



**ASSESSMENT OF SWEETPOTATO (*Ipomea batatas* L.) PRODUCTION AND
EVALUATION OF DIFFERENT STORAGE MATERIALS FOR ROOTS TO BE USED
AS A SOURCE OF PLANTING MATERIAL**

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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A THESIS SUBMITTED TO THE SCHOOL OF PLANT AND HORTICULTURAL
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LISTS OF ABBREVIATIONS

3S	Sand Storage Sprout
ANOVA	Analysis of Variance
CIP	International Potato Center
CRD	Complete Randomized Design
CSA	Central Analysis Agency
CV	Coefficient of Variance
DAP	Di ammonium Phosphate
DMC	Dry Matter Content
FAO	Food and Agriculture Organization
GLM	Generalized Liner Model
HH	Household
LSD	Least Significant Difference
Masl	meter above sea level
NPK	Nitrogen Phosphate Potassium
OFSP	Orange Fleshed Sweetpotato
RDMC	Root Dry Matter Content
SAS	Statistics Analysis Software
SNNPR	South Nations Nationalities and People's Region
SPSS	Statistics Package for Social Science
WFSP	White Fleshed Sweetpotato

DEDICATION

This thesis is dedicated to my beloved grand mom, W/ro Woleteberhan Bassore, whom I lost when I was in between class and final exam. May God rest her soul in peace!!!

STATEMENT OF THE AUTHOR

I declare that this thesis is a result of my own work that all sources of materials used for writing have been duly acknowledged and I have not plagiarized the work of others. I solemnly declare that this thesis has not been submitted to any other institutions anywhere for the award of any academic degree, diploma, or certificate. This thesis has been submitted in partial fulfillment of the requirements for an advised MSc degree in plant and horticulture science specialization in horticulture at Hawassa University and is deposited at the university library to be made available to borrower under the rule of the library. Brief quotation from this thesis may be made without requiring special permission provided that accurate and complete acknowledgement of the source is made. Requests from this manuscript for extended quotation from or replication of the thesis in whole or in part may be granted by the head of the School of Plant and Horticulture Science or the Coordinator of Graduate studies when in his or her judgment the proposed use of the material is for scholarly interests. In all other instances, permission must be obtained from the author.

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Date of Submission.....

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Assessment of Sweetpotato (*Ipomea Batatas* L.) Production and Evaluation of Different Storage Materials for Roots to Be Used As a Source of Planting Material

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ABSTRACT

Sweetpotato is commonly known as the poor man's crop in Ethiopia and one of the food security crops in the country. However, its production and productivity is constrained by the limited access of quality planting material at the onset of the rainy season. Therefore, a household survey was conducted to determine its major production constraints in the three major sweetpotato growing Kebeles (Gere Bulgita, Tikare Kokere and Wera Boshera) of Misrak Badewacho district. Purposive sampling technique was used to select the households. The result revealed that drought (27%), rodents attack during storage (42%), shortage of planting materials (15%) and lack of suitable storage (30%) were identified as the major sweetpotato production constraints in the study area. Based on the survey result the second experiment was conducted to evaluate the storage and growth performance of roots of selected sweetpotato varieties under different storage types as sources of planting materials. The experiment was consisted of three sweetpotato varieties (Awassa-83, Ogan-Sagan and Wolaita-local) with five storage types (straw, soil, ash, sawdust and sand storage) in Complete Randomized Design in three replications. Result revealed that, the combination of Awassa-83 variety and sand storage were performed better in percentage of decay, weight loss and weevil damage; whereas the main effects of variety and storage types were significantly different in length of vine and number of vine per storage. Thus, Awassa-83 variety stored in sand storage showed better performance after storage and can be recommended for maintaining the storage roots during dry periods and access of quality vines at the onset of the rainy season.

Key words: Sweetpotato, Constraints, Variety, Storage, Planting Materials

1. INTRODUCTION

Sweetpotato (*Ipomoea batatas* L.) is one of the most important food security crops in the world and it covers around 120 countries with an approximate production of 106 million tons from 8 million ha (FAO, 2016). It is the 3rd most important root and storage root crops in the world, after potatoes and cassava (Naidoo *et al.*, 2016). Asia is the world's largest sweetpotato producing continent with the production of 79 million tons (about 75% of this is from China alone) followed by Africa (FAO, 2016). In East Africa, it is the second most important storage root crop after cassava (Low *et al.*, 2017). It can be grown in several agro-ecological zones or environmental conditions due to its adaptation (Hongyu *et al.*, 2014; Niringiye *et al.*, 2014; Andrade *et al.*, 2016; Gurmu *et al.*, 2017).

Sweetpotato is grown in several agro-ecological zones and usually plays significant roles in the farming and food system of the majority of the community in the south, south west and eastern parts of Ethiopia. It is commonly grown by farmers in complex, mixed cropping system where they normally plant several varieties with different characteristics in a single plot. The vast majority of sweetpotato producers are producing sweetpotato using mainly local varieties, family labour and manure. As a result, they have much lower yield of 6 to 8 t ha⁻¹, although they can potentially provide over 50 to 60 t ha⁻¹ (Markos and Loha, 2016).

The International Potato Centre reports that average yields of sweetpotatoes in sub Saharan Africa are 10-times lower among smallholders than those observed among commercial producers (CIP, 2018). Sweetpotato is considered as a good food security crop in sub-Saharan Africa because of its hardy nature, they do not require as much labor as some other staple crops and it

often serve as a reserve crop when grain crops fail (Adam *et al.*, 2015). It provides a healthy diet for millions of people in Ethiopia (Gurmu *et al.*, 2015a).

In Ethiopia, it is the 2nd most important storage root crop after enset (CSA, 2015). SNNPRS and Oromia regions are the main sweetpotato producing area in Ethiopia (Gurmu *et al.*, 2015b) and it is commonly cultivated as an integrated crop along with livestock (Belehu, 2003). The storage roots are mostly boiled, fried, roasted or baked for their rich sources of dietary energy (Oduola *et al.*, 2018; Olaitan, 2012), quite essential for their beta carotene and vitamin C (Motsa *et al.*, 2015; Naico and Lusk, 2010), and it is also an imperative source of antioxidants and anthocyanidins (Oladoye *et al.*, 2013).

Shonga *et al.* (2013) reported that farmers grew sweetpotato on characteristically small sized plots in Ethiopia. In order to boost productivity of sweetpotato, researchers in other African countries recommended to increase the farm size allocated to sweetpotato (Mmasa *et al.*, 2012).

Despite the numerous importance of sweetpotato, its production is below the world average and its potential yield in Ethiopia. The average yield in Ethiopia is 36 t/ha (CSA, 2019).

Thus, achieving sustainable production of sweetpotato has been the highest priority of the country. Its production is curtailed by a number of biotic, abiotic, socioeconomic and post-harvest factors. The biotic stresses include diseases, insect pests and weeds, whereas the abiotic factors are drought, heat and low soil fertility (Ndunguru *et al.*, 2009). Constraints related to socioeconomic and quality attributes of sweetpotato includes a lack of access to improved varieties, and to planting material (Belehu, 2003; Tadesse, 2006; Tofu *et al.*, 2007). Mmasa *et al.* (2012) also reported that shortage of planting material, lack of capital, drought, pests and diseases are the major sweetpotato production constraints in many parts of Africa.

On the other hand, good quality planting material is also the critical input to provide good crop stands (Setimela *et al.*, 2004). Namanda *et al.* (2011) also explained that traditional vine cutting sources are usually failed to provide sufficient planting material at the onset of the rainy season after long dry season. This shows the problem for the access of planting materials during the main production season. As a solution to solve such problem, farmers usually use small storage roots as a means of propagation for sweetpotato by storing it underground during dry period (Gibson, 2009).

The high perishability nature of sweetpotato storage roots during storage period is also remains a major constraint across sub-Sahara Africa. However, by using appropriate storage treatments shelf-life can be extended up to 1 year (Sugri *et al.*, 2017). Farmers in the Misrak Badawacho District, Hadiya Zone (Southern Ethiopia) store their sweetpotato storage roots *in-situ* methods (in ground storage) and harvest them gradually when they need it. Similar trends are also reported from Uganda (CIP, 2005). Moreover, various traditional sweetpotato storage methods are also used such as heap, in-ground storage, platform and pit in Nigeria, Indonesia, Zimbabwe and Malawi (Woolfe, 1992).

Currently, both traditional and modified traditional methods of storage are practiced in developing countries including most Sub Saharan Africa (Abidin *et al.*, 2016; Sowley *et al.*, 2015). These include in-ground storage, heap storage, platform storage, pit storage and under shade covering with grass are amongst others (Dandago and Gungula, 2011). The physiological weight loss of sweetpotato storage roots was higher (25%) after 25 days of storage in exposed heap storage, but in sand medium or sawdust the losses were 15% and 17%, respectively, even after 75 days of storage (Chattopadhyay *et al.*, 2006). Appropriate storage of sweetpotato storage

root for planting material ensures to provide sufficient quantities of planting material after long dry season (Okello *et al.*, 2015).

Researchers at the International Potato Center (CIP) are consequently promoting a practice that allows farmers in sub-Saharan Africa (SSA) to produce their own vines in time for the planting season. It consists of storing sweetpotato storage roots in dry sand following the harvest, planting them in seedbeds 6-8 weeks before the rainy season, and watering them to produce enough vines to plant when the rains begin known as Triple-S for storage in sand and sprouting. This technology can result in earlier harvests, providing food and income at a time that is commonly known as “the hunger season” (CIP, 2018).

Also, the household-level sandbox storage method was recommended for being able to extend the shelf life of storage roots by 2 months as (Abidin *et al.*, 2016). In this study sand, storage and sprouting system have been developed to preserve storage roots in dry cool sand, which are planted prior to the onset of the rainy season and produce sprouts for vine multiplication prior to planting. However, the use of such locally available materials for storage of sweetpotato storage roots particularly to use as a source of planting material were not studied in Ethiopia. Therefore, there is a need to explore methods that prolong shelf-life of sweetpotato storage root which can ensure sufficient and early availability of planting material at the right time for early planting. The information in roots of sweetpotato varieties under different storage materials as sources of planting material is also limited.

Therefore, understanding the production practice with its constraints and improving shelf life of its root for planting materials and selection of appropriate storage type is important. In view of filling such technical gap, this research work was conducted with the following objectives.

1.1 General objective

To assess the practices and constraints of sweetpotato production and to evaluate locally available storage materials for sweetpotato storage roots later to use as source of planting material

1.2 Specific objectives.

- To assess the practices and constrains of sweetpotato production in Badawacho district, Hadiya Zone
- To evaluate the effect of different storage materials for storage roots of sweetpotato to use as source of planting material.
- To identify the appropriate storage material for sweetpotato storage roots enabling to producing quality planting material (vine).

2. LITERATURE REVIEW

2.1 The sweetpotato crop

Sweetpotato is a perennial plant that has long trailing vines and leaves but it is treated as an annual crop when it is cultivated for its storage roots (Lebot, 2010). The development of the crop from establishment to harvesting can take 90-150 days, depending on the variety and the environmental conditions under which the crop is grown. Sweetpotato storage roots are eaten while vines are used as planting materials and animal feed. It is grown in several agro-ecological zones and usually plays significant roles in the farming and food system of the majority of the community in the south, south west and eastern parts of the Ethiopia. It is commonly grown by farmers in complex, mixed cropping system where they normally plant several varieties with different characteristics (yield, maturity, palatability, time to maturity, storage root size and shape, storage root colour, storability in the ground, pest and disease tolerance, drought tolerance, and sweetness) in a single plot (Markos and Loha, 2016)..

The low yields of sweetpotato in Sub Saharan Africa could be attributed to; limited availability of adapted high yielding varieties, poor agronomic practices, pest and disease attacks and inadequate availability of high quality planting material among other constraints (Markos and Loha, 2016). The low sweetpotato yields will not be sustainable with growing human populations, increasingly unreliable rainfall and, the increasing demand and importance of sweetpotato in the local food system. It is conventionally propagated using vegetative vine-cuttings or sprout (Braun, 2001). Botanical seeds can be used as sweetpotato planting material but only for breeding purposes due to crop heterozygosity and inability for the seed to germinate except after special treatment (Maniyam *et al.*, 2012; Markos and Loha, 2016).

Sweetpotato storage roots also can be used as a source of planting material, however, sprout from actively growing plants are preferred because they are assumed to be free from soil-borne pests and diseases besides producing a relatively more uniform crop (Dannien *et al.*, 2013). Planting date experiments justified early planting with the onset of rainfall in non-irrigated fields (Markos and Loha, 2016). The results of fertilizer regimes varied across locations and varieties. The majority of sweetpotato producers in the region are using local varieties, family labour and manure. As a result, they obtained much lower yield (6 to 8 t ha⁻¹) than it's potentially (50 to 60 ha⁻¹ production (Markos and Loha, 2016). Besides in sub-Saharan Africa its production is 10-times lower among smallholders (CIP, 2018).

Timely access by farmers to sufficient quantities of clean planting material is a challenge in areas with a long dry season due to limited knowledge of technologies to conserve vines (Okello *et al.*, 2015). A final challenge affecting smallholder sweetpotato producers is poor storability of storage roots compared to grain crops (Abidin *et al.*, 2016). Low crop yields are usually caused by a multitude of interacting biophysical, socio-economic and management constraints that determine final production on farmers' fields (Fermont *et al.*, 2009). Sweetpotato is reputedly drought tolerant produces appreciable yields with limited soil moisture and in marginally fertile soils where most other crops fail to produce (Jones *et al.*, 2012; Markos and Loha, 2016).

2.2. Contribution of sweetpotato to household's livelihood

Sweetpotato is an important staple crop in warm, semi-arid tropics and wet sub-tropics particularly in sub-Saharan Africa (SSA). The crop is currently grown in more than 110 countries globally across diverse agro-eco-climatic zones (Srinivas, 2009; Beyene *et al.*, 2015; Abidin *et al.*, 2016). Sweetpotato is reputedly drought tolerant with ability to produce appreciable yields with limited soil moisture and in marginally fertile soils where most other crops particularly tropical cereals would fail (Jones *et al.*, 2012; Markos and Loha, 2016).

Sweetpotato is one of the world's most important food crops, especially in developing countries, due to its high yield potential and adaptability to a wide range of environmental conditions (Lebot, 2010; Wang *et al.*, 2011). It is usually used as staple food, animal feed and a raw material for different industrial product. Some sweetpotato varieties, especially the orange fleshed sweetpotato are rich in β -carotene. The orange fleshed sweetpotato could play a crucial role in preventing vitamin A deficiency that leads to blindness and maternal and pre-school children mortality in many of the developing countries (WHO, 2009; Wang *et al.*, 2011; Gurmu *et al.*, 2015a). Due to rapid increase in demand for grain both as food and feed, there is an urgent need substitution of grain starch with other starch substrate like sweetpotato for food security and bioenergy production (Oduola *et al.*, 2018).

It is one of the food security crops in Ethiopia grown by smallholder farmers (Tadesse, 2006; Tofu *et al.*, 2007; Gurmu *et al.*, 2015b). The storage roots are mostly boiled, fried, roasted or baked for their rich sources of dietary energy (Oduola *et al.*, 2018), quite essential for their beta carotene and vitamin C (Motsa *et al.*, 2015), and also it is an imperative source of antioxidants and anthocyanidins (Oladoye *et al.*, 2013).

