ASSESSMENT OF SWEETPOTATO (*Ipomoea batatas* (L.) Lam) SEED SYSTEM AND THE EFFECT OF VINE CUTTING PORTIONS ON PERFORMANCE OF SELECTED VARIETIES

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I dedicate this work to my beloved husband Deneke Deslegn, my mother Jamila Hussein, my brother Badiru Shukre for their love and support.

STATEMENTS OF THE AUTHOR

I, the witness candidate, declare that this MSc thesis is my original work and all sources of materials used for this thesis have been duly acknowledged. I seriously state that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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This MSc equivalent thesis has been submitted for examination with my approval as thesis advisor.

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Signature ______________

Place and Date of Submission: ______________

ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
AVRDC	Asian Vegetable Research and Development Center
CIP	International Potato Center
CSA	Central Statistical Agency
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Statics
INA	Impact Network Analysis
LSD	Least Significance Difference
NARS	National Agricultural Research System
NGO	Non-Government Organization
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
VPC	Vegetatively Propagated Crops

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ABSTRACT

Sweetpotato is an important subsistence crop with high food and nutrition security significance in Southern Ethiopia including Sidama Region. The productivity of sweetpotato in Ethiopia is very low compared to the global average. The low productivity of sweetpotato in Ethiopia is often linked to multitude of factors, but mainly ascribed to seed vine inaccessibility, lack or less adoption of improved varieties and use of sub-optimal agronomic practices, particularly related to seed vines. The present study was conducted with the objective of assessing sweetpotato seed system and evaluation of the performance of selected varieties established from different vine cutting portions in Sidama Region, Ethiopia. The seed system assessment was conducted in 2018/2019 involving 120 sweetpotato growing households from four Kebeles of Boricha and Dale woredas while the field experiment was done at Hawassa University research field. Survey results revealed that sweetpotato production in Sidama mainly occurs in smallholder settings on average farm size of ≈ 0.15 ha under variable socio-economic contexts. The highest average number of planted sweet potato seed vines (6855.53) per household was reported from Debub Mesenkele whereas the lowest (1704.03) was reported from Hanja Chafe. Most farmers used vine with middle cutting portions and medium seed age in studied area. Farmer's meet their seed needs from multiple sources including own-saving, free purchasing, institutional donations, and exchange with relatives and fellow farmer friends across the community, but they heavily rely on their own stocks and on immediate circle of relatives and friends. The field experiment consisted three cutting portions (apical, basal and middle) combined with four selected varieties (Awassa-83, Alamura Hawassa -09 and Kabode) arranged in factorial-RCBD using three replications. The result revealed that from the 20 examined response parameters, only three including marketable root yield (ton/ha), root dry weight (g) and leaf area (cm^2), were significantly affected by vine cutting portions and varietal interaction effects. The remaining 17 parameters showed only main effect factors either for vine cutting portion, variety or both. The apical vine portion with total root yield of 38.5 ton/ha produced almost twice as high as basal cutting portion (19.8 tone/ha). Similarly, for marketable root yield (ton/ha), taking vines from older basal portion instead of the tender terminal apical regions of vines can decrease total marketable root yield by up to 51.43 %, depending on varieties. Variety Hawasa-09 out-performed the other three varieties for yield and yield component traits including total root yield (49.6 ton/ha), total root number and marketable root number. In the inter-trait correlation analysis, significant ($p < 0.05$) and negative correlations showed that early bud sprouting ($r = -0.51$) and crop maturity ($r = - 0.49$) did not favor for higher marketable root yields. Overall, sweetpotato production in Sidama is constrained severely by limited access to the required quantity of good quality seed-vines. From our experiment, regardless of varietal differences, apical seed-vine portions out-performed for important yield and yield component traits. We recommend evaluation of more number varieties accompanied by GXE multi-locations trials for evaluation of vine cutting portion for use as planting materials.

Keywords: *Sweetpotato, seed-vine, cutting-portion, varieties, seed system, root yield, Sidama, Ethiopia*

1. INTRODUCTION

1.1 Background and Justification

Sweetpotato (*Ipomoea balatas* (L.) Lam) is one of the world's most commonly grown root crops (Onunka *et al*., 2011) and the most vital crop for world food security (CIP, 2020). It is herbaceous dicotyledonous plant that belongs to *Convolvulaceae* family, and believed to have originated in the northern parts of South and Central America (Zhang *et al*., 2000; Gichuki *et al*., 2003; Lebot, 2010). It is an evergreen plant with long trailing vines and leaves, but when grown, it is regarded as an annual crop (Huaman, 1999; Lebot, 2010). Sweetpotato, is ranked seventh most valuable food crop in the world after wheat, rice, maize, potato, barely and cassava, (ASHS, 2007*,* Jan low *et al*., 2015).

Compared to other storage root crops, sweetpotato has the benefits of a high yield capacity and adaptability to a broad range of agro-ecologies, including drought-affected environments (Lebot, 2010). The crop is a source of vitamin A that is used to avoid health issues linked to vitamin A deficiency. Feeding the sweetpotato vines to cows as a supplement to a basal diet of other forage improved milk yield and productivity of dairy systems (Etela *et al*., 2008).

Among starchy root and tuber crops, sweetpotato ranks only second after Irish potato (*Solanum tuberosum L*) in production and third in consumption after Irish potato and cassava (*Manihot esculenta*) in many parts of tropical Africa (Urgessa *et al*., 2014). The crop is cultivated in an area of 8.62 million ha in 117 countries worldwide with production of 105.19 million tons for annual and average yield of 12.20 t ha^{-1} (FAOSTAT, 2016). Although China has a maximum share of global sweetpotato production, approximately 95 percent of the global sweetpotato production comes from developing countries (CIP, 2020), and Africa is the largest sweetpotato growing Continent in the world (FAO, 2016).

In terms of sweetpotato production, Ethiopia is ranked fifteenth in the world (Dan *et al*., 2013). After ensete (*Ensete ventricosum (Welw) Cheesman*), potato and taro sweetpotato is the fourth important root crop in terms of area cultivated (58, 272.58 ha) in the country (CSA, 2020). The productivity of < 10 ton/ha in Ethiopia (CSA, 2014) is low compared to average productivity of > 13 ton/ha in developed countries (FAOSTAT, 2012) and the average performance of the world (20-50t/ha) (Çalifikan *et al*., 2007) .The Southern Nations, Nationalities and People's Regional State (SNNPRS), Sidama Regional State and Oromia Regional States are the major producers of sweetpotato. Particularly, in Southern Ethiopia's sweetpotato production is mainly concentrated in three areas including Sidama, Wolayta and Gamo Gofa (Gurmu *et al*., 2015); and these areas are highly dependent on this crop for food security (Gurmu *et al*., 2015). In the 2019/2020 (*Meher*) cropping season, a total of 132,787 households cultivated 5,512.93 ha of sweetpotato and obtained 770,807.51 quintals of production in Sidama (CSA) Country wide productivity. Sweetpotato is commonly propagated by using vine cutting, also known as seed vine cutting. Although the crop is not devoid of sexual propagation and vegetative propagation from sprouted roots, the use of vines as a planting material has several advantages. First, it enables farmers to use all storage roots for consumption or for sale instead of reserving some of it for planting purposes; Secondly, plants originating from vine cuttings are free of diseases born from the soil. . Thirdly, vine cuttings yield and perform more than sprouts and grow more uniform tubers in size and shape (Belehu, 2003).

A well-established seed systems has an important role in the distribution of high-quality seed and improved varieties; give farmers access to affordable disease free, disease-resistant, high-quality seed (Buddenhagen, 2017).However, local seed systems are responsible in providing the bulk of sweetpotato seed vines for most farming societies of developing countries including in Ethiopia (Lipper *et al*., 2010). These systems are characterized by prominently “self-regulated” seed transactions with farmers leading control over vine selection, production, quality controlled and distribution (Almekinders and Louwaars, 1999). Limited formal institutional support for regulation and monitoring of seed vine system put sweetpotato seed vine security as main challenge for producers, an important aspect of building seed vine security, timely access to sufficient quantity and quality of vine cuttings(Pautasso *et al*., 2012) is to understand the contacts among companies of individuals, households, communities, organizations, institutions, norms and rules that makeup seed system and provide seeds for crop production (Pautasso *et al*., 2012).

In fact, the low productivity and under-exploited production potential of sweetpotato in Ethiopia and in other developing countries might be linked to multitude of factors, but mainly ascribed to seed vine inaccessibility, lack or less adoption of improved varieties (Gurmu *et al*., 2015) and use of sub-optimal agronomic practices particularly related to seed vines (Essilfie *et al*., 2016).

As per studies, understanding seed systems, particularly how vine cuttings are circulated and accessed, in combination with correct vine cutting agronomic management, can dramatically increase sweetpotato production and productivity. The choosing of the seed vine section is an important aspect of seed management agronomy. Young sections of vines are typically associated with better yields, and this may be a stronger motivator for the use of apical cuttings than weevil-infested basal regions of the vines (McEwan, 2016Gibson *et al*. (2009) found that cuttings from young plants (2-4 months) or from the younger apical portion of a vine produce higher yields than cuttings from old plants or from the middle or basal portions of the vine.

Varieties and cutting characteristics are significantly associated factors influencing sweetpotato yield and yield components (Essilfie *et al*., 2016). Sweetpotato yield may be increased by using better varieties or good planting materials or combination of both. Cuttings from the apical part of the shoot are considered a better planting material than cuttings from the middle or basal vine (Mukhopathyay, 1990). Apical cuttings can ensure better rooting; faster shoot growth and early closure of the establishment (Lencha *et al*., 2016) and higher marketable and total tuber yield (Tewe *et al.,* 2003). Idoko *et al*. (2017) found that basal vine cuttings are typically thick and woody, often fail to develop and there is a greater likelihood of weevil incidence due to proximity to the crown portion where sweetpotato weevil multiplies.

Although a total of 29 varieties are reported as released in the Ethiopia (NVR, 2020), only handful of them are circulated among farming communities. As the result, the Ethiopian farmers have little choice as to the variety, quality or timing of planting material (Sperling and Longley, 2002) since 80-90% of the seed system informal (Johnson *et al*., 2008). The common factors often ignored by farmers are improved varieties and sources of planting materials for cuttings, but they can significantly affect the yield of sweetpotato.

1.2 Statement of the Problem

Farmers in Sidama area use local varieties of all cuttings without considering their cutting portions and sources for planting purpose. The existing seed vine accessing practices as well as effect of these sub-optimal seed vine cutting consideration not been inefficiently investigated. Therefore contributing and improving production and productivity of sweetpotato by cutting portions and varieties. In view of filling such technical gap, this piece of research work was conducted with the following objectives:-

1.3 Objectives:-

General objective:-

- Assessment of sweetpotato (*Ipomoea Batatas* (*L.*) Lam) seed system and the effect of vine cutting portions on performance of selected varieties

Specific objectives:-

- Assessing the seed systems of sweetpotato in order to identify types of vines used, map the vine sources and key actors in the vine pathway
- Compering varietal difference on yield and yield components resulting from different cutting portions of sweetpotato vines
- Identifying the best cutting portion of sweetpotato seed that enhances yield and yield components

2. LITERATURE REREVIEW

2.1Origin and Distribution of Sweetpotato

Sweetpotato (*Ipomoea batatas*) is a dicotyledonous root crop that belongs to the family Convolvulaceae which includes several species of root crops. The approximately 50 genera and more than 1000 species of *Convolvulaceae batatas* is the only crop of major importance (Woolfe, 1992). The sweetpotato comes from Central and South America (Zhang *et al*., 2004). It has been found growing in the wild from Central America across the Pacific and transferred by Spanish and Portuguese traders to warmer regions of Asia and Africa (Alleman *et al*., 2004).

