Potato Improvement Program (MoA, variety registry, 2014). Most of the potato genotypes that have been developed and released in Eastern Africa before 2008 either had genes for vertical resistance to LB or horizontal resistance to LB in the presence of unknown resistance (major R) genes, thus named population "A" clones (Landeo *et al.*,1997). A particular feature of this breeding population is that horizontal resistance was improved in the presence of undesired, unknown major (R) genes for vertical resistance (population A). Their presence made the recognition of true horizontal resistance and effective gene frequency upgrading more difficult rather than contributing to the overall resistance, (Landeo *et al.*, 1997). Although the Ethiopian Potato Improvement Program has shown progress over the years, further improvement is still needed, particularly in accelerating varietal selection and release schemes and increasing adoption and diffusion rates (Gebremedhin, 2013). Diffusion of new varieties has been sluggish and limited; thus old potato varieties are still produced by a significant number of farmers in large land areas. In other words, new varieties are struggling to reach larger areas or replace the old ones. Farmers would like to replace their old varieties with new ones because of diminishing productivity, but they usually are not aware of the release of new ones and even if they are, limited availability and farmer's access to seed of such varieties are prohibitive. Therefore, the lacks of quality seed in sufficient amount and at affordable prices are the major limiting factors for varietal diffusion.

Agronomy: The suboptimal agronomic techniques practiced by potato growers in Ethiopia are undoubtedly one of the contributing factors to the existing low average national yield. Agronomic studies have been undertaken by different research centers to develop a package of optimum management practices, for the improved cultivars.

Therefore, research on planting dates, planting depth and method of planting, fertilizer rate, method and time of application, as well as number of hilling during the growing period for seed and ware potatoes, plant population for seed and ware potato productions comprise the major components of the agronomic research.

Time of planting: Planting time varies with location, variety and the growing season. It influences incidence of late blight and has significant impact on tuber yield and quality. To secure maximum yield, potato should be planted during the time favorable conditions prevail for better growth and development of the crop. Planting from, early June was recommended as optimum planting time for Emdiber (Gurage zone), Holetta (central Ethiopia) and other similar agro-ecological areas (Berga *et al.,* 1994). Similarly, May first to mid May and from May first to June first are recommended as optimum planting dates for late blight susceptible and moderately tolerant/resistant potato cultivars around Adet and similar agro-ecologies. Abdul Wahab and Semagne (2008) recommended that last week of May to mid June as an appropriate planting time for optimum potato production in the high lands of Ankober (North Shewa) and other similar agro-ecologies.

Depth of planting: Even though optimum planting depth varies with soil moisture content, soil temperature etc., under Holetta condition planting at 15cms depth followed by 10 and 20 cm are best for yield and minimum insect pest attack.

Seed tuber size and plant population: Seed tuber size and population density are among the most determining factors of the production and productivity of potato. A potato tuber may at the end of dormancy grow one or more sprouts, and after planting variable proportion of these sprouts develop into main stems. A plant may have variable number of stems depending up on the tuber size, number of eyes per tuber and storage conditions of the planted seed tuber. The stem numbers per tuber in turn affects the number of tubers set, the growth and longevity of the haulm and therefore yield (Gebremedhin *et al.*, 2008). Closer intra-row spacing of 10 or 20cm in rows of 75cm apart would be beneficial for seed and larger seed tubers (45-55mm) do better than the smaller ones. Wider intra-row spacing of 30 or 40cm are better, again on rows 75cm apart, for ware. Similarly, considering the amount of seed tuber required type of output and synergism with other cultural practices, seed tuber size of 35-45mm diameter, 60cm inter-row spacing and ridging once at 3-4 weeks after crop emergence is recommended for seed potato production. However, 35-45mm diameter seed tuber, 75cm inter-row spacing and ridging once after 3-4 weeks from crop emergence is found optimum and recommended for ware potato production at Adet and its surroundings (Tesfaye *et al.,* 2008). Generally, use of 75 cm inter-row spacing is found suitable for ware potato production and 60cm inter-row spacing is found ideal for seed tuber potato production.

Fertilizer rate: Potato, as a high yielding crop is a heavy consumer of nutrients. Many factors may affect the total nutrient consumption of the potato crop. Reports indicate that the effects of season, variety and rate and time of N, P and K fertilizer applications resulted in the removal of mineral nutrients in fresh tubers in the following ranges: N, 2.28–3.57; P, 0.40–0.62 and, K, 3.70–5.41 kg/t (Gunasena, 1969). However, the diversity of soil types, moisture and nutrient regimes, cropping sequences, fertilizer uses and climatic conditions as well as biotic factors such as weeds, pests and diseases all may affect the state of soil nutrient flux and use by the growing crop. The extent of use of fertilizer may also be dictated by factors like market prices and the economic status of a farmer (Gebremedhin *et al.*, 2008). Considering these problems, area specific and economically feasible fertilizer rates were recommended by different research centers for different potato growing areas across the country. According to Tesfaye and co-workers (2008) fertilizer rates of 108/69 and 81/69 kg/ha N/P_2O_5 are economically feasible in South Gondar and Gojam areas, respectively. Similarly, 110kg/ha nitrogen and 70.5kg/ha P_2O_5 are recommended for optimum potato tuber yield in nitosol and light vertisol in the highlands of North Shewa (Abdul Wahab and Semagne, 2008). Berga and co-workers (1994) also reported that 165/90 N/ P_2O_5 recommended as feasible rate for the central Shewa area and this recommendation is still in use in the central and Southern part of the country as a blanket recommendation. By the same token, 146/138 N/ P_2O_5 was recommended for the highlands of Hararghe. These recommendations may not work for the current market, soil fertility status and other climatic variables. Therefore, considering the variability of the input-output market and soil fertility status, detail soil test based fertilizer rate studies should be carried out.