2.3 Sweetpotato production practices and cropping syvine in Ethiopia

Sweetpotato is one of the priority food security crops in Ethiopia. Likewise, in Gamo Gofa farmers placed sweetpotato second after maize. In Wolayta, it was ranked after maize and enset. In Sidama, it is the sixth crop after maize, enset, common bean, coffee and khat. Overall, sweetpotato stands the fourth important food crop in the study zones. Among storage root and storage root crops, it is the second after enset (Gurmu *et al.*, 2015b).

Sweetpotato is grown in several agro-ecological zones and usually plays significant roles in the farming and food system 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 system where they normally plant several varieties with different characteristics (yield, maturity, palatability, time to maturity, storage root size and shape, storage root colour, storability in the ground, pest and disease tolerance, drought tolerance, and sweetness) in a single plot (Markos and Loha, 2016).

In Ethiopia sweetpotato ranks the first in total production (42.84%) and the second in area coverage (25.43%) next to Irish potato from storage root and storage root crops (CSA, 2014). It is drought resistant, hardy and can grow in marginal areas which can contribute improved food security. Sweetpotato is an integral part of cropping system in the eastern, southern and southwestern parts of the country (Tofu *et al.*, 2007). The young leaves and vines can also consumed as vegetables or animal fed to livestock (CIP, 1995). Different sweetpotato production constraints were identified by Gurmu *et al.* (2015b) and major of production constraints in Ethiopia are drought and shortage of planting material, disease and pest, post-harvest constraints and poor access to market was one of the serious impediments affecting sweetpotato production.

Shortage of planting materials, affecting sweetpotato production, is partly caused by severe heat and drought that was described by many of the respondents. A shortage of suitable land was considered to be another challenge. This is because the land holdings of most of the households are small, averaging less than one hectare (CSA, 2003). Although disease and pests are among major constraints of sweetpotato, the farmers were less concerned about these constraints because the lack of planting materials and shortage of suitable land were the dominant constraints, stopping production of the crop entirely (Gurmu *et al.*, 2015b).

In the same work done by Gurmu *et al.*, (2015b), , the major post-harvest constraints of sweetpotato were identified by the farmers as : poor access to markets at 22.6%, poor market prices (19.1%), low yield (14.2%), low dry matter content of storage roots of existing varieties (13.6%), a lack of knowledge about sweetpotato processing and preservation (11.7%), access to processing equipment (11.1%) and the logistics of transporting a heavy, bulky crop (7.7%) to market.

2.4 Sweetpotato Storage root Storage Practice

African farmers have tried various methods to extend the shelf life of their sweetpotatoes, which include storing the storage roots in soil, grass or ash, placing them in storage pits, or simply leaving them in the field and harvesting them piecemeal. However, such storage methods are usually only effective for a month or two, after which storage root quality declines due to rotting, infestation by pests and physiological deterioration (Abidin *et al.*, 2016). Tadesse *et al.* (2017) also reported that piecemeal harvesting was the dominant practice among poor potato farmers (60% of respondents) in Ethiopia.

Since 2011, scientists from the International Potato Center (CIP) have been conducting research trials on the use of sand storage to improve the shelf life of sweetpotato storage roots in Sub Saharan Africa countries that include Burkina Faso, Malawi and Ghana. Therefore, several technologies have been applied in the tropics to prolong the shelf life of sweetpotato storage roots such as growing of varieties with desirable storability qualities, pre-harvest curing by cutting of vines prior to harvesting time, and post-harvest storage using pits and clamps. The current farmers' village-level storage methods are mostly unsatisfactory leading to average losses of 20–25% in sweetpotato (Hayma, 2003).

In a recent study, the household-level sandbox storage method was recommended for being able to extend the shelf life of storage roots by 2 months (Abidin *et al.*, 2016). Countries where these technologies have been tried include India (Ray and Ravi, 2007), Tanzania (Rees *et al.*, 2003; Tomlins *et al.*, 2007) and Uganda (Hall and Devereau, 2000) and variable results have been registered depending on the country and materials used. In Uganda, clamps were tried on an experimental basis in Soroti (Hall and Devereau, 2000). The technique seemed effective for storing fresh sweetpotatoes for up to 3 months, long enough to make a difference when local food security is most uncertain (Hall and Devereau 2000) but it varied with cultivar. On-going work in Uganda (UAO annual report, 2013) revealed that curing sweetpotato storage roots by cutting off vines 4-5 days prior to harvest reduced rotting by 17% and the resulting storage roots stored under farmer conditions for 40 days. In Tanzania, in-ground curing for 14 days significantly reduced skinning injury at harvesting in storage roots that had been subjected to mechanical damage.

In some cases, ash, soil, sawdust and a cocktail of materials are added to improve shelf-life. The use of some of these methods for storage have often yielded irregular results with extreme

weight loss, sprouting, decay and damage by *Cylas* spp., starting from 3-6 weeks after storage. Integrated pre and postharvest treatments and design considerations that can reduce these limitations are required to reduce current losses. Effective management rather than sophisticated of such technologies is critical in reducing current losses (Sugri *et al.*, 2017).

2.5 Constraints and conservation methods of sweetpotato storage practice

Storing sweetpotato has many benefits to the farmers, but, harvesting as soon as they mature are also important for intensive land use (CIP, 2018). Sweetpotato generally has a short shelf life that is reported to be 7–10 days under tropical market conditions (Rees *et al.*, 2003). This may vary depending on the cultivar and storage conditions (Ray *et al.*, 2010).

The fact that the sweetpotato storage roots are tender and it will lose its quality after harvest due to weight loss during storage. This will affect the texture and some losses could also occur due to pest and disease attack in storage. During storage, the storage roots are very perishable because they contain high moisture content (60-75%) hence low mechanical strength as well as high susceptible to microbial decay. They have high respiratory rate and the resultant heat production softens the textures which make them susceptible to damage. Postharvest quality deterioration emanates from respiration, weight loss, microbial attack, weevil damage and sprouting (Sugri *et al.*, 2017).

Sweetpotato has a high respiratory rate immediately after harvest and the resultant heat production softens the texture. All these attributes make them a highly “perishable” commodity. As a consequence, once detached from the plant, sweetpotato cannot be stored for a long time. As the storage root is a living organ, low levels of metabolism are necessary to maintain the

integrity of the cells. On the other hand during storage in pits and clamps, oxygen levels can be reduced and anaerobic respiration could be occurred which also affect the lives of the storage roots. Thus, understanding the control of the switch to anaerobic respiration and appropriate storage material in respect of appropriate sweetpotato variety is a paramount important to minimize this problem (Ray and Nedunchezhiyan, 2012; and Sugri *et al.*, 2017).

The farmers' village-level storage methods were mostly unsatisfactory which leads to average losses (20-25%) sweetpotato (Hayma, 2003). In a recent study, the household-level sandbox storage method was recommended for being able to extend the shelf life of storage roots by 2 months (Abidin *et al.*, 2016). In sub-Saharan Africa (SSA), including Ethiopia, sweetpotato storage roots are kept only for a few weeks, and its storage roots are perceived to have especially short shelf lives. This short shelf life reduces its health benefits. It also reduces marketing opportunities, since most storage roots are sold during the weeks following the harvest, when prices are normally low due to a glut. And it results in a shortage of planting material at the beginning of each rainy season (Abidin *et al.*, 2016).

However, Namanda *et al.* (2013) developed the triple-S system that allow production of sweetpotato planting material from small storage roots stored in dry sand. Moreover, according to Mutandwa (2008) this storage method can remain relatively fresh the sweetpotato storage roots for three to six months.

2.6 Sweetpotato Planting Material Conservation Method

Namandaa *et al.* (2013) noted that, most farmers leave the sweetpotato planting materials in the field and this could heavily infested the materials with virus and other pests and diseases which resulted in reduction of the final yield by half. This result was proofed with planting of

conserved sweetpotato storage roots under sand and planted 10 cm deep and watered for 5-10 weeks before the onset of rains (Namanda *et al.*, 2013). Similarly, Belehu (2003) also reported that high density conservation could result to increased yield in sweetpotato. Moreover, Shields and Fletcher (2013) also reported similar results in Uganda.

Shortage of planting material, lack of capital, drought and pests and diseases were reported as sweetpotato production constraints in Tanzania. Thus, as coping strategies some farmers indicated used clean planting materials, and improved varieties tolerant to drought, pests and diseases in order to have improved yields (Mmasa *et al.*, 2012).

Researchers noted that people sometimes ate the storage roots they were storing to produce planting material, which indicated that sand storage can also be used to preserve sweetpotato storage roots for consumption. This allows people to sell and eat fresh sweetpotato for more months of the year, which makes the crop more attractive and marketable, and enables it to improve the incomes, food security and nutritional status of resource-poor farm families (Abidin *et al.*, 2016).

2.7 Sweetpotato genotypic difference under different storage materials

Sweetpotato generally has a short shelf life that is reported to be 7–10 days under tropical market conditions (Rees *et al.*, 2003). This may vary depending on the cultivar and storage conditions (Ray *et al.*, 2010). The experience of working with clamps in East Africa has shown variable results in terms of weight loss, rotting and sprouting with varietal differences Hall and Devereau (2000).

Similarly, Mtunda *et al.* (2001) noted that the shelf life of sweetpotato storage roots varies from a few days to few weeks according to the cultivar, conditions prevailing at the time of harvest, and

during storage. Sweetpotato losses weight through transpiration and respiration and there is a high possibility of decay in those stored storage roots (Abidin *et al.*, 2016).

In Malawi, sweetpotato varieties and storage types were compared and they found that, pit-steps method were emerged to be superior and continued to store the storage roots up to 6.5 months. Moreover, sand storage has shown a great potential to be promoted to the sweetpotato farmers in Malawi and Ghana (Chattopadhyay *et al.*, 2006).

Zhang *et al.* (2002) also evaluated the nutritional properties of sweetpotato and they found that starch content was decreased during 180 days of storage but α -amylase activity increased during the first 2 months of storage, followed by a continuous decrease to a level similar to that at harvest. There was considerable genotypic variation in digestibility, with up to 27% reduction in digestibility after 120 days in storage. Glucose and sucrose concentration increased at early storage and then remained fairly constant. Storage reduced flour pasting viscosities, with up to 30% decline in peak viscosity.

2.8 Effect of storage materials on shelf life and quality of sweetpotato storage roots

Pit storage generally considered to be cheap for the rural communities since it requires minimum materials. Grass based technique involves the use of dry grass to create dry and cool conditions within the storage area. This avoids the development of fungal diseases that normally thrive under humid and warm conditions (Dandago and Gungula, 2011). Setiawati *et al.* (1994) also reported that, storage of sweetpotato fresh storage roots in a room (with ordinary room temperature and air humidity) for one month caused 15% storage root damage. However, storage root damage is lower if it covered with humid rice straw mulch, although the storage root storage roots tend to sprout . Similar study was conducted in Zimbabwe on the effectiveness of using

soil, ash and grass as means of preserving sweetpotato storage roots and they found that soil bank is the most effective storage method if qualities of storage roots are considered. However, weights of storage root storage roots for ash and grass were not statistically different from the soil treatment and some storage root storage roots were discolored (Mutandwa and Tafara, 2007).

10 sand storage trials was conducted by Abidin *et al.* (2016) in Tanzania and they found that, out of a total 3,432 OFSP storage roots, an average of 62% was used for food, 27% were planted to produce vines for planting material, 21% were thrown away due to rot and damage by diseases and pests. Storage for this length of time using traditional methods, on the other hand, would have resulted in 100% loss. Meanwhile, storage roots from these sand storage trials were examined and an average of 58% of the storage roots used for food were of premium quality for good market prices or making delicious OFSP fries.

When farmers store their sweetpotato storage roots in sand at the beginning of dry season, their family enjoys a reliable supply of nutritious OFSP. Taste tests showed that storage roots that have been stored in sand for 4 months are of an eating quality comparable to fresh harvested storage roots. And four months after the harvest, the farm-gate price of a 50 kg bag of storage roots was two to four times higher than during the harvest season (Abidin *et al.*, 2016).

Mutandwa and Tafara (2007) noted that, ash based technique involves mixing ash powder with sweetpotatoes and the ash will act as an absorbent to moisture and has a repelling effect on pests. Ash has alkaline properties, which are not conducive to development of diseases. Amoah *et al.* (2011) also investigated the storage performance of sweetpotato storage roots in an evaporative cooling barn with three different pre-storage treatments (ash, brine and *Lantana camara* extract)

over 12 weeks duration and they found that by the 12th week, the *Lantana camara* treatment yielded better results. The *Lantana camara* treatment also recorded the lowest weight loss of 28%, lowest shrinkage of 3.8%, lowest severity of decay and sustained less weevil damage at 47.5% compared with the other treatments. Sprouting was however, higher than the other treatments. Namanda *et al.* (2013) also found that, 79 and 65% cumulative loss was recorded from straw and ash storage respectively.

Sweetpotato sprouted almost twice as much in the sand basin storage as compared with the others method (Chattopadhyay *et al.*, 2006). Sand storage provided a modified atmospheric condition by limiting the supply of oxygen and maintaining low temperature as well as a barrier for entry of sweetpotato weevils as Namanda *et al.* (2013). In a recent study, the household-level sandbox storage method was recommended for being able to extend the shelf life of storage roots by 2 months (Abidin *et al.*, 2016).

3. MATERIALS AND METHODS

3.1 Experiment-I: Assessment of sweetpotato production practices and constraints in Misrak Badawacho District, Hadiya Zone, SNPPRS

3.1 .1 Description of the study area

The study was conducted in three major sweetpotato producing Kebeles (Gere Bulgita, Tikare kokare and Wera Boshera) in Misrak Badawacho District of Hadiya Zone of Southern Nations, Nationalities and Peoples' Regional States (SNNPRS) of Ethiopia during 1st August 31st August 2018/2019 cropping season. The site is 345 km from Addis Ababa. The mean annual temperature and rainfall pattern received in the study area is 20.1⁰C and 800 mm to 1500 mm, respectively, and it has bimodal rainfall pattern. The short or small rainy season (*belg*) is extending from middle January to May and the long or in some heavy rainy season (*meher*) is during the months of July and November. However, there is a marked fluctuation between years in the pattern of rainfall distribution in the area. The district covers an altitude range of 1580–2050 m above sea level. A global positioning system (GPS) was used to determine the locations of the surveyed area (Fig. 1 and Table1).

The population of the district is about 171,524 which is 85,210 male and 86,314 female, out of the total population about 143,267 live in rural *Kebeles* and 28,257 live in town. The majority of the people in the districts depend on Agriculture. The area is divided into two different ecological zones, most of the *Kebeles* (30) represents in *woina dega* type and some of the *Kebeles* (9) represents in *kola* types of agro ecology. The predominant farming system of the study area is a mixed farming system with the main food crops of maize, enset, haricot bean, Irish potato, taro and sweetpotatoes. While, tef, coffee, sugarcane, khat, banana and hot pepper are among the cash crops cultivated in the zone. Cattle, sheep, poultry and donkey are the main livestock types.