Sweetpotatoe's are cultivated in over 100 countries around the world however; it is cultivated widely in all tropical and subtropical regions, particularly in Asia, Africa and the Pacific (FAOSTAT, 2010). In recent years, the crop has not been cultivated commercially, although subsistence farmers are now increasingly aware of the need for this crop in urban centers and towns, in order to increase food safety in the long term, subsistence farmers grow sweetpotato plants as asingle crop or integrated with other food crops such as cassava (Manihot esculenta), taro (Colocasia esculenta), yam, and vegetables (Tjintokohadi *et al*., 2007). The main economic commodity is the storage roots, and while the vine tips are the main propagating material, intermediate shoots are very rarely consumed or used in compost as green manure (Lebot, 2010).

The sweetpotato is an ancient crop produced with early cultivation starting around 3000 B.C. within the prehistoric cultures of Central and South America (Lewthwaite, 2004). The findings of a recent study (Roullier *et al*., 2011; Wennekes *et al*., 2013) support this hypothesis that there have been at least two domestications, one in the Caribbean/Central America and one in north-western South America, leading to two domesticated gene pools (the Northern and Southern ones. From 2500 until 2000 B.C. the crop has been widely grown in Peru and Mexico

(Lewthwaite, 2004). The contemporary version of the crop is cultivated across cultures and continents in the tropical and subtropical regions of the globe (Huaccho and Hijmans 2000; Lewthwaite, 2004), although the roots of its domestication remain uncertain (Wennekes *et al*., 2013).

2.2 The Use of Sweetpotato

Among the crops that play a special role in food security, nutrition and customer value, sweetpotato provide services for poor farmers and consumers in developing countries, in extreme soil and climate conditions that are prevalent in developing countries, particularly in Africa, crops perform better than major crops in the world (Zerihun, 2009). Ethiopia is among those countries producing sweetpotato mainly for food despite the general consideration of the crop as less important by most people. Sweetpotato is used as an industrial raw material in some developing countries by light industry to manufacture starch, natural dyes and fermented goods such as wine, ethanol, lactic acid, acetone and butanol (Duvernaya *et al*., 2013). It is among the crops rich in carbohydrates sweetpotato has numerous potential uses and benefits. Sweetpotato storage roots are boiled as food and eaten or chipped, dried and milled into flour that is then used to prepare snacks and weaning foods for infants (Kidmose *et al*., 2007). Importantly, almost every portion of the sweetpotato plant is used by farmers as livestock feed (Claessens *et al*., 2008). Sweetpotato vines and weakened (inadequate for human consumption) roots may be used as useful farm animal feed (Adugna, 2008). The sweetpotato root is rich in vitamins A, B6, C, zinc, riboflavin, pantothenic acid and folic acid (Abd El-Baky *et al*., 2009). These tubers are of excellent food quality and provide an excellent supply of anti-oxidants and carotenes (Woolfe, 1992). The crop has many industrial uses, according to Berberich *et al*.(2005), which can generate new economic and livelihood practices for farmers and rural households and can also add nutritional value to food systems (Bovellbenjamin, 2007).

It has been stated that the sweetpotato has many health benefits that have been related to its phytochemical components. Within the background of African cropping systems, it has many advantages: it produces food in a relatively short period, ii) it produces reliable yields in sub-optimal growth conditions, iii) it needs lower labor inputs (suitable for vulnerable households) than other staples, vi) it serves as an alternative food source for urban populations, facing rising cereal prices, and v) it provides alternative food sources for urban populations (Oswald *et al*., 2009).

2.3 Climate Requirements of Sweetpotato

Sweetpotatoe's are a perennial crop grown annually in the tropics and subtropics (Purseglove, 1991; Leighton *et al*., 2010). Wherever there is adequate water to promote their growth, sweetpotato are grown; optimal annual well-distributed rainfall ranges between 750-1000 mm for growth (Kathabwalika, 2013). Sweetpotato is adapted to the southern, southwestern, and eastern regions of the tropical (*Kwolla*) and subtropical (*Woina daga*) zones (http:/www.ethiotreasures.plus.com/pages/climate.htm) (2002). Quite high precipitation contributes to excessive growth of vines (Workayehu *et al*., 2011; Heerden and Laurie, 2008). Irrigation might be required if the rainfall level is below 500 mm, but it should be stopped before harvest in order to prevent the roots from rotting. Sweetpotato is an annual warm season, needs a climate for optimum production with a mean average temperatures of 18-29^{0}C, a soil temperature of about 30^{0}C and maximum sunshine. A frost-free duration of 110-170 days is required and growth can be impeded below the average daily temperatures of 20^{0}C. The crop grows best where there is relatively high light intensity (Etela *et al*., 2008; Heuzé *et al*., 2015).

2.4 Sweetpotato Propagation

The sprouts or slips produced from storage roots are excellent planting materials for commercial farmers around the world (Khan *et al*., 2008). Sweetpotato is widely propagated by vine cuttings (Nedunchezhiyan & Ray, 2010) because the easiest and cheapest means and general practice in the tropics is to acquire planting material direct from mature crops (Gibson, 2009). Vegetative propagation preserves the individual plant's selected features and allows the best stock possible to be multiplied (Stenvall *et al*., 2006). The use of tissue culture and micro propagation are other methods of rejuvenating and improving individual sweetpotato lines (Bryan *et al*., 2003).

Sweetpotato propagation is carried out by vegetative propagation using one of the following methods: whole storage roots are sprouted (sprouts are then used as planting materials) and stem or vine cuttings are used from plants used for processing or from plots for multiplication. Smallholder farmers seldom receive planting material from extension workers, but they mainly cut vines from their own sweetpotato fields or purchase cuttings from their neighbors (Low *et al*., 2009). Vine cuttings are normally planted vertically with three to four nodes in the soil at an angle or horizontal to the earth; propagation is primarily through the use of vine cuttings chosen from the previous crop (Gaba and Singer, 2009) It is advisable to plant vine cuttings by planting the core with both ends left exposed (Nedunchezhiyan *et al*., 2012). The easiest way of cultivating sweetpotato vine cutting is to place it in the soil with half or two thirds of its length sitting under the soil surface (Belehu, 2003). Horizontal, vertical and loop planting orientations can also be used in the cultivation of sweetpotato (Parwada *et al*., 2011; Chagonda *et al*., 2014). The suggested spacing is 30 cm between plants and 70-100 cm between rows when growing sweetpotato for storage roots (Low *et al*., 2009). Although closer spacing is preferred, farmers use a population range of 25 000 to 125 000 plants per hectare for wide plants (Nedunchezhiyan *et al*., 2012). It is recommended to cut the slips an inch above the soil level and they must be at least 22 cm tall for ease of cutting and planting, but sprouts have less vigor and do not perform well for too long (Department of Agriculture Fisheries and Forestry 2013).

Earlier research has shown that the sweetpotato vine generation system influences the storage root yields of subsequent crop populations, the method of propagation is one of the key reasons for the rapid formation of plants and the early formation of its thick roots in sweetpotato (Novak *et al*., 2007).

2.5. Seed System of Root and Tuber Crops

Seed protection is important for food security, but seed systems for roots, tubers, and other vegetatively propagated crops (VPCs) differ from those for true seed crops (Coomes *et al*., 2015). Moreover, considering their value for food security, nutrition, and rural livelihoods, seed systems for roots and tuber crops receive relatively little attention from development-oriented research and commercial seed sector actors (Almekinders *et al*., 2019). While VPC seed has become more widely available in recent years, farmers may not have access to seed of the right quality and quantity at the right time (Bentley *et al*., 2018). However, arguments and experiences indicate that in certain cases, the economic viability of these models cannot be assured, for example, since farmers' effective demand for seed from vegetatively propagated crops is unknown (Almekinders *et al*., 2019). As previously mentioned, the vegetative nature of root and tuber crops planting content presents significant challenges for a commercial seed company (Andrade-Piedra *et al*., 2016) .Farmers prefer to save seed over many years because VPCs tend to stay true to varietal form for generations. However, there is a problem with this approach: multiplying VPC seed without obtaining fresh seed to true via diseased stock can threaten degeneration of the process as pests and diseases accumulate over successive propagation cycles

(Bentley *et al*., 2016). To reduce the yield gap in root and tuber crops, more efficient seed systems are needed that deliver climate-smart varieties and reduce disease spread, this necessitated the establishment of systematic seed programs to deal with a large number of varieties that were tailored to a variety of farmers' socioeconomic and agro-ecological circumstances (Almekinders and Louwaars, 2012; Tripp, 2002). These programs struggled to effectively address this, resulting in: I seed distribution for varieties that were not locally adapted; (ii) costly seed production; (iii) poor seed quality; and (IV) late seed delivery. For example, seed quality is a key determinant of tuber yield and quality in root and tuber crops (Sthapit *et al*., 2008).

Root and tubers contribute a major share of traditional food system in Ethiopia. The principal root and tuber crops in Ethiopia include enset, potato, taro, yams, anchote; cassava, tannia, and sweetpotato (EIAR, 2015).Currently, many of these crops are used as a major staple diet in South and Southwestern part of Ethiopia. However seed distribution of root and tuber crops for farmers was limited. Seed systems can be defined as the ways in which farmers produce, select, save and acquire seeds (Sthapit *et al*., 2008).The farmers', informal or local seed systems cover methods of local seed selection, production and distribution (Louwaars, 2007). For example in Ethiopia, seed potato supply chains are underdeveloped and participants along the chain are not well-coordinated (Abebe *et al*., 2012). These not only for potato for all root and tuber crops supply of seed underdeveloped in Ethiopia. There is no formal seed system operating for clean/healthy potato seed multiplication and distribution in Ethiopia. Hirpa *et al*. (2010) reported that potato seed production in Ethiopia is basically informal, which in most cases operates by recycling planting materials from previous crop harvest. This has led to significant losses in yield and tuber quality over the seasons (Tsoka *et al*., 2012).

Seed is a key input for improving crop production and productivity however , establishing new seed systems has often been challenging, especially in low-income countries (Buddenhagen, 2017). Increasing the quality of seeds will increase the yield potential of the crop by large amounts and is therefore one of the most economical and productive supplies to agricultural production, healthy seeds are the basis for achieving a healthy crop (FAO, 2006). In Ethiopia, different seed production systems exist parallel to one another: informal seed systems, community-based seed systems, formal seed systems (government supported) and commercial seed systems. The informal seed systems (self-saved seed or farmer-to-farmer seed exchange) accounts for 80-90% of the seed used by smallholder farmers (Zewdie *et al.,* 2008). Main source of seed is the farmer-to-farmer sweetpotato seed exchange, but with limited quantities available at the beginning of the rainy season and re-cycling of vines, the accumulation of sweetpotato virus diseases and root yields will decrease by up to 98 percent, therefore, one of the main constraints to growing access to and use of quality disease-free seed is the lack of access to and use of quality disease-free seed (Rajendran *et al.*, 2017).

Lack of sustainable seed systems (including virus management, seed quality and supply) is one of the key constraints to sweetpotato productivity in SSA (Low *et al.,* 2009). The existing seed systems for sweetpotato have operated at a local scale, based on diverse farmer practices for selection, multiplication and exchange of planting material. Recent survey evidence also indicates that the lack of sustainable seed systems is one of the key constraints to improving sweetpotato productivity in Sub Saharan Africa (SSA). For example, a CIP survey of National Agricultural Research Systems (NARS) priorities in 2005 reported that “virus management, seed quality and supply systems” was ranked as the highest priority for future research and development (R&D) (Fuglie, 2006). Ordinarily, smallholder farmers use seed from their previous harvest, seed from neighbours and relatives, or in some circumstances seed from the market or local agrochemical-input supply shops. Even for regular seed lot replacement, these sources are often sufficient or the most rational seed sources for farmers. The ‘actual’ demand for seed can only is assessed when there is a sufficient supply of quality seed, which is not the case for most crops and in most countries in Africa. ‘Farmers’ demand’ for seed is usually estimated by research and development actors on the basis of area planted with the crop and an ‘expert guess’ of a replacement rate (McEwan *et al*., 2015).Ensuring that farmers can have timely access to adequate quantities of quality planting material remains still a challenge (McEwan *et al*., 2015).

