Journal of Agricultural and Crop Research
Vol. 7(7), pp. 106-118, July 2019
doi: 10.33495/jacr_v7i7.19.127
ISSN: 2384-731X
Review Paper

Sweetpotato Research and Development in Ethiopia: A Comprehensive Review

Fekadu Gurmu

South Agricultural Research Institute, Hawassa Research Centre, P. O. Box 6, Hawassa, Ethiopia.

Email: fekadugb@gmail.com

Accepted 3rd July, 2019.

Abstract. In Ethiopia, sweetpotato is widely grown in south, southwestern and eastern parts by small-scale farmers. However, the productivity of the crop remained low (8 t ha^{-1}) for a long time and the production of the crop was also declining due to many factors including recurrent drought, lack of planting materials, shortage of farmer preferred varieties, poor extension system, market and postharvest related problems. Various research and development activities have been undertaken to mitigate the above problems and some of the findings have been published in different outlets. There are some review articles on specific aspects of sweetpotato in Ethiopia such as breeding, agronomy research, disease research, entomology research and nutrition. There are also various articles published on food and nutrition, postharvest management, marketing and seed system of sweetpotato. However, there is no a comprehensive reference source of these information. Therefore, this article highlights the major and important research and development works that have been conducted on sweetpotato in Ethiopia. It highlights the historical background of sweetpotato research in Ethiopia from early introduction to the current stages of modern breeding activities. The agro-ecological adaptation of sweetpotato in Ethiopia, area of production and number of households involved in sweetpotato production and contribution of sweetpotato for food and nutrition security are highlighted. Moreover, genetic improvement of sweetpotato, agronomy research, diseases and insect pests research, postharvest handling and marketing, seed system and food, and nutrition studies are discussed. Various research results have been obtained and registered since the inception of research on sweetpotato in Ethiopia, including development of different varieties (>25), development of agronomy and plant protection technologies and guidelines, development of postharvest handling and food preparation manuals, seed standards and production guidelines. The availability of these outputs in a compiled and comprehensive ways is very important for enhancing production and productivity of sweetpotato in Ethiopia and to influence the policy makers to consider sweetpotato as one of the major food and nutrition security crops in Ethiopia. This article can be used as a good reference resource for researchers, students, agricultural extension workers and NGOs working in Ethiopia in the area of root crops in general and sweetpotato in particular.

Keywords: Agronomy, breeding, food and nutrition, marketing, plant protection, postharvest handling, seed system.

INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is one of the globally important crops ranking seventh and fifth in production in the world and in Africa, respectively (ASHS, 2007; low *et al*., 2015; CIP, 2007). It is mainly grown for human food and animal feed. It produces storage roots which are rich in carbohydrate, vitamins such as A, B complex, C, E and minerals such as potassium, calcium and iron. According to Zhang *et al*. (2000) and Gichuki *et al.* (2003), Central America is considered as the primary center of diversity of sweetpotato based on molecular markers study and most likely the center of origin since the highest diversity was found in this region. Globally China is the leading sweetpotato producing country with production of 70,963,630 metric tons (MT), followed by Nigeria (3,478,270 MT), Tanzania (3,345,170 MT) and Ethiopia (2,701,599 MT). China contributes annually more than half of the world's total sweetpotato production.

In Ethiopia, sweetpotato is widely grown in south, southwestern and eastern parts by small-scale farmers with limited land, labor and capital. Ethiopia is one of the largest sweetpotato producing countries in the world. According to the Central Statistical Authority (CSA, 2018) reports, sweetpotato occupied about 53,499 hectares of land with a total annual production of 1.85 million tons during the main growing season only.

However, the productivity of the crop remained low (8 t ha^{-1}) for a long time and the production of the crop is also declining due to many factors including recurrent drought, lack of planting materials, shortage of farmer preferred varieties, poor extension system that doesn't encourage production of root crops, market and postharvest related problems (Fekadu *et al*., 2015a). Sweetpotato viruses, sweetpotato weevil and sweetpotato butterfly are the major sweetpotato production constraints in Ethiopia. Low root dry matter content (RDMC) in the orange fleshed sweetpotato (OFSP) varieties and a lack of knowledge on postharvest storage and processing are also some of the prevailing constraints of the crop (Kapinga and Carey, 2003; Tesfaye, 2006; Assefa *et al*., 2007; Ndunguru *et al*., 2009; Fekadu *et al*., 2015a).

Various research and development activities have been undertaken to mitigate the above problems and some of the findings have been published in different outlets. There are some review articles on specific aspects of sweetpotato in Ethiopia such as breeding with respect to self- and cross-incompatibilities in sweetpotato (Fekadu *et al*., 2013, 2018), agronomy research (Daniel and Gobeze, 2016), disease research (Shiferaw *et al*., 2014, Megersa, 2018), entomology research (Ermias *et al*., 2013) and nutrition (vitamin A) (Fekadu *et al*., 2015b). There are also various articles published on different aspects of the crop including food and nutrition (Amagloh *et al*., 2012; Yibeltal *et al*., 2016; Mesfin *et al*., 2017; Abebe and Dereje, 2018; Laryea *et al*., 2018), postharvest management and marketing (Parmar *et al*., 2017) and seed system (Getahun *et al*., 2015) etc. However, there is no a compiled reference source on research and development works on sweetpotato in Ethiopia. Therefore, this paper highlights the major and important research and development works that have been conducted on sweetpotato in Ethiopia with regard to breeding and genetic studies, agronomy, crop protection, postharvest management, marketing, seed system and nutrition. It can be used as a good reference paper for researchers, students, agricultural extension workers and NGOs working in Ethiopia in the area of root crops in general and sweetpotato in particular.

HISTORICAL BACKGROUND

The production of root crops in Ethiopia started 3000 years ago with domestication of indigenous root crops such as the Ethiopian dinich (*plectrantus edulis*) (Buzayehu and Firdu, 2009). Even if no well documented evidences are available, the production and consumption of indigenous root crops like Anchote (*Coccinea abyssinca*) counted many thousand years back. The production and utilization of introduced root crops (Irish potato, sweetpotato and cassava) also counted so many hundred years and they are served as staple food in wider areas of the country (Buzayehu and Firdu, 2009).

Research on the various root and tuber crops has been going on since the establishment of the Institute of Agricultural Research (IAR) in Ethiopia in 1966 under horticultural crops research division at different research centers and in higher learning institutions in a fragmented manner. According to Gebremedhin *et al* (2008), in 1997, after realization of the contribution of the root crops towards household food security, local industries and natural resources base conservation, the research was reorganized at national program level consisting three projects (Enset, potato, sweetpotato and other root crops). The projects have been coordinated by different regional and federal research centers: Enset, potato and sweetpotato and other root crops by Areka, Holeta and Hawassa, respectively (Gebremedhin *et al*., 2008). Currently, root crops research is nationally coordinated by Hawassa Research Center of the South Agricultural Research Institute.

Sweetpotato research and development has been started before five decades with other root crops research and has recorded tremendous achievements in terms of variety development, recommendation of management practices including agronomic, crop protection and postharvest managements and nutrition. The sweetpotato research program had a good collaboration with regional and international organizations and programs such as the Regional Network for the Improvement of Potatoes and Sweetpotatoes in Eastern and Southern Africa (PRAPACE), Dissemination of New Agricultural Technologies in Africa (DONATA) and Vitamin A for Africa (VITAA). The International Potato Center (CIP) has been the source of germplasm for sweetpotato research in Ethiopia and has been supporting the program through finance, short-term trainings, supplying research equipment and facilities. So far, different sweetpotato varieties have been developed from the exotic materials that were introduced from CIP and from local collections. Although these varieties are intended for increasing production and productivity, however, the productivity of the crop has remained much lower (< 8 t/ha) which might be attributed to biotic and