Ridging: Ridging, which refers to the practice of hilling or earthing up the soil around the potato plant, is a normal practice in potato production. Ridging is practiced to obtain sufficient earth or soil around the potato plant and form a well-shaped ridge that helps to loosen the subsoil for good aeration and/or to cover the tubers set with sufficient layer of soil. On lighter soils ridging presents no difficulty, and it is very useful if the soil depth is shallow. However, on heavier soils, ridging may present a problem unless it is done under low soil moisture conditions. Proper ridging increases tuber yield by creating favorable condition for tuber initiation and development. Poor ridging in potato may expose the tuber to sunlight, high temperature, disease and insect damage. Studies show that a yield loss as high as 8% have been registered due to poor ridging. The frequency and optimum of ridging may depend on variety, soil structure and workable soil depth (Gebremedhin, 2013). The highest yield was obtained from plots with four and three times ridging. Generally, increasing ridging frequency substantially reduced green tubers from 53.3% in no ridging to 29.5% at four times ridging. In a similar study conducted at Adet, ridging frequency had no significant effects on parameters like tuber size, marketable and total yields. The results under Holetta conditions showed that yield and tuber quality can be affected by ridging and at least twice ridging is very necessary. Light soil and heavy rainfall areas require more frequent ridging. Whereas, in light red soils care has to be taken to reduce insect damage and greening by modifying planting distance and increasing frequency of ridging. In ware potato production, good cover-up of soil does substantially increase marketable tuber yield due to less greening (Gebremedhin *et al.*, 2008)

Intercropping: Intercropping of potato with maize is a common practice in northwest Amhara region. Consequently, an experiment was conducted at Adet for two consecutive years (1997-1998) to identify economically feasible intercropping pattern. The result was also statistically analyzed using total monetary value (TMV) of the system and economic yield of each component crop. Moreover, the land equivalent ratio (LER) of each intercropping system was calculated. From this work intercropping of potato with maize in 2:1 and 1:1 (potato: maize) row spatial arrangement are found superior in their order and recommended for potato production at Adet and its surroundings (Tesfaye *et al.*, 2008). In addition, intercropping study of potato and maize was made at Bako for three cropping seasons. Maize and potato were arranged in 1:1 ratio alternating within a row (15 x 75cm) and between rows (37.5 x 30 cm) including sole planting (75 x 30 cm). The yield of potato in an intercropped field was as high as sole potato in one of the three study seasons. Intercropping was found economically advantageous than sole cropping as the maize grower could get potato yield as bonus in addition to maize yield (Gebremedhin *et al.*, 2008).

Crop protection

Potato Disease Management: The potato is prone to many diseases caused by either bacteria, fungi, viruses or mycoplasma. Late blight, caused by *Phytophthora infestans*, remains the most devastating disease in potato resulting in economic costs that sum up to 5.2 billion euros, globally. The use of resistant varieties is a powerful, viable and environmentally friendly alternative or supplement for the current, commonly deployed chemical control strategies (Haesaert *et al.*, 2015). Late blight is generally the most important disease wherever potatoes are grown in the country. Traditionally the crop is grown during the off-season using the short rain that falls during February–April and sometimes with supplementary irrigation when available. The main reason for not growing potato during the long rainy season, despite the high yielding potential, is the severe threat posed by late blight. The local varieties do not cope with the disease pressure in the main rainy season and often are wiped out particularly in the highlands. Viruses and bacterial wilt are also very important diseases affecting potato production (Bekele and Eshetu, 2008). Among these, late blight (LB), followed by bacterial wilt (BW), potato leaf roll virus (PLRV), and potato virus Y (PVY) were the most important diseases. Late blight was widely distributed where the crop is grown under rain fed conditions (Bekele and Yayinu, 1994). In this report, BW was detected and found restricted to the mid-and low altitudes. Currently, however, it has also been recorded in high altitudes (>2400 masl); virus diseases were more prevalent at mid and low altitudes than at higher. Studies on host-plant resistance, loss assessment, cultural control measures, and integrated management have been conducted on many diseases. Promising results have been obtained. The level of economic loss of late blight has been determined for some varieties. Furthermore, the use of integrated pest management (IPM) in reducing blight damage has been emphasized. The result showed that early planting of moderately late blight tolerant varieties with one or two fungicide applications significantly reduced the disease, thereby, highly increasing the tuber yield. Attempts have been made to determine the physiological races of *P.infestans*. Results of chemical control trials indicated that a fungicide (Ridomil MZ 63.5% WP) containing Mancozeb and Metalaxyl was very effective in controlling late blight (Bekele and Yayinu, 1994). In a host resistance study, potato varieties that are tolerant to late blight, early blight and bacterial wilt have been identified (Baye and Gebremedhin, 2013).

An integrated bacterial wilt control research was conducted in a farmer participatory approach, where different options were compared. The options were (a) an improved package (IP) that consisted of clean seed, a less susceptible variety, and improved cultural practices, (b) a farmer package (FP), which consisted of a farmer's variety and farmers' seed, planted under the farmers' cultural practices, (3) clean seed of a less susceptible variety planted in farmers' cultural practices (CSFCP), and (4) farmers seed planted under improved cultural practices (FSICP). All the options significantly reduced wilt incidence and increased potato yield as compared to FP; with IP performing best. The options were all economically beneficial and resulted in marginal rates of return of 1034% for IP, 805% for CSFCP and 634% for FSICP (Berga 2001; Berga *et al*., 2005).

Potato is naturally infected by over 36 viruses. About 50% of these viruses are dependent on potato for their survival and spread, while others usually have major hosts apart from potato. Viruses and virus diseases constitute a major constraint to potato production in developing countries including those of SSA. The diseases are often overlooked because the symptoms are usually not as striking as those incited by fungi and bacteria. The virus diseases cause reductions in yield quality and quantity (Salazar and Accatino, 1990). Berhanu and co-workers , (2011) described that, evidence of the occurrence of potato viruses in Ethiopia was first reported in studies conducted in central, south and southeast Ethiopia during the 1984 and 1985 crop seasons. The results of these consecutive studies indicated the presence of *Potato virus X* (PVX), *Potato virus S* (PVS), *Potato leaf roll virus* (PLRV), *Potato virus Y* (PVY), *Potato virus A* (PVA) and *Potato virus M* PVM). The effect of viruses on potato production is primarily due to their accumulation on seeds causing degeneration within short period of production cycles. There is a need, therefore, to strengthen the tissue culture laboratory in order to supply disease-free seed to producers and minimize the effect of viruses on potato yield. In addition, the existing sites for seed production should be strengthened. It is also crucial to forge strong linkages between potato seed producers and the research system. The potato plant can become systematically infected with viruses following transmission either mechanically or through vectors. Whereas, nearly all of these viruses are transmitted vegetatively through seed tubers. PVY and PLRV, the two economically most important potato viruses, PLRV and PVY are horizontally transmitted by aphid vectors under natural conditions. Green peach aphid (*Myzus persicae*) is the most important vector of these two viruses worldwide, while other aphids like potato aphid (*Macrosiphum euphorbae*) are less efficient vectors.