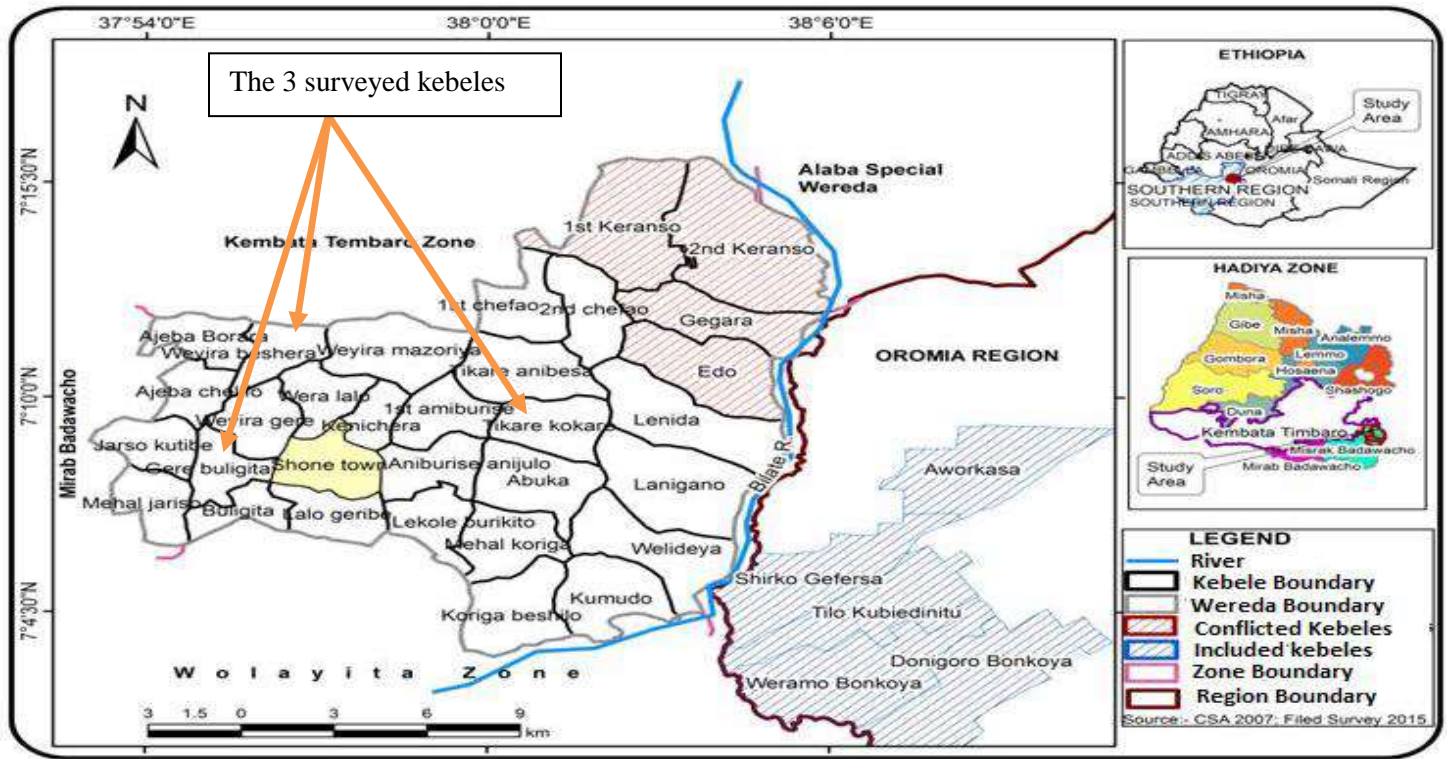


Figure 1: Administrative map of surveyed area

Source: The district agriculture office

3.1.2 Sampling procedure and sample size

Among the sweetpotato producing areas in the District the three *Kebeles* (Gere Bulgita, Tikare kokare and Wera Boshera) were selected purposely. Then, 60 sweetpotato producing farmers were selected randomly. Therefore, 20, 20 and 20 households from Gere Bulgita, Tikare Kokere and Wera Boshera *Kebeles* were selected respectively.

To triangulate the surveyed data, focused group discussion was also done with key informants. The key informants were sweetpotato producers with broad knowledge on diverse social issues in the study area, government officials and development agents in the District. For the interviews both males and females were represented through purposively sampling.

3.1.3 Data collection procedures

For the purpose of this study, qualitative and quantitative data was collected from both primary and secondary sources. The primary sources of data was collected by using structured questionnaire which is attached in (Appendix 7.1) from sweetpotato producers (households) in the selected *Kebeles* (Tikare Kokare, Gere Bulgita and Wera Boshera). A total of 60 farmers were interviewed in the three *Kebeles*. In addition to the primary data, secondary data was gathered from various unpublished documents like Kebeles and districts agriculture office weekly and annual reports.

3.1.4. Data collection

Socio demographic data, such as, important crops grown in the area, total farm size, total sweetpotato area coverage, extension system, sources of planting material, sweetpotato seed system, storage system, pre and post-harvest sweetpotato production constraints, sweetpotato production season, sweetpotato varieties grown in area, sources of the varieties, agronomic

practices, importance of sweetpotato and generally the production system data were collected through a structured questionnaire.

3.1.5 Data Analysis

The collected data were analyzed using Statistical Package for the Social Sciences (SPSS, version 20). The important descriptive statistical measures such as percentage, frequency, and mean were used to summarize and categorize the research data.

3.2. Experiment-II: Evaluation locally available storage materials for storage roots of selected sweetpotato varieties as sources of planting material

3.2.1. Description of the study area

The experiment was conducted at Hawassa University from 1st of March up to 30 July, 2019. The site is located in 273 km south of Addis Ababa at the coordinates of 7°4' N latitude and 38°31' E longitude with an altitude of 1669 meter above sea level. The average annual minimum and maximum temperature of the area is 12⁰C and 27⁰C, respectively. The area receives a bi-modal rain fall and its range is in between 674 and 1365 mm (AARC, 2001). During the storage period, the average temperature and relative humidity of the storage rooms were 26.61⁰C and 52.82% respectively (Fig. 3). The room temperature and relative humidity were recorded in every one week at morning and afternoon for the experimental periods (from 1st March- 31st May).

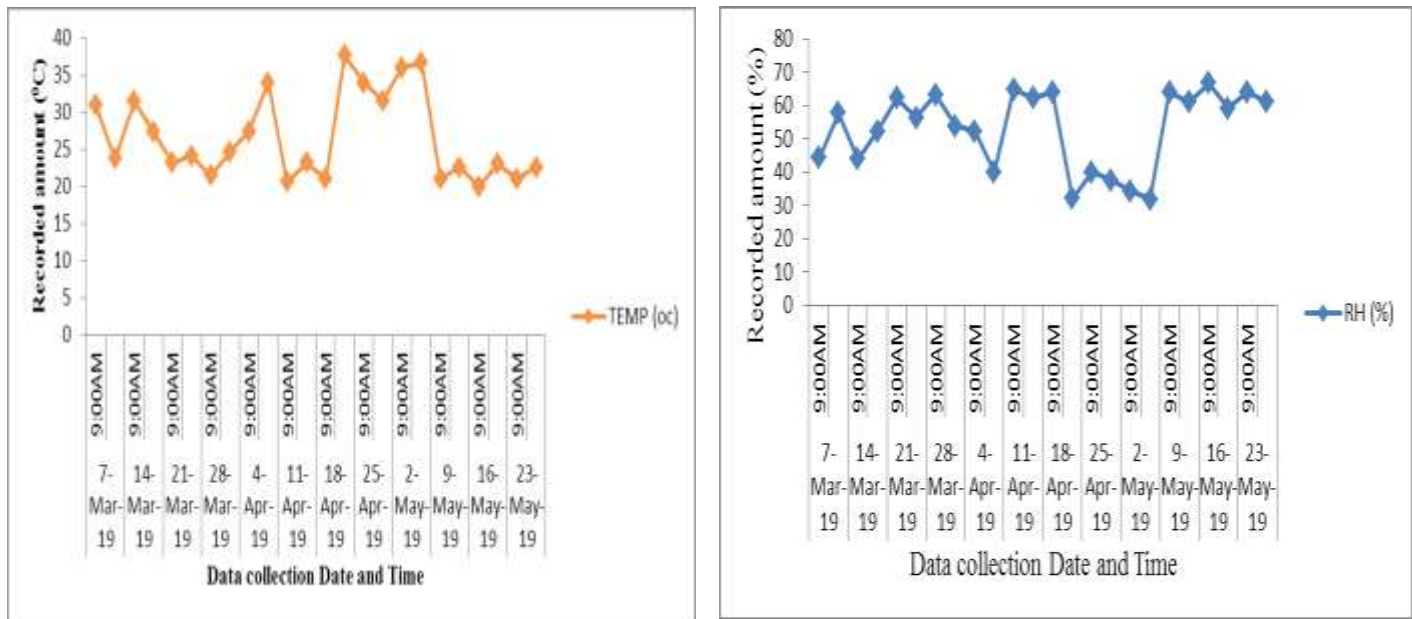


Figure 3 : Temperature and Relative humidity of the storage room during the storage time

3.2.2 Experimental materials, treatment and design

The treatment consisted of five storage materials (grass straw, sand, sawdust, soil and ash) and three sweetpotato varieties (Ogan-Sagan, Awassa-83 and Wolaita (Local variety)). Fresh harvested sweetpotato varieties were used in this experiment (Table 2). These varieties were selected based on resistance to drought, adaptability, storage root dry matter content, taste, storage root yield, resistance to disease and insects, earliness and cook ability. Thus, the three selected varieties are better performing in the study area and to the above parameters (Gurmu *et al.*, 2015b).

Table 2: Sweetpotato variety description

Name of variety	Year of Release	Breeder/Maintainer	Mean total yield (t ha ⁻¹)
Awassa-83	1997/98	AwARC/SARI	36.6-45
Ogan-Sagan	Unknown	Ministry of Agriculture /MOA	35 – 40
Wolita (Local variety)	-	Community	17.5 -35

Source: MoANR Plant variety release June, 2016

The treatments were combined factorially giving a total of 15 treatment combinations (Table 3). The design of the experiment used was Completely Randomized Design (CRD) with three replications. In each storage materials there was about 2 kg of sweetpotato storage roots. After 3 months of storage period, the viable storage roots were planted on the pot and its growth performance was evaluated. Soil was used as a media for planting after storage; whereas, irrigation and other agronomic management practices were equally applied.

Table 3: Treatment combinations for storage materials and sweetpotato variety

Sweetpotato varieties	Storage materials				
	Straw	Sand	Sawdust	Soil	Ash
Awassa-83	(T2) Straw + Awassa-83	(T5) Sand + Awassa-83	(T7) Sawdust + Awassa-83	(T6) Soil + Awassa-83	(T4) Ash + Awassa-83
Wolaita (Local variety)	(T8) Straw + Wolaita (Local variety)	(T13) Sand + Wolaita (Local variety)	(T14) Sawdust + Wolaita (Local variety)	(T3) Soil + Wolaita (Local variety)	(T1) Ash + Wolaita (Local variety)
Ogan-Sagan	(T10) Straw + Ogan-Sagan	(T9) Sand + Ogan-Sagan	(T11) Sawdust + Ogan-Sagan	(T12) Soil + Ogan-Sagan	(T15) Ash + Ogan-Sagan

3.2. 3 Experimental procedures and storage room management

Freshly harvested three varieties of sweetpotato storage roots were collected from Areka Agriculture Research Center. All storage roots were harvested on the same day. Storage roots of uniform size and free from insect, disease and mechanical injuries were selected directly in the field from 2018/19 growing period. The same amount (about 2 kg) of storage roots was stored in treatment-wise storage materials. The procedures were taken from CIP triple “S” or sweetpotato storage training manual (2018). The experiment was terminated in 3 months and its sprouting performance was evaluated after planting in pots having 4 well performed storage roots from each treatments using soil as media.

3.2.4 Data collection

Storage parameters

During the storage of 3 months, the following sweetpotato storage root post-harvest shelf life incidence parameters were determined at intervals of two weeks.

Number of days to start fibrous root: The number of days to start fibrous root formation was counted during the storage periods.

Number of days to start sprout: The number of days to start sprout was counted during the storage periods.

Weight loss: Percent weight loss was determined every two weeks by the difference between initial and final weight of the storage roots divided by its initial weight and multiplied by 100% (Amoah *et al.*, 2011; Teye *et al.*, 2011).

Percent of color change: the color changed storage roots were counted from each treatment and divided for total number and it was multiply by 100%.

Percentage of weevil damaged storage roots: The weevil damaged storage roots were recorded during the storage periods in each treatment divided for total number and it was multiply by 100%.

Decay percentage: The decay damaged storage roots were divided by its total and it was multiply by 100%.

Percentage of cumulative storage roots loss: The amount of removed storage roots due to weevil damage and decay from the total stored storage roots divided by total stored storage roots then multiply by 100% to get the cumulative loss. It was done at the end of storage.

The sprouting performance evaluation parameters

Day to 50% slip emergence: The number of days was counted after planting to 50% of the storage roots get sprout in each pot.

Number of slip after plant: The number of sprout ed seedlings among planted storage roots was observed and then counted simply in each pot.

Length of vine (cm): It was recorded by measuring length of the sprout from the soil surface to the tip of the sprout after 60 days of planting.

3.2.5 Data analysis

The parameters considered in this study were subjected to analysis of variance (ANOVA) using GLM procedure in SAS version 9.2 Mean separation was done using Least Significant Difference(LSD) at 5% probability level.

4. RESULTS AND DISCUSSION

4.1 Experiment-I: Assessment of sweetpotato production practices and production constraints in Misrak Badawacho District, Hadiya Zone of Southern Ethiopia

4.1.1 Households and farming characteristics

The majority (95 %) of the interviewed households was males and the rest (5%) were female. The average family sizes of (50%) the interviewed households were between 4-6 members. The majority (45%) of the households' heads interviewed age were in between 38-48 years of which they are the most productive group. Most (68%) of them were attended their education from 5th to 10th grade and only 2% are illiterate that make easy to accept a new technology for their sweetpotato production system. Farm sizes were very small (45%) from 1 and half *timad* up to only 2 *timad* indicating only less than half hectare. Sweetpotato grown on maximum one *timad* (1/4th ha) and below in one planting season (Appendix Table 2).

The survey results were seem similar with Shonga *et al.* (2013) who reported that, farmers grew sweetpotato on characteristically small sized plots in Ethiopia. In order to boost productivity of sweetpotato, researchers in other African countries recommended to increase the farm size allocated for sweetpotato production (Mmasa *et al.*, 2012).

Majority of households kept a limited number of animals such as cow, oxen, donkey, goat, sheep and chicken which were used as another income generation with crop production. In the area crop production was the primary income source with 95% followed by livestock production 2% and small scale income generation activity in the nearby local markets 2% (Fig. 4). This result is

similar to Gurmu *et al.* (2015b) who did the same study to the neighbor zone (Woliyta) which is almost similar agro-ecology and production system.