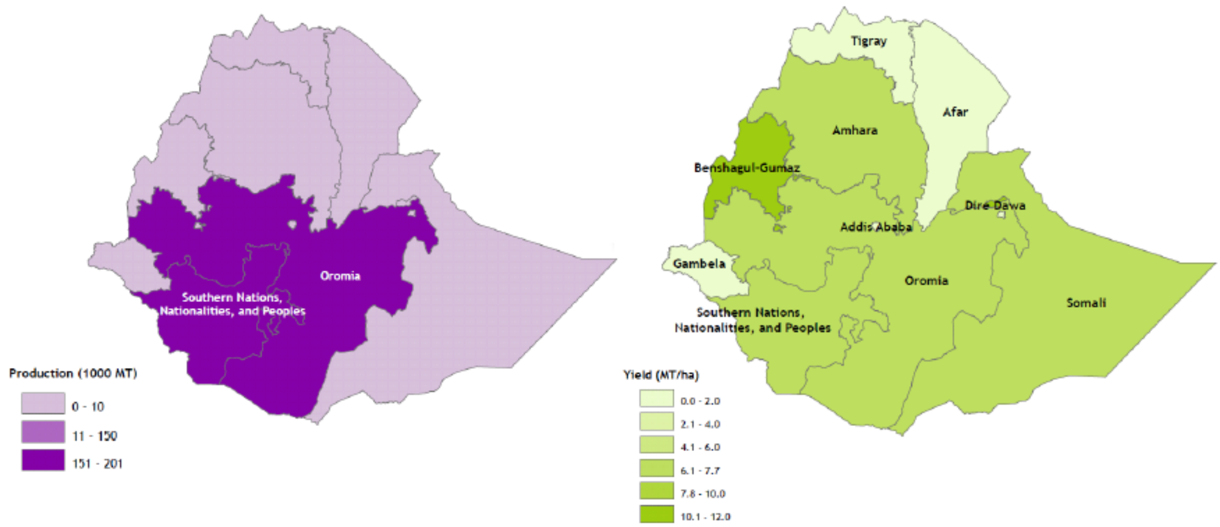

Figure 1. Sweetpotato production and yield by region in 2011. Source: Jones *et al*. (2013).

abiotic factors such as recurrent drought, reduction in soil fertility, diseases, insect and vertebrate pests (Fekadu *et al.*, 2015a). The other problem is that even though there are improved technologies, however, there are no any formal institutions that multiply and supply quality planting materials. The product quality and nutritional importance in terms of major nutrient quantities (both macro- and micro-nutrients) are not well exploited. There is still an urgent need to generate high yielding varieties with desirable farmers' traits, processing and nutritional quality traits and with resistance to biotic and abiotic stresses. Adoption and/or generation of crop protection mechanisms, processing equipments and analysis of the nutritional facts of the crop also need great attention. The multiplication and delivery of improved quality planting materials at least at basic and pre-basic seed level is also critically needed.

AGRO-ECOLOGICAL ADAPTATION

In Ethiopia, sweetpotato is largely produced in mid and lower altitudes of the country where the altitude is less than 2000 meters above sea level (masl). The optimum range is 1500-1800 masl. It performs poorly and the maturity period is also extended when planted in areas with more than 2000 meters elevation (Terefe, 2003; Fekadu and Tesfaye, 2016). Sweetpotato is a warm weather crop and the optimum temperature for storage root growth is about 25°C. When temperature falls below 10°C, growth is severely retarded. It is a sun loving crop and yields better where the light intensity is relatively high. Optimal conditions for sweetpotato are found in regions that receive annual average rainfall of 750 to 1000 mm, with 500 mm falling during the non-growing season. This makes it relatively easy to propagate and maintain vine growth that will be used as planting material during the next season (Terefe, 2003). Although the crop with stand the drought conditions, the yields are considerably reduced if the drought occurs within the first six weeks after planting or at the time of storage root initiation (Edmond and Ammerman, 1971; Kay, 1973).

The best soil required for sweetpotato production is sandy loam and clay subsoil. It can also be grown in loamy to clay loam soil. Laterite soils of good depth and better fertility can also be considered suitable for sweetpotato production. Heavy clay soil which becomes hard after drying hinders the development of storage roots and sandy soils cause the development of long cylindrical pensile like storage roots (Terefe, 2003). Highly fertile soil favors luxuriant growth of vines and unfavorable growth for storage root development. Generally, sweetpotato requires well drained soils. Sweetpotato is very tolerant to soil acidity (pH < 5.0). However, soil pH between 5.2 and 6.7 is appropriate for sweetpotato (Rai and Yadav, 2005).

AREA OF PRODUCTION AND NUMBER OF HOUSEHOLDS PRODUCING SWEETPOTATO

Sweetpotato has been cultivated over several years and it is among the most important roots and tuber crops grown in Ethiopia. The Ethiopian Central Statistical Agency (CSA) reports indicated that sweetpotato occupied about 53,499 hectares of land with a total annual production of 1.85 million tons with productivity of 33.4 tons per hectare during the main growing season alone. The largest producing regions in the country are the South Nations, Nationalities and People's Region (SNNPR) and Oromia regional state (Figure 1). It is also grown in Benishangul Gumuz, Harari, Gambella, Amhara

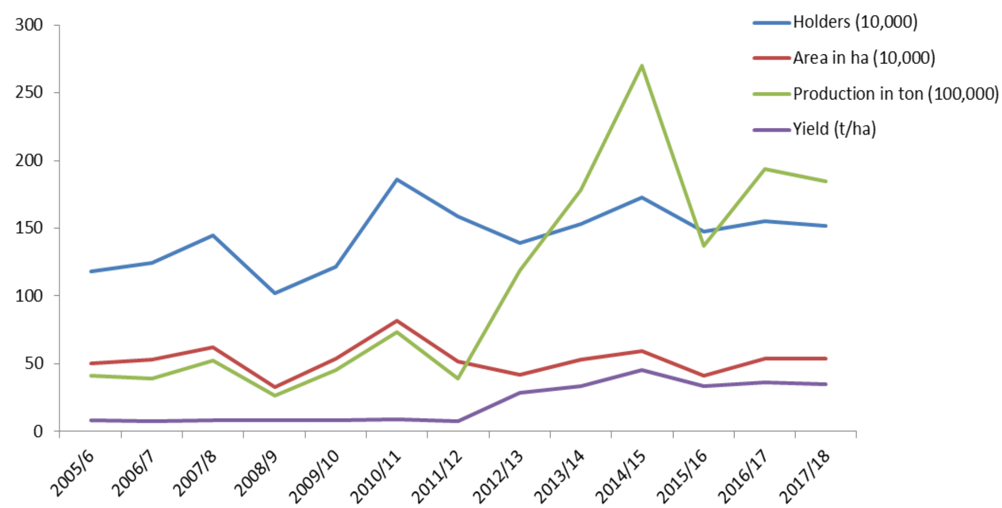

Figure 2. Sweetpotato production trends in Ethiopia (2005-2018). Source: Adapted from CSA (2005-2018).

and Tigray regions in smaller quantities. In the South, Southwestern and Eastern parts of the country, small-scale farmers with limited land, labor and capital nearly always grow sweetpotato for household food security purposes. The crop is able to perform best and provide high yield under marginal conditions with minimum/no inputs in terms of fertilizer, pesticides and labor. Consequently, its importance grows as population pressure increases on land resources causing the productivity of land to decline sharply (Gebremedhin *et al*., 2008).

The frequent drought in production ecologies, incidence of sweetpotato viral disease, lack of market and alternate utilization possibilities have greatly hindered the expansion of the production of this crop in Ethiopia. In spite of all these hindering factors, sweetpotato served as emergency relief crop in the country at the time of either natural or manmade disasters. Also as it is entirely usable crop: roots for human consumption and roots and tops for animal feed, it is planted by many farmers of SNNPRS and Oromia as choice crop to alleviate food and feed shortage. The trends of sweetpotato production in Ethiopia over the last 14 years (2005-2018) are presented in Figure 2. The trend shows that the production and productivity of the crops has been increasing, especially as of 2012, both at national level as well as at the largest producing region (SNNPR) and the largest producing zone in the SNNPR (Wolayta zone).

CONTRIBUTION OF SWEETPOTATO FOR FOOD AND NUTRITION SECURITY

Sweetpotato is a rich source of carbohydrates and dietary fibers. Especially orange fleshed sweetpotato (OFSP) contains β-carotene, a precursor of vitamin A, and its leaves are rich in proteins. The roots also contain vitamins C, B complex, and E as well as potassium, calcium, and iron. Purple-fleshed sweetpotatoes contain anthocyanin which has antioxidant and anti-cancer properties. According to a report by Mary (2004), anthocyanin isolates and anthocyanin-rich mixtures of bioflavonoids may provide protection from DNA cleavage, estrogenic activity (altering development of hormone-dependent disease symptoms), enzyme inhibition, boosting production of cytokines (regulating immune responses), anti-inflammatory activity, lipid peroxidation, decreasing capillary permeability and fragility, and membrane strengthening.