Potato Insect Pest Management: Potato is attacked by a number of insect pests. In the past over two decades, the major insect pests that stay on potato did not shift and have included: cutworms (*Agrotis* spp. and *Euxoa* spp.), red ants (*Dorylus spp.),* potato aphid (*Macrosiphum euphorbiae*), green peach aphid (*Myzus persicae*) and the potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) (Bayeh and Tadesse, 1994). Among these insects, potato tuber moth (PTM), cutworms, and aphids are the most important ones. Research has been conducted to generate information on management options against these economically important insect pests. Many survey reports indicated that PTM was known to damage potato only in warmer areas, though major production areas are mainly in the highlands. Monitoring of PTM was conducted using PTM sex pheromone trap at Holetta. The result showed that the peak months were January, February, and June. Unlike the field situation, monitoring in the store showed no obvious peak record (Bayeh and Tadesse, 1994). Aphids in potato, though, were more important as vectors of virus diseases than as pests. Monitoring work was conducted using yellow water traps at Holetta, and during the monitoring different aphid species were recorded.

The peak months were January, April, and November–December. According to Bayeh and Tadesse, (1994) the dominant species were Brassica aphids, green peach aphids, and potato aphids. In this work an attempt was made to correlate the population fluctuation with some abiotic factors, temperature, (minimum and maximum), rainfall, and wind speed. The result showed that rain fall and low temperature had negative effects, whereas the influence of the other two factors was non-significant.

Seed/planting material production: The Ethiopian Potato Improvement Program, with almost 35 years of CIP's technological support through its regional office in Kenya and its headquarters in Peru, has been able to release more than 31 varieties; however, the rate of adoption and diffusion has been quite limited. Of the released varieties, Belete, Jalenie, Gudenie, Guassa, and Gera are the most widely grown potatoes at present. In most cases, the main limiting factor for variety diffusion was insufficient amount of clean seed due to limited formal seed system. Currently the national mean yield in Ethiopia is low which is about 10.8 t/ha (CSA, 2014) but could easily be doubled or tripled. Moreover, the adoption and coverage of 25.2% of the total potato area in the country with improved varieties has partly contributed for the witnessed productivity gain (Labarta *et al*., 2012). Potato's production value is estimated at 403 million USD (CSA, 2014). Perhaps the most significant constraint to increasing productivity and overall production is the chronic shortage of good quality seed tubers of the productive varieties.

A pre-requisite to a successful and sustainable seed scheme is a continuous supply and maintenance of pathogen free early generation seed potato. This is the responsibility of research institutions in the country. To provide these disease free planting materials, a number of research activities have been conducted. Evaluation of some rapid multiplication techniques (stem cutting and aeroponics) were made under local conditions. Tuber yield increased with increasing number of stem cuttings per hill from 1 to 3 and with closer spacing. Stem cutting results revealed that the rooting abilities of stem cuttings differed with cultivar and media, where as fine sand was found to be the best locally available medium (Berga *et al.,* 1994b). Currently, Millions of mini-tubers are being produced under rapid multiplication for experimental and pre-basic seed in our TC labs and aeroponics structures at Bahirdar and Holetta. The conventional multiplication rate of potato (1:3) is promoted to 1:30 by rapid multiplication techniques (RMT) especially by using aeroponics system (Abebe *et al*., 2014).

Postharvest Management: In Ethiopia potatoes are basically stored for two purposes: ware and seed, but mostly in inappropriate storage facilities. Farmers use different traditional potato storage systems depending on the use. However, these storage facilities are not proper to keep the quality of tuber for more than 1–2 months (Endale *et al*., 2008). Since potato tuber is a living botanical organ, it loses weight and quality during storage. Farmers keep potatoes in the ground for a long period or forced to sell their produce at low prices during harvesting and buy seed tubers at high prices during planting. A study on extended harvesting period in Alemaya revealed that yield of marketable tubers was reduced by 60% when tubers were harvested at 210 days after planting as compared to a harvest at 120 days (Berga, 1984). Similarly Gebremedhin (1987) reported that significant yield reduction (70-100%) was obtained as harvesting was delayed from about 125 days to 230 days at Holetta.

Therefore, the low-cost diffused light store (DLS) for seed tubers developed by CIP has been evaluated under the Ethiopian condition. It was found to be very useful and efficient storage technique. Consequently, it has been adopted by many potato farmers' in many parts of the country. Agajie and coworkers , (2008) reported that, 87% of the central part and 25% in the north and west are using DLS to store their improved variety seed potato. Thus, practical training was given to farmers in different parts of the country and they are aware of the new seed storage technology that is, DLS. Generally, better quality seed tubers are obtained with storage in DLS than in traditional dark storage, resulting in increased productivity in the country.

In DLS tubers can be stored 8-9 months without much loss. They also produce 3-4 sprouts, which are green and strong consequently giving high yield. If possible seed store should be covered with aphid proof screen to avoid insect entrance.

Scio-economics and research extension: Technology transfer is both a technical and nontechnical process, and it should be carried out in collaboration with stakeholders. The main objective of technology transfer is to improve peoples' welfare steadily gradually and continuously. In Ethiopia, there are still some drawbacks of technology transfer such as inappropriate channels, applicability of the technology, and lack of integration. A number of potato technologies were promoted through participatory seed multiplication and scaling-up from production to utilization in different parts of the country. These promotional activities sought to facilitate the diffusion and adoption of potato technologies that will improve potato production. To transfer these new technologies, activities were conducted in two phases.

In the first phase, participatory seed multiplication was conducted over the last 10 years. During this time, researchers, farmers' research groups (FRG), development agents (DA), subject matter specialists (SMS), development project workers, nongovernmental organizations, and other stakeholders were involved in planning, technology dissemination, awareness creation, monitoring, and evaluation. This was to promote adoption of new technologies by producers.