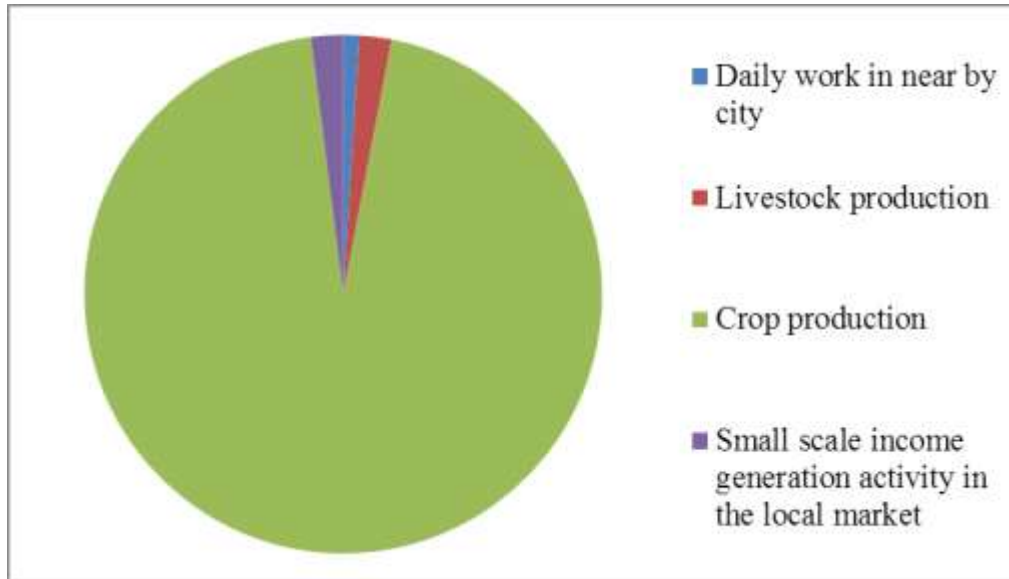


Figure 4: Proportion of income sources of the respondents in the surveyed area during 1st August to 31st August cropping season 2018/2019

4.1.2 Crops grown in the study area

The dominant crops grown in the study area are maize, teff, enset, coffee, potato, khat, sweetpotato, hot pepper, banana and sugarcane (Table 4). As it was mentioned by most of respondents, maize is the indispensable crop for their livelihood and teff is the second followed by enset, haricot bean and coffee, depending on the village. Apart from these dominant crops, other crops were also mentioned by farmers as valuable ones in their farming system. These crops were primarily grown for household's consumption and for sale to earn cash for other family obligations such as clothing and medical costs.

In Gere Bulgita kebele sugarcane and hot pepper was the dominant cash crop and it was the same in Wera Boshera Kebele. As it was reported by Gurmu *et al.* (2015b), maize was the number one crop followed by root and storage root crops such as enset, sweetpotato and potato. Sweetpotato

plays a crucial role in sustaining food security for most of households in the three Kebeles. Although, sweetpotato was a very valuable crop in the areas, its production was not that much satisfied the needs of every farmer.

Table 4: Major Crops grown by the farmers (%) in surveyed kebeles during 1st August to 31st August cropping season 2018/2019

Wera			Tikare			Gere		
Boshera	Frequency	In %	Kokere	Frequency	In %	Bulgita	Frequency	In %
Maize	20	100%	Maize	20	100%	Maize	20	100%
Teff	20	100%	Teff	20	100%	Teff	20	100%
Potato	12	60%	Potato	15	75%	Potato	6	30%
Tomato	9	45%	Banana	17	85%	Coffee	12	100%
Banana	20	100%	Khat	7	35%	Banana	14	100%
Khat	20	100%	Sweetpotato	20	100%	Khat	11	79%
Sweetpotato	20	100%	Enset	4	100%	Sweetpotato	20	100%
Enset	20	100%	Coffee	9	100%	Enset	16	100%
Coffee	20	100%	Tomato	5	56%	Tomato	13	81%
Hot pepper	4	20%	Sorghum	7	78%	Hot pepper	20	100%
Sugarcane	7	35%	Sugarcane	3	33%	Sugarcane	20	100%
Cabbage	3	15%	Tarro	4	44%	Cabbage	12	60%
Tarro	6	30%	Cabbage	2	22%	Tarro	18	90%

4.1.3 Sweetpotato cropping system

Cropping system indicated that, 39% of farmers used mixed cropping, 34% mono-cropping, 24% intercropping and 3% practice relay cropping with other food crops (Fig. 5). Similar results were reported by Kivuva *et al.* (2005). Mixed cropping with other food crops was the most preferred method, meaning farmers prefer planting crops in a mixture to spread the risk of failure to harvest in case of drought or any other unexpected constraint. However, some farmers planted sweetpotato as a mono crop. Most farmers used relay in planting sweetpotato, probably because

this planting method leads to better yields than the other types of cultivation as (Githunguri and Migwa, 2007).

Sweetpotato cropping system was not varied across Kebeles. In the area, farmers have been used similar practices and methods for sweetpotato farming. These practices include the use of hand tools like local made hoes and shovels in smaller land sizes, while they use oxen in bigger plots to prepare the soil for planting. In the areas, weeding and harvesting was done manually. Rotation with maize was practiced in which maize was planted during main rain season and sweetpotato planted after maize harvesting. Due to scarcity of land, rotation with maize was done on every crop season. Similar finding was reported by Fawole (2007) in Nigeria, where sweetpotato was intercropped with other crops for food security and households' incomes.

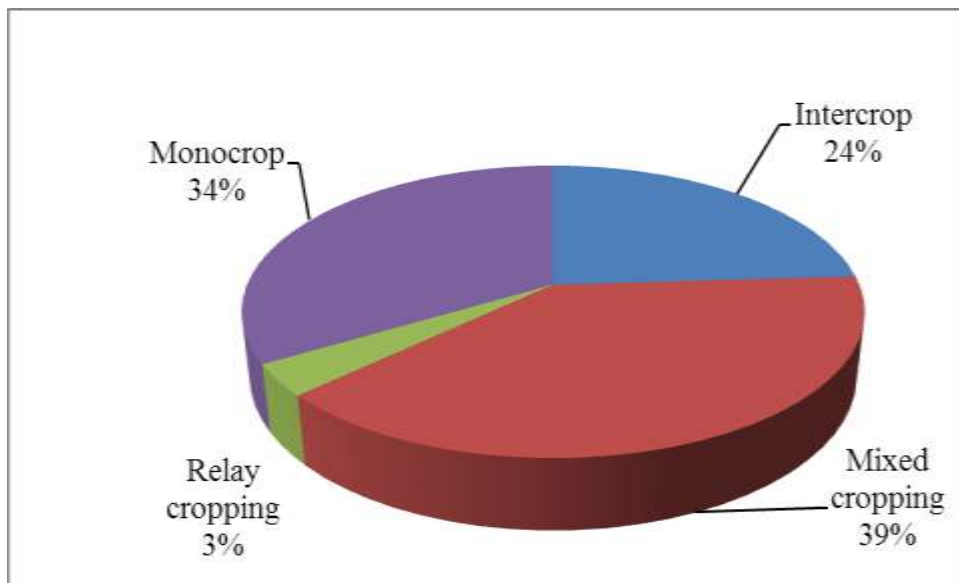


Figure 5: Sweetpotato farming systems in surveyed area during 1st August to 31st August cropping season 2018/2019

Most farmers (92%) were used manure and the rest (8%) of the farmers used inorganic fertilizers for sweetpotato production (Fig. 6). From the survey result, farmers preferred to use manure rather than inorganic fertilizers such Urea, DAP and NPK. Kivuva *et al.* (2005) reported in the survey result, most farmers (45%) used manure and less than 10% of the farmers used inorganic fertilizers for sweetpotato production.

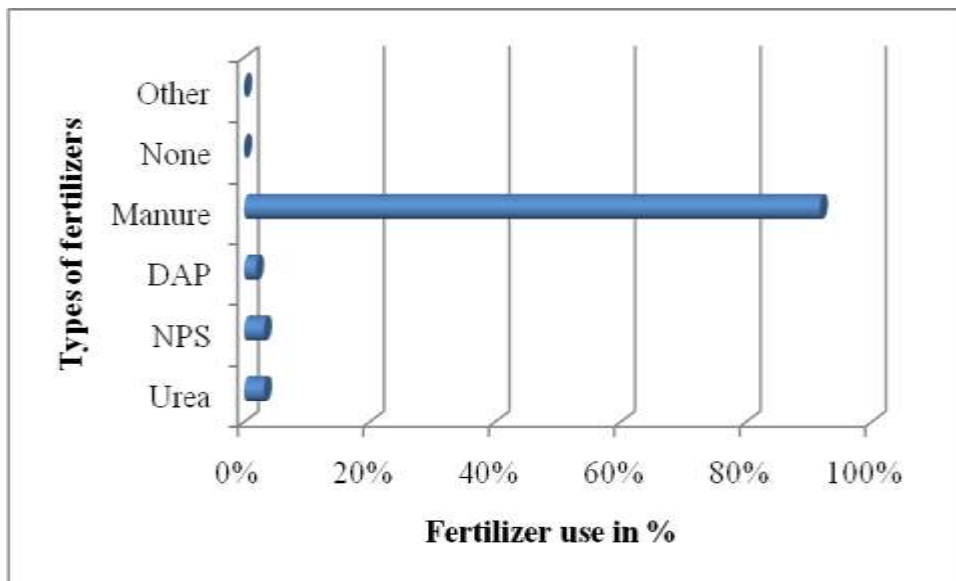


Figure 6: The percent of fertilizers use in the surveyed area during 1st August to 31st August cropping season 2018/2019

4.1.4 Sweetpotato production status, constraints coping strategies

Sweetpotato production was low in the surveyed area under farmer condition due to biotic, abiotic and socio-economic factors. However, it is one of the priority food security crops in the district. In all studied Kebeles farmers placed sweetpotato as a one of best crops. Among root and storage root crops, it is the fourth after enset, taro and potato. The majority of the respondents (82%) indicated that sweetpotato is their priority crops from its important characters and they produce as other major crops (Table 4). Time for sweetpotato planting not varied

among Kebeles. Most farmers (68%) planted sweetpotato during January-March depended on onset of long and short rains and harvested from June-September mostly depending on consumption need.

Sweetpotato is known as a relatively drought tolerant crop. However, due to the global climate change, even this crop is now affected by heat and drought, and its yield potential is being diminished through burning the foliage part of the crop or limiting vegetative production and drying the farm for harvesting in the area. Therefore, the study areas farmers follow different coping system or strategy for this constraint.

Majority of farmers stated that they maintain planting materials and multiply it around the home (31%) or in wetlands (26%) to ensure they had clean and enough planting materials at the onset of rains (Fig. 8). These results are similar to those reported by Namandaa *et al.* (2013) who demonstrated that sweetpotato planting material sourced from swamp or irrigated on farm plots were infested with virus and getting it from volunteer plants after rains led to planting delays. There is significant need to develop a working system of developing clean and enough planting materials for Sweetpotato ready to plant at the onset of the rains.

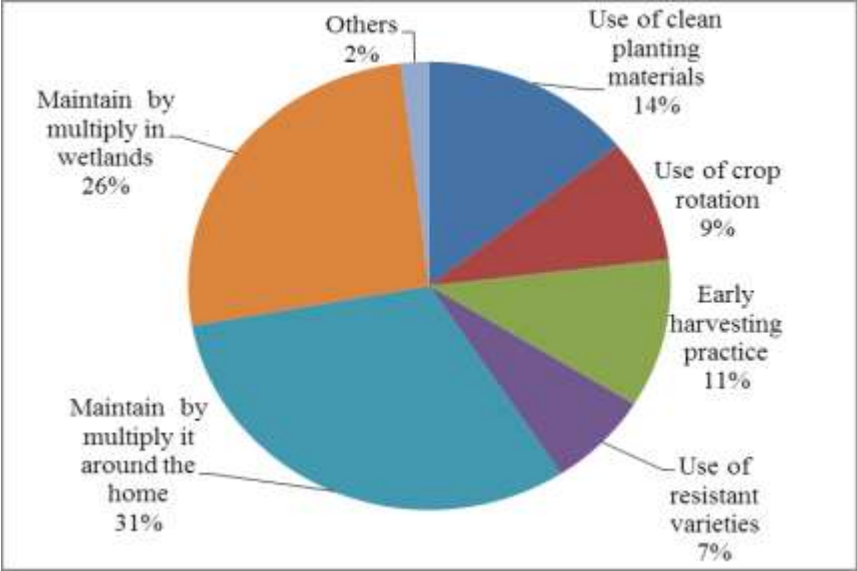


Figure 8: Percent of respondents on strategies of coping constraints in the survey area during 1st August to 31st August cropping season 2018/2019

4.1.5 Sources of sweetpotato planting materials

It is evident from Table 5, in respective of Wera Boshera, Gere Bulgita and Tikare Kokere kebele, 65%, 60% and 60% of farmers used vines for sweetpotato propagation from previous season than others options. Therefore, most of the farmers got their planting materials from their own fields and exchanging or buying planting materials from neighbors in the study area. Despite remarkable role of sweetpotato in the study area, its productivity is very low compared to yield potential because of having inappropriate planting materials. Most farmers leave the planting materials in the field as sources from last season volunteer plants for the next planting.

Table 5: Sources of sweetpotato planting materials in the surveyed area during 1st August to 31st August cropping season 2018/2019

Name of Kebele	Sources method	Frquency	In %
Gere Bulgita	Saved from previous harvest	12	60%
	Certified seed from research center	1	5%
	Borrowing from neighbors	3	15%
	From woreda agriculture office	3	15%
	Buy from local market /farmer	1	5%
	Other	0	0%
	Total	20	100%
Tikare Kokere	Saved from previous harvest	12	60%
	Certified seed from research center	2	10%
	Borrowing from neighbors	3	15%
	From woreda agriculture office	2	10%
	Buy from local market/farmer	1	5%
	Other	0	0%
	Total	20	100%
Wera Boshera	Saved from previous harvest	13	65%
	Certified seed from research center	2	10%
	Borrowing from neighbors	3	15%
	From woreda agriculture office	2	10%
	Buy from local market /farmer	0	0%
	Other	0	0%
	Total	20	100%

4.1.6 Sweetpotato planting material conservation method and farmer's information on triple- S method

Most farmers conserved planting materials by multiplying it in around the home, by letting it from the last planting season and by multiplying it in wetland area (Fig. 9). As results, most farmers get sweetpotato planting materials from the field for the next planting season. Consequently, the materials are heavily infested with virus and other pests and diseases. The aftermath is a reduction of the yields. Sweetpotato planting material sourced from swamp or irrigated on farm plots were infested with virus and getting it from volunteer plants after rains led to planting delays. These results are similar to those reported by Namandaa *et al.* (2013) who demonstrated that sweetpotato planting material sourced from swamp or irrigated on farm plots were infested with virus and getting it from volunteer plants after rains led to planting delays.

There is an urgent need to develop a technology to provide clean and enough planting materials for sweetpotato producers at the onset of the rains. Most farmers preferred higher planting densities indicating a preference for intensive farming to maximize the production of their scarce land.