Kosambo *et al*. (1998) stated that root crops, in general, are rich in nutrients and protect us from different diseases such as diabetes (carotenoids, fiber and chlorogenic acid). Unlike other starchy vegetables, sweetpotato is considered to be an anti-diabetic food. Sweetpotato has low glycemic index, which means that the sweetpotatoes release sugar into the bloodstream slowly, unlike other starchy foods. This steady release of sugar is what aids in controlling the blood sugar levels of individuals so that it does not go low or high (https://parkeviewrehab.com/15-health-benefits-of-sweet-potatoes-according-to-science).

Sweetpotato also protects muscle cramps (potassium), improve immune system (beta carotene, vitamin C, iron, carotenoids, vitamin B-complex and phosphorus), heart diseases (potassium and vitamin B6). Fetal development (folate, which is very essential for healthy fetal cell and the development of tissue. arthritis, relief (zinc, magnesium, beta-carotene), digestion (fiber, beta-carotene and vitamin C), stomach ulcers (vitamin B-complex, beta carotene, potassium, vitamin C and calcium), eye health, skin benefits, asthma (vitamin A and C protect cells and have anti-inflammatory effect), they also protect health from bronchitis and weight loss (Kosambo *et al*., 1998).

TRENDS OF SWEETPOTATO RESEARCH IN ETHIOPIA

This section discusses about the genetic diversity of sweetpotato, research trends on breeding and genetics, agronomy and cropping system, plant protection, postharvest management and marketing, seed system and nutrition studies that have been conducted on sweetpotato in Ethiopia.

Genetic diversity of sweetpotato

Sweetpotato belongs to the morning glory or Convolvulaceae family. This family includes about 55 genera and more than 1000 species (Watson and Dallwith, 2000). It is hexaploid (6x = 90) and usually considered the only species of *Ipomoea* of economic importance. It was introduced to Africa by explorers from Spain and Portugal during the 16th century (Zhang *et al*., 2000).

East Africa is one of the areas suggested as the secondary center of diversity for sweetpotato (Gichuki *et al*., 2003). In Ethiopia, sweetpotato has been cultivated for the last several years and over 95% of the crop is produced in the south west, eastern and southern parts, where it has remained for many years as one of the major subsistence crops especially in the periods of drought (Adhanom *et al.*, 1985; Endale *et al.,* 1992). The crop is highly heterozygous and hence there is extensive variability within species which is available for exploitation by plant breeders (Jones *et al*., 1986; Engida *et al.,* 2007).

Sweetpotato is one of the most under exploited crop in the developing world (Rees *et al*., 2003). It importance of identifying local germplasm with desirable traits has long been recognized by breeders (Rees *et al*., 2003). Local germplasm is more desirable than exotic ones since in most cases such accessions are better adapted to the local agro-ecological environments. Many of the recently introduced clones have shown high yield potential though they were very susceptible to the devastating sweetpotato virus disease (SPVD). This indicates the need for local breeding programs that exploit the potential of local germplasm (Mwanga *et al*., 2002).

Genetic improvement of sweetpotato in Ethiopia

Sweetpotato improvement in Ethiopia has been underway since 1966 for over 50 years. The improvement work was mainly through germplasm introduction, evaluation and selection of best yielding varieties with resistance to disease and insect pests. Collection of locally available sweetpotato germplasm and selection of best genotypes is the second approach being practiced by the sweetpotato improvement program of the country. The third approach, crossing and evaluation of progenies for various traits is less practiced in Ethiopia until recently. A crossing program was started in Ethiopia in 2013 with the objective of improving the dry matter contents of the OFSP varieties and to enhance their yields and resistance to viruses. Tremendous results have been obtained with the three breeding approaches where over 25 varieties (six OFSP) with various traits have been released and disseminated to farmers (Table 1). The root yield of the varieties ranged from 16 t/ha (Adu variety) to 48 t/ha (the newly released variety, Hawassa-09). The varieties are grouped in to three based on their maturity groups. The first groups are early maturing groups that take 90 to 120 days; the second groups are medium maturing groups that take 121-150 days while the third groups, late maturing ones, take over 150 days to mature. The early maturing groups are recommended for lowland areas with short rainy seasons while the medium and late maturing groups are recommended for mid-altitude areas that receive medium to high rainfall during the growing period (Table 1).

In the first controlled crossing that was conducted in 2013, five traits, namely root dry matter content (RDMC), β-carotene content, resistance to virus disease (SPVD), root yield and harvest index (HI) had been considered for genetic study. Combining ability, heterosis and heritability of the traits had been examined (Fekadu *et al*., 2018). The GCA and SCA mean squares were significant ($p < 0.01$) for all the five traits studied. The GCA to SCA variance ratios were 0.96, 0.94, 0.74, 0.96 and 0.97 for RDMC, β-carotene content, SPVD, fresh root yield and HI, respectively, indicating that the inheritance of these traits was controlled mainly by additive genes. Both the GCA and the SCA effects were important in controlling the expression of β-carotene content. Two sweetpotato parents that had significant positive GCA effects for fresh root yield had been identified. Progenies of crosses involving high level of positive heterosis for RDMC and fresh root yield had also been identified for further study. Relatively high narrow sense heritability (h^2) was obtained for β-carotene content (79.8%) and HI (48.6%). However, the h^2 estimates of RDMC, SPVD and fresh root yield were low at 19.0, 14.9 and 20.4%, respectively (Fekadu *et al*., 2018).

Genotype x environment (G x E) and stability study on sweetpotato germplasm was also conducted in Ethiopia by various authors (Engida *et al*., 2011; Fekadu *et al*., 2017a). The authors reported the presence of significant G x E interaction of a cross-over type for storage root yield implying differential ranking of sweetpotato genotypes across locations and years. They suggested the need to consider both wider and specific adaptation in OFSP varietal evaluation for yield and yield components.

Table 1. List of released sweetpotato varieties in Ethiopia (1983-2017).

No.	Variety	Year of release	Altitude	Maturity days	Flesh colour	Yield (qt/ha)	Center of release
1	Kulfo (LO-323)	2005	1200-2200	150	Orange	270	Hawassa
2	Tulla (CIP 420027)	2005	1200-2200	150	Orange	285	Hawassa
3	Kero (TIS-8250)	2005	1200-2200	150	Orange	354	Hawassa
4	Kudade (TIS-1499)	1997	1200-2200	90-120	Cream	241	Hawassa
5	Falaha (TIS-3017(2)	1997	1200-2200	90-120	White	167	Hawasa
6	Dubo (I-444)	1997	1200-2200	90-120	White	217	Hawasa
7	Guntute (AJAC-I)	1997	1500-1800	120-150	Orange	354	Hawasa
8	Bareda (375)	1997	1200-2200	120-150	White	296	Hawasa
9	Damota (Guralowlow)	1997	1200-2200	120-150	Cream	307	Hawasa
10	Awassa-83	1983	1200-2200	150-180	White	366	Hawasa
11	Koka-12	1987	1200-2200	120-150	Pale orange	177	Hawasa
12	Koka-6	1987	1200-2200	120-150	Cream	269	Hawasa
13	Belella (192040-I)	2002	1200-2200	90-120	Cream	183	Hawasa
14	Temesgen (192009-VIII)	2002	1200-2200	90-120	White	176	Hawasa
15	Ordollo (192009-IX)	2005	1200-2200	150	White	173	Hawasa
16	Jari (CN-2059-1	2008	1650-1850	133	Yellow	192	Sirinka
17	Birtukane (saluboro)	2008	1650-1850	150	Orange	199	Sirinka
18	Berkume (TIS 8250-2)	2007	1650-2000	188-195	White	195	Haromaya Univ.
19	Adu (Cuba-2)	2007	1650-2000	150-180	Cream	160	Haromaya Univ.
20	Ballo (Koka-18)	2006	1400-1800	120	White	294	Bako
21	Beletech (192026-II)	2004	1200-2200	150	White	184	Hawassa
22	Dimtu	2005	1200-2200	120	White	-	Hawassa
23	Ogansegan	-	1200-2200		White	-	MoA
24	Mae	2010	300-980		White	-	Werer
25	Hawassa-09	2017	1200-1800	120-150	Cream	480	Hawassa

Source: Ministry of Agriculture Crop variety registration bulletin (1983-2017).