In the second phase, before launching the actual activity, an inception workshop was held with all stakeholders. Researchers played a catalytic role. On the basis of group consensus, the seed, which is maintained during the evaluation and seed multiplication phase one, was distributed to all members of the FRG, bringing the productive seed (a technology) closer to farmers. Currently, potato farmers are using almost all components of the potato production package. Throughout the whole process of evaluation, seed multiplication, and scaling-up of improved technologies, participation of farmers and stakeholders was useful to promote the diffusion and adoption of improved technologies, knowledge, and skill of quality seed production, and postharvest handling. This established the farmer-to-farmer seed exchange and information dissemination system. In the process, a number of field days were organized to demonstrate the production, postharvest handling, and utilization of potato. In general, technical backstopping and creating good public-private partnership and technology transfer system are the most important issues that need more attention.

Sweet potato

Varieties developed: To date, a total of 24 sweet potato varieties have been released in Ethiopia, among which six are orange fleshed. Among the 24 varieties, Awassa-83 is the most dominantly grown variety in most of the sweet potato growing areas of the country. Farmers prefer to grow this variety due to its high yielding potential, high total biomass and high dry matter content as compared to other varieties.

Available Germplasm: The major source of germplasm for sweet potato improvement has been the International Potato Center (CIP). Most of the sweet potato varieties that have been developed in Ethiopia are of CIP origin. Currently, more than one thousand improved seeds with different characters were introduced from CIP and are under screening. Crossing of sweet potato in Ethiopia started in 2013 and currently some clones with better yield, beta-carotene and dry matter contents have been developed and are being evaluated under multi-location trials. The released varieties are maintained at Hawassa Research Center to serve as source of planting materials.

Agronomy: In sweet potatoes, like in all other crops, agronomic factors/management practices 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, farmers' practices cannot effectively and efficiently address the different agronomic challenges and problems faced by growers. The production and productivity of the crop has thus remained low due to poor management, among other major reasons (Girma *et al., 2008*)

The sweet potato improvement research program undertakes different works that can help alleviate the existing production and productivity barriers of the crop through the use of not only improved varieties but also appropriate management practices. Good management would enable farmers to exploit the potential of improved or local sweet potato varieties for higher yield and quality produce.

Seedbed Preparation: Different seedbed 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. Flat planting is recommended for areas like Hawassa where the soil type is more of sandy that can easily percolate water. But, generally in moisture stress areas or during non-rainy season, tied ridge is the most universally recommended method of growing sweetpotato (Girma *et al*, 2008).

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 use as well as market. Spacing experiments at different locations showed different results and as a result spacing combinations of 60 cm x 30 cm for Hawassa and Areka, 100 cm x 30 cm for Tepi and 60 cm x 35 cm for Jima were recommended. The recommendations have considerable difference in spacing between rows varying from 60 up to 100 cm. This difference has an implication on quantity of planting material and cost of production. There might be a need to further look in to the problem and identify the reasons behind and see the possibility for cost effective recommendation (Girma *et al*, 2008).

Soil Fertility Management: Soil fertility decline is noted as the principal cause for crop yield reduction in Ethiopia. This has happened due to continuous cultivation, removal of crop residue for livestock feed and fuel wood, insufficient fertilizer supply, erosion and poor soil management. This aspect may assume serious dimension in root and tuber crops production, particularly sweetpotato as the crop is a heavy feeder of nutrients. Therefore, it is essential to replenish soil fertility to sustain crop growth and high yield. The nutrient requirement of the crop depends on the type of the soil and expected yield. Efforts have been made in Bako on farm, Hawassa, Areka, Loko and Nedjo to mitigate low soil fertility problems. But the recommendations from such experiments are not in use currently by farmers. Another experiment conducted in SNNPR at Halaba special district indicated that application of 46 kg P_2O_5 and 92 kg Nitrogen gave better yield. However, this result has to be verified at similar locations before recommendations are given.

Crop protection: The major insect pests of sweetpotato in Ethiopia are sweetpotato weevil *(Cylas puncticollis L.)*, sweetpotato butterfly (*Acraea acerata),* sweetpotato hornworm (*Agrius convolvuli),* tortoise beetles (*Aspidomorpha spp*.,) and virus transmitters such as Aphids (*Aphis gossypii)* and white fly (*Bemisia tabaci)*. Among these insect pests, the most serious ones are the sweetpotato weevil and sweetpotato butterfly which can cause a yield reduction of 60-80% (Temesgen *et al*., 2008). The sweetpotato weevil larvae and adults feed on the roots, causing extensive damage, both in field and storage, in many parts of the world. Roots may be initially attacked during storage or may be contaminated with eggs or larvae from the field. Such contaminations may not be readily visible to the naked eye and apparently healthy roots may be stored only to be attacked when eggs hatch and larvae begin to feed. Previously uninfected roots are also exposed to attack. The weevil may go through several life cycles during a prolonged storage period. Weevil damage produces quantitative losses and aesthetically unappealing roots which may be discolored and have bitter taste. The weevil also stimulates the production of phenolic compounds, leading to brown discoloration of the flesh and also phytoalexins such as ipomeamarone (Woolfe, 1992). In Ethiopia, losses due to the insect pest range from 20-75% (Emana, 1990) and 70-80% (Temesgen *et al*., 2008). Studies had been made on cultural control methods such as planting date, time of harvesting, crop rotation, variety screening and integrated pest management. The second most important insect pest of sweetpotato is the sweetpotato butterfly (*Acrea acerata*) which was reported to cause over 60% defoliation (Temesgen *et al*, 2008). A study was made at Hawassa and Areka to investigate the effect of planting date on the yield of sweetpotato and infestation of sweetpotato weevil. The findings of the study indicated that early planting, besides increasing yield through plant growth vigor, is associated with significant reduction in sweetpotato weevil infestation (Temesgen *et al*, 2008).

Among the pathogens, viruses, fungi and bacteria are responsible for economic losses of sweetpotato worldwide. Different types of viral, fungal and bacterial diseases have been recorded in Ethiopia. However, the most devastating sweetpotato disease in Ethiopia is the sweetpotato virus (Tadesse et al., 2013; Mekonnen et al., 2014). In east Africa in general, over 90% sweetpotato yield reductions have been associated with viruses (Gibson et al., 1998). Since late 2004 to 2011 four types of viruses namely, Sweetpotato feathery mottle virus (SPFMV), Sweetpotato chlorotic stunt virus (SPCSV), Sweetpotato virus (SPVG) and Sweetpotato virus 2 (SPV2) were identified and recorded in the country.) In 2012 other six viruses, namely, C-6 virus, sweetpotato caulimo-like virus (SPCaLV), Sweetpotato chlorotic flecks virus (SPCFV, Sweetpotato latent virus (SPLV), Sweetpotato mild speckling virus (SPMSV) and Cucumber Mosaic Virus (CMV) were identified and recorded (Mekonnen *et al*, 2014).