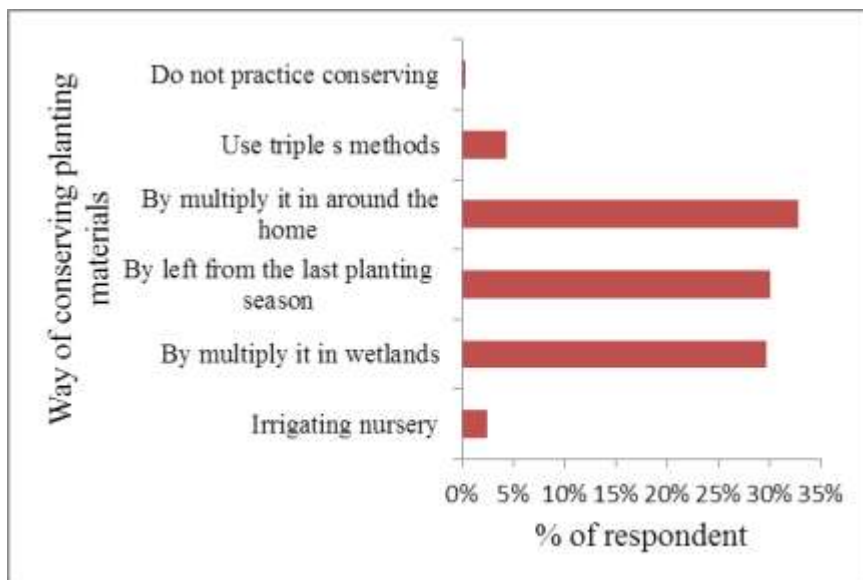


Figure 9: Methods of sweetpotato planting material conservation by farmers during 1st August to 31st August cropping season 2018/2019

Currently, A ‘sand, storage and sprouting’ (triple S) system has been developed to preserve storage roots in dry cool sand, then planted prior to the onset of the rainy season and produce sprout s for vine multiplication. As (CIP, 2018), this technology can result in earlier harvests, providing food and income at a time that is commonly known as “the hunger season”. However, from the total number of the respondents, about 60%, 85% and 70% in Gere Bulgita, Tikare Kokere and Wera Boshera kebeles has information about triple S respectively (Table 6).

The information was circulated from training that held by CIP cooperation with district agriculture office. One of the Tikare Kokere *Kebele* agriculture experts said that, even they did training with video on the triple-S methods. Sweetpotato planting materials were mainly recycled from the previous crop, since only very small farmers used certified planting material. This shows that most of farmers do not have an alternative. This may explain why sweetpotato yields continue to be low because of a shortage of clean and enough planting materials.

Table 6: The farmer’s information about triple- S method in the surveyed area during 1st August to 31st August cropping season 2018/2019

Name of kebele	Total respondents	Yes/No	No	In %
Gere Bulgita	20	Yes	12	60%
		No	8	40%
Tikare Kokere	20	Yes	17	85%
		No	3	15%
Wera Boshera	20	Yes	14	70%
		No	6	30%

4.1.7 Commonly grown and farmers’ preferred sweetpotato varieties in area

Sweetpotato varieties which were grown in the three Kebeles are presented in (Fig. 10). Awassa 83 (41%), Ogan-Sagan (29%), Wolaita (local variety) and (17%) were the common varieties in the three Kebeles. Awassa 83 variety (41%) was the most popular variety in the three Kebeles than others because of high yielding potential per unit area. Farmers received new sweetpotato varieties from district agriculture office and NGOs like CIP mostly. Wolita (Local variety) was one of the common local varieties in the area that the name of variety was given by the farmers from the name of place where they got.

In the study areas, farmers were preferred the good variety by its high storage root dry matter content or having big size like Awassa 83, cooking quality and having good taste during eating like Ogan-Sagan which is very delicious as the respondents mentioned. This result confirmed with other studies that, African farmers preference for the production of sweetpotato were based on dry matter content (Kapinga and Carey, 2003; Tumwegamire *et al.*, 2004; Ssebuliba *et al.*,

2006; Kwach *et al.*, 2010). This is also true in Ethiopia as reported by Tadesse (2006) and Tofu *et al.* (2007).

On the other hand the farmers’ selection criteria for sweetpotato varieties were similar to those reported from Rwanda where plant establishment, early maturity, drought tolerance, tolerance to pests and diseases, high storage root dry matter content, high storage storage root yield and cooking qualities Ndirigwe *et al.* (2005). Moreover, Zawedde *et al.* (2014) reported that higher yield, taste, and maturity period were primary criteria for adopting new cultivars in Uganda.

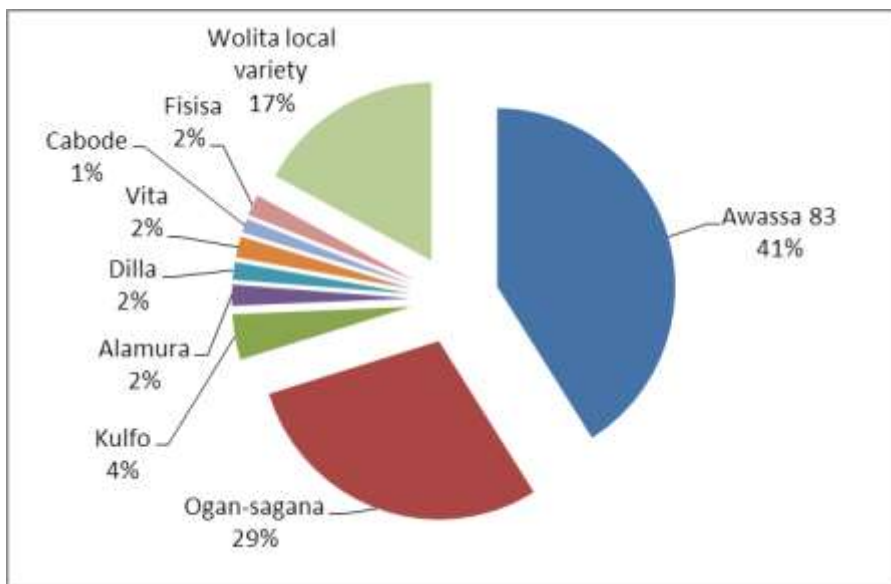


Figure 10: Sweetpotato varieties distribution in the survey area during 1st August to 31st August cropping season 2018/2019

4.1.8 Contribution of sweetpotato production to households’ livelihoods

Sweetpotato plays a crucial role in sustaining food security in the surveyed area. About 95% of respondents produce for their livelihood consumption (Table 7). It has a significant contribution for individual household consumption. As Markos and Loha (2016), sweetpotato is grown in

several agro-ecological zones and plays significant roles in the farming and food system of the majority of the community in the south, south west and eastern parts of Ethiopia.

During the harvesting time, farmers sold part of the produce to meet cost of family and other community obligations like social life. However, there was no long term storage method for sweetpotato after harvesting.

Table 7: Uses of sweetpotato in surveyed area during 1st August to 31st August cropping season 2018/2019

Contribution of sweet potato	Total respondents	No	In %
For household consumption	60	57	95%
To generating household income		2	3%
None		0	0%
Other		1	2%

4.1.9 Sweetpotato production constraints

4.1.9.1 Major pre-harvest constraints affecting sweetpotato production

Different sweetpotato production constraints were identified in the district. The major pre-harvest constraints as identified by respondent were heat and drought (27%), rodents (25%), and a shortage of clean and enough planting materials (15%) was recorded as (Table 8). Rodents, heat and drought and shortage of clean and lack of enough planting materials were the most important pre-harvest sweetpotato production constraints in the area. This result was similar to Markos and Loha (2016) who noted that the low yields of sweetpotato in sub-Saharan Africa could be due to limited availability of adapted high yielding varieties, poor agronomic practices,

pest and disease attacks and inadequate availability of high quality planting material among other constraints.

Different scholars reported that, lack of clean and enough planting material is a big head ach for the growers. For example, Gurmu *et al.* (2015b) reported that for many (87.6%) of the Ethiopian farmers indicated that a shortage of planting material was one of the serious impediments affecting sweetpotato production. This calls for researchers to devise methods for production of enough and clean sweetpotato planting materials. This also concurs with Mmasa *et al.* (2012) who reported that shortage of planting material, lack of capital, drought and pests and diseases as sweetpotato production constraints.

Shonga *et al.* (2013) in their review on sweetpotato production constraints, they reported that, average yield of sweetpotato in Ethiopia was 8 t ha⁻¹ which is very low relative to Asian countries (18 t ha⁻¹). This indicates production constraints need to be addressed to improve the productivity of the sweetpotato.

Moreover, Fugile (2007) also reported that, unavailability of healthy planting materials and high yielding cultivars was amongst the hindrances in improving sweetpotato production. As a clonally propagated crop, utilization of vines from stock with latent infection speeds the buildup, multiplication and spread of sweetpotato viral disease. Gutiérrez *et al.* (2003) also suggested that, production of healthy planting material is a major solution to control sweetpotato viral disease. Farmers preserved their planting materials in home gardens and valley bottoms. Additionally, farmers have used local and low yielding sweetpotato landraces for decades. Tairo *et al.* (2004) reported similar practices in Kenya and Tanzania.

Among the respondents, 23% of the farmers indicated that shortage of planting material was one of a serious problem affecting sweetpotato production which is link with this study. This problem is also linked to severe heat and drought that was described by many of the respondents. Severe drought limits vegetative production and reduces planting material availability particularly during the long dry season. Although disease and pests are among major constraints of sweetpotato, the farmers in the study area were less concerned about these constraints as shown by their rankings. However, the postharvest loss becomes a major limiting factor in prolonging storage duration of sweetpotato. This result is supported by Xie *et al.* (2018).

Table 8: Percent of pre- harvest sweetpotato production constraints in the surveyed area during 1st August to 31st August cropping season 2018/2019

Constraints	Total respondents	No	In %
Heat and drought	60	16	27%
Rodents		15	25%
Shortage of land		2	3%
Diseases		3	5%
Insect pests		5	8%
Lack of draft power like oxen		1	2%
Shortage of money to cover input costs		1	2%
Shortage of planting materials		14	23%
Weeds		2	3%
Lack of training on pre harvest management		1	2%
Other		0	0%
Total		60	100%

4.1.9.2 Post-harvest constraints

As it was explained by the respondents in the surveyed area, Rodents attack during storage (42%), lack of suitable sweetpotato storage (32%) and insect pest's problem during storage (10%), were the major post-harvest constraints of sweetpotato (Table 9).

The survey results were similar with Xie *et al.* (2018) who found that, postharvest loss becomes a major limiting factor in prolonging storage duration of sweetpotato. The storage system was especially a big head ache for the producers in the area. Munish *et al.* (2006) explained that, during storage, the storage roots are very perishable because they contain high moisture content (60-75%), and due to high respiratory rate and the resultant heat production soften the storage root textures which make them susceptible to damage and microbial decay.

Table 9: Major Post- harvest constraints in surveyed area during 1st August to 31st August cropping season 2018/2019

Constraints	No of respondents	In %
Lack of knowledge about suitable storage	19	32%
Rodents attack during storage	25	42%
Poor market prices	2	3%
Low dry matter content of storage roots	1	2%
Poor access to markets	1	2%
Limited access to processing equipment	2	3%
Logistics of transporting a heavy, bulky crop	1	2%
Insect pests problem during storage	6	10%
Lack of training on post- harvest management	3	5%
Total	60	100%

From all the respondents, 96% were preferred in-situ storage; whereas, the rest were used, harvesting them as and when they are needed for food (Fig. 11). This result was similar with Gurmu *et al.* (2015b) that was done in Gamo Gofa Zone, Southern Ethiopia. Of all respondents, 1.6% in Gamo Gofa was using solar energy to dry sweetpotato storage root slices after harvest and the rest of the respondents (98.4%) stored the storage roots in-situ in the soil, harvesting them as and when they were needed for food.

Post-harvest problems affecting sweetpotato were mostly related to its short shelf-life, which is affected by the general physiology of the storage roots. According to Xie *et al.* (2018), postharvest loss becomes a major limiting factor in prolonging storage duration of sweetpotato. During storage, the storage roots are very perishable because they contain high moisture content (60-75%), and due to high respiratory rate and the resultant heat production soften the storage root textures which make them susceptible to damage and microbial decay(Munish *et al.*, 2006).

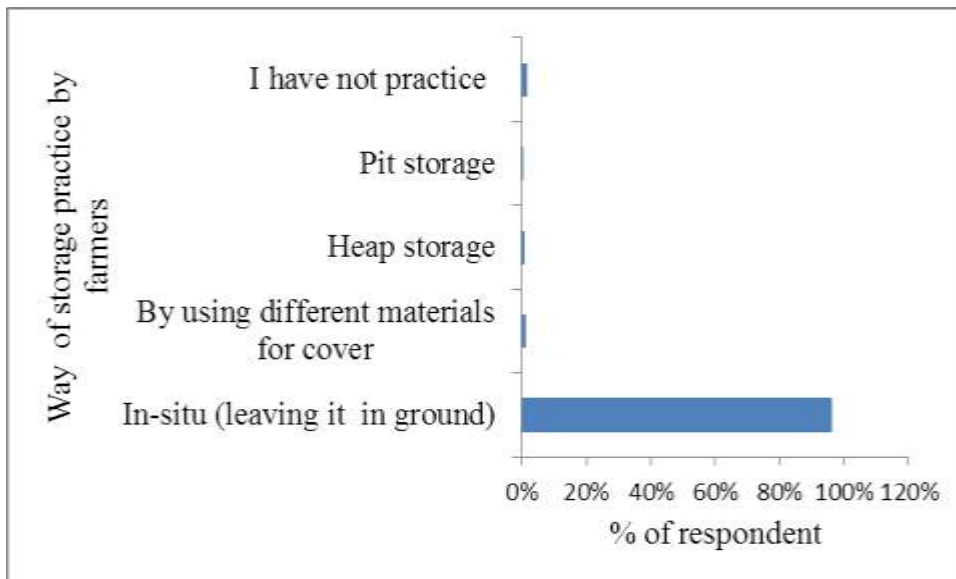


Figure 11: Ways of sweetpotato storage practice by farmers in surveyed area during 1st August to 31st August cropping season 2018/2019

4.1.9.3 The major Sweetpotato storage root storage problems

The major Sweetpotato storage root storage problems in surveyed area were described by the respondents as rodents (35%), lack of knowledge about suitable storage and insect pests (mainly weevil) (12%)(Table 10). The results from this study were in agreement with those reported by Shonga *et al.* (2013) who reported that farmers grew sweetpotato on characteristically small sized plots in Ethiopia. This is because farmers try to produce enough only for subsistence use, as there is no long term storage method for sweetpotato after harvesting. Leaving the storage roots un-harvested will result in considerable losses as they lose their quality and are typically infested heavily by weevil. The farmers believed that some rain is favorable for extending the lives of the storage roots in the soil. Most of the farmers practiced in-situ storage methods and harvest them gradually when they need it. A similar trend was reported from Uganda (CIP, 2018).

Sweetpotato is predominantly sold fresh after harvest. Poor, uncoordinated markets dominated by middlemen who set and control product prices diminish farmers' economic returns. Since the crop is perishable and there are no developed storage and processing facilities, harvest losses are expected. Fugile (2007) reported strong need for improvement of postharvest utilization and marketing infrastructures for perishable commodities.

Table 10: Sweetpotato storage root storage problems in surveyed area during 1st August to 31st August cropping season 2018/2019

Constraints	No of respondents	In %
Lack of knowledge about suitable storage	18	30%
Rodents attack during storage	21	35%
Limited access to processing equipment	2	3%
Insect pests (mainly weevil)	11	18%
Lack of training on post- harvest management	3	5%
Heat (sun)	3	5%
Rain	0	0%
Theft	2	3%
Others	0	0%
Total	60	100%

4.2 Experiment-II: Evaluation locally available storage materials for storage roots of selected sweetpotato varieties as sources of planting material

4.2.1 Storage parameters

4.2.1. 1 Number of days to start sprouting before planting or termination of storing

Number of day to start sprouting from the total stored storage roots in each treatment was significantly ($P<0.001$) affected by the types of storage material. However, the main effect of variety and interaction effect with storage material showed not significantly ($P>0.05$) different (Appendix Table 1).