However, the authors indicated that the influence of G x E on nutritional contents such as β-carotene, dry matter, starch, protein, zinc and iron contents is less as compared to root yield (Fekadu *et al*., 2017a,b).

Agronomy research on sweetpotato in Ethiopia

Sweetpotato is generally adapted to tropical and warm temperate regions. It is cultivated between 40° latitudes of northern and southern hemispheres. Although it can be grown in altitudinal ranges between sea level and 2500 meter above sea level (masl) (Ramirez, 1992; Huaman, 1999), however, in Ethiopia, it is better adapted to an altitude that range between 1500 to 1800 masl. Root yield, number of roots and proportion of marketable roots decline with increasing altitude (Negeve *et al*., 1992). The minimum and maximum temperatures are 15 and 33°C, respectively where the optimum temperature is 25°C (Negeve *et al*., 1992; Ramirez, 1992; Belehu, 2003). When the temperature drops below 10°C, the growth of the crop is severely retarded. Sweetpotato is sensitive to frost (Negeve *et al*., 1992) and therefore its cultivation is confined to the tropics and warm temperate regions. Sweetpotato is a short day plant as reported by various authors (Ramirez, 1992; Belehu, 2003; Andrade *et al.*, 2009). It needs light for maximum vegetative development, while short days promote flowering and root growth.

Moisture is a critical factor for sweetpotato growth and production. Rainfall between 750-1000 mm per annum is ideal for sweetpotato production in Ethiopia. The crop should receive about 500 mm rainfall during its growing season (Belehu, 2003). The soil should be moist during planting and during growth period for at least two months (Ramirez, 1992). This helps to achieve good germination, establishment and yield. Although sweetpotato is a drought tolerant crop, it should get sufficient moisture during storage root initiation, 50 to 60 days after planting. Sweetpotato is not tolerant to water logging and hence good drainage is essential during excessive rain. The crop can be grown in a wide range of soils but it performs best on sandy loam soils. It performs poorly in soils with poor aeration such as clay soils (Ramirez, 1992; Belehu, 2003).

Light-textured soils generally encourage the production of roots with smoother skins whereas heavy clay loam soils often result in rough and irregular shaped roots. Sweetpotato performs well on slightly acidic or neutral soils with pH of 5.5 to 6.5. Both excessively alkaline and acidic soils reduce yields (Ramirez, 1992).

Sweetpotato is grown in several agro-ecological zones and usually plays significant roles in the farming and food systems of the majority of the community in the south, south west and eastern parts of the country. It is commonly grown by farmers in complex, mixed cropping systems where they normally plant several varieties with different characteristics (yield, maturity, palatability, time to maturity, root size and shape, root colour, storability in the ground, pest and disease tolerance, drought tolerance, and sweetness) in a single plot (Daniel and Gobeze, 2016).

The general recommendations on land preparation, planting materials preparation, methods of planting, plating time, plant population are discussed in the sweetpotato manual that was prepared by Hawassa Agricultural Research Center (Fekadu and Tesfaye, 2016). The land should be prepared well in advance (at least two weeks) before planting and it should be prepared intensively (at least three time plowing). Vines should be collected from fresh field that is not more than three months old. The upper and middle parts of the vines are recommended than the basal parts for better survival, freeness from diseases and better yield. Vines of 20 to 30 cm length are recommended based on the vine inter-node length of the varieties. If the inter-node length is short or medium (3 to 5 cm), short vines of 20 to 30 cm can be used. But for varieties with long inter-node length (> 6 cm), long vines of 30 to 40cm should be used. This is because inter-node length determines the number of nodes that are grown to roots and shoots. Sweetpotato can be grown on flat ground, mounds or ridges. If the soil is sandy loam type, flat bed can be used but if the soil is not light, ridges are recommended for good drainage. Mounds are recommended for areas with high rainfall and for heavy soils. Ridge plating is generally recommended in Ethiopia (Fekadu and Tesfaye, 2016). Two third (about 20 cm of the cutting) should lie beneath the soil surface. Cuttings should be kept in the shade and well watered for 2 to 3 days before panting for hardening. The distance between ridges should be 60 cm and between plants 30 cm, resulting in a total plant population of 55,555 cuttings per hectare.

Planting date experiments justified early planting with the onset of rainfall in non-irrigated fields (Daniel and Gobeze, 2016). The results of fertilizer regimes varied across locations and varieties. Thus generation and promotion of site specific fertilizer recommendations are of paramount importance for root crops like sweet potato. Weeding should be done twice on 30 to 40 days and 70 days after planting (Fekadu and Tesfaye, 2016; Daniel and Gobeze, 2016). Sweetpotato can be intercropped and rotated with different crops for soil fertility management, to increase land productivity, and to break pests and diseases.

Sweetpotato diseases and insect pests research in Ethiopia

Among various factors that affect the yield and related traits of sweetpotato, sweetpotato diseases and insect pests are the major ones. They are known to cause a yield reduction as high as 98% (Kapinga *et al*., 2005). The major sweetpotato disease in Ethiopia is sweetpotato virus disease (SPVD), while the minor ones are leaf spot, Alternaria blight and scab.

Sweetpotato diseases

Sweetpotato virus disease (SPVD) is the most devastating disease of sweetpotato in Africa (Geddes, 1990; Lenné, 1991) and worldwide (Carey *et al*., 1999). In east Africa, over 90% yield reductions have been associated with viruses. Infection may cause up to 100% yield loss. The virus infection affects both the quantity and quality of sweetpotato (Tewodros *et al*., 2011). Greater than 20 viruses are known to infect cultivated sweetpotato worldwide (Fuglie, 2007).

In Ethiopia, SPVD was not considered as a limiting factor until 2004 (Abraham, 2009). Since late 2004, however, it has been recognized as an important disease that greatly reduces yield of sweetpotato (Geleta, 2009). Currently, SPVD is the major economically important disease in Ethiopia. In a study conducted from 2004-2011, four types of viruses namely, Sweetpotato feathery mottle virus (SPFMV), Sweetpotato chlorotic stunt virus (SPCSV), Sweetpotato virus G (SPVG) and Sweetpotato virus 2 (SPV2) were identified and recorded in the country (Shiferw *et al*., 2014). Among the four types, the synergistic infection of SPFMV and SPCSV was reported to cause 37% root yield reduction (Tesfaye *et al.*, 2013). The prevalence of SPVD in Ethiopia is reviewed and documented by Shiferaw *et al*. (2014) and Megersa (2018). In addition, sweetpotato stem blight caused by Alternaria spp. is also considered as intermediate and sometimes threatening sweetpotato production and productivity in the country. Sweetpotato viruses are transmitted by various methods such as presence of virus infected plants (source plants), movement of infected cuttings as planting materials without sanitary control and vectors such as Aphids and white flies. Aphids directly infest sweetpotato, causing leaf curling, deformation, stunting and wilting of plants. In order to manage these threatening diseases, it is recommended to strengthen local quarantine system, training of farmers, experts and multipliers. Moreover, it is also important to clean and distribute virus free planting materials to reduce the present status of the disease and its effect on the resource poor farmers and multipliers (Shiferaw *et al*., 2014; 2016; Fekadu and Tesfaye, 2016).

Disease management strategies such as cultural practices, phytosanitary measures, control of vectors and deployment of genetic resistance to prevent or limit the extent of damage have been recommended. Among these, use of disease resistant genotypes is an ideal option in terms of effectiveness and sustainability for managing any plant disease in general and SPVD in particular (Maule *et al*., 2007; Miano, *et al*., 2008; Shiferaw *et al*., 2017). Cleaning sweetpotato plants through tissue culture technology and planting the cleaned ones in new and isolated field is another approach that is being practiced in Ethiopia. The detail of virus cleaning and indexing is given under seed system section.

Sweetpotato insect pests

Some of the important insect pests of sweetpotato are sweetpotato weevil, sweetpotato butterfly, tortoise beetles, aphids, white fly and cut warm. Among these pests, sweetpotato weevil and sweetpotato butterfly are the most devastating insect pests in Ethiopia (Adhanom *et al.*, 1985; Emana and Adhanom, 1989; Ferdu, 1999; Ferdu *et al*., 2009). Adult sweetpotato weevils feed on the epidermis of vines and leaves while the larvae feed on roots. Sweetpotato is also highly affected by vertebrate pests, among which porcupines, mole rats and monkeys are the major ones.