Planting material production: Foundation planting materials of sweetpotato are primarily produced by Hawassa Research Center. The center has been producing pre-basic and basic planting materials of the crop and selling to various vine multipliers. Multiplication of the planting materials starts with cleaning of the planting materials from diseases, especially viruses in a tissue culture laboratory at Arkea Research Center. Then the cleaned materials are produced in insect proof net tunnels as pre-basic seeds. The vines derived from the net tunnels are then multiplied in open field as basic seeds. The vines from the basic fields are sold to private vine multipliers for further multiplication in order to meet the huge demands from various organizations. Currently, there are registered private commercial sweetpotato vine multipliers in Ethiopia such as Jara Agro-industry, Ezera PLC, Muluneh Boru farm PLC, Mulualem farm, Ayzman PLC, Wamole seed enterprise and Hulume seed enterprise. Almost all of these multipliers mainly focus on multiplication of sweetpotato vines and sell to governmental organizations (GOs) and non-governmental organizations (NGOs). Then the GOs and NGOs distribute the vines to farmers, especially during severe and prolonged drought.

In 2014/15 alone, more than two million basic sweetpotato seeds/cuttings have been sold from Hawassa Research Center to various organizations such as Ayzman PLC, Agri-Service Ethiopia, Lutheran World Federation, KOGOVED PLC, Jara Agro industry and FAO. Similarly, the multipliers were selling millions of cuttings to various GOs and NGOs. Through the collaborative project between SARI and CIP, considerable amount of cuttings were distributed to different districts in SNNPR and Oromia regions. Accordingly, 5,135,000 vines in 2011, 6,190,166 vines in 2012, 225,000 vines in 2013, 1,088,000 vines in 2014 and 4,420,000 vines in 2015 were distributed to different districts of SNNPR and Oromia.

Postharvest handling: Duration of harvest is a function of variety, soil type (nutrient), availability of other foods, household size, disease and pest infestation and weather conditions. Sweetpotato roots are ready for harvesting from 3 months after planting. Varieties such as Awassa 83, mature in 6 months after planting, Guntute 5 months and Belela 3 months. If the crop is harvested too early the roots will not be fully developed;

too late, the roots may be fibrous and possibly pest-infested thus reducing yields. Harvesting can be done on a piecemeal basis and whole crop harvesting. The practice involves harvesting small quantities and normally starts as early as 2 months after planting for some varieties. Varieties with longer maturity period are usually more suitable for piecemeal method than early maturing ones which have all their roots maturing at almost the same time. Sweetpotatoes should be handled with care after harvesting to prevent cutting, skinning, and yellowing. The roots must also not be exposed to the sun for more than an hour or so after digging. To prevent infection by disease-producing organisms, the roots should be kept in ventilated area until used or sold. There is no storage facility for sweetpotato in Ethiopia and therefore the shelf-life of the crop is very short.

Sweetpotato is among crops that have short shelf-life since the roots contain about 70% water. Limited knowledge about sweetpotato processing and preservation, and lack of processing equipment makes sweetpotato postharvest handling among the major constraints of sweetpotato as described by farmers in the major sweetpotato growing areas of the country (Gurmu *et al.*, 2015).

Therefore, there should be a postharvest handling technology to prolong the shelf-life of the crop. In most of the growing areas, sweetpotato root is consumed boiled and there were no postharvest handling technologies. Sweetpotato can be processed into numerous traditional products by mixing its flour with cereals and legume crops. The root can be processed to make bread, enjera, flour, cookies, wot (stew), local beer and juice. Given proper training, and access to appropriate equipment, farmers could make a range of food items from sweetpotato. This would reduce the postharvest losses of the crop and help maximize its utilization.

Scio-economics and research extension: A survey by Gurmu *et al.* (2015) showed that the major pre-harvest production constraints of sweetpotato constitute: heat and drought (21.6%), shortage of planting materials (20.1%), shortage of land (15.7%), diseases (10.0%), insect-pests (9.4%), a shortage of draft power (8.1%), shortage of money to purchase inputs (7.9%), a shortage of labour (5.1%) and weeds (2.0%). Similarly, poor access to markets (22.6%), poor market prices (19.1%), low yields (14.2%), low preferences due to low root dry matter content (13.6%), a lack of knowledge on processing (11.7%), a lack of processing equipment (11.1%) and transportation problem (7.7%) were identified as the major postharvest constraints. The major farmers' selection criteria for sweetpotato varieties were resistance to heat and drought (19.6%), dry matter content (16.4%), taste (14.3%), root yield (13.6%), resistance to disease and insects (13.3%), earliness (11.6%) and cooking ability (8.9%). Similar results were reported by Tadesse *et al.* (2006) that farmers prefer sweetpotato varieties based on characteristics like resistance to diseases/pests, marketable tuber size and colour, and ease of intercropping and palatability.

Since most farmers (98.4%) store the roots *in-situ* in the soil and practice piece-meal harvest, the roots are affected by insect pests (mainly weevils), diseases and rodents and the quality deteriorates (Gurmu *et al.*, 2015).

According to Million *et al.*, (2008) the sweetpotato marketing system was relatively not well developed because of various reasons. Although the sweetpotato marketing channel was very long, the volume of transaction and the incremental profit margin that traders obtained was very low. From the total number of sample traders interviewed, 86% were retailers and 6% wholesalers, while the remaining 8% were assemblers. Except for the wholesalers, almost all retailers and assemblers were operating within production areas. The same study indicated that sweetpotato consumption increases during May and June mainly because during these months, household grain reserves were usually finished and the price of cereals mostly tends to rise. Hence, people consumed more sweetpotatoes. Due to increased demand during this period, farmers who had irrigation facilities were encouraged to produce sweetpotato and got better prices. Nevertheless, the major supply of sweet potato remained to be influenced mainly by price of other crops and its own price, availability of moisture or rainfall, and occurrence of insect pests. Lack of high yielding varieties was also one of the important factors influencing the market supply of sweetpotato.