The sprouts emerging from total stored storage root was delayed in straw and sand storage material types (78.33 and 56.00, days respectively). Whereas, sawdust storage showed early (16.33) sprouts emerging from total stored storage roots (Table 11). This might be due to the moisture contain condition of sawdust. The sprouting of storage roots during storage is negative in this study, but in case of sand storage there was delay in sprouting, that was positive for this study. The loss of sprout in straw storage was because of dryness or had not good condition of storage roots due to losing of viability. This result was in agreement with Ray and Ravi (2005) who reported that delayed harvest and moist conditions resulted in very rapid sprouting in sweetpotato storage roots.

Table 11: Day to start to sprout as influenced by main factor effect of storage type

Variety	Day to start to sprout
Ogan-Sagan	44.80
Awassa-83	37.40
Wolita (Local variety)	43.00
LSD_{0.05}	0.22
Storage type	
Ash	29.33 ^c
Sand	56.00 ^b
Sawdust	16.33 ^e
Soil	28.67 ^d
Straw	78.33 ^a
LSD_{0.05}	0.29
CV (%)	11.87
Interaction	Ns

Means followed by the same letter (s) with in the same column are not significantly different at 5% level of significance, **CV**; coefficient of variance, **LSD** least significant difference

4.2.1.2 Decayed Percentage

The percent of stored storage roots rot in each basin was significantly ($P < 0.001$) influenced by main effect of varieties and storage material types as well as by interaction effect of the two factors (Appendix Table 1).

The interaction of ash storage with Ogan-Sagan variety and the straw storage with all types of varieties were highly decayed. The lowest decay was observed at interaction of all varieties stored in sand. Awassa-83 decayed less in sand than all other varieties. The others were in between of them (Fig. 12). The high decay of storage roots of all varieties in ash storage might be due to high temperature condition and lack of aeration in the ash that facilitate storage root rot.

According to Ray and Ravi (2005) the predisposing factors to microbial attack were mechanical injury and insect infestation. Among all the storage method, storage root in sand basin was better than others because decay was minimal and the samples had little infection for the 3 months period. Bukar and Magashi (2008) also reported that during storage, the storage roots are very perishable because they contain high moisture content (60-75%) hence low mechanical strength as well as high susceptible to microbial decay. This implies that, as sweetpotato losses weight through transpiration and respiration, there is a high possibility of decay in those storage roots. According to Sugri *et al.* (2017), the high respiratory rate in the storage root and the resultant heat production were softens its textures which make them susceptible to damage.

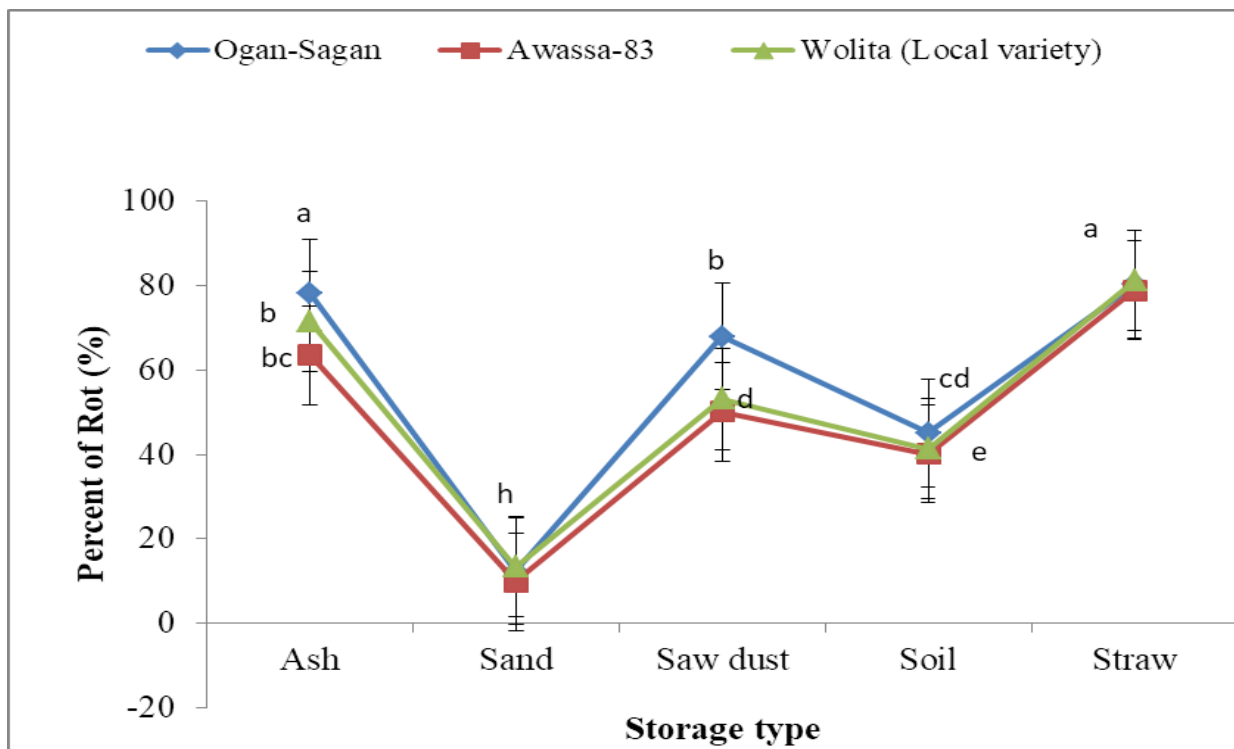


Figure 12: Interaction effects of sweetpotato varieties and storage materials on decay percentage

4.2.1.3 Percentage of storage root color change

Analysis of variance showed that the percent of storage roots that changed color over the storage period was significantly ($P < 0.001$) influenced by main effect of variety and storage type as well as by their interaction effects (Appendix Table 1).

Storage roots of Ogan-Sagan variety stored in ash and straw showed maximum color change. Ogan-Sagan variety is white storage root skin by its nature that changed its color to gray and black color. The minimum color change was recorded in the soil and sand storage with the three varieties. This is may be due to providing a modified atmosphere by maintaining low temperature in the basin. The others interaction were in between of them (Fig. 13).

There were several types of color changes associated with sweetpotato apart from sprouting which was independently observed. It was generally observed that the type of physiological disorder depends on storage materials. Mutandwa and Gadzirayi (2007) assessed the effectiveness of three techniques of sweetpotatoes storage in soil, ash and straw, and they reported that, considering the value of storage root color and weight loss, preservation in soil was most recommended. This was similar to other studies that highlight the importance of using sank bank as a means of preserving sweetpotato storage roots. Nonetheless, in terms of maintaining freshness of the stored storage roots, all three methods were recommended to resource-constrained farmers in Zimbabwe. Storage roots stored in the sand-bank suffered less weight loss and color change compared to ambient conditions. Sand-bank storage may provide a modified atmosphere by limiting the supply of oxygen and maintaining low temperature.

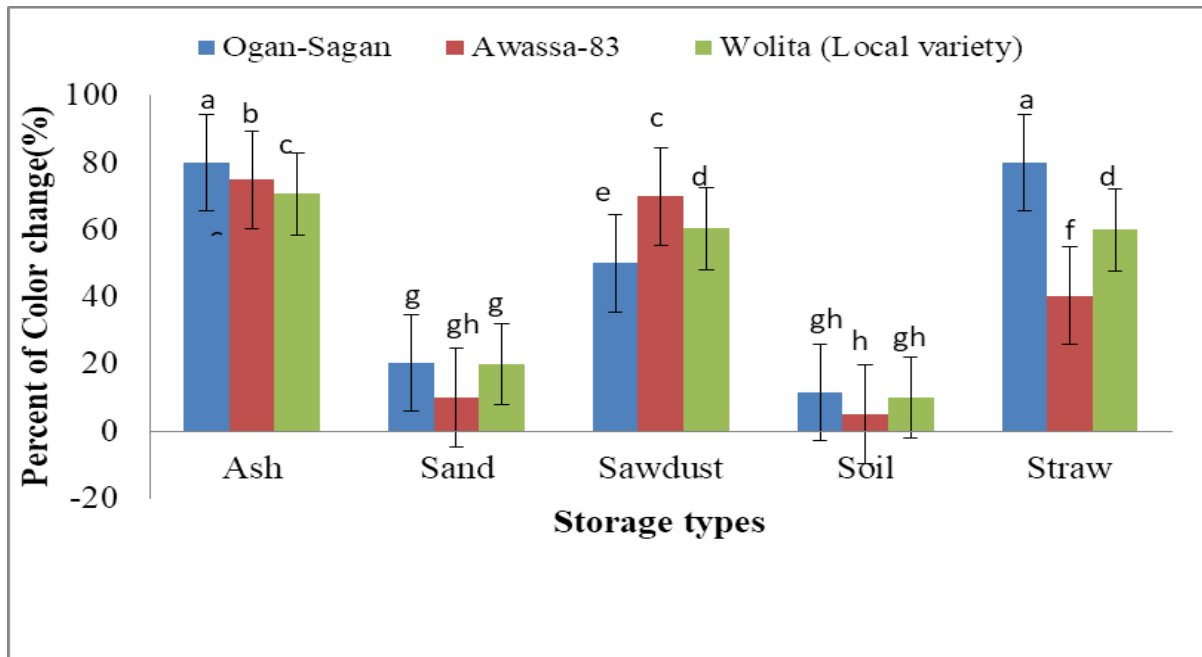


Figure 13: Interaction effects of sweetpotato varieties and storage materials on color changes

4.2.1.4 Weight loss

The amount of weight loss of sweetpotato storage roots were significantly ($P < 0.01$) affected by the main factors of storage types and variety as well as the interaction effects (Appendix Table 1).

Ogan-Sagan and Wolaita varieties stored in straw showed a highest percent of weight loss than the other interactions. At the end of the third month, all variety of storage roots stored in sand showed lowest weight loss (Fig14). The current findings support earlier suggestion that physiological weight loss of sweetpotato cultivars was higher (25%) after 25 days of storage in exposed heap storage, but in the sand medium or sawdust the losses were 15% and 17%, respectively, even after 75 days of storage (Chattopadhyay *et al.*, 2006).

Consistently low weight loss was recorded in storage roots from 3 weeks of storage. In all the storage types except straw storage type there were sprouting, due to this the weight loss was minimum in the first month and after second month it starts to increase. This result was agree with Sugri *et al.* (2017) that weight loss during the first 4 weeks of storage was lower, but it was marginal by 8 weeks in storage. This is may be due to as Degras (2003) report, that high temperature under storage condition was likely to result in high rates of respiration, increased rates of metabolic breakdown which could result in increased levels of storage root weight loss. During the storage period, storage roots lose weight owing to respiration and transpiration because of there was a high temperature record in the green house during storage.

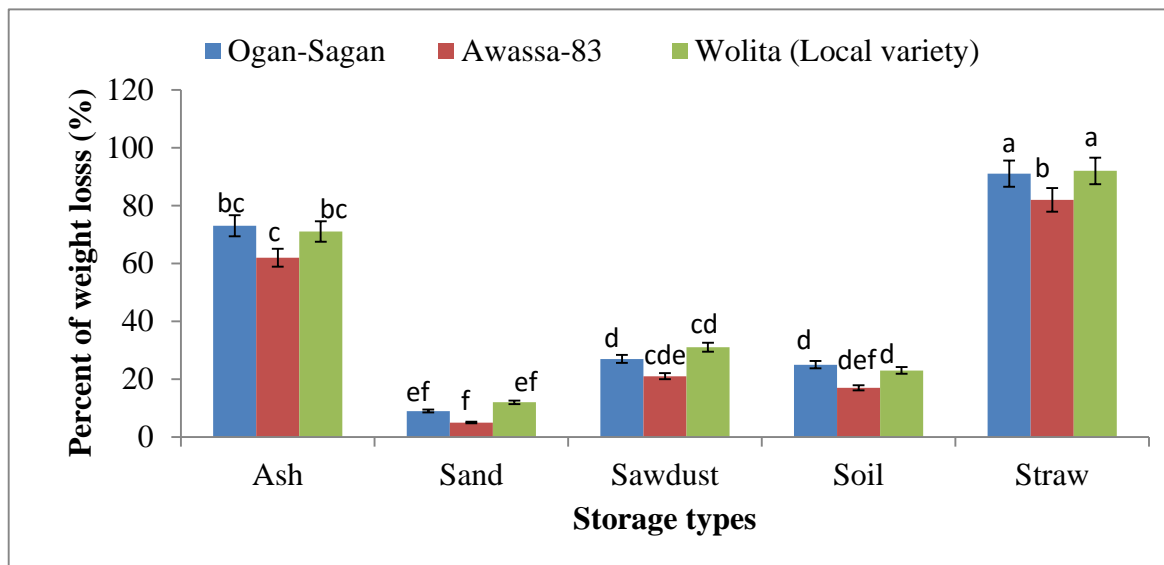


Figure 14: Interaction effects of sweetpotato varieties and storage materials on weight loss

4.2.1.5 Percentage of weevil damage

The results in Table 13 showed that the percent of weevil damage in each basin was significantly ($P < 0.001$) influenced by the main effects of variety and storage material as well as by the interaction effect of the two factors (Appendix Table 1).

Weevil damage in three months storage was significantly higher in the interaction of straw storage with Ogan-Sagan and Wolaita varieties than all other interaction effects. While, in the interaction of sand with three of varieties there were low weevil damage. The damage caused by weevils during storage could be reduced significantly with this method was because of sand is not favorable for weevil and since storage roots were isolated from each other in the sand. The other interaction results shows statistically similar as showed in the Table 12.

The data on the low incidence of weevil damage of the storage roots stored in the sand basin method indicate that the sand medium served as a block restricting the movement of the weevils from one storage root to the other, while in the other storage they could easily move from one storage root to another to cause extensive damage (Namanda *et al.*, 2013). This also shows that careful removal of all weevil infested storage roots before storage was important for improved storage life of sweetpotato storage roots. According to Ray and Ravi (2005) the predisposing factors to microbial attack were mechanical injury and insect infestation.

Table 12: The interaction effect of sweetpotato variety and storage materials on weevil damage

	Ogan-Sagan	Awassa-83	Wolita (Local variety)
Ash	50.00 ^f	40.66 ^{ef}	40.33 ^{ef}
Sand	13.33 ^g	11.33 ^g	11.33 ^g
Sawdust	56.33 ^{cd}	60.33 ^{b^{cd}}	60.66 ^{b^{cde}}
Soil	73.00 ^{bc}	70.66 ^b	71.66 ^b
Straw	100.00 ^a	52.66 ^{cdef}	100.66 ^a
LSD_{0.05}		1.49	
CV (%)		14.75	

Means followed by the same letter (s) with in the same column are not significantly different at 5% level of significance, CV; coefficient of variance, LSD least significant difference

4.2.1.6 Percentage of Cumulative losses

Percent of cumulative losses over total stored storage roots under different storage materials and varieties was significantly ($P < 0.01$) influenced by main effect of varieties and storage material as well as by heir interaction effect (Appendix Table 1).