Some of the control measures for the insect pests are use of clean/uninfested planting materials (especially vine tips), removal of volunteer plants, crop debris, discarded and unharvested storage roots, flooding the field for 24 hours after completing a harvest, mulching to keep the soil moist and prevent cracks. Timely planting and harvesting to avoid a dry period, removal of alternate wild hosts, planting away from weevil-infested fields, hilling-up of soil around the base of plants and filling in of soil cracks, applying sufficient irrigation to prevent or reduce soil cracking, plough the field after harvest to expose the pests to predators, use of resistant or less-susceptible varieties and dipping sweetpotato cuttings in chemicals such as diazinon 60% EC before planting (Ermias *et al*, 2013; Fekadu and Tesfaye, 2016).

Postharvest handling and marketing

Sweetpotato is a perishable crop that is not stored for a long time after harvest especially in developing countries where there are no storage facilities. Farmers in these countries poorly handle it and the roots suffer significant postharvest losses along the value chain (Parmar *et al*., 2017). Current global estimates suggest that 45 to 54% of roots and tubers are spoiled due to problems related to postharvest in sub-Saharan Africa (Gustavsson *et al*., 2016). Although Ethiopia is the fourth largest producer of sweetpotato in the world, however, little information is available regarding the postharvest handling practices and associated food losses. According to a review article by Jones *et al*. (2012), in Ethiopia, information on sweetpotato postharvest handling practices, storage and magnitude of losses is almost nonexistent.

Fekadu *et al.* (2015) identified the major postharvest constraints of sweetpotato as poor access to markets at 22.6%, poor market prices (19.1%), low yield (14.2%), low dry matter content of roots of existing varieties (13.6%), a lack of knowledge about sweetpotato processing and preservation (11.7%), no access to processing equipment (11.1%) and the logistics of transporting a heavy, bulky crop (7.7%) to market.

As reported by Parmar *et al*. (2017), harvesting of sweetpotato starts in the morning carries on until evening for market deliveries. In most cases, the harvesting period extend to 2 to 3 months after maturity, which increases the risk of sweetpotato weevil attack especially in the dry season (main harvest). This is because the farmers store the roots in the soil since they do not have any storage facilities (Fekadu *et al*., 2015). In the study conducted by Parmar *et al*. (2017), about 90% of the respondents (farmers and collectors) explained that they protect freshly harvested roots from direct sunlight, mostly by putting them in the shade or covering them with vines and polypropylene sacks. Polypropylene sacks were used for packaging and transportation of commercial sweetpotato roots consignments from the farm to the retail market.

Parmar *et al*. (2017) indicated that at the retail level, roots were kept in the same polypropylene sacks until sold, parts of the batch were taken out gradually, sorted by size and displayed on the sacks or on the ground for sale. In order to include extra weights and transport to distant markets, extended bags are used for packing. But for the nearby markets, non-extended bags are used to transport the roots. Depending on the distance to the market, three major modes of transportation are available in Ethiopia. These are donkeys, donkey carts and mini-truck with capacities of 1, 3 and 45 sacks, respectively (Parmar *et al*., 2017).

A study by Parmar *et al*. (2017) indicated the presence of three common paths by which the sweetpotato roots reach the final step of retailing in Ethiopia. In the first, collectors pick up roots from many farmers and bring them to the wholesaler from where retailers purchase. The second path is where farmers sell directly to wholesalers without any involvement of collectors. The third one is where the farmers and collectors sell directly to retailers, mostly at small village-level markets. Figure 3 presents the postharvest value chain of sweetpotato in Ethiopia from collection of roots to marketing (Parmar *et al*., 2017).

The products are packed and transported to wholesale/

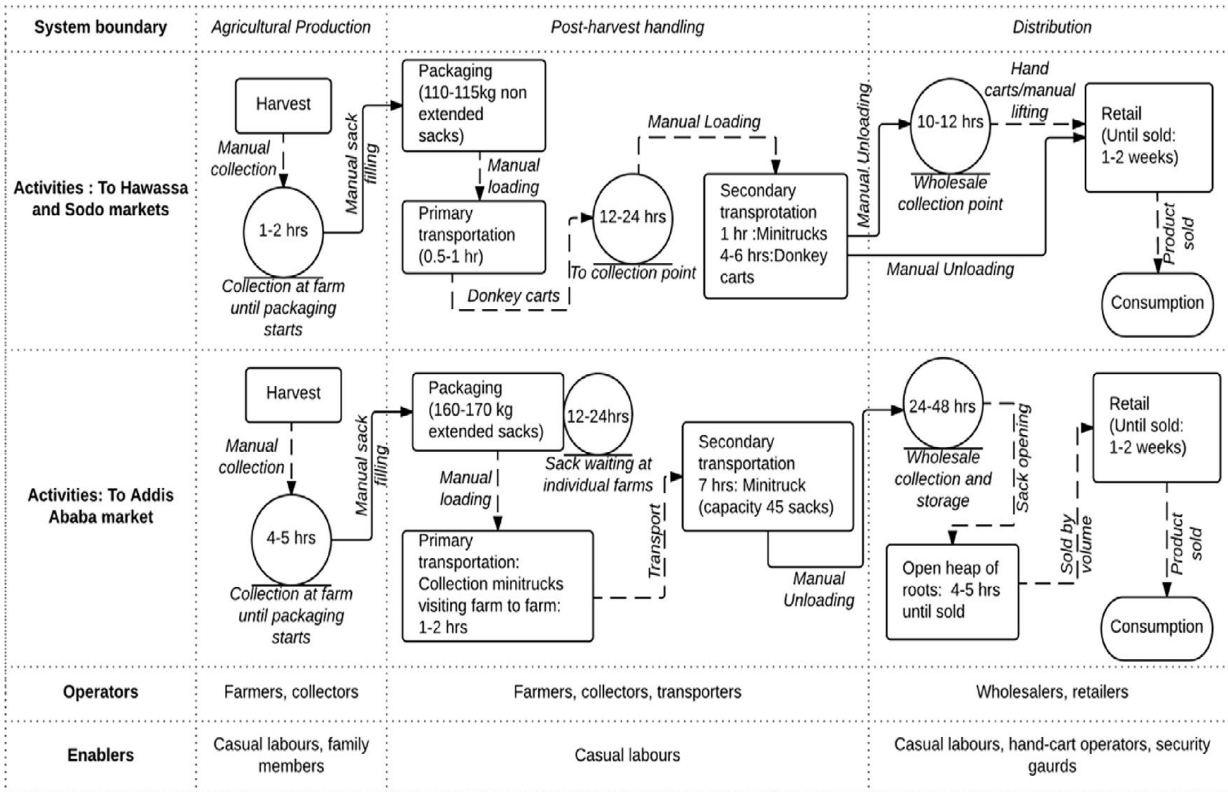

Figure 3. Sweetpotato post-harvest value-chain actors and activities in the major growing areas. Source: Parmar *et al.* (2017).

retail market as soon harvested and the value chain actors perform no curing and storage activities at any stage of the value chain. There are no sorting, grading, packaging or any other value-adding activities. There are delays of 1 or 2 days after packaging depending on the distance to the market and the transportation systems. During these delays, the products are normally kept under shelter or outside in the shade at ambient environmental conditions, packed in polypropylene sacks (Parmar *et al*., 2017). Mechanical injuries, weevil infestation and lack of storage/curing facilities were found to be some of the primary causes of postharvest losses. The same study indicated that sweetpotato is consumed in the form of boiled whole roots and there are no value added primary or secondary processed products. There are small street vendors who sell boiled sweetpotato roots with local sauces (datta or awaze). This was previously consumed by economically poor members of the society but currently any one can purchase and consume it, including university students, in different towns of the country.

According to Getahun *et al*. (2015) the main processes of sweetpotato value chain include input supply, technical support (extension service), production, processing, trading and consumption. The primary actors in a sweetpotato value chain are planting material and other input suppliers, farmers, traders, brokers, processors, retailers and consumers (Figure 4).