In general, sweetpotato farmers are aware of signs that show the planting material is poor quality, but often link the symptoms to drought rather than to pests and diseases (Gibson *et al*., 2009). The sweetpotato seed system is almost totally informal, with only occasional formal distributions of new varieties by agricultural research centers or NGOs (Namanda *et al*., 2011). The crop is generally propagated from farmer to farmer by vine cuttings obtained from mature crops.

2.6. Sweetpotato Varieties Grown in Ethiopia

Farmers' adoption of new crops or varieties depends on a number of selection criteria which they may consider, including yield, disease and pest resistance, maturity time, form of growth (spreading versus erect), taste, and nutritional value.), other variables such as leaf form, skin and flesh color, texture and probable existing market demand may also be included in the criteria (Ssebuliba *et al*., 2006).In sweetpotato, varieties play an important role in improving yield, but difference between yield genotypes of sweetpotato and other desirable characteristics (Tesfaye, *et al*., 2011).

Most of these types however are outdated and are not in development. Farmers currently produce only three varieties, namely Awassa-83, Kulfo and Tula. In areas where pressure from sweetpotato virus diseases is poor, these varieties have relatively better root yields. However they are one of the key breeding targets is resistance to sweetpotato virus disease, since sweetpotato virus disease is the major sweetpotato disease in East Africa (Mwanga *et al*., 2002; Ndunguru *et al*., 2009). Infected by the sweetpotato virus disease in hot spot areas and the root yield is strongly affected. From a range of genotypes introduced from the International Potato Center (CIP) and Asian Vegetable Research and Development Center (AVRDC), Hawassa-09 the variety was chosen primarily for sweetpotato virus disease resistance and high root yield.

From varieties for example Hawassa-09 was officially released as a new variety and recorded in Ethiopia in (2017) due to its excellent performance after performing a multi-stage comparative study over locations and years as a new variety due to excellent performance (Gurmu.and Mekonen,2017). And newly established varieties however, with little is known about its agronomic and nutritional characteristics which call for further studies (Larbi *et al*., 2007). Osiru *et al*. (2009) stated that genotype output information and yield adaptation would be highly beneficial for cultivar production in various agro-ecological zones. Sweetpotato has a high range, each of which has different morphological features, such as leaves, stems and tubers, (Laurie *et al*., 2013). Recent research efforts have focused on developing varieties with improved yield and nutritional value, low fertility adaptation, drought tolerance, resistance to pests and diseases (Ndunguru *et al*., 2007).

2.7. Varietal Difference in Growth, Yield and Yield Components of Sweetpotato

With cultivars, stem length and number of branches per plant differ (Belehu, 2003). A large leaf area genotype can easily capture sunlight and therefore perform better photosynthesis than those with a small leaf area needed for carbohydrate synthesis in the plant (Kareem, 2013).Variety showed different performance on leaf area and each of the varieties grown had different leaf character (Saitama *et al*., 2017). Fongod *et al*. (2012) who observed that there was a significant variation among sweetpotato accessions for morphological characters, petiole length, internode diameter, leaf area, internode length and fresh weight, dry weight, dry matter content and yield. Significant differences were recorded in vine length, leaf area as well as tuber yield among genotypes (Kathabwalika *et al*., 2013).

Productivity of each variety will be different even in the same environmental conditions. Therefore, the selection of suitable sweetpotato varieties is very important for increasing yield and yield components. Due to leaf shedding due to leaf senescence, farmers and researchers achieved fresh vine yields of 11 to 40 ton per hectare sweetpotato with lower vine yield (Belehu, 2003; Niyireba *et al*., 2013). Naskar (1987) also reported similar findings may be due to higher yield attributes (number of root per plot, root length and mean root girth .Thiyagu *et al*. (2013) who reported that different genotypes respond differently in terms of root yield, number, size and marketability and variation in yield attributes may be a varietal character.

Afuape *et al*. (2011) observed that the number of marketable and unmarketable roots, total number of roots, and weight of marketable and unmarketable roots, total root weights, marketable roots and number of branches are traits that are important to differentiate sweetpotato genotypes and also Deslegn *et al*. (2015) reported that variation between sweetpotato genotypes in yield and other desirable trait. Vinaja (2006) and Yadeta *et al*. (2011) reported that while variability for most of the yield components in sweetpotato is attributable to genetic factors.

2.8. Effect of Cutting Portions on Growth, Yield and Yield Components

Growth of sweetpotato affected by cutting portions .The majority of sweetpotato plants branched amply, while others branched less (Gasura *et al*., 2010) and Cuttings from the shoot apex give more branches because by initiating more roots, they quickly develop in the soil and thus facilitate the subsequent development of branches and more root tubers than semi hardwood and hardwood cuttings (Belehu, 2003).This idea supported by Mukatar *et al*. (2010) also observed a significant increase in the number of branches per plant. The highest vine length was recorded by apical cutting than the other vine portions; this may be due to the young age of the cutting that gives it high vigor and the ability to root faster (Idoko *et al*., 2017). In their study, Lencha *et al*. (2016) found that the number of leaves per plant in the apical portion was significantly greater than in the middle or basal portion.

Vine cuttings in the apical and middle section are also considered the best planting materials for higher root yield (Lencha *et al*., 2016) and other scholar reported that apical cuttings of sweetpotato had significantly higher marketable and complete tuber yield than the middle followed by the basal cuttings (Tewe *et al*., 2003). However, basal parts of the vines are typically thick and woody with poor establishment, apical cutting is favored, and they are closer to the crown portion where weevil sweetpotato multiplies (Belehu, 2003; Nedunchezhiyan *et al*., 2012). While apical stem cuttings are expected to be disease-free and weevil-free, middle and basal cuttings are mainly planted due to a lack of planting material at the beginning of the rainy season (Low *et al*., 2009). If there is a shortage of supply of planting material causing a small decrease in expected yield, middle and basal stem cuttings can be planted (Belehu, 2003). Some researchers, however, find both apical and middle stem cuttings that give higher storage root yields (Nedunchezhiyan *et al*., 2012). Belehu (2003), who noted that farmers do not favor basal stem cuts because they result in very low root yields and similar, Idoko *et al*. (2017) found that basal vine cuttings are typically thick and woody, often fail to develop and there is a greater likelihood of weevil incidence due to Proximity to the crown portion where sweetpotato weevil multiplies while apical shoot cuttings grow more vigorously and generate large storage roots compared to middle and basal portion cuttings. Apical cuttings can ensure better rooting and establishment and faster growth of shoots and early closure for weed destruction (Edmond, 2004).

Mulkhopathyay *et al*. (1990) found that the apical vine portion was the best planting material because it produces more branches, resulting in higher root yield production. Earlier establishment and increase in root circumference of the apical portion of vine over the middle and basal portion was recorded (Essifie *et al*., 2016).Both the apical and middle stem cuttings were found by some researchers to offer greater storage root yield (Nedunchezhiyan *et al*., 2012).

3. MATERIALS AND METHODS

Combinations of two methodologically independent approaches were used in this study: (i) assessment of sweetpotato seed system, in Sidama Ethiopia and (ii) study on the effect of vine cutting portions on root yield and yield components of selected varieties in Sidama region, Ethiopia.

3.1 Assessment of Sweetpotato Seed System as Survey

3.1.2 Study area and sampling

Seed system assessment study was conducted in two major sweetpotato growing *Woredas* (Boricha and Dale) in Sidama Region, Ethiopia during 2018/2019 growing season. A multistage sampling procedure was used to select representative *Kebeles* and respondents in the study area. In the first stage, the two *Woredas* were selected purposely as they have largest area under sweetpotato production in the study Region (Sidama Zone Agricultural Offices Report, 2014). The Boricha and Dale *Woredas* are located at 6°46′N and 38°04′E latitude and 7°01′N and 38°24′E longitude respectively. Boricha has an estimated total population of 121, 641 while Dale has 242,658 (Boricha *Woredas* Agriculture office, unpublished data of 2021).

In the second stage, purposive sampling was adopted to select the *Kebeles* cultivating sweetpotato in each of the selected *Woredas*. From a total of 28 *Kebeles* identified as sweetpotato growers Woredas (17 *Kebeles* in Boricha and 11 in Dale *Woreda*), two *Kebeles* from each *Woreda* were randomly selected. Accordingly, Soyama and Debub Mesenkele *Kebeles* from Dale and Fulasa Aldaada and Hanja Chafe *Kebeles* from Boricha *Woreda* (Figure 1) were selected for seed system assessment. In each of the identified four *Kebeles*, sweetpotato cultivating respondent households, n = 30 were randomly selected, bringing the total sample size considered in the study to 120 households.

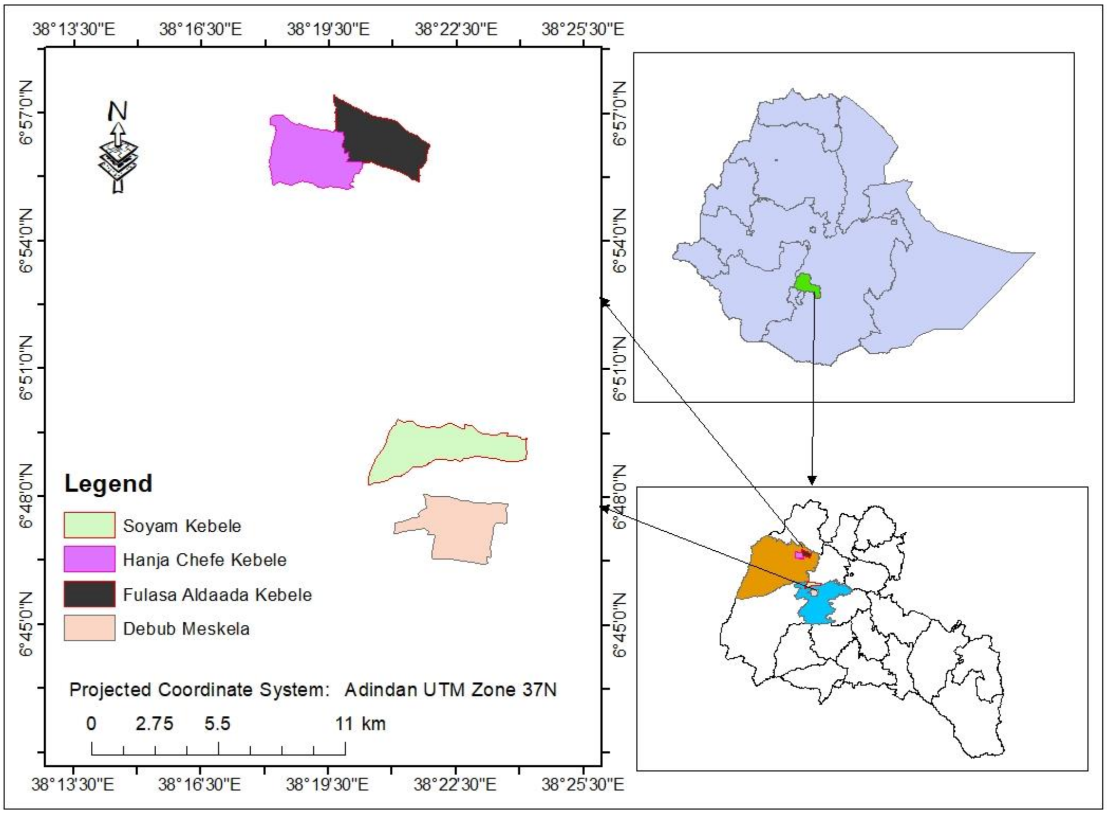


Figure 1.Map of the study area showing four Kebeles in Boricha and Dale woreda in Sidama Region, Ethiopia

3.1.2. Data and data collection

Two focus group discussions (FGD) each comprising 8 – 10 members were conducted in each *Wordeas* to obtain basic data on sweetpotato seed systems before in-depth seed system survey. Sweetpotato garden and seed system survey was conducted in each *Kebele* with the assistance of trained enumerators in the local languages *Sidama Afu*. Only one interview was conducted at each household with participation of all family members, as households operate as a collective entity sharing crop resources and seed exchange information.