Ogan-Sagan and Wolita (Local variety) storage roots stored in straw showed maximum cumulative losses. The lowest cumulative loss was observed on storage roots of all varieties stored in sand (Table 13). This is due to straw may be a good condition for weevil multiplication and decay or rot of storage roots; whereas, in case of sand storage with varieties, sand can provide un-conducive condition for weevils. This results in agreement with different scholars findings. According to Namanda *et al.* (2013), the cumulative loss in first month was significantly low in sand storage methods. Straw storage constantly recorded a significantly higher loss compared with other storage materials. And also, stored storage root quality of 3

varieties assessed at 1.5, 3.5 and 6.5 months showed that granary stores provided better storage conditions in aspects of decay incidence, termite and rodent damage (Atuna.*et al.*, 2018).

In other studies, In India, under traditional conditions, sweetpotato storage roots showed 32-60% loss due to weevil damage after two months of storage (Ray and Ravi, 2005). Two recent reports on breaking postharvest bottlenecks in long-term sweetpotato storage in Ghana and Malawi reveal possible long-term on-farm storage in simple containers or pits at ambient conditions. Due to this results rather than sand storage type, the others are less in avoiding loss for the storage roots.

Table 13: The interaction effect of sweetpotato variety and storage materials on cumulative loss

	Ogan-Sagan	Awassa-83	Wolita (Local variety)
Ash	70.33 ^b	50.33 ^{cd}	60.66 ^{bc}
Sand	30.00 ^{efg}	21.33 ^g	21.66 ^{fg}
Sawdust	50.33 ^{cd}	40.33 ^{de}	40.33 ^{de}
Soil	40.66 ^d	40.00 ^{def}	40.00 ^{def}
Straw	100.00 ^a	61.66 ^{bc}	100.00 ^a
LSD_{0.05}		1.55	
CV (%)		14.81	

Means followed by the same letter (s) with in the same column are not significantly different at 5% level of significance, CV; coefficient of variance, LSD least significant difference

4.2.2 The sprout performance evaluation after storage

4.2.2.1 Day to 50 % sprouts

The analysis of variance showed that the number of day to 50% sprout was significantly ($P < 0.001$) affected by both main factors variety and storage type. However the interaction effect of variety and storage type showed not significantly ($P > 0.05$) affected (Appendix Table 1).

From the three varieties Ogan-Sagan took a long day to 50 % sprout; while, both Awassa-83 and Wolita (Local variety) varieties take shorter days. In case of storage type, ash took longer number of days than others. However, straw storage recorded fewer amounts of sprouts (Table 15).

Ahn *et al.* (1980) indicated that the effectiveness of different storage treatments is closely linked with the conditions under which the crop was grown. According to Amoah *et al.* (2010), storage root damage is lower if the storage roots are covered with humid rice straw mulch, although the storage roots tend to sprout. This report contradicted with our result.

4.2.2.2 Number of sprout s per storage root after plant

The types of storage material significantly ($P < 0.001$) affected number of sprout s per storage root. However, variety and the interaction effect of variety and storage material showed not significant ($P > 0.05$) effect on number of sprout per pot (Appendix Table 1).

During observation the storage roots stored in sand showed the highest number of sprout with good quality. The sawdust and soil storage types showed statistically similar results. While, the storage roots stored in the straw storage was recorded less number of sprouts during data collection. This finding is opposite to Amoah *et al.* (2010) that storage root damage is lower if the storage roots are covered with humid rice straw mulch, although the storage roots tend to

sprout. Probably the dry straw that we used to store storage root caused the storage roots for stay with viability and less sprouts after planting due to the dry condition of it. The findings of Chattopadhyay *et al.* (2006) seem like our results who reported no sprouts in the straw medium storage.

Sweetpotato sprouted almost twice as much in the sand basin storage as compared with the others method. Therefore, the observed sprouts in the sand storage could be an indication of good quality and viability of storage roots after 3 months of storage as reported by van Oirschot *et al.* (2007). Timely access by farmers to sufficient quantities of clean planting material is a challenge in areas with a long dry season due to limited knowledge of technologies to conserve vines (Okello *et al.*, 2015). Poor storability of storage roots compared to grain crops is a challenge affecting sweetpotato production by smallholder farmers (Abidin *et al.*, 2016).

4.2.2.3 Length of vine (cm)

The analysis of variance showed that the vine length of the sprout was significantly ($P < 0.001$) affected by storage material. However, the main effect of variety and interaction effect of variety and storage material showed non-significant ($P > 0.05$) effect on sprout length (Appendix Table 1).

Sand storage resulted in the highest vine length of the sprouts of all storage materials. However, straw storage type showed less sprouts emerged. The ash and soil sprouts were shorter than the sawdust storage materials (Table 14). Recently, researchers are promoting dry sand storage to help farmers to extend the shelf life of sweetpotato storage roots (Namanda *et al.*, 2013). The technique grew out of the Triple S approach, which uses sand storage to preserve enough sweetpotato storage roots to plant in irrigated seed beds six-to-eight weeks before seasonal rains start, to produce vines for planting.

Researchers noted that people sometimes ate the storage roots they stored for the purpose of produce planting material, which indicated that sand storage, can also be used to preserve sweetpotato storage roots for consumption. This allows people to sell and eat fresh sweetpotato for more months of the year, which makes the crop more attractive and marketable, and enables it to improve the incomes, food security and nutritional status of resource-poor farm families (Abidin *et al.*, 2016). Therefore, storing sweetpotato in dry sand can provide enough and clean planting materials for the farmers during dry season for planting (Fig. 15).

Table 14: Days to 50% sprout, number of sprout per storage root and length of sprout s of sweetpotato varieties under different storage types

Variety	Day to 50% sprouting	Number of slip /storage root	Vine Length of slip (cm)
Ogan-Sagan	16.51 ^a	17.99	35.19
Awassa-83	16.50 ^b	17.98	35.19
Wolita (Local variety)	16.49 ^b	17.98	35.26
LSD_{0.05}	0.51	2.4	4.76
Storage types			
Ash	16.50 ^a	13.83 ^c	26.29 ^d
Sand	14.83 ^b	40.27 ^a	67.83 ^a
Sawdust	18.83 ^b	17.16 ^b	44.98 ^b
Soil	12.50 ^b	17.94 ^b	32.94 ^c
Straw	5.16 ^c	2.16 ^d	11.94 ^e
LSD_{0.05}	0.66	3.1	6.15
CV (%)	17.71	18.4	18.36
Interaction	Ns	Ns	Ns

Transformed data by +0.5, Means followed by the same letter (s) with in the same column are not significantly different at 5% level of significance, CV; coefficient of variance, LSD least significant difference, ns non- significant

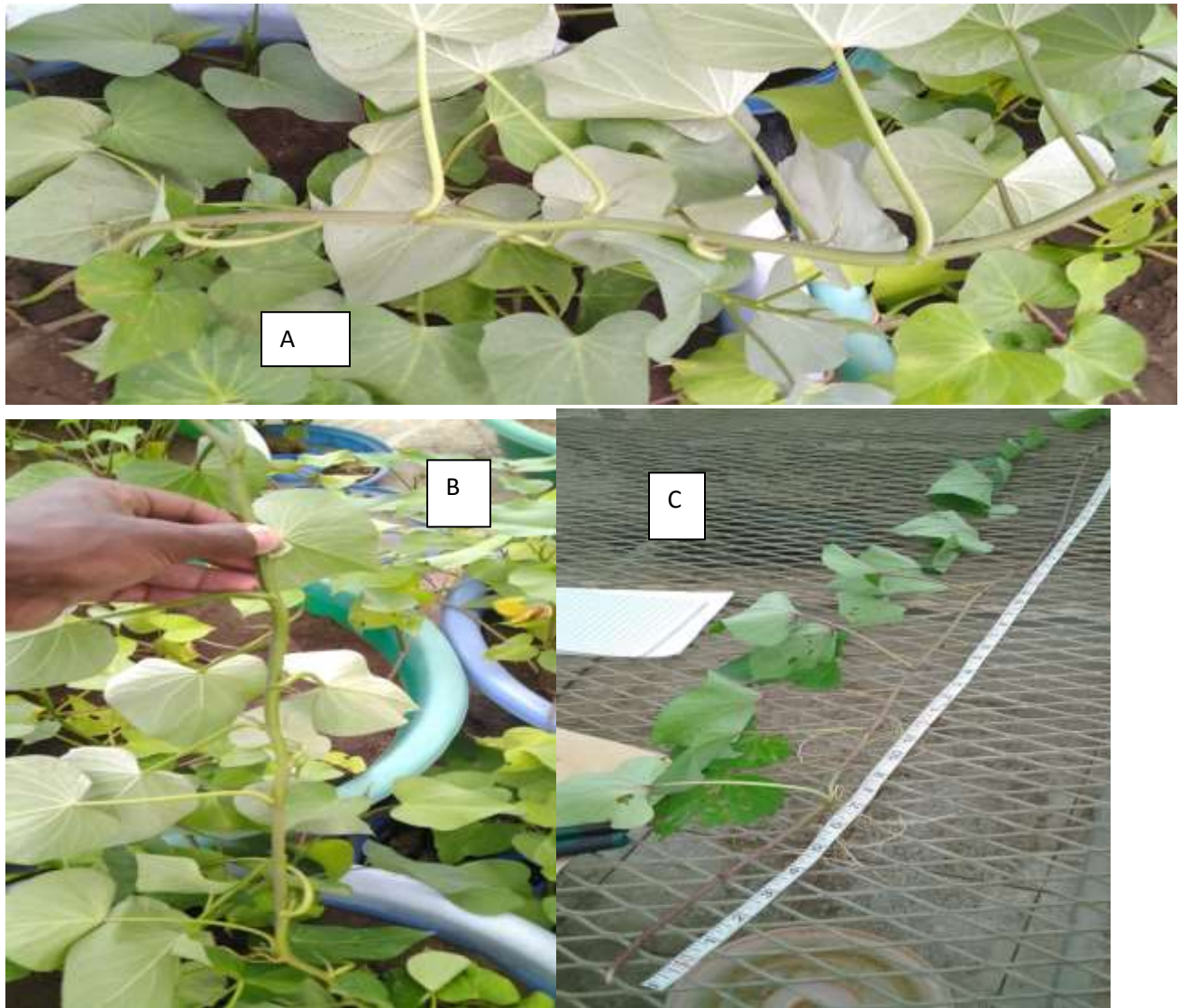


Figure15: Sprout performance of selected sweetpotato varieties in sand storage (A=Wolita (Local variety), B=Awassa-83 and C=Ogan-Sagan variety).

5. SUMMARY AND CONCLUSION

The main objectives of this research were to assess the sweetpotato production practices and identifying the major constraints in Misrak Badewacho district of Sothern Ethiopia and experimentally to evaluate sweetpotato varieties under different storage types for the source of planting materials.

The survey was conducted during 1st August 31st August of 2018/2019 cropping season by participating 316 households in three major sweetpotato growing Kebeles (Gere Bulgita, Tikare Kokere and Wera Boshera). Multi-stage semi-purposive sampling was carried out for selecting households. A structured questionnaire was randomly administered to the sweetpotato growing farmers in the Kebeles. This was also supplemented by secondary data collected from agricultural office of respective district and kebeles. Data on household's demographics, sweetpotato production practice, sources of planting materials, cultural practices, and production constraints were collected and analyzed using statistical package for social sciences (SPSS).

Most (68%) of them were attended their education from 5th to 10th grade and only 2% are illiterate that make easy to accept a new technology for their sweetpotato production system. Farm sizes were very small (23%) from 1 and half timad up to only 2 timad indicating only less than half hectare. Sweetpotato grown on maximum one timad (1/4th ha) and below in one planting season. Sweetpotato productivity was low in the surveyed area under farmer condition due to biotic, abiotic and socio-economic factors. However, it is one of the priority food security crops in the district. In all studied Kebeles farmers placed sweetpotato as a one of best crops. Among root and storage root crops, it is the fourth after enset, taro and potato. The majority of the respondents (95%) indicated that sweetpotato is their priority crops from its important characters. However, some respondents (5%) did not grow sweetpotato or grow it as a

complementary crop in their backyards. Time for sweetpotato planting not varied among Kebeles. Most farmers (68%) planted sweetpotato during January-March depended on onset of long and short rains. About 89% of the farmers harvested sweetpotato from June-September mostly depending on consumption need. Most farmers did not use triple S (Sweetpotato Sand Storage and Sprouting) while only 4% start to practice it in area. However, from the total number of interviewer 96% has information about triple S from CIP training. Varieties Awassa 83, ogan-sagana and wolita (Local variety) were grown by most of the farmers interviewed in the three Kebeles. Varieties received for the past year were Awassa 83, kulfo, alamura, dilla, vita, cabode and fisisa. The farmers got these varieties from district agriculture office and some from NGOs like CIP.

The major identified pre-harvest sweetpotato production constraints in Misrak Badawacho district included rodents (28%), heat and drought (21%), shortage of clean and enough planting materials (15%). Furthermore, lack of knowledge about sweetpotato processing and preservation (39%), lack of training on post -harvest (15%) and insect infestation (11%) were identified as the major post-harvest constraints. Most farmers store sweetpotato storage root in-situ but they reported challenges of rodents (27%), lack of suitable storage (22%) and insect pests (mainly weevils) (12%). A majority of households stated that they would maintain planting materials and multiply it in around the home (31%) or wetlands (26%) to ensure they had clean and enough planting materials at the onset of rains. Therefore, most of the farmers got their planting materials from their own fields and exchanging or buying planting materials from neighbors in the study area. Therefore, to improve sweetpotato production in the area, these production constraints need to be addressed.

To evaluate different locally available storage materials for the storage of sweetpotato for later use as source of planting material, an experiment was conducted in Hawassa University College of Agriculture green house from 1st March – 30 July 2019. The experiment consisted of three sweetpotato varieties (Awassa-83, Ogan-Sagan and Wolaita (Local variety)) with five storage types (straw, soil, ash, sawdust and sand storage). The treatments were assigned in Completely Randomized Design (CRD) with factorial arrangement in three replications. The data analysis was done using GLM procedure in SAS version 9.2 Mean separation was done using Least Significant Difference(LSD) at 5% probability level. The result revealed that days to fibrous storage root formation, days to formation of sprout , number of sprout per pot and vine length were significantly ($P<0.05$) affected by storage types. Days to 50% sprout emergence, was significantly ($P<0.05$) affected both by main effects of storage type and variety. Color change, weevil damage, number of rotten storage root, weight loss and cumulative loss were significantly ($P<0.05$) influenced by the interaction of storage types and variety. Awassa-83 storage roots stored in the sand significantly lowered loss in all physical storage root qualities like color change, weevil damage, rotten of storage root and weight loss cumulative loss except for sprouts after planting.

The findings of this study, therefore, suggests that sweetpotato, especially Awassa 83 variety which is a popular variety in the Misrak Badawacho woreda can be stored in sand basin up to three month which can allow for getting new planting material after storage to ensure availability of enough planting materials at onset of rains for the farmers. As results, the sand storage with Awassa-83 variety storage root performed better than other treatments and can be recommended for planting material sources due to tolerance of decay, regeneration and multiplication rate during replanting it after planting of storage. Sand basin storage method should be encouraged at

the household-level as it provides an opportunity to timely access for enough sweetpotato cuttings for early planting materials in areas with prolonged dry periods. However, to give conclusive recommendation further study should be undertaken over time.