Sweetpotato seed system in Ethiopia

The informal seed system takes the largest share where sweetpotato seeds/vines are shared among neighboring farmers either for free or through purchase from the local market. However, this approach has some limitations such as wide spread of diseases and insect pests, limited use of improved varieties, variety degeneration and varietal mixtures. Therefore, in order to mitigate the above problems, the formal seed system has been started with the support of various actors such as the South Agricultural research institute (SARI), International Potato Center (CIP) and Ethiopian Institute of Agricultural Research (EIAR). The formal seed value chain starts with cleaning of sweetpotato varieties in tissue culture and the clean plantlets are acclimatized in screen houses, virus indexed and the virus indexed vines are harvested and planted in insect proof net tunnels for pre-basic seeds production. The pre-basic vines are then transferred to isolated open fields for basic seed production (Figure 5). The commercial vine multipliers purchase the basic seeds from research centers, multiply and sell the vines to different government organizations (GOs) and non-government (NGOs) for distribution to root producing farmers (Getahun *et al*., 2015). The sweetpotato seed guidelines for the full certification (pre-basic, basic, certified and quality declared seeds) is already developed with the involvement of SARI, EIAR, Ministry of

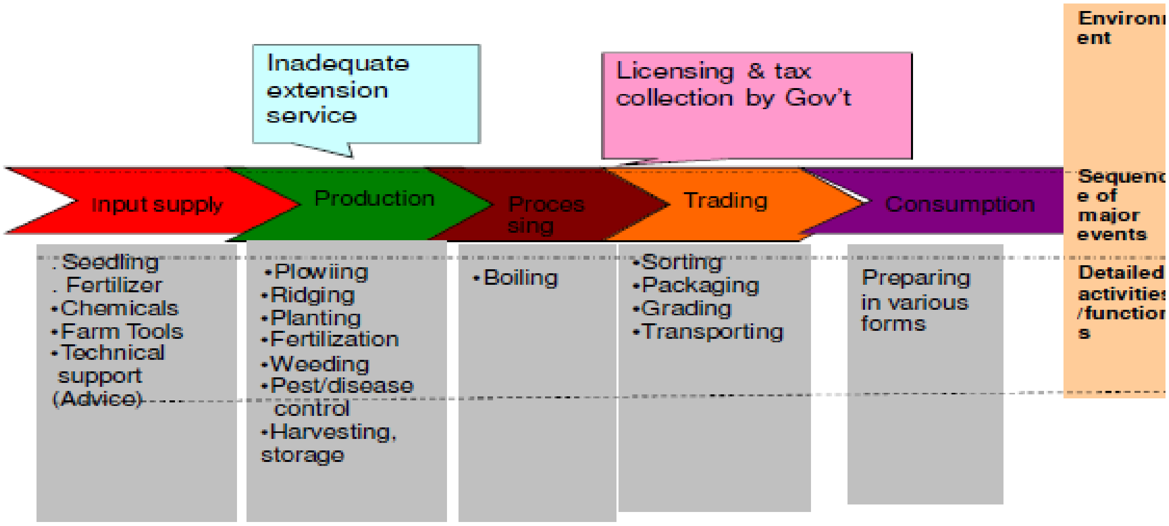

Figure 4. Sweetpotato value chain map in Ethiopia. Source: Getahun *et al.* (2015).

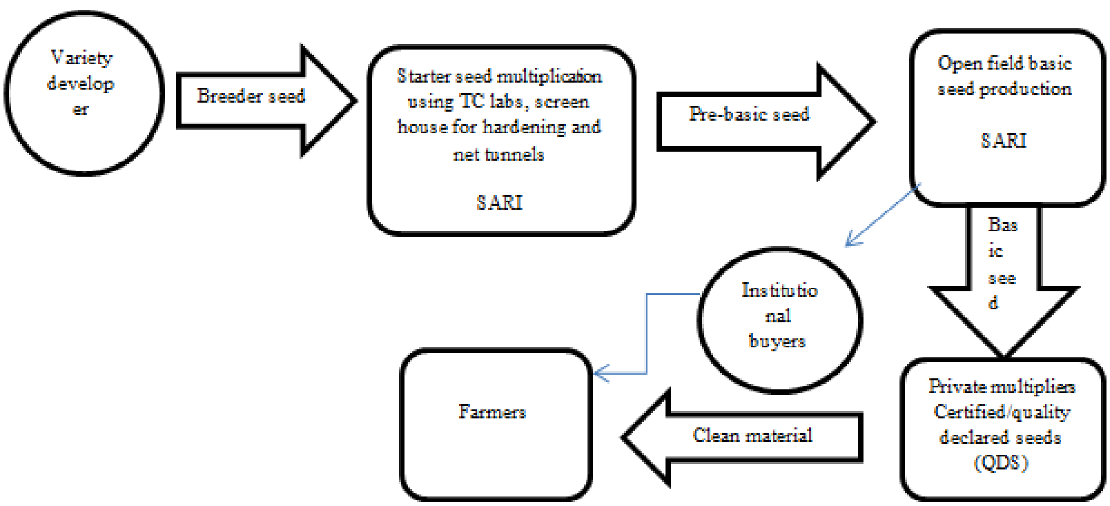

Figure 5. Steps followed in the formal seed system of sweetpotato in Ethiopia.

Agriculture, Ethiopian Agriculture Transformation Agency and Ethiopian Standard Agency; it is approved and being implemented. There are Regional Agricultural Inputs Quality Control and Quarantine Authorities (AIQCQA) that approve the quality of pre-basic and basic seeds produced by the research institutions before the vines are sold to multipliers. The same authorities control the quality of vines produced by each multiplier before they sell the vines to institutional buyers.

Food and nutrition studies on sweetpotato

Deficiency of micro-nutrients such as vitamin A and minerals, especially iron (Fe) and zinc (Zn), affects nearly two billion people worldwide (Allen *et al*., 2006; Tulchinsky,2010). The deficiencies increase susceptibility to other diseases. Pregnant and lactating mothers, and young children, are highly affected by nutrient deficiencies since they need relatively high levels of vitamins and minerals (Nabakwe and Ngare, 2004; WHO, 2009a). Vitamin A deficiency is the major health problem worldwide that leads to blindness, retarded growth and death, particularly in developing countries. It largely affects pre-school children, pregnant and lactating mothers, and the rural poor (WHO, 2009b).

A review made by Fekadu *et al*. (2015) indicated that different strategies have been used to control VAD. The strategies include vitamin A supplementation of large doses in the form of capsules, fortification of commonly consumed food items such as oil, sugar, breakfast cereals and grain flour, and dietary diversification which includes eating food items naturally rich in pro-vitamin A such as yellow/orange root crops, leafy vegetables and yellow/orange fruits. Orange-fleshed sweet potato (OFSP) is a good, low-priced and sustainable source of vitamin A (Burri, 2011; Fekadu et al., 2015b). OFSPs are not only sources of β-carotene but also source of anthocyanins, phenolics, dietary fiber, vitamin C, folic acid and minerals (Woolfe, 1992; Bovell-Benjamin, 2007; Burri, 2011). According to Fekadu et al (2017b), OFSP varieties that are currently bred in Ethiopia contain better amounts of various macro- and micro-nutrients such as β-carotene (20.01 mg 100 g^{-1}), protein (7.08%), iron (2.55 mg 100 g^{-1}), zinc (1.42 mg 100 g^{-1}), fructose (4.45%), glucose (5.34%) and sucrose (16.20%). The leaves of sweetpotato also serve as nutritious vegetable for humans (Woolfe 1992). Sweetpotato leaves are good sources of protein, β-carotene, some of the B vitamins, iron, and other minerals. Therefore, sweetpotato leaves are also being promoted as vegetables in Ethiopia.

Sweetpotato can be mixed with various crops like cereals (such as wheat, tef, maize, sorghum) and legumes (such as beans, soybean, cowpea, field pea etc) to develop complementary foods. Different proportions of mashed OFSP or its flour have been mixed with flour of various crops and the best combinations have been identified. All the studies showed that the complementary foods have better nutritional contents than when they are used alone (Abebe and Dereje, 2018; Amagloh *et al*., 2012; Yibeltal *et al*., 2016; Mesfin *et al*., 2017; Larea *et al.*, 2018). The nutritional and anti-nutritional factors of mashed OFSP or its flour mixed with various crops have also been studied and reported by various researchers.

CONCLUSION

Sweetpotato is widely grown in south, southwestern and eastern parts of Ethiopia by small-scale farmers with limited land, labor and capital making Ethiopia one of the largest sweetpotato producing countries in the world. However, the productivity of the crop remained low for a long time and the production of the crop is also declining due to many factors including recurrent drought, lack of planting materials, shortage of farmer preferred varieties, poor extension system that doesn't encourage production of root crops and market problems. Various research and development activities have been undertaken to mitigate the above problems and some of the findings have been published in different outlets. However, there is no a compiled reference source on research and development works on sweetpotato in Ethiopia.