Survey questioner (Appendix 1) was administered to collect data Socio-demographic and socio-economic, farming practices and production trend, sweetpotato planting material and their selection and sweetpotato varieties and seed sources were recorded

3.1.3. Data analysis

The data was analyzed using descriptive statistics such as means, percentages and standard deviations. The differences between individual *Kebeles* and *Woredas* for quantitative data sets were tested using analysis of variance (ANOVA). Statistical Package for the Social Sciences (SPSS) version 20 software was used for data analysis (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, version 20.0. Armonk, NY: IBM Corp). An instance of sourcing seeds for different varieties from different actors was visualized using an R package Circlize (Gu 2014).

3.2. Evolution of Varieties and Cutting Portions Used for Planting

3.2.1 Description of experimental area

The experiment was conducted under irrigation at Hawassa University, Main Campus field during 2018/2019 short rainy season from January to June. The site is located at 275km south of Addis Ababa at the coordinates of 7˚04' N latitude and 38˚31' E longitude with an elevation of 1700 meters above sea level. Hawassa average annual rainfall and temperature are 900-1100mm and 27°C, respectively, the area's annual average maximum and minimum temperatures were 26°C and 12.4°C, respectively(Roro and Tesfaye,2019).

3.2.2 Experimental materials and design

The experiment was designed with four sweetpotato varieties and three levels of vine cutting portions in factorial arrangement. A total of 12 treatment combinations were arranged in a Randomized Complete Block Design (RCBD) with three replications. The four varieties were (Awassa-83, Alamura, Hawassa-09 and Kabode) whereas three vine cutting portions were (apical, middle and basal) all of which were obtained from Hawassa Agricultural Research Center (HARC). Awassa-83 and Hawassa-09 were released in 1983 and 2017, respectively. While Alamura and Kabode were released recently in 2019

3.2.3 Land Preparation and management

The experimental land was cleared and ploughed three times by manpower to soften the soil. After which the clods were crushed, weeds were removed and the piece of land was divided into three blocks each containing 12 plots for each treatment combination. The land was leveled and the plots were laid out using measuring tape, garden line and pegs. Each plot size was (3 m x 3m). The vine cuttings of uniform age and cutting portions (apical, basal and middle) of equal size (30cm), were planted on the ridges by inserting two-third of the length of the vine cuttings into the soil at inclined 45^o position. Total number of plots was 36; each plot had five rows with the distance between rows and plants (0.6 m and 0.3 m), respectively. Distances of 0.5m and 1m were maintained between plots and blocks respectively**.** The number of plants per row was ten and the total number of plants per plot was 50 with experimental area of (11m x 41.5m) that means 456.5 m^2. Water was applied daily in all plots till all vines established properly. Then each plot was watered at three days interval. No fertilizer was applied for all plots during the experiment. All plots were kept free from weed through hand weeding. Only plants from middle three rows were used for data collection.

3.2.4 Data collected

A total of 20 parameters including, phenological, growth related yield and yield related traits were evaluated. Summary of the evaluated quantitative characters together with their descriptions is provided in (Table 1).

Table 1 Evaluated quantitative characters and their descriptions

No.	Response character traits	Description
Crop phenology and establishment		
1	Days to first bud sprouting	Recorded by counting the days from planting to when 50% of the vine cuttings sprouted
2	Crop established stand-count	The number of established stands of plants that successfully established after planting the vines were counted
3	Days to 50% maturity	Recorded by the counting the days starting from planting to at leaves of 50% of the plants were turned yellow
Growth parameters		
4	Leaf area (cm2)	Five randomly selected plants were measured by using leaf area instrument
5	Primary branches numbers	Branches from main plant were counted from five randomly selected plants and averaged to express as branch number per plant

6	Secondary branches number	A side branch subsidiary to its parent branch or primary branch counted from five randomly selected plants and averaged to express as branch number per plant
7	Internode length(cm)	The three internodes located in the middle section of the vine of from five randomly selected plants were measured and the mean calculated
8	Petiole length(cm)	Was measured from the base to the insertion of the leaf to the point of attachments to the vine and finally averaged
9	Vine thickness(cm)	Three vines in the middle section of the vine from five randomly selected plants were measured using a caliper
10	Vine length(cm)	The height of plant was measured from the base of the plant to the tip at the time of harvesting and expressed as cm
Root yield and yield components		
11	Total root number	Measured as marketable and unmarketable a number of storage roots produced by the plants in three middle rows
12	Marketable root number	Was determined by counting those having the weight of more than 100g
13	Unmarketable root number	Was determined by counting the number of tuberous roots having the weight of less than 100 g as well as those that were blemished
14	Marketable root yield (ton/ha)	This was included a total mass of roots that a size range of 100 to 500 g and free of diseases and defects (Amanti et al., 2009)
15	Total root yield(ton/ha)	Expressed as harvested fresh roots weight of three central rows converted tot on ha-1
16	Unmarketable root yield(ton/ha)	This was included a total mass of roots with <100 g (under size) > 500 g (over size) tubers with disease and other defects (Amanti et al., 2009)
17	Root dry weight(g)	Fresh root samples of 100-200 g were taken from each plant in the three middle rows and later dried in an oven at 80oC till constant weight then measured the weight by sensitive balance
18	Storage root length(cm)	Recorded as mean vertical length from the bottom to the tip of roots from five randomly selected plants
19	Storage root diameter(cm)	Expressed as the mean diameter of the middle portion of roots of five randomly taken plants and measured using a caliper
20	Root dry matter content (%)	Calculated by using the loss weight and the fresh sample weight according to the following dry matter (%)= Dry weight of sample / fresh weight of sample x 100

3.2.5. Data analysis

After testing ANOVA assumptions, analysis of variance (ANOVA) for the collected quantitative parameters was performed using SAS Version 9.0 (SAS Institute, 2012) .Treatments mean comparison was done using least significance difference (LSD) at 5%.

4. RESULTS AND DISCUSSION

4.1. Assessment of Sweetpotato Seed System

4.1.1. Socio-demographic characteristics of sweetpotato

Sweetpotato is produced in variable socio-demographic context both at household and *Kebele* levels in Sidama Region (Table 2 and Table 3). The survey result showed that majority (93.3%) of the respondents from 120 sweetpotato growing households were headed by men while the remaining (6.7%) were female headed households who are either widowed or divorced, meaning that household resource leaders are mostly male in the studied areas, as in other parts of Ethiopia and many developing countries (Kivuva *et al.* 2014). Most (35.8%) of the interviewed households had the age ranging from 31- 40 years, whereas lowest (15%) of them were (51- 60 years) (Table 2), implying that most of the interviewees had active age supporting production labor and easily understanding new production technology. Most of the interviewees were married (95%) and only very few were widowed (0.8%) or single (2.5%). Majority (58.3%) of the farmers attended junior (5- 8 grade) level, while a little less than one-fifth (17. 5%) of the farmers had never been to school.

Table 2.Household socio-demographic characteristics of sweetpotato farmers in Sidama

Variables	Frequencies	Percentage
Sex of HH head		
Male	112	93.3
Female	8	6.7
Age of HH head (years)		
20-30	21	17.5
31-40	43	35.8
41-50	38	31.7
51-60	18	15
Education level of HH head		
Never been to school	21	17.5
Read and write	15	12.5
Primary (1-4)	13	10.8
Junior (5 - 8)	47	39.2
Secondary (9 -10)	19	15.8
Tertiary (10 -12)	5	4.2
Marital status		
Single	3	2.5
Married	114	95
Widow	1	0.8
Unmarried	2	1.7

Result showed that significant variations were observed among four studied *Kebeles* of household demographic and socio-economic characteristics. With the exception of household size, all other variables including farming experience, household head age and landholding size were significantly (P<0.05) different among *Kebeles* (Table 3). The sweetpotato farmers in Boricha *Kebeles* were older farmers with larger landholding sizes than farmers residing in the *Kebeles* of Dale *Woreda*. With the mean age of (44±7.31) years and crop farming experience of (20.53± 7.79) the farmers from Fulasa Aldaada of Boricha were the oldest and more experienced sweetpotato farmers along with the Debub Mesenkele farmers. Land holding size is bigger in Boricha than Dale *Woreda*; with Hanja Chafe *Kebele* farmers have mean landholding size of (2 ha) (Table 3). Land is important for production; however in studied area had small land hold size especially in Dale *Woreda*. The reason might be due to the higher number of population residing in Dale than Boricha *Woreda.*

Table 3.Household socio-demographic and socio-economic characterstics of sweetpotato growing farmers in Sidama

Kebeles	Age of HH	HH Size	Total landholding of size (ha)	Farming experience in agriculture(Year)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Hanja Chafe	41.27±6.45[b]	4.83±1.74	2±0.69[a]	17.9± 5.34[b]
Fulasa Aldaada	44±7.31[a]	4.9±1.76	1.3±0.53[b]	20.53±7.79[a]
Soyama Debub	32.83±7.56[c]	5.3±1.57	0.67±0.36[c]	17.03±7.91[b]
Mesenkele	41.83±9.73[b]	5.9±1.95	0.73±0.27[c]	21.83±7.58[a]
Mean	39.98±8.85	5.23±1.79	1.18±0.72	19.33±7.40
Significance	*	Ns	*	*

* = statistically significant at $P < 0.05$; HH – household

4.1.2. Sweet potato farming experience and production trends

The survey result showed the presence of significant (P<0.05) variation among the four *Kebeles* of Sidama Region in sweetpotato farming practices (Table 4). The interviewed households cultivated sweetpotato for about an average of 6.5 years. Dale had long year of sweetpotato farming experience than Boricha. Dale *Woreda* had long sweetpotato farming experiences relatively larger sweetpotato farm sizes and more number of vines planted. In Boricha, small sweetpotato farm sizes below (0.15 ha) are prevalent. Other areas in Ethiopia also produce Sweet potato on characteristically small sized plots (Shonga *et al*. (2013).

According to the focus group discussion of the households, the highest number of sweetpotato seed vines were planted in the last two cropping seasons (2018/2019 and 2019/2020) in their areas. During this period slight increment (4783.3) vine cutting) in the number of planted vines was recorded. The highest number of planted sweetpotato seed vines (6855.53) per *Kebele* was reported from Debub Mesenkele whereas the lowest (1704.03) was reported in Hanja Chafe in last (2018/2019) cropping season and similar trend was observed in (2019/2020) cropping season. The farmers indicated trend of increasing demand for quality sweetpotato vines for planting.