Cassava

Varieties developed: Variety trials for yield and other agronomic trials had been started at Hawassa, Jima, Bako, and Melka Werer research centers since 1975 on some introduced germplasm of cassava. Through the effort of national and regional research institutes, more than 80 germplasm were introduced as integral parts of cassava variety development. Some of these were tested at different agroecological locations from 1996-2001 in Ethiopia and two most promising varieties (Qulle and Kello) were officially released for production. They give 27 and 28 t/ha, which is by far higher than the world average 9.4 t/ha (MoA, 2006).

Available Germplasm: Different cassava germplasm were locally collected and introduced from cassava growing countries (Uganda, Kenya and Tanzania) in the form of botanical seeds. More than 500/five hundred/ germplasm with different morphological and nutritional traits are maintained at Hawassa and Jima agricultural research centers with the objectives of evaluating them for higher storage root yield, low hydrogen cyanide content, high dry matter content, earliness, biomass yield and adaptability to local agroclimatic conditions. Among the germplasm orange fleshed clones with higher beta-carotene content, which is a precursor for vitamin A, are found to be maintained for further evaluation.

Agronomy: Low soil fertility, nutritional imbalances, soil salinity, crop field management like weeding are among the factors that reduce cassava yield in addition to the inherent genetic potential. Cassava is a crop that extracts large amounts of nutrients from the soil, especially N, P and K. A study showed that cassava required about 200kg/ha of Nitrogen, 100kg/ha Phosphorus and 100kg/ha potassium to give an average fresh storage root yield of 23.9t/ha (Bernando and Hernan 2012). The presence of weeds during the first 60 days of the crop cycle was observed to reduce yields by about 50% compared with cassava that was free of weeds throughout the cropping cycle (Bernando and Hernan 2012).

In Ethiopia, little cassava agronomic research has been conducted. Spacing trials were conducted at Amaro and Hawassa during 2004-2005 cropping seasons. For optimum cassava production a spacing of 80cm X 80cm was recommended for Amaro while a spacing of 100 cm x 80cm was recommended for Hawassa and similar agroecologies (Gobeze *et al.*, 2005).

Intercropping cassava with haricot bean, cowpea, soybean and mung bean, reduced cassava yield by 27, 37, 52 and 50%, respectively. However, intercropping cassava with haricot bean, cowpea, soybean and mung bean resulted in 82, 49, 48 and 62% greater land use efficiency than for either crop grown alone. (Legese and Gobeze , 2013)

The HCN content as affected by the soil nutrient amount especially that of potassium(K_2O) was studied and concluded that at lower doses of potassium application, root HCN content was relatively high. It substantially decreased at higher rates of potassium, which indicates the need for further experimentation with more cultivars and other sources of potassium. Although potassium is found important in reducing the HCN content of cassava roots, other locally available and cheap sources of potassium such as wood ash can alternatively be used by the mainly subsistent farmers who usually cultivate the crop (Endris,S. 1977).

Nitrogen and P fertilizers effect on storage root yield was conducted in different agroecologies of the country (Hawassa, Jinka, Goffa and Bonga) and had shown a significant yield increase as compared to the untreated check with some exceptions at Hawassa where no significant difference was among the tested N & P rates. The highest storage 31.8 t/ha was obtained from application of 100 kg/ha urea & 50 kg/ha DAP. The result is by far higher than the control which received no fertilizer (Personal communication).

Crop protection: The main diseases affecting cassava are cassava mosaic virus (CMV), cassava bacterial blight, cassava anthracnose, and root rot. Pests and diseases, in combination with poor agronomic practices, combine to cause high yield losses in Africa (AIC, 2002). Although there is no tangible evidence on the occurrence of viral diseases, cassava root rot blight and leaf spot were observed in Ethiopia. In the same way, cassava white flies (*bemisia tabaci*), cassava green mite *(mononychellus tanqjo)*, cassava mealy bug *(phenacoccus manihoti)*, cassava white scale *(aonidmytilus albus)*, elegant grasshoppers (*zonocerus spp*), termites and vertebrate pests (monkeys, wild pigs, goat's rats, and birds) are the most important pests.

The most important insect pests attacking cassava in the production areas in Ethiopia are cassava scale insect (*Aonidoytilus albus),Cassava green mite (Mononychellus tanqjoa) and Red spider mite (Tetranychus spp)* (Ermias *et.al.*, 2012). Among these, cassava scale insect was the most serious one. Cassava scale *(Aonidomytilus albus)* (Cockerel) (Hem: Diaspididae) was reported for the first time in 2001 at Amaro. It was affecting the production and productivity of cassava in southern Ethiopia, Amaro especial Wereda (Mesele *et al.*, 2007).

Very few research activities have been conducted in Ethiopia to manage cassava scale insect damage. To study the biology, field abundance and seasonal patterns of cassava pests (scale insect) pot and field experiments were conducted. But the results have not been released for farmers to apply. Chemical and germplasm screening for cassava scale insect were also conducted. Accordingly clear variation among the germplasm for the reaction against cassava scale insect was observed. A total of 11 promising germplasm were found and promoted to further evaluation (Mesele and Ermias 2014, unpublished).

Moreover chemicals screening including untreated control were evaluated in insect hot spot areas under natural infestation. Two chemicals, dimethoate and Deltanate were found to be very effective. The management options have not been popularized by the researchers to be utilized by cassava farmers (Mesele and Ermias 2014, unpublished).

Seed/planting material production: One of the most important problems of cassava production is the lack of quality planting materials and formal seed production system in the country beyond breeder and pre-basic seed multiplication by research centers. Two improved varieties are multiplied on more than 8ha of land at Hawassa, Dilla, Arbaminch, Areka, Goffa and Jima for different purposes. From these multiplications a number of cuttings (more than 4 million cuttings) were distributed for further multiplication, research and production.

In the year 2014/2015, Hawassa agricultural research center sold more than 950, 000 cuttings and generated more than ETH Birr 325,925.