This paper highlights the major research and development works that have been undertaken on sweetpotato in Ethiopia. The contribution of sweetpotato for food and nutrition security in Ethiopia is very much pronounced at the community level although it is not much appreciated by the policy makers due to their focus mainly on cereals (maize and wheat) and legumes (common beans and chick peas). Various research activities have been conducted on sweetpotato in Ethiopia including variety development, crop management options such as the development of agronomy and plant protection guidelines, development of postharvest handling and food preparation manuals, seed standards and production guidelines. The availability of these outputs in a compiled and comprehensive ways is very important for enhancing production and productivity of sweetpotato in Ethiopia and to influence the policy makers to consider sweetpotato as one of the major food and nutrition security crops in Ethiopia.

ACKNOWLEDGEMENTS

The South Agricultural Research Institute (SARI), Ethiopian Institute of Agricultural Research (EIAR) and the International Potato Center (CIP) are duly acknowledged for financially supporting the sweetpotato research and development activities in Ethiopia. My special gratitude goes to the Irish Aid nutrition project of CIP for their financial support.

REFERENCES

Abebe H, Dereje G (2018). Evaluation of Nutritional and Anti Nutrition Factors of Orange-fleshed Sweet Potato and Haricot Bean Blended Mashed Food for Pre-school Children: The Case of Dale Woreda, Southern Ethiopia. Food Sci. Technol. 6(1):10-19. doi: 10.13189/fst.2018.060102.

Abraham T (2009). Increasing Crop Production through Improved Plant Protection. Volume II. Plant Protection Society of Ethiopia (PPSE). PPSE and EIAR, Addis Ababa, Ethiopia.

Adhanom N, Tsedeke A, Emana G (1985). Research on insect pests of roots and tuber crops: Review of crop protection research in Ethiopia: Proceedings of the first Ethiopian Crop Protection Symposium, 4-7 February, Institute of Agricultural Research, Addis Ababa, Ethiopia.

Allen L, Benoist B, Dary O, Hurrell R (2006). Guidelines on Food Fortification with Micronutrients. World Health Organization and Food and Agricultural Organization of the United Nations, Geneva.

Amagloh FK, Hardacre A, Mutukumira AN, Weber JL, Brough L, Coad J (2012). Sweet potato-based complementary food for infants in low-income countries. Food Nutr. Bullet. 33(1):3-10.

ASHS, American Society for Horticultural Science (2007). Sweet potato promises hunger relief in developing countries. Science Daily. https://www.sciencedaily.com/releases/2007/11/071102084811.htm. Accessed on 01.06.2019.

Andrade M, Barker I, Cole D, Dapaah H, Elliott H, Fuentes S, Gruneberg W, Kapinga R, Kroschel J, Labarta R, Lamaga B, Loechl C, Jan L, Lynam J, Mwanga R, Ortiz O, Oswald A, Thiele G (2009). Unleashing the Potential of Sweetpotato in sub-Saharan Africa: Current Challenges and Way Forward. Working paper 2009-1. International Potato Center (CIP), Lima, Peru.

Assefa T, Teshome A, Engida T, Tesfaye T (2007). Summary of progress on orange-fleshed sweetpotato research and development in Ethiopia. In: Proceedings of the 13th International Society for Tropical Root Crops (ISTRC) Symposium, Arusha, 9-15 November, 2003. ISTRC, Arusha, Tanzania.

Bovell-Benjamin AC (2007). Sweetpotato: A review of its past, present, and future role in human nutrition. In: Adv. Food Nutr. Res. 2007. National Institutes of Health, Bethesda, Maryland, USA.

Burri BJ (2011). Evaluating sweetpotato as an intervention food to prevent Vitamin A deficiency: comprehensive review. Food Sci. Food Safety 10:118-130.

Buzayehu T, Firdu A (2009). Root Research and development in Root & tuber crops in Ethiopia, Hawassa University, College of Agriculture, Department of Plant and Horticultural Science, Hawassa, Ethiopia.

Carey EE, Gibson RW, Fuentes S, Machmud M, Mwanga ROM, Turyamureeba G, Zhang L, Ma D, Abo El-Abbas F, ElBedewy R, Salazar L (1999). The causes and control of virus diseases of sweetpotato in developing countries: is sweetpotato virus disease the main problem. In: Impact on a changing world. International Potato Center Report for 1997-98. pp. 241-248.

CSA (2018). Ethiopia Agricultural Sample Survey 2017/2018: Report on Land Utilization (Private Peasant Holdings, Meher Season). Central Statistical Agency (CSA), Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia.

Daniel M, Gobeze L (2016). Sweet Potato Agronomy Research in Ethiopia: Summary of Past Findings and Future Research Directions. Agriculture and Food Sciences Research, 3(1): 1-11.

Edmond J, Ammerman G (1971). Sweet potatoes; Production, Processing, Marketing, Avi publishing CO. Westport, USA, p. 334.

Emana G, Adahanom N (1989). Survey of sweet potato insect pests in southern Ethiopia. Newsletter, Committee of Ethiopian Entomologists 3(2): 16-19.

Endale T, Terefe B, Mulugeta D, Geleta L (1992). Improvement studies on Enset and Sweet potato. Proceedings of the 2nd National Horticultural Workshop in Ethiopia, December 1-3, 1992, Addis Ababa, Ethiopia.

Engida T, Dechassa N, Sastry EVD (2007). Genetic variability for yield and other agronomic traits in sweet potato. J. Agronom. 6:94-99.

Engida T, Mihiretu C, Asfaw K, Mekonen D, Tesfaye T (2011). Genotype x environment interactions and yield stability of orange fleshed sweetpotato varieties grown in Ethiopia. In: Tropical Roots and Tubers in a Changing Climate: A Critical Opportunity for the World, 2-6 November, 2009, Lima. International Society for Tropical Root Crops (ISTRC), Lima, Peru.

Ermias S, Mesele G, Tesfaye T, Elias U (2013). Review of Entomological Research on Sweet Potato in Ethiopia. Discourse J. Agric. Food Sci. 1(5):83-92.

Fekadu G, Shimelis H, Mark L (2013). Self- and Cross-incompatibilities in Sweetpotato and Their Implications on breeding. Aus. J. Crop Sci. 7(13): 2074-2078.

Fekadu G, Shimelis H, Mark L (2015a). Diagnostic assessment of sweetpotato production in Ethiopia: constraints, post-harvest handling and farmers' preferences. Research on Crops 16(1):104-115.

Fekadu G, Shimelis H, Mark L (2015b). The Potential of Orange-Fleshed Sweetpotato to Prevent Vitamin A Deficiency in Africa. International Journal of Vitamin and Nutrition Research 84(1): 65-78.

Fekadu G, Tesfaye T (2016). Sweet potato production and post-harvest handling. A manual prepared for agricultural experts (unpublished).

Fekadu G, Hussein S, Mark L (2017a). Genotype-by-Environment Interaction and Stability of Sweetpotato Genotypes for Root Dry Matter, β-carotene and Fresh Root Yield. Open Agriculture (De Gruyter Open) 2:473-485.

Fekadu G, Hussein S, Mark L (2017b). Evaluation of candidate orange-fleshed sweetpotato clones for nutritional traits. Acta Agriculturae Scandinavica, Section B - Soil Plant Sci. 67(7):651-659.

Fekadu G, Hussein S, Mark L (2018). Combining Ability, Heterosis and Heritability of Storage Root Dry Matter, Beta-Carotene and Yield-related Traits in Sweetpotato. Am. Soc. Horticult. Sci. 53(2):167-175.

Ferdu A (1999). Biology and economic importance of the sweet potato butterfly in Ethiopia. PhD Thesis. Swedish University of Agricultural Science. Uppsala, Sweden.

Ferdu A, Baye M, Emana G, Temesgen A, Eyobe T, Mesele G, Biruk W (2009). Review of Entomological Research on Root and Tuber Crops in Ethiopia. pp. 1- 46.

Fuglie KO (2007). Priorities for Sweetpotato Research in Developing Countries: Results of a Survey. Hort. Sci. 42:1200-1206.