Table 4.Sweetpotato farming experience in studied *kebeles* of Boricha and Dale

Kebeles	S.Potato farming experience (Year)	Sweetpotato farm size (ha)	Vines planted in 2018/19	Vines planted in 2019/20
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Hanja Chafe	4.70±1.76^{c}	0.04±0.06^{c}	1704.03±1089.5	2284.67±1680.7
Fulasa Aldaada	5.73±1.89^{bc}	0.13±0.11^{b}	4586.67±2799.7	4778.67±2703.5
Soyama	8.33±4.14^{a}	0.29±0.16^{a}	5986.87±2599.3	6311.87±2832.3
Debub Mesenkele	7.10±3.43^{ab}	0.16±0.06^{b}	6855.53±2864.8	7247.90±3411.6
Mean	6.5	0.15	4783.3	5155.7
Significance	*	*	*	*

The survey result also showed that farmers in the studied area have different perception of the trend of sweetpotato production. Most (51.7%) of interviewed respondents in studied area indicted a decreasing trend of sweetpotato production. However, about (18.3%) sweetpotato producers perceive that the production trend has been unchanged.

At *Kebele* level, as indicated in (Figure 2 A) majority of respondents perceived a decreasing trend of sweetpotato production. More number of farmers from Soyama (70%) and Fulasa Aldaada (63.3%) indicated decreasing trend of sweet potato production. However, in Hanja Chafe farmers (40%) indicated slight increase in production where as in the Debub Mesenkele farmers (40 %) perceived sweet potato production has been unchanged.

From the focus group discussion most farmers believe that the decreasing trend of sweetpotato production is due to as shortage of arable land and disease devastate on sweetpotato, limited supply of planting vines or combination of these factors (Figure 2 B). Shortage of reliable supply of sweetpotato seed vines and lack of land was reported by (40.8 %) and (30%) of the individual farmers corroborating the results of focus group discussion. Most number of respondents from Hanja Chafe (53.3%), and Soyama (40%) reported shortage of land as an important factor limiting sweetpotato production in their area. However farmers of Debub Mesenkele (60%) and Fulasa Aldaada (53.3%) indicated lack or shortage of sweetpotato planting material as a pressing problem for production.

Overall, farmers in studied area responded that shortage of planting material and land are serious problem of affecting sweet potato production in Sidama. Similar findings were reported by Gurmu *et al*. (2016) who asserted that foremost important sweetpotato production limitations are shortage of planting materials, shortage of land and diseases. Wanjala *et al.* (2020) also indicated lack of access to quality sweetpotato planting material for improved varieties.

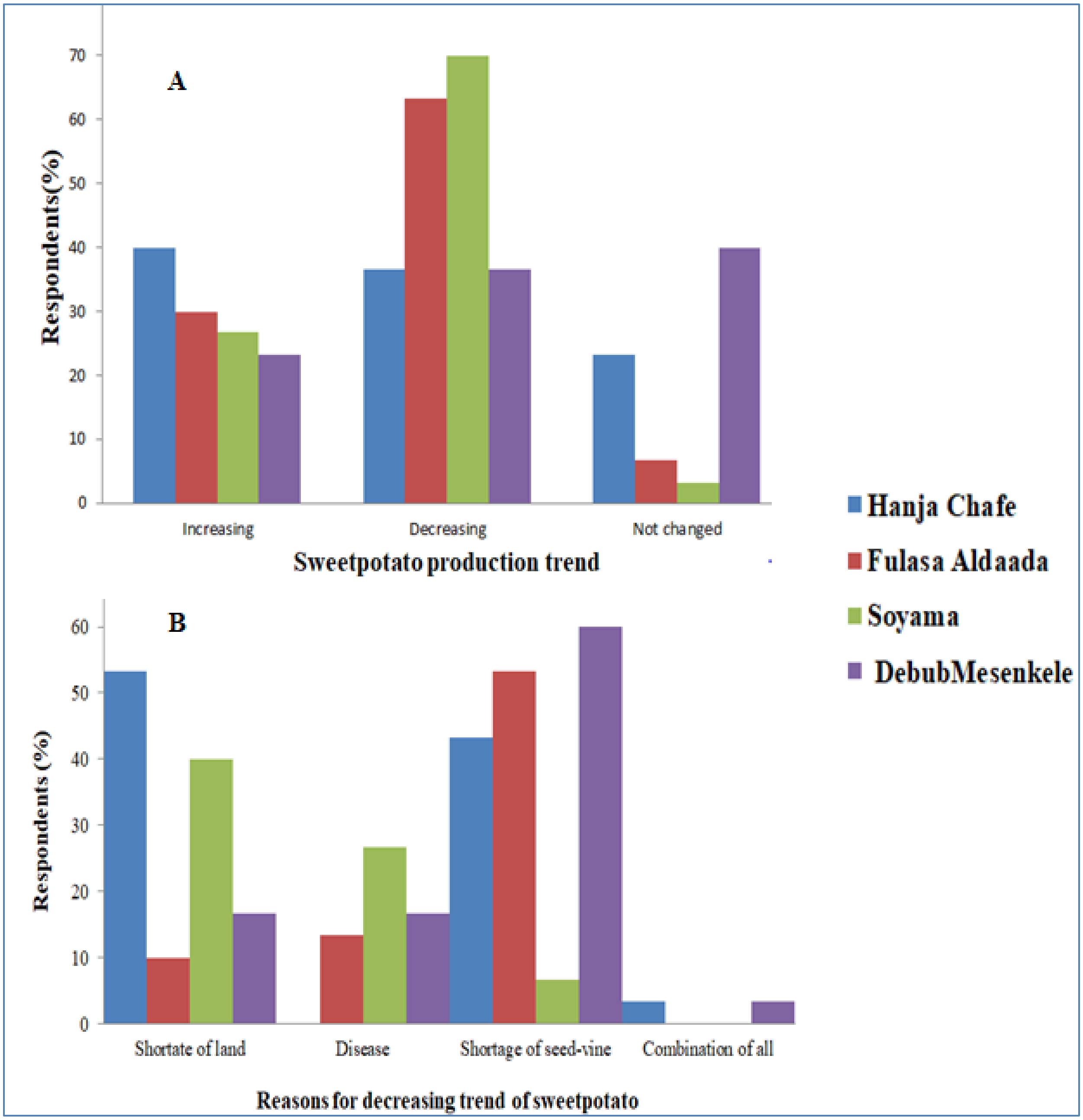


Figure 2 Perceived trends of sweetpotato production in studied *Kebeles* of Sidama (A) and reasons ascribed for decreasing trends of sweetpotato production (B)

4.1.3. Sweetpotato planting materials and their selections

Farmers in the study area consider various characteristics of planting materials for production of sweetpotato (Table 5). Prominent factors are plant parts (roots and vines) used as sources of planting materials, relative mother plant age (young, medium and old) and portions (apical, middle and basal) of the vine cutting selected for planting material. From the total of 120 farmers interviewed, most (67.5%) respondents used vines as planting materials and only few used roots (32.5%) as major sources of planting materials. At *Kebele* level, great majority of the farmers (53.3 - 80 %) used vines as major source of planting materials in all the four *Kebeles*. However, in Hanja Chafe *Kebele* farmers use both roots (46.7%) and vines (53.3%) as planting material sources. The Sidama farmer’s preference to use vines for panting material is in agreement with (Nedunchezhiyan & Ray, 2010) who reported that sweetpotato is widely propagated by vine cuttings because vines are easiest and cheapest means and, the general practice in the tropics is to acquire planting material directly from mature crops (Gibson, 2009).

Regarding the age for planting purpose farmers rarely consider very old and very young plant parts as source for planting materials; in fact, most respondents (76.7%) use medium aged plant parts as planting material source. Among the studied *Kebeles* the residents of Debub Mesenkele (83.3%) and Soyama (80%), reported frequent use of medium aged plant parts for planting materials. Similarly, seed vine cutting portions is also highly scrutinized characteristics for consideration of sweetpotato planting materials. Although, either basal, middle or apical portions of vine cuttings are reported, most (69.2%) preferred and frequently used part is the middle portion of vine. Comparing the *Kebeles* most (83.3%) farmers of Debub Mesenkele framers use middle vine cutting portion. Most farmers used middle cutting portions and medium seed age without any ascribed reasons. However, many scholars stated that apical cutting portion of vine is best as sweetpotato planting material (Lencha *et al*., 2016; Sam *et al*., 2021).

Table 5.Characteristics of sweetpotato planting materials used by different number of households in the studied areas of Sidama, Southern Ethiopia

Kebeles	Seed source (%)		Seed age (%)			Seed-vine portions (%)		
	Root	Vine	Young	Medium	Old	Apical	Middle	Basal
Hanja Chafe	14(46.7)	16(53.3)	1(3.3)	22(73.3)	7(23.3)	5(16.7)	22(73.3)	3(10)
Fulasa Aldaada	8(26.7)	22(73.3)	9(30)	21(70)	0(0)	4(13.3)	21(70)	5(16.7)
Soyama	6(20)	24(80)	5(16.7)	24(80)	1(3.3)	5(16.7)	15(50)	10(33)
Debub Mesenkele	11(36.7)	19(63.3)	2(6.7)	25(83.3)	3(10)	5(16.7)	25(83.3)	0(0)

Where %=percent

4.1.4. Sweetpotato varieties and seed sources

Seed vines of different varieties are the main important inputs for sweetpotato production. Four sweetpotato varieties were reported to be cultivated in the studied areas (Figure 3). Half of the interviewed households reported that they use local varieties for production. Awassa-83, was the most commonly used released variety in studied areas with about 27 (22.5 %) of the households reported its use in 2018/2019 cropping seasons. Awassa-83 variety is most widely cultivated and more adapted in Southern Ethiopia including Sidama for the reason that it was released longtime ago in 1997. On the other hand, varieties such as Kulfo (released in 2005) and Hawassa-09 (released in 2017) were less common and were not widely cultivated.

Regarding studied *Kebeles*, many farmers 16 (53.3%) in Debub Mesenkele used local varieties whereas in the Debub Mesenkele few number 2(6.7%) of farmers used recently released (Hawassa-09) varieties. In all the studied *Kebeles*, local variety dominated the sweet potato cultivation (Figure 3). However, in Hanja chafe about seven (23.3%) of the farmers used released varieties, the reason might be the geographic proximity Hanja Chafe to the Regional capital Hawassa and service providers such as research centers, office of Agriculture who might have contributed to the difference in use of released varieties across studied *kebeles.*