Postharvest management: Upon harvesting, cassava starchy storage root suffers a rapid deterioration that renders it unpalatable and unmarketable within 24 -72 hrs depending on the environmental conditions. Except farmers' preservation methods of cassava after harvesting and/or leaving in the ground after maturity no other postharvest methods have been designed in Ethiopia despite its significant and critical value. Farmers preserve cassava roots through extended harvesting after maturity, chopping and sun drying, converting chips into flour and store in ordinary jute sack under low temperatures (Tesfaye *et al.*, 2013).

Though research on postharvest handling of cassava is lacking, a number of anti-nutritional and nutritional analysis of cassava varieties were conducted. Mulugeta and Eskindr (1999) studied effect of storage methods and cooking practices on the total hydrogen cyanide content of cassava cultivars. They obtained a high reduction of 98.6-99.3% in total hydrogen cyanide in sun dried flour compared to roots stored underground trench (19.9-23.5%), and refrigerator (-33.6%). They also tried to show that cooking reduced the total hydrogen cyanide from 61.0 to 98.2% depending on cultivar and practice of cooking.

An experiment on detoxification of cassava was conducted and interesting results were obtained. Processing methods such as washing, boiling, drying and fermenting with flour of cereals were evaluated to increase nutritional content and reduce cyanide levels. They concluded that peeling, solar drying and fermentation were found to be the best methods to removing the cyanide content of cassava by 99.7% and blending with cereal flours improved nutritional quality of cassava-based foods (Aweke *et al*., 2012).

Analysis of HCN, moisture and fiber content of garri produced from different cassava varieties were conducted by Hawassa College of Agriculture. The total moisture, cyanide and fiber contents varied from 26.1-40.0 %, 1.5-2.8 mg HCN/100 g and 1.8- 2.4%, respectively. The Kello44/72 and MM96/5280 varieties with the lowest cyanide and comparable fiber contents are most suitable (Enidiok *et al.* 2008). From this study it could be concluded that moisture content of cassava roots are inversely related to the total cyanide content.

Scio-economics and research extension: Status, Potentials and challenges of Cassava production, processing, marketing and utilization assessment of cassava in selected SNNPR was conducted. The assessment result indicated that cassava stands first in both production and productivity followed by sweetpotato and maize in Belg (short rainy season) while during Meher (long rainy season) the reverse was observed (at Amaro, Kindo Koisha, Debma Gofa, Konso and Arbaminch) (Tesfaye et al., 2013).

In the study area, the Area allocated for improved and local cultivar cassava on average is 0.19 and 0.30 ha, respectively. Land preparation for all crops under cassava farming system was carried out using outdated and labor intensive tools such as hoe (66%) and oxen plough (33%) of sample farmer's average for the five districts. Cassava is used to generate income by selling fresh cassava root from the farm and/or the nearby local market. In the same way, processed cassava products especially cassava chips and flours were consumed and sold in the study areas. Most of the farmers obtain planting materials from their own savings but a few had gotten from relatives, friends and other sources. The two improved varieties introduced to the farmers were kello (44/72 red) and Qulle (104/72 Nigerian red). The adoption rate for the improved varieties by the sampled farmers in the study area on average was only 30%. Major constraints to cassava production include insect pest attack , lack of early maturing varieties, shortage of land, low moisture stress and low market demand and/or price. Thus it was recommended that labor saving farm implements, management of cassava scale insects and existing post-harvest processing equipment need to be employed to improve cassava production and productivity. Development of early maturing cassava varieties is a pertinent solution to solve problems related to long maturing cassava varieties (Tesfaye et al., 2013).

Demonstration and pre-scaling up: The adaptation of high yielding, disease resistant and low HCN containing varieties released in Ethiopia is being practiced at different agroecological locations (Somale, Gambela, Mytsemri, Asayta, Tepi, Gambella, Pawe and Alamata). Varieties Qulle and Kello have shown an excellent performance in some of these areas beyond their recorded yields at Hawassa and other centers in the south. The case in point is Pawe, where they yielded 54.6 and 66.3 tons per ha. In North western Tigray A total of 10 male and five female farmers participated in the demonstration and popularization of cassava varieties released so far. For this purpose 374 cuttings from Qulle, 319 cuttings from Kello and 50 cuttings from local varieties were distributed to the selected farmers. Pre-scaling up of cassava varieties using two released cassava varieties, was carried out at Silte, Hossana and Burji. Totally 220 farmers participated in the pre-scaling up activity. The farmers found that the improved varieties were better than their own cultivars in root yield, earliness and palatability.

Enset (*Ensete ventricosum*)

Enset is the backbone of the southern, central and south western parts of Ethiopia. This perennial crop mostly covers the densely populated areas. Had it not been for enset, the livelihood of the inhabitants would have been greatly threatened in the past many decades. The high yield per unit area coupled with its ability to withstand drought makes enset an ideal and strategic crop for the populace (Mesfin *et al*, 2008).

The enset Improvement Program has focused on variety improvement, agronomy, crop protection, storage technology, food science (utilization), seed production techniques, socio-economic studies and research-extension. In the genetic improvement high priority was given to the development of high yielding, bacterial wilt tolerant varieties, with wide adaptability and desirable horticultural characteristics and culinary qualities. The agronomic research, on the other hand, emphasized the development of appropriate cultural practices such as planting dates, plant density, fertilizer rate and time of application, and depth of planting.

Variety development: So far six high kocho yielding enset varieties with early to late maturity cycle adapted to low, mid and high altitude areas have been released. Morphological characterization of enset clones based on phenotypic traits has been done at Areka Agricultural Research Centre (Tabogie, 1997; Yeshitila and Diro, 2009; Bekele *et al*., 2008). However, morphological characterization of the clones is rudimental and a well-established taxonomic classification and descriptor list are lacking. In addition, attempts have been made to document and analyze clonal identity using farmers' classification. In these cases, clonal names reported in the literature are associated with only limited phenotypic data provided by farmers (Shigeta, 1991). Molecular characterization of enset clones was conducted using AFLP (Tsegaye, 2002; Negash, 2001) and RAPD techniques (Birmeta, 2004). However, enset accessions considered in their studies were from limited growing areas. Efforts were also made to genotype some enset clones using molecular markers developed for *Musa* with the assistance of Generation Challenge Program (GCP)

Available Germplasm: Since 1994, enset clones were collected from their major growing areas of SNNPR and Oromia regions, and more than 652 enset vernaculars are collected and conserved *ex situ* by Areka Agricultural Research Center, the Southern Agricultural Research Institute

Multiplication of disease free planting materials of enset through tissue culture provides opportunity to manage the spread of bacterial wilt disease, which is threatening enset production. Attempts have been made to optimize protocols for *in-vitro* propagation of enset (Zeweldu and Ludders, 1998; Tesfaye, 2002; Diro, 2003). Recently, enset in vitro propagation protocol has shown the possibilities of obtaining about 50 shoots per shoot tip explant (Girma, 2009, Personal communication).