Gebremedhin W, Endale G, Berga L (2008). Overview of trends in root and tuber crops research in Ethiopia. pp. 1-5. In: Gebremedhin Woldegiorgis, Endale Gebre and Berga Lemaga (editors.) Root and Tuber crops: The untapped resources, IAR, Addis Ababa Ethiopia.

Geddes AMW (1990). The relative importance of crop pests in sub-Saharan Africa. Natural Resour. Instit. Bullet. No. 36(6):69.

Gichuki S, Berenyi M, Zhang D, Hermann M, Schmidt J, Glössl J, Burg K (2003). Genetic diversity in sweetpotato [*Ipomoea batatas* (L.) Lam.] in relationship to geographic sources as assessed with RAPD markers. Genetic Resources and Crop Evolution 50:429-437.

Gustavsson C, Sonesson U, van Otterdijk R, Meybeck A (2016). Global food losses and food waste: extent, causes, and prevention. Doi:10.1098/rstb.2010.0126. https://parkeviewrehab.com/15-health-benefits-of-sweet-potatoes-according-to-science. Accessed on 14/06/2019.

Huaman Z (1999). Sweetpotato (*Ipomoea batatas*) Germplasm Management. International Potato Center (CIP), Lima, Peru.

International Potato Center, CIP (2007). Sweetpotato in Africa. https://cipotato.org/research/sweetpotato-in-africa/. Accessed on 01.06.2019.

Jones D, Gugerty M, Anderson L (2012). Sweetpotato Value Chains in Ethiopia, Evans School of Public Affairs, University of Washington. EPAR Breif No. 29:11.

Kapinga RE, Carey EE (2003). Present status of sweetpotato breeding for eastern and southern Africa. In: Rees, D., Oirschot, Q.& Kapinga, R., editors. Sweetpotato Post-harvest Assessment: Experiences from East Africa. Natural Resources Institute, Chatham, UK.

Kapinga R, Anderson P, Crissman C, Zhang D, Lemaga B, Opio F (2005). Vitamin A partnership for Africa: a food based approach to combat vitamin A deficiency in sub-Saharan Africa through increased utilization of orange fleshed sweetpotato. Chronica Horticult. 45(3):12-14.

Kay DE (1973). Crop and Product digest 2: root crops tropical products institute, London, p. 245.

Kosambo L, Carey EE, Misra AK, Wilkes J, Hagenimana V (1998). Influence of age, farming site, and boiling on pro-vitamin: A content in sweet potato (*Ipomoea batatas* (L.) Lam.). J. Food Anal. 11:8-9.

Laryea Damian, Faustina Dufie, Wireko-Manu, Ibok Oduro (2018). Formulation and characterization of sweetpotato-based complementary food. Food Science & Technology 4: 1517426. https://doi.org/10.1080/23311932.2018.1517426. Accessed on 12/06/2019.

Lenné JM (1991). Diseases and pests of sweetpotato: south-east Asia, the Pacific and East Africa. Natural Resources Institute Bulletin No. 46 pp.viii+116.

Low J, Nyongesa M, Quinn S, Parker M (eds) (2015). Potato and sweetpotato in Africa. Transforming the value chains for food and nutrition security. Boston (USA). CABI International. ISBN 978-1-78064-420-2. p. 632.

Mary AL (2004). Anthocyanins and Human Health: An In Vitro Investigative Approach. J. Biomed. Biotechnol. 5:306-313.

Maule AJ, Caranta C, Boulton MT (2007). Sources of natural resistance to plant virus: status and prospects. Mol. Plant Pathol. 8(2):223-231.

Megersa KE Barkessa (2018). A Review on Sweet potato (*Ipomea batatas*) Viruses and Associated Diseases. Int. J. Res. Agric. For. 5(9):1-10. ISSN 2394-5907.

Mesfin W T, Glaston MK, Eneyew TM, John K (2017). Teff-Based Complementary Foods Fortified with Soybean and Orange-Fleshed Sweet Potato. J. Food Res. 6(1):112-122.

Miano D, Labonte D, Clark C (2008). Identification of molecular markers associated with sweetpotato resistance to sweetpotato virus disease in Kenya. Euphytica 160:15-24.

Mwanga ROM, Kriegner A, Cervantes-Flores JC, Zhang DP, Moyer JW, Yencho GC (2002). Resistance to sweetpotato chlorotic stunt virus and sweetpotato feathery mottle virus is mediated by two separate recessive genes in sweetpotato. J. Am. Soc. Horticult. Sci. 127:798-806.

Nabakwe EC, Ngare KD (2004). Health and nutritional status of children in Western Kenya in relation to Vitamin A deficiency. East Afr. J. Publ. Health 1:1-8.

Ndunguru J, Kapinga R, Sseruwagi P, Sayi B, Mwanga R, Tumwegamire S, Rugutu C (2009). Assessing the sweetpotato virus disease and its associated vectors in northwestern Tanzania and central Uganda. Afr. J. Agric. Res. 4:334-343.

Negeve JM, Hahn SK, Bouwkamp JC (1992). Effect of altitude and environments on sweetpotato yield in Cameroon. Tropical Agriculture-Trinidad 69:43-48.

Parmar A, Oliver H, Barbara S (2017). Post-harvest handling practices and associated food losses and limitations in the sweetpotato value chain of southern Ethiopia. NJAS - Wageningen J. Life Sci. 80(2017):65-74.

Ramirez GP (1992). Cultivation, harvesting and storage of sweetpotato products. In: David, M. and N. Solveig, editors. Proceedings of the FAO Expert Consultation on Roots, Tubers, Plantains and Bananas in Animal Feeding, Cali, Colombia. 21–25 January, 1991. FAO, Rome. pp. 203-215.

Rees D, Van Oirschot Q, Kapinga R (2003). Sweet potato Post Harvest Assessment: Experiences from East Africa. Chatham, UK.

Shiferaw M, Fikre H, Fekadu G, Elias U (2014). Sweetpotato Diseases Research in Ethiopia. Int. J. Agric. Innov. Res. 2(6):2319-1473.

Shiferaw M, Fekadu G, Tesfaye T (2017). Evaluation of Elite Sweetpotato Genotypes for Resistance to Sweetpotato Virus Disease in Southern Ethiopia. Int. J. Adv. Res. 5(7):77-83.

Terefe B (2003). Agronomical and Physiological Factors Affecting Growth, Development and Yield of Sweetpotato in Ethiopia. Ph.D. Thesis, University of Pretoria, Pretoria, South Africa.

Tesfaye T (2006). Evaluation of Root Yield and Carotene Content of Orange-fleshed Sweetpotato Clones Across Locations in Southern Region of Ethiopia. MSc Thesis, Hawassa University, Hawassa, Ethiopia.

Tesfaye T, Fikre H, Mesele G (2011). Prevalence, incidence and distribution of sweetpotato virus: Its effect on the yield of sweetpotato in Southern Region of Ethiopia. Int. J. Sci. R.es. 2(1):591-595.

Tewodros T, Tielye F, Adane A (2011). Survey and serological detection of sweetpotato *Ipomoea batatas* (L) Lam.) viruses in Ethiopia. J. Appl. Biosci. 41:2746-2756.

Tulchinsky TH (2010). Micronutrient deficiency conditions: global health issues. Publ. Health Rev. 32:243-255.

WHO (2009a). Trace Elements in Human Nutrition and Health. World Health Organization, Geneva.

WHO (2009b). Global Prevalence of Vitamin A Deficiency in Population at Risk from 1995-2005. WHO Global Database on Vitamin A Defficiency. World Health Organization, Geneva, Switzerland.

Woolfe JA (1992). Sweetpotato: An Untapped Food Resource. Cambridge University Press, Cambridge, United Kingdom.

Yibeltal J, Menen Z, Pragya S, Hiwot A (2016). Formulation of Maize-Based Complementary Porridge Using Orange-Fleshed Sweet Potato and Bean Flour for Children Aged 6-23 Months in Kachabira Woreda, Southern Ethiopia. Int. J. Food Sci. Nutr. Eng. 6(4):87-101. DOI: 10.5923/j.food.20160604.03.

Zhang D, Cervantes J, Huamàn Z, Carey E, Ghislain M (2000). Assessing genetic diversity of sweetpotato [*Ipomoea batatas* (L.) Lam.] cultivars from tropical America using AFLP. Genet. Resour. Crop Evol. 47:659-665.

http://www.sciencewebpublishing.net/jacr