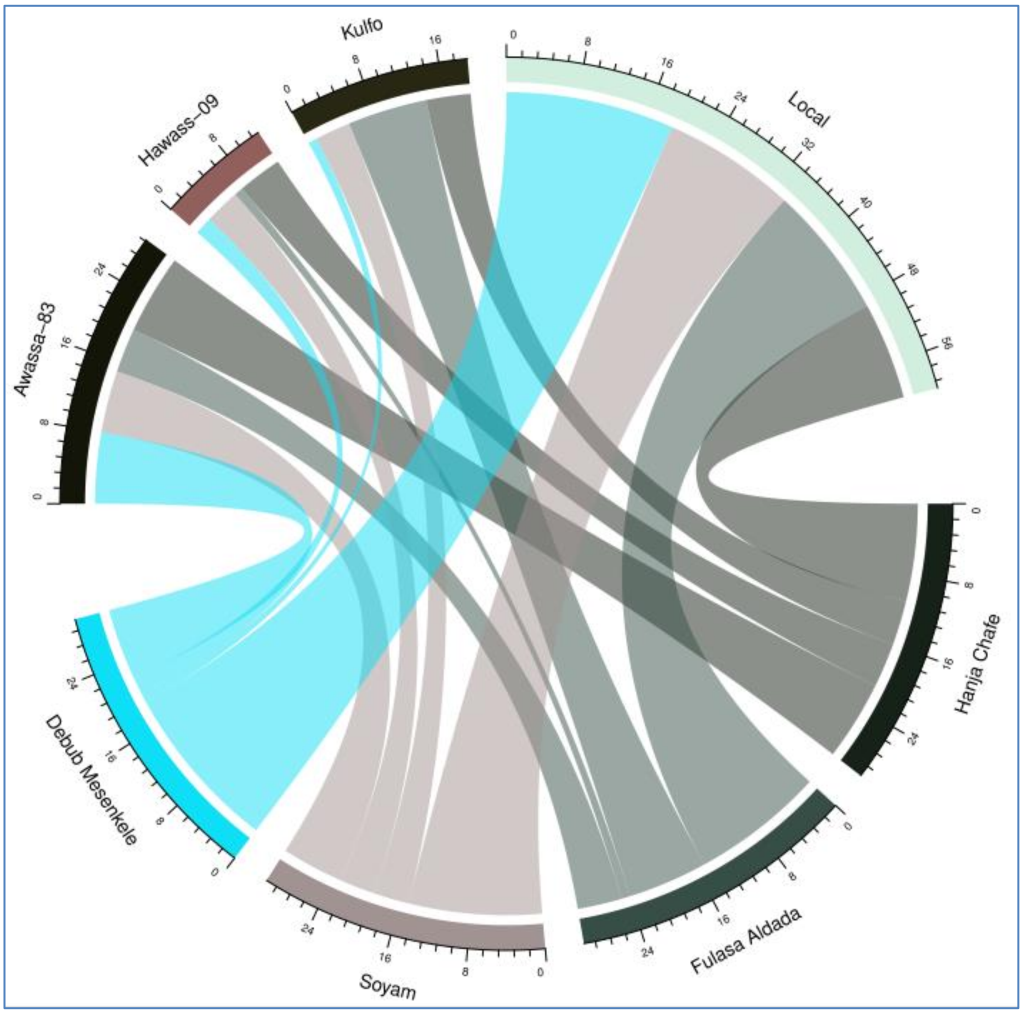


Figure 3 Number of farmers in different *kebeles* cultivating various types of sweetpotato varieties in Sidama, Ethiopia

The lack of seed vine distribution channel and access to the farmers might be possible reason of the limited use of improved varieties. In order to meet their seed need Sidama sweetpotato farmers access seeds from multiple sources including own-saving, purchasing from local markets, institutional donations and exchanges with relatives and fellow-farmer friends (Figure 4). The 120 interviewed farming households mentioned 150 seed sources, a total of 130 (86.7 %) from either own-farm, relative and friendship circles. The result is comparable across the four Kebeles, own-saved vine stocks are the major sources sweetpotato planting materials. Sweetpotato planting materials were largely reused from the preceding crop, since only a very slight portion of the farmers indicated they used good quality planting material (from Research Centers, RC). This indicates that either most farmers are unaware of the value of using safe, approved planting materials or that they do not have a viable alternative. This result is in agreement with Fuglie (2007) who surveyed sweetpotato production constraints in a number of countries and found that a lack of clean and sufficient planting material as well as limited institutional supports as a major constraint.

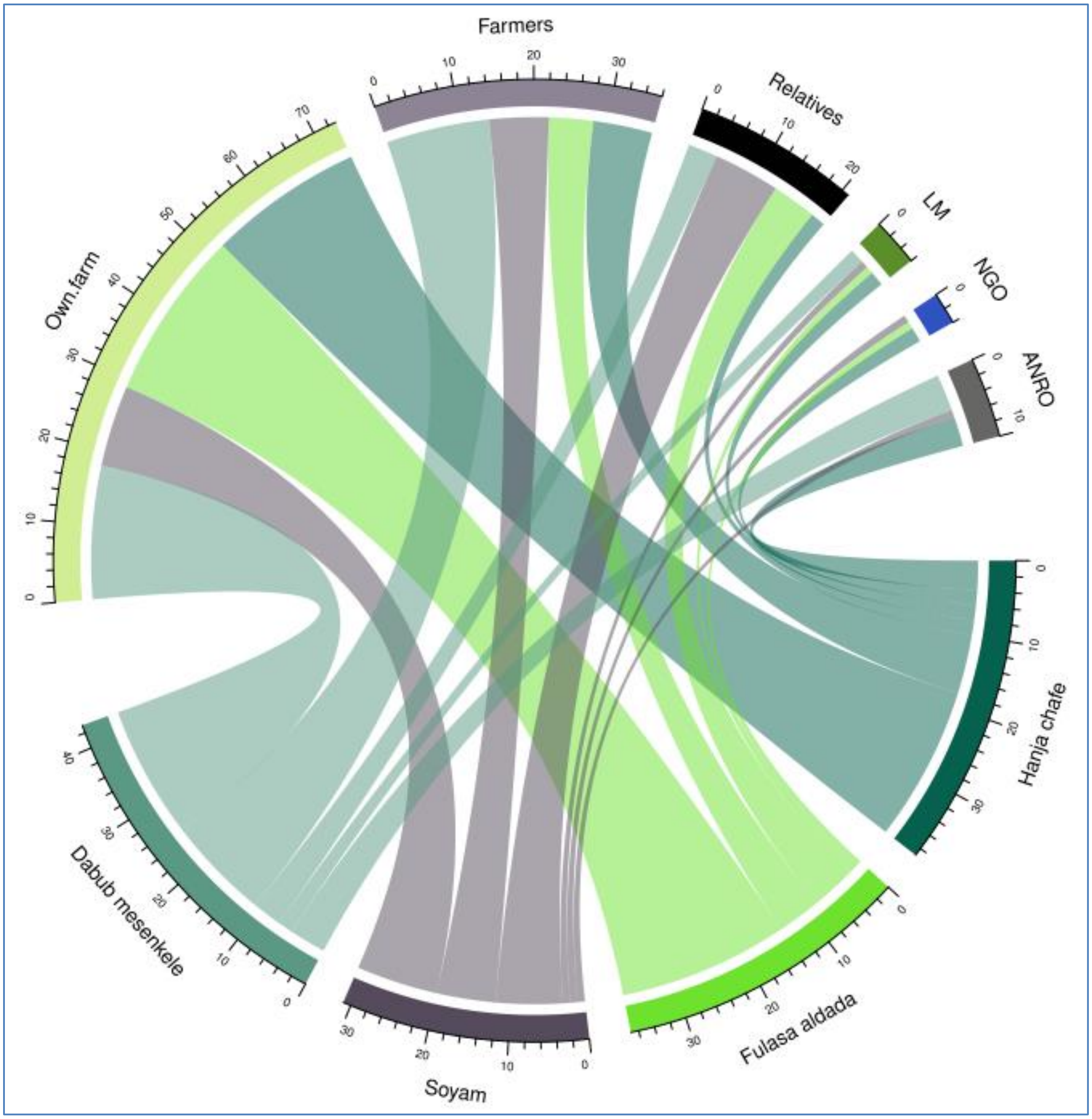


Figure 4 Number of actors cited as important sweetpotato seed-vine sources in the exchange pathways in Sidama, Ethiopia

ANRO = Agriculture and Natural Resource Office; LM = local market; NGO = non-governmental organization

4.2. Effect of Vine Cutting Portion and Varieties on Phenology, Growth, Yield and Yield Components of Sweetpotato

4.2.1. Impact of vine cutting portions and varieties on crop phenology and establishment

Results of the analysis of variance showed that only the main effects of vine cutting portions and varieties were significantly (P<0.001) for crop phenology (days to first sprouting and 50% maturity) and established stand-count (Table 6; Appendix Table 1).Vine cuttings from basal portion sprouted significantly (P<0.001) late than the vines from apical and middle portions (Table 6). Basal portion of vine cutting sprouted 13.7 days and 11 days late as compared to the middle and apical vine portions. The variation among cutting portions in days to sprouting might be due to gradient of cell division activity along the vine cutting; proximity to meristemtic regions where cell division and growth is active to promote easy sprouting in the apical and middle portion cuttings than the basal portions. Idoko *et al*. (2017) also gave evidence that basal vine cuttings are usually thick and woody, sometimes completely fail to establish. In addition, there is a greater chance of sweet potato weevil (*Cylas formicarius* F.) incidence and infestation in the basal portions of cuttings due to proximity with the crown or tuberous root portion where sweet potato weevil multiplies compared to the terminal tender cutting parts such as apical and middle portions.

The results of sprouting phenology of vine cutting portions were translated into crop-stand establishment and maturity. The tender apical terminal portions of vine cuttings not only sprouted earlier but also resulted in better crop establishment and earlier 50% maturity. The apical cutting portions had resulted in significantly (P< 0.05) highest number established crop-stand counts followed by middle vine cutting portion; however, the basal cutting portion had smallest proportion of crop-stand counts established (Table 6). Consequently, the crops established from the terminal tender apical portions of vine cuttings took only 132.5 days to reach 50% maturity, whereas, crops form the middle and basal vine cuttings portions took statistically comparable days to reach 50% maturity with 137 and 140.2 days, respectively (Table 6). The hypothesis of cell division activity in the apical cutting portion that might trigger earlier establishment and crop cover as well as subsequent resource (eg. light and nutrient) competition advantage ensuring earlier maturity (Idoko *et al*., 2017). Our findings strongly support the previous reports (Lencha *et al*., 2016) stating that tender apical cuttings may ensure better rooting and establishment and faster shoot growth and maturity than relatively older basal cutting portions.

The other treatment main effect, sweetpotato varieties, also showed significant ($P<0.05$) difference on days to first bud sprouting, established stand-count and days to50 % maturity. Among the varieties, Kabode sprouted significantly ($P<0.05$) earlier than the remaining three varieties Awassa-83, Alamura and Hawassa-09; the latter three took statistically comparable longer days to sprouting (Table 6). Similarly, Kabode along with Awassa-83 and Hawassa-09 had comparable and highest number crop stand establishment counts. The variety, Kabode took only 129.8 day to reach 50% maturity which was statistically significant compared to Alamura, Awassa-83 and Hawassa-09. The recently released Alamura was late maturing with 144.1 days. Similar result of sweet potato varietal differences in sprouting, stand establishment and maturity were reported by Tesfaye *et al*. (2011) as significant variation among sweet potato genotypes in phonological traits crop stand counts. These sweet potato varietal differences might be related to the inherent genetic variation existing among the varieties for the phenology of sprouting, maturity and vigor for stand establishment.