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7. APPENDIX

7.1 Survey Work Questionnaire

Hawassa University, Collage of Agriculture, School Of Plant and Horticultural Sciences

This research survey questionnaire is purely for academic purpose with the title of **Assessment of Sweetpotato (*Ipomea Batatas L.*) Production Practices and Constraints in Misrak Badawacho District, Hadiya Zone SNNPRS**. Respondents of this questionnaire are assured of confidentiality of any view expressed in relation to this research. I therefore, entreat you to provide information as accurate as possible for true results.

Thank you for your kind co-operation!
Tinsae Abrham

1. General information

Interviewer name: _____
 Date of interview: _____ Interview number: _____
 Zone: _____ Woreda: _____
 Kebele: _____ Location/ *goti* _____

1.1 General household information

Name of household head	
Sex of Household head	1= Male 2 = Female
Age of Household head, in years	
Educational level of Household head	1=None (illiterate), 2=read and write, 3=Primary (1-4), 4=Junior (5-8), 5=Secondary (9-10), 6=Tertiary
Name and responsibility of respondent (different from Household head)	2=wife 3=Son 4. Daughter; name _____
Marital Status of the Household head	1. Single 2. Married 3. Divorced 4. Widowed 5. Others
Household size	
Religion	1. Orthodox 2. Catholic 3. Muslim 4. Protestant 5. Any other specify

1.2 Family characteristics

Family characteristics

No	Name (Each family member)	Age	Sex*(use code)	Education (Years)	Relationship** (use code)	Occupation
1						
2						

3						
4						
5						
6						
7						
8						

* 1. Male 2. Female ** 1. Husband 2. Wife 3. Son 4. Daughter 5. Relatives 6. Hired 7. Others

1.3 Labor and Landholdings

1.3.1 Farm holding size ? 1= <0.2 ha 2= >0.2 ha

1.3.2 Name of landholding type in *timad* (fill the following table)

No	Name of landholding type	Size in (timad)	Remark
1.	Grazing land		
2.	Wood land		
3.	Arable land		
4.	Sweetpotato farming land		
5.	Other (specify)		

1.4 Access to facilities

Type of facility	Do you have access 1 = Yes 2 = No	If yes, distance in km	Self-perception on the facilities 1 = Good 2 = Average, 3 = Poor	If no, why (use codes)
All weather road				
Schools				
Health services				
Animal health services				
Credit services				
Public telephone services				
Agricultural extension service				
Markets (nearest)				

Codes: 1 = No access, 2 = Financial constraints, 3 = Not available, 4 = Political instability, 5 = Insecurity, 6 = Cultural beliefs, 7 = Religious beliefs, 8 = No need

In detail questioners

1. Other occupation: do you have off farm activity? Yes = 1 No = 2
If yes, what off farm activity do you have? 1= daily laborer; 2= petty trade; 3= handicrafts;
4= other (specify).....

2. What are the most important crops in your area?
.....

Code: 1= Maize; 2= Teff; 3=Wheat; 4= Sweetpotato; 5= Enset; 6 Coffee= 7 Taro; 8 = Yam ;9=
Fava bean; 10= Haricot bean; 11= Mung bean; 12= Cassava; 13= Tomato; 14= Cabbage; 15=
Beetroot ; 16=Potato; 17= Onion; 18= Garlic

Why?
.....

3. Do you have production problem? Yes=1 No =1
If yes, what is the main production problem? 1= draught; 2= lack of improved varieties; 3=soil
Fertility; 4= pest and insect; 5= rain shortage; 6= lack of variety.

4. Which season is severing for production of root and storage root crops? 1= wet season;
2= dry season.

5. Which crop is the most susceptible to erratic rain?
1= sweetpotato; 2= potato; 3=cassava; 4= Enset; 5= teff; 6= maize; 7= taro; 8= wheat

6. Which crop is susceptible to change in temperature? 1= sweetpotato; 2= potato;
3=cassava; 4= Enset; 5= teff; 6= maize; 7= taro; 8= wheat

7. Farm diversification: How many crops do have every growing season? _____

8. Intercropping; do you practice intercropping? 1=Yes; 2= No

9. Why do you practice intercropping? 1= economical value; 2= ecological value; 3=
minimizing the risk off crop failure; 4=combination of all; 5= other (specify).....

10. Soil moisture: How do you deal with lack of rainfall? 1 = planting different cultivars; 2=
trees traces; 3= supplementary irrigation; 4= planting different crops; 5= water
harvesting; 6= other (specify).....

11. How many times you plant per
year?.....

Sweetpotato production – information

12. Do you cultivate sweetpotato? Yes=1 No = 2

13. If no, why? 1= Lack of cultivars; 2= Lack of crop's knowledge; 3= Ecological reasons;
4= Not economically profitable; 5=lack of training; 6= other reasons (specify)...

14. Do you get advice, or visit from agricultural extension officer? 1= yes; 2= No

15. If yes, how often? 1=every season; 2= every year; 3= more often 4= seldom; 5= other (specify).....

16. Which sweetpotato variety is used mostly?.....
 If you produce sweetpotato, please fill in the following information.

Types of sweetpotato varieties	How long has it been used?	Area planted(Ha or timad/season)	How much do you produce? (Kg/season)	Amounts sold?	Amounts consume?

16. Why do you use these cultivars? 1= high -yielding; 2= drought resistance; 3= nutritional value; 4=viruses and diseases resistance; 5= adaptable to local climate; 6= Market value; 7= other (specify).....

17. How many local sweetpotato varieties in your environment.....
 Name them.....

18. Where do you get sweetpotato’s cultivars?
 a. 1= saving from previous harvest; 2 =exchange with neighbors; 3= local market; 4= local agricultural office; 5= research institutions; 6= other specify.....

19. Sweetpotato seedbed preparations: tillage 1 = machine; 2= manual labor; 4= zero tillage; 5= oxen tillage; 6= other (specify).....

19 Planting time: when do you plant sweetpotato? 1= April; 2= May; 3= June; 3= June; 4= July; 5 August 6= after August (specify).....

20 Weed management: How do you mange weeds in sweetpotato field? 1= mechanization; 2= hand weeding; 3= draught power; 4= biologically; 5= herbicides 6= other methods.....

21. How do you mange soil fertility on your farm? 1= crop rotation 2= intercropping 3= planting legumes 4= crop residues 5= general fertilizers. 6= animal manure.

22. Fertilizers and manures used DAP/Urea/TSP/Manure/compost
 How much DAP/ha.....Urea/ha.....TSP/ha.....
 Manures/hacompost.....

23. From where do you get this recommendation? ARC/GO/AO.....

24. Do you intercrop sweetpotato with other crops? Yes= 1 No=2

25 If yes, which crop is intercropped with sweetpotato? 1= Maize; 2= wheat; 3= barely; 4= potato; 5= cassava; 6= enset.

26 Harvest: How do you harvest? 1= hand; 2= machinery; 3= hand hoeing; 4=other (specify).....

27 Pesticides: do you use pesticides? 1 = synthetic 2= organic 3= without pesticides 4 = other (specify).....

28 What is the source of labor for Sweetpotato production?

1. Family labor 2. Hired labor 3.Labor exchange 4.Cooperation

29 How many years of experience do you have in sweetpotato farming?

30 What type of planting material you used for sweetpotato? a) vine cutting b) Sprout ed storage roots, c) both

31 When you use sprout ed sweetpotato storage roots a) always b) for planting after the long dry season, c) during the main planting time

32 Which one do you think better planting material a) Vine cutting b) sprout ed storage roots

33 Why.....

34 From where do you get the planting materials for sweetpotato?

.....

Sources of seed: CODES

- 1= home-saved/own stocks 2= carryover-maize hybrids 3=friends/neighbors/relatives
4= local market 5= agro-input dealer 6= community-based seed groups 7= government
8= NGO /CIP 9= contract grower 10= other (specify)

35 Can you get enough amounts to plant sweetpotato? 1/ yes 2/no

36 If yes? How.....

37 If no? Why.....

38 Do you have problems to get enough amount of planting materials or cuttings? 1/ yes 2/ no

39 If yes? What are the problems.....

40 If no? How do you get or How do you acquired planting materials?

.....

How acquired: CODES

- A= save/own stocks from last season B=exchange/barter C= gift (friend/neighbor/relatives) D= purchase/buy) E= vouchers/coupons (sometimes w/fairs)
F=direct seed distribution G= seed loan H= food aid I= money credit J= seed for labor
K= other (specify)

41 Are you producing sweetpotato in the rain or in irrigation season?

.....

42 Is the sweetpotato coverage increasing or decreasing...

.....

Why?

43 What are the importance of sweetpotato.....

42. What are Traditional Equipment's and farming syvines for sweetpotato Farming, harvesting and storage.....

a. Traditional equipment's in sweetpotato farming? 1) For ware

.....

2) For sprout ed seed storage root

.....

b. Traditional storage structure

- 1) For ware sweetpotato
- 2) For sprout ed seed root.....
- 43 Do you practice to store sweetpotato root? 1/ yes 2/ no
- a/ If yes?
- 1/ For what purpose.....
- 2/ For how long time?
- 3/ What was the problem when you store.....
- 4/ What materials use for store.....
- b/ If no?
- why.....
- 44.Do you know about sand storage? 1/ yes 2/ no
- If yes? Are you applying before? 1/ yes 2/ no
- If yes? How was the result? 1/ good 2/ not good
45. Do you know about sweetpotato root storage and sprout ing for getting new planting materials or cuttings? 1/ yes 2/ no
- If yes? Are you applying before? What was the result.....
- If no? What do you think if it is a good way to get enough planting materials source for planting.....
46. What type of seed syvines in your environment? (Formal/Informal/Community Based Cooperatives).....
47. Is there any quarantine for the seeds? Yes/No If yes, when is the quarantine taking place? (During Growing/at harvesting/during purchasing).....
- How many times?Is it enough? 1/ Yes 2/no
48. Is the growing season and environment changed from time to time? 1/Yes 2/No
- If yes, explain how it is changed especially in terms of soil fertility, temperature and rain fall?
- Soil fertility Increasing/Decreasing.....
- Temperature Increasing/Decreasing.....
- Rain Fall Increasing/Decreasing.....
- Rain Fall Normal/Abnormal frequency.....
49. Important diseases and insect pests of sweetpotato
- Insects
- a. b..... c.
- d. e.
- Diseases
- a.....b..... c.....
- d.....e.
50. How you control such pests? 1/ Chemicals 2/ Cultural practices 3/ IPM or 4/What if any other?
51. If chemicals are used, name the chemical?
- Where do you find the chemical?.....
- How many times you apply the chemical?
52. How was the sweetpotato productivity in the last decade?
53. By how much it's productivity minimized?.....
54. Possible reasons for this reduction?
- a.
- b.

- c.
- d.
- e.

55. Solutions taken by you?

- a.
- b.
- c.
- d.
- e.

56. Distance to the nearest market from home.....

Is the price of sweetpotato you are going to sell is enough? 1/ Yes 2/No

Price Birr Per kg ?

57. What are the most important constraints of sweetpotato production in order?

- a.
- b.
- c.
- d.
- e.
- f.

58. What will be the possible solutions (put for each constrain)?

59. What are the opportunities to grow sweetpotato?

60. Are you happy in growing/producing sweetpotato?

61. What is your plan in the future a) Continue to plant sweetpotato b) change with another crop?

What should be done by the following actors for the sweetpotato production?

a. The government

.....

b. Research Centers

.....

c. Universities

.....

d. NGO

.....

62. Do you have any comment.....

.....

Thank you for your time!!!

7.2 Appendix table 1: Mean square values for the parameters sweetpotato storage

Parameters	Mean square			R2	Root mean square	Error mean square
	Variety	Storage type	Variety*Storage type			
Color Change	45.86***	63.41***	3.97***	0.93	0.96	0.92
Start to Sprout	0.00ns	108.80***	0.16ns	0.99	0.3	0.09
Weevil Damage	7.80***	95.70***	9.80***	0.95	0.87	0.76
Rot infestation	37.08***	70.13***	6.11***	0.98	0.48	0.23
Weight Loss	0.03*	1.46***	0.04**	0.95	0.09	0.01
Cumulative Loss	10.68***	56.44***	2.24**	0.93	0.8	0.65
Day to 50% sprout	2.48*	44.22***	0.65ns	0.93	0.68	0.47
Number Of Sprout	0.00ns	1828.97***	0.00ns	0.96	3.21	10.36
Vine length (cm)	0.05ns	5009***	0.02ns	0.94	6.37	40.66

7.3 Appendix table 2: Education level, HH size, Landholding in (*timad*), Sex and Age status of the study area

Description	No of respondent	In %
Sex		
Male	57	95%
Female	3	5%
Total	60	100%
Age		
from 18 to 28	16	27%
from 28 to 38	12	20%
from 38 to 48	27	45%
from 48 to 58	3	5%
from 58 to 68	2	3%
Above	0	0%
Total	60	100%
Education level		
None (illiterate)	1	2%
Read and write	3	5%
Primary (1-4)	9	15%
Junior (5-8)	41	68%
Secondary (9-10)	4	7%
Diploma	2	3%
Other	0	0%
Total	60	100%
HH family size		
from 1-4,	3	5%
from 4-6	30	50%
from 6-8	9	15%
from 8-10	16	27%
from 10-12	2	3%
Above	0	0%
Total	60	100%
Landholding in (timad)		
from 1/2 to 1	2	3%
from 1 to 1 1/2	2	3%
from 1 1/2 to 2	27	45%
from 2 to 3	9	15%
from 3 to 4	16	27%
Above	4	7%
Total	60	100%

SKETCH OF BIOGRAPHY

The author, Tinsae Abrham Amanuel was born on 14th of April 1988 in Offoda kebele West Badewacho woreda of Hadiya zone, SNNPR state of Ethiopia. He attends both primary and secondary school in Dessie Catholic Kidanemhired School and the preparatory class at Shone preparatory school. He joined Mekelle University in 2008 and he was graduated on June 10/2010 in B.Sc. from department of Dry Land Crop & Horticulture Science (Horticulture stream) under College of Agriculture and Veterinary Medicine. After graduation he join West Badewacho woreda agriculture and rural development office as an agricultural input quality assurance and distribution expert and serve for one and half year and in the same office serve as an early warning and food security officer for half year. After this he joined NGO under Ethiopian Catholic Church social and development commission coordinating office of Hossana as a project Development Agent in Drought Recovery and Rehabilitation (DRR) project in Shone Misrak Badewacho woreda at Hadiya zone, SNNP region after this as a project Community Development Worker at Teza Sustainable Livelihood Development (TSLD) project in Kadida Gmela woreda at Kambata Tambaro Zone, SNNP region in the same organization also as a Field Supervisor at Emergency Food Support (EFS) project at the same organization in Shone Misrak Badewacho woreda at Hadiya zone, SNNP region. And back to government office as an Environmental Protection and Forest Development expert and unit coordinator at Shone city administration, at Hadiya Zone SNNPR. Currently he works with MSF Spain in Yirgacheffee office as a supply activity officer. He took different trainings like: Short term TVET program on basic computer training at Abeba Computer technical and vocational training institution Addis Abeba, Training on Result Based Management (RBM) and Project Design Implementation and Monitoring organized by the Ethiopian Catholic Church Social and development commission (ECC-SDCO) in collaboration with Caritas Germany, Training on **Sphere** organized by joint Ethiopia program of CAFOD, SCIAF and Trociare , Training on Disaster Risk Reduction (DRR) organized by joint Ethiopia program of CAFOD, SCIAF and Trociare .