Agronomy and Physiology: Agronomic practices (spacing, fertilizer, propagation methods and nursery management). Most of the research on enset has concentrated on agronomic studies (Bezuneh 1996). Agronomic research was developed mainly by Areka, among which propagation (seed/vegetative), planting time, spacing, frequency and rate of organic and inorganic fertilizer application and frequency of transplanting are the major ones (Diro,1997; Belehu, 1996; Tabogie *etal*.,1996; Haile *etal*.,1996; Diro *et al*.,1996).

According to the recommendations, during sucker production from the corm to propagation, splitting the corm in to two at equal position and planting the two half corm independently, on 1m x1m spacing on 30-40cm deep hole at 45^0 tilted on upright position by covering 10cm deep with top soil provide strong and large number of suckers. In addition to that, direct transplanting of suckers in to main field on 1.5m between plant and 3m between rows spacing give better yield and shortened maturity time of the crop; compared with multiple transplanting. In the main field application of 10kg compost or 45g DAP and 117.5g urea per year per plant also increases the yield of the crop and shortens its maturity time.

Crop Protection: Various diseases of enset have been reported. Some of these are leaf damaging fungal diseases, corm rot, sheath rot and dead heart leaf rot of enset with unknown causal agents. Root knot, root lesion and black leaf streak nematodes are also known as enset production constraints (Quimio and Mesfin, 1996). There are also viral diseases of enset known as mosaic and chlorotic leaf streak diseases. However, based on the distribution and extent of damage, Enset bacterial wilt disease caused by *Xanthomonas campestris pv. musacearum* is the most destructive and highly invasive disease that is considered a threat to enset production system.

Most of Fungal diseases of enset are not as such threatening to crop production relative to bacterial wilt. Foliar fungal diseases largely affect the crop at the early growth stage by causing leaf spot and blight. These later coalesce and severely affect the photosynthetically active leaf area of the crop. As the crop gets older, it resists most of the fungal pathogens. Among the fungal diseases, corm and root-rot diseases were found as devastating especially on young seedlings (Mesfin *et al*.,2008).

Seed/planting material production: In the last five years, on average 10,000 to 15,000 suckers/year of released enset varieties and bacterial wilt tolerant enset clone (mazia) have been multiplied and distributed to more than 727 farmers and to universities (Wolkite University, Wachemo University) by Areka Agricultural Research Centre. In collaboration with different organizations, like Concern Ethiopia and FAO hundreds of thousands' of planting materials were distributed to farmers.

Postharvest handling or management: Little research is done on enset towards improving postharvest handling and management. Traditional enset fermentation increases types and numbers of microbs and contributes to the reduction of nutrients in Kocho and its spoilage (Tariku, 2012). The traditional postharvest managements are also tedious and highly labor intensive, unhygienic and associated with great yield losses. According to Atnafua and coworkers (2008), the use of white plastic sheet is recommended as good storage material for kocho. But, the effect of chemicals released from plastic sheet in the process of fermentation on the human health needs investigation.

Scio-economics and research extension: Survey has been done on bulla Value chain and the result shows that rural retailers, assemblers, whole sellers and urban retailers are engaged in bulla transaction and trade. They rarely add value to this product, but make available to consumers in their locality. Moreover, baseline survey on enset production constraint and disease mapping were conducted on major enset producing areas. Enset bacterial wilt disease is the number one constraint to enset production followed by moisture stress and mole rat attack.

Demonstration and pre-scaling up: Efforts have been made on promotion and dissemination of Enset production technologies. Hundreds of thousands of improved enset suckers, 32 processing devices and 180 scrappers are among technologies disseminated in the past. On the other hand, attempts have been made by Awassa and Areka Agricultural Research Centers to introduce and demonstrate improved enset decorticator and squeezer and reports showed that the technologies were accepted by the participant farmers.

Recommendations and the way forward

Root & tubers crops will continue to play a significant role in the Ethiopian food system because: 1) they contribute to the energy and nutrition requirements over the next two-three decades; 2) they are produced and consumed by many of the world's poorest and most food insecure households; 3) they are an important source of employment and income in rural, often marginal areas, including for women; and 4) they adapt to a wide range of specific uses, from food security crop to cash crop, from food crop to feed crop, from the latter to raw material for industrial uses, and from fresh food to high-end processed product. To realize the potential of root and tuber crops, a combination of new technologies and improvements in the institutional and policy environment will be required.

A set of constraints along the R&T crops value chain has to be considered simultaneously, to ensure higher yields, better income and a significant contribution of R&T crops farming to food security and improved livelihoods in the country. For example high yielding varieties have to be released that have good resistance to the major disease of the crops and low degeneration rate as well as good table and processing qualities. These varieties should have wide adaptability, with a potential to produce well in the different agroecolgies of the various regions. If seed of these varieties is made available to growers, using rapid multiplication technologies such as aeroponics and farmers learn to keep the quality of their seed/planting materials for a longer time through on farm seed maintenance technologies and suitable seed storage, there is a great potential to boost R &T productivity and production, especially if these are coupled with best cultural practices like soil fertility management and disease control measures as well as storage technologies.

To achieve the required /planned in research and development of root and tuber crops the following area should get more focus:

- Working in partnership to avoid duplication of efforts and promote complementarities
- Strengthening the capacity at all levels (Human power, Laboratory and Budget).
- Empower farmers through continuous training, follow up visits and M&E
- Give emphasis to Quality Declared Seeds (Standards for disease and insect pest limits, Packaging, Prices, Marketing and Seed certification).
- Highly decentralized seed/planting material multiplication schemes allow farmers in remote areas to gain access to affordable quality seed.
- Quality seed needs to be clearly separated from ware products through branding, labeling, and the creation of separate seed value chains.

- Targeted Research (agroecology based research, drought, climate change, nutrition, industrial use)

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