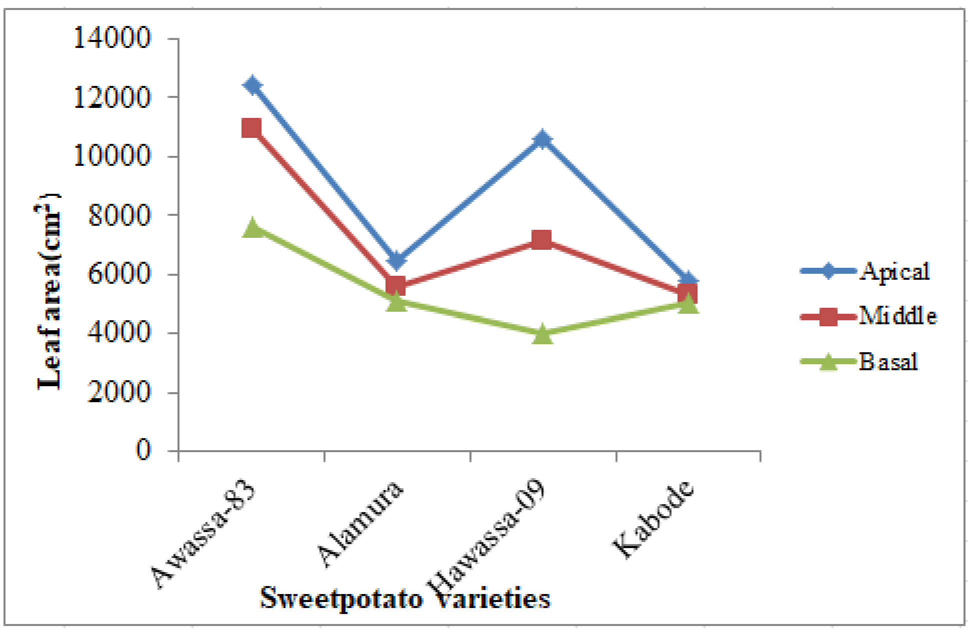
Table 6 Mean comparison of cutting portions and varieties on phenology and established

Treatments	Days to first bud sprouting	Established stand-count	Days to 50 % maturity
	Cutting portions		
Apical	22.4^{b}	43.3^{a}	132.5^{b}
Middle	25.1^{b}	33.1^{b}	137.0^{a}
Basal	36.1^{a}	27.7^{c}	140.2^{a}
LSD(**0.05**)	3.5	2.07	3.7
	Varieties		
Awassa-83	31.1^{a}	36.7^{a}	137.7^{b}
Alamura	31.6^{a}	31.8^{b}	144.1^{a}
Hawassa-09	27.5^{a}	34.8^{ab}	134.6^{b}
Kabode	21.2^{b}	35.4^{a}	129.8^{c}
CV (%)	15.1	9.2	3.2
LSD (0.05)	4.1	3.13	4.3

CV (%) = Coefficient of variation; LSD = list significant difference; means in the same column followed by the same letter(s) are not significantly different at P = 0.05

4.2.2. Impact of vine cutting portions on growth of sweetpotato varieties

From the seven growth parameters (number of primary branches, secondary branches, internode length, petiole length vine thickness, vine length and leaf area) only leaf area affect by vine cutting portion and varieties were significant (P<0.001) interaction effect (Appendix Table 2 and3; Figure 5). Mean comparisons for leaf area (cm^2) revealed that the tender apical vine cutting portion of variety Awassa-83 (12433cm^2) had statistically superior leaf area than other treatment combinations (Figure 5). The result indicated that the leaf area showed decreasing trend along the continuum from apical to basal vine portions for all four varieties. Comparable and statistically significant pronounced reduction in leaf area was observed for the three varieties (Alamura, Hawassa-09 and Kabode) established from basal cuttings. Comparing the highest leaf area (apical cutting from variety Awassa-83) with lowest leaf area (basal cutting from Hawassa-09), sourcing older basal vine cutting portion instead of tender terminal parts of vine cutting had decreased leaf area at least by 32%. In line to the current finding, Saitama *et al*. (2017) reported significant reduction of leaf area in sweetpotato genotypes grown from different vine cutting portions. Moreover, Kathabwalika *et al*. (2013) asserted that relatively fibrous old terminals of sweetpotato vine cuttings generated significantly smaller leaf area in different genotypes than vines from apical portions, implying the less green surface of leaf area for capturing sunlight for photosynthesis. It is well established that genotypes with relatively larger leaf area can easily trap sunlight and hence carry out photosynthesis required for carbohydrates synthesis with better efficiency than those with small leaf area (Kareem, 2013).



(cm$^{2)}$; Means followed by different letters on the individual bars of the figure are statistically significant

Figure 5 The interaction effect of sweetpotato vine cutting portion and varieties on leaf area.

Other vine related parameters such as primary branches, secondary branches, internode length, vine length, vine thickness and petiole length showed non-significant variation for interaction effect being only affected by the main factor effect of genotypes and vine cutting portions. In this regard, the ANOVA result revealed that the number of primary and secondary branches significantly varied both due to main effect of cutting portion (P<0.001) and varieties (P<0.001) (Table 7). The apical vine cutting portion had generated the highest number 6.5 and 18.8 of primary and secondary branches per plant, respectively. While the lowest number of 4.5 and 12.3 primary and secondary branches per plant were obtained from the basal cutting portion respectively (Table 7).

Regarding the other vine traits, statistically significant (P< 0.001) longest vines (160 cm) with extended internode length (5.4 cm) were recorded from stands established from apical cutting portions, whereas the shortest vines (95 cm) with shortest internode lengths (4.2 cm) were recorded from basal vine portions (Table 7). The longest vines with elongated internode length were also the thickest (0.5 cm) vines that were recorded from stands raised from the tender apical cutting portion, but the thinnest (0.3cm) vines were recorded from basal cutting portion (Table 7). Similar pattern was also observed with the leaf petiole length; the longest (27.7cm) and shortest (19.3cm) leaf petioles were recorded from the apical and basal vine cutting portions, respectively (Table 7)

Table 7 Mean effects of cutting portions and varieties of sweetpotato on different growth parameters

Treatments	Primary branches (#)	Secondary branches (#)	Internode length (cm)	Petiole Length (cm)	Vine thickness (cm)	Vine length (cm)
			Cutting portion			
Apical	6.5^{a}	18.8^{a}	5.4^{a}	27.7^{a}	0.5^{a}	162.2^{a}
Middle	5.3^{b}	15.4^{b}	4.8^{b}	23.4^{b}	0.4^{b}	114.4^{b}
Basal	4.5^{c}	12.3^{c}	4.2^{c}	19.3^{c}	0.3^{c}	95.2^{c}
LSD	0.3	0.9	0.4	2.4	0.01	13
			Varieties			
Awassa-83	5.4^{b}	13.9^{c}	3.6^{c}	22.9^{ab}	0.5^{b}	114.04^{b}
Alamura	6^{a}	19.4^{a}	6.5^{a}	25.6^{a}	0.4^{c}	146.4^{a}
Hwassa-09	5.6^{ab}	15.5^{b}	5.6^{b}	20.9^{b}	0.4^{c}	146.4^{a}
Kabode	4.9^{c}	13.1^{c}	3.6^{c}	24.5^{a}	0.6^{a}	91.5^{c}
CV (%)	7	7.3	10.1	12.4	8.5	12.5
LSD 0.05	0.4	1.1	0.4	2.8	0.01	15

= number; CV (%) = Coefficient of variation; LSD = list significant difference; means in the same column followed by the same letter(s) are not significantly different at $P = 0.05$

The crop stand established from the apical tender terminal portion gave highest number of primary and secondary branches, longest leaf petioles, longest vines and internodes, as well as thickest vines. The better performance of apical portion of vine cutting for all the six vine growth parameters compared to basal portion might be related to the apical meristem. The shoot apical meristem is region of cells capable of division and growth in shoot tips in plants and responsible for giving rise to the primary plant body parts such as stems, leaves, and lateral shoots (including primary and secondary branches) during shoot ontogeny (Kwiatkowska, 2008). This is because the active cell division results in increase in number and size of cells which results in growth over time. The results are in line with the findings of several previous studies who reported significant increase in number of branches, lengths of vine, internode and petiole per plants established from apical vine cutting of sweetpotato (Idoko *et al.* (2017; Lencha 2016; Muktar *et al.*, 2010; Belehu,2003). In the case of basal portion, pressure from disease and pest accumulation in the basal cutting portions due to the proximity of this portion to tuberous root crown might also slow the growth of vegetative shoot traits.

Regarding varietal differences, the variety main effects for all the six growth parameters were significantly (P<0.05) varied. Both the highest number of primary branches and secondary branch (19.4) branches per plant were recorded for the variety Alamura, whereas the lowest primary branch (4.9) and secondary (13.1) branches were recorded for the Kabode variety (Table 9).Variety Alamura had also produced statistically significant (P<0.05) longest petioles (25.6cm) and internodes (3.6 cm) while the Hawasa-09 generated the shortest (22.9cm) petioles. Awassa-83 and Kabode produced statistically comparable shortest internodes as compared to other varieties (Table 7). Shortest (3.6cm) and thickest vines (0.6 cm) were recorded from Kabode but Alamura and Hawassa-09 yielded statistically comparable longest and thinnest vines (Table 7).

Among the most recently (2019/2020) released variety Alamura, which was selected as a candidate variety for the current experiment performed well for many growth parameters. Often researchers select and release new varieties when the desirable traits outsmart the existing varieties. The findings corroborate several previous studies reporting sweetpotato varietal differences in growth parameters including number of branches, lengths of vines internode and petiole per plants as well as thickness of vines (Wanjala *et al*.,2020; Lam, 2016; Laurie *et al*., 2013; Fongod *et al*., 2012; Belehu, 2003). These sweetpotato varietal differences might be related to the inherent genetic variation existing among the varieties for the growth parameters and implies potential for selection of the traits whenever needed.

4.2.3. Impact of cutting portion on storage root yield and yield components

4.2.3.1. Storage root number and yield

The storage root yield (ton ha^{-1}) and storage root number both estimated as marketable, unmarketable and total showed significant difference only for main effects of vine cutting portion and varieties, except the marketable root yield. The analysis of variance indicated that the marketable root yield (ton ha^{-1}) showed significant (P<0.001) variation for interaction effects of vine cutting portion and varieties (Figure 6; Appendix Table 4). Accordingly, the highest marketable storage root yield (49.6 ton ha^{-1}) was obtained from Hawassa-09 established from apical vine cutting. The joint lowest marketable storage root yield was obtained from varieties Awassa-83, Alamura, Kabode all established from basal cuttings, and variety Awassa-83 and Alamura established from middle of vine cuttings (Figure 6). Comparing the highest marketable root yield (Hawassa-09 from apical vine cutting) with maximum lowest marketable storage root yield (Awassa-83 from basal vine cutting), taking vines from older basal portion instead of the tender terminal regions of vines had decreased marketable storage root yield by 51.43% This yield deficiency is statistically comparable for Alamura and Kabode both established from basal cuttings, and variety Awassa-83 and Alamura established from the middle of the vine cutting portions (Figure 6).The findings clearly indicate the importance selecting seed vines considering positons of the vine cutting portions and corroborates previous reports suggesting tender apical cuttings of sweetpotato vines for better crop stand establishment and subsequent better yield (Tewe *et al*., 2003). However, the yield is also a function of varietal differences on top of the vine cutting portions as observed in previous studies confirming the findings of the present study (Afuape *et al*., 2011).

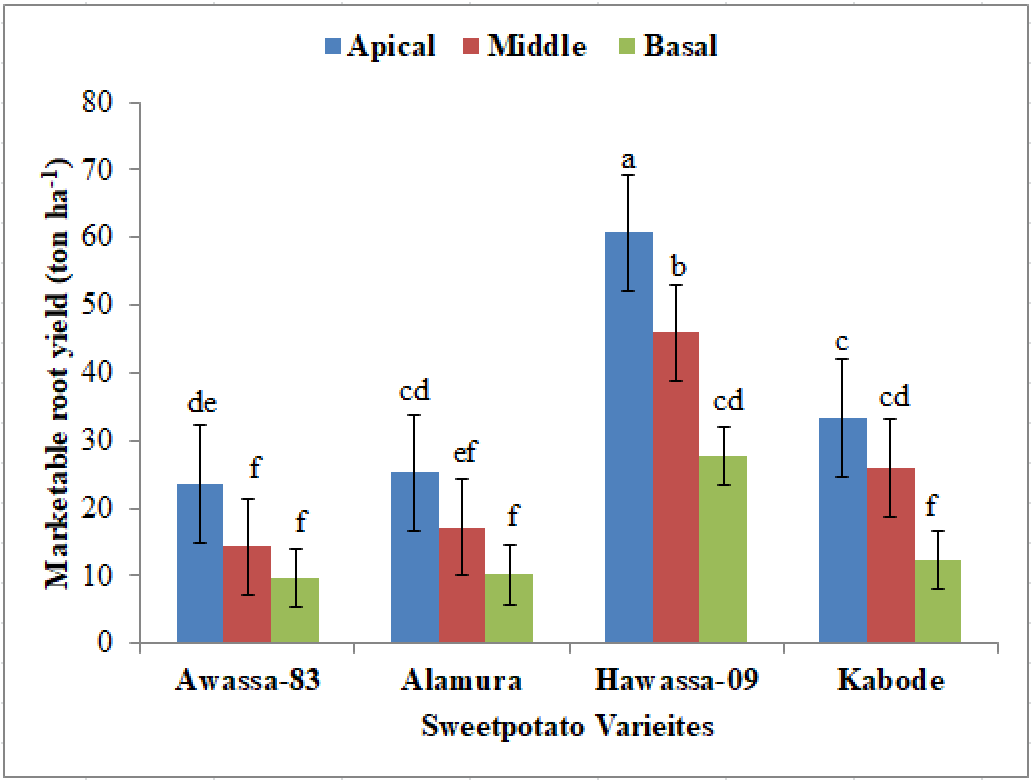


Figure 6.The interaction effect of sweetpotato vine cutting portions and varieties on marketable root yield (ton/ha)

The ANOVA showed that the main effects of vine cutting portions and varieties were found to be significant (*P*<0.001) for other yield parameters including total and unmarketable root yield (ton ha^{-1}) as well as root number (total, marketable and unmarketable) (Appendix Table 4; Table 8).

Table 8 Mean effects of sweetpotato vine cutting portion and varietal differences on storage root yield and numbers

Treatments	Root Number (#)		Root Yield (ton /ha)		
	Total	Marketable	Unmarketable	Total	Unmarketable
Vine Cutting portions					
Apical	51.6^{a}	47^{a}	4.6^{c}	38.5^{a}	2.7^{b}
Middle	42.1^{b}	35^{b}	7.1^{b}	29.1^{b}	3.3^{b}
Basal	33.2^{c}	23.3^{c}	9.9^{a}	19.8^{c}	4.8^{a}
LSD	3.5	3.8	1	4.2	0.6
Varities					
Aawssa-83	34.2^{c}	27.1^{c}	7.1^{ab}	20^{b}	4.1^{a}
Alamura	41.7^{b}	35.5^{b}	6.2^{b}	22.1^{b}	4.6^{a}
Hawassa-09	52^{a}	43.8^{a}	8.2^{a}	49.6^{a}	4.8^{a}
Kabode	41.1^{b}	34^{b}	7.1^{ab}	24.8^{b}	0.9^{b}
CV (%)	10	13	16.8	17	22.3
LSD 0.05	4.1	4.4	1.1	4.8	0.7

= number; CV (%) = Coefficient of variation; LSD = List significant difference; means in the same column followed by the same letter(s) are not significantly different at $P = 0.05$

All storage root number traits including, marketable, unmarketable and total storage root number showed significant (P<0.001) differences only for main effects of vine cutting portions and varietal differences (Appendix Table 4; Table 8). Regarding the vine cutting portions, significantly (P<0.001) the highest total storage root number (51.6) and marketable storage root number (47) were recorded for apical portions of the vine cutting; whereas the lowest total storage root number and marketable storage root numbers were obtained from the basal cutting portion (Table 8). The basal portion resulted in the highest (9.9) unmarketable storage root number, lowest marketable storage root number and lowest total storage root number. The highest number of storage roots counted for cutting portion from apical position might be related to the active cell division in the terminal region resulting in increased cell size and number, subsequently causing faster growth over time in different plant parts. The results are in line with the findings of several previous studies who reported significant increase in number of roots and other vegetative parts for crops established from apical vine cutting of sweetpotato (Idoko *et al.*,2017; Lencha 2016; Muktar *et al*., 2010; Belehu 2003; Tewe *et al*., 2003).

Concerning the varietal differences, the highest total, marketable and unmarketable storage root number were obtained from variety Hawassa-09 jointly followed by Alamura and Kabode; while the lowest (34.2) total storage root number and the lowest marketable storage root number (27.1) were recorded from variety Awassa-83 (Table 8). The reason for varietal differences in root numbers might associate to the genetic variation among sweetpotato genotypes. The evidence of varietal difference in root number of sweetpotato genotypes was supported by Vinaja (2006) and Yadeta *et al*. (2011). Similarly, Thiyagu *et al.* (2013) and Deslegn *et al.* (2015) also reported that different genotypes of sweetpotato responded differently for root number and other yield attributes. Afuape *et al.* (2011) also observed that total numbers of sweetpotato roots are important descriptor markers to differentiate sweetpotato genotypes.

The highest (38.5 ton/ha) total storage root yield and lowest unmarketable storage root yield (ton/ha) was obtained from apical cutting portion; while the lowest (19.8 ton/ha) total storage root yield and the highest unmarketable storage root yield was recorded from basal cutting portion (Table 8). The storage root yield difference might be associated to the inherent characteristics of the tender terminal portion vines which are quicker to get established and fasten growth (Kwiatkowska, 2008). In line with the present result, Tewe *et al*. (2003) reported that apical cuttings of sweetpotato had significantly higher marketable and total tuber yield than the middle portion followed by the basal cuttings. Mulkhopathyay *et al*. (1990) also found apical vine portion to be the best planting material as the produced more branches which resulted in production of higher root yield. Similarly, Lencha *et al* (2016) also stated that apical and middle portion of vine cuttings as best planting materials producing higher root yield. Furthermore, Gibson *et al*. (2009.) found that cuttings taken from young crops (2–4 months) or from the younger apical portion of a vine generated greater yields than cuttings taken from old crops or from middle or basal parts of the vine. The lowest root yield obtained from the basal cutting can be attributed to their thick and woody nature, sometimes resulting in failure to establish and their greater chance of weevil incidence due to their proximity to crown portion Idoko *et al*. (2017). Likewise, Belehu (2003) also asserted that basal stem cuttings are not preferred by farmers since they result in very low root yield.

Regarding the varietal main effects, the highest (49.6 ton/ha) total storage root yield was produced by variety Hawassa-09 as compared to other varieties. However, the joint lowest storage total root yield was obtained from all the remaining three varieties (Table 8). Similarly, the lowest (0.9 ton/ha) unmarketable storage root yield was observed by variety Kabode, while the joint highest unmarketable storage root yield recorded from the remaining three varieties (Table 8). The varietal differences in the storage root yields might be attributed to the inherent genetic variability in the varieties for the yield trait. This finding is in agreement with Tesfaye *et al.* (2011) who investigated varietal differences of sweetpotato genotypes for yield and other desirable traits. Several other studies also asserted the varietal differences for total root yield and unmarketable root yield in sweetpotato (Kathabwalika *et al*., 2013; Thiyagu *et al*. 2013; Afuape *et al.* 2011; Tesfaye *et al.* 2011; Elfinesh, 2008).

4.3.2.2. Storage root yield components

Except for storage root dry weight (g), yield component parameters such as storage root length (cm), root diameter (cm) and root dry matter content (%) had only significant main effect variations ((Appendix4).The vine cutting portions and varietal differences were significantly (P<0.001) interacted to influence the root dry mass accumulation of sweetpotato (Appendix 4;

Figure 7). The significantly joint highest storage root dry mass was accumulated on Awassa-83, Hawassa-09 and Kabode established from apical vine portion. Likewise, variety Hawassa-09 and Kabode established from middle vine cutting portion also stored statistically comparable storage root dry mass. The basal cuttings of Hawassa-09 resulted in better storage root dry mass accumulation than the middle cuttings of Awassa-83 and Alamura. Our findings indicate that the root dry matter weight accumulation is a function varietal differences and vine cutting portion used for planting. Our work is in agreement with Fongod *et al*. (2012) who reported significant variation among sweetpotato accessions established from vines of apical and basal portions for dry weight.

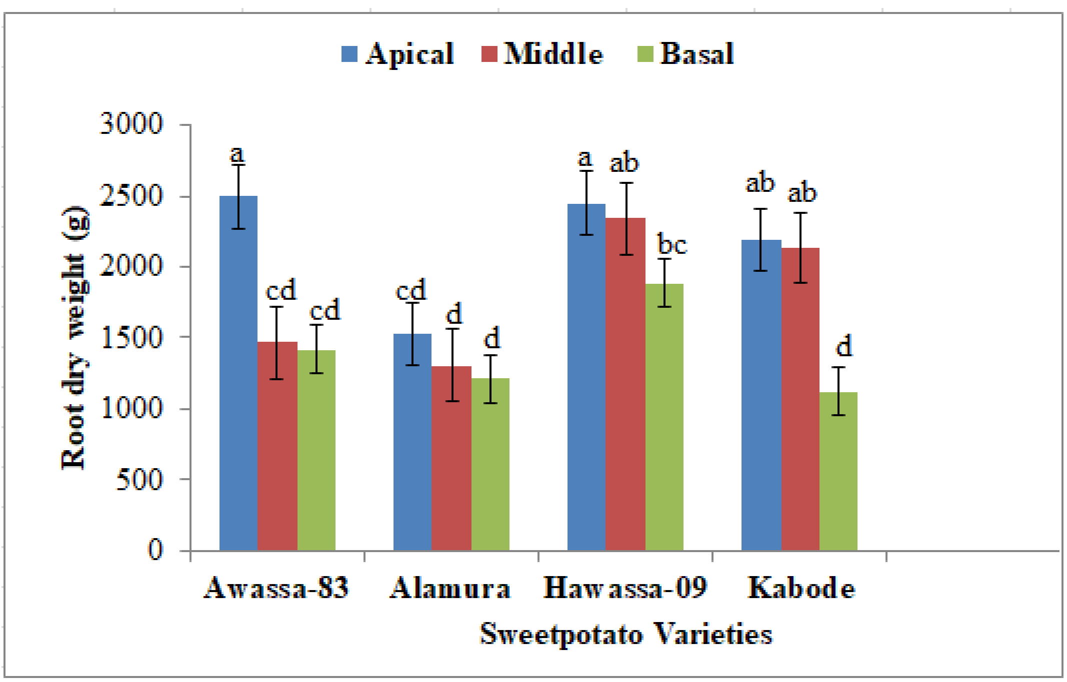


Figure 7 The interaction effect of sweetpotato vine cutting portions and varieties on root dry weight (g)

Table 9 Main effects of sweetpotato vine cutting portion and varietal differences on storage yield components

Treatments	**Storage root length (cm)**	**Storage root diameter (cm)**	**Root dry matter Contant (%)**
		Cutting portions	
Apical	24.1[a]	8.6[a]	11.7
Middle	18.8[b]	6.3[b]	12.9
Basal	15.5[c]	5.3[b]	14.7
LSD(**0.05**)	1.5	1.2	3.1
		Varieties	
Awassa-83	17.8[c]	6.6[b]	17.3[a]
Alamura	19.1[bc]	6.2[b]	11.9[b]
Hawassa-09	19.7[ab]	8.2[a]	8.6[c]
Kabode	21.4[a]	6.0[b]	14[b]
CV (%)	9.6	20.9	26.3
LSD (0.05)	1.8	1.3	3.3

CV (%) = Coefficient of variation; LSD = list significant difference; means in the same column followed by the same letter(s) are not significantly different at $P = 0.05$

The three yield component variables including storage root length (cm), storage root diameter (cm) and root dry matter content (%) showed only main effect variations and not interactions of cutting portion and varieties. Root dry matter content was only significant ($P< 0.05$) for varietal differences, whereas the storage root length and diameter were significant at ($P< 0.05$) both for cutting portion and varieties. Regarding the vine cutting portions, the longest (24.1 cm) and the shortest (15.5 cm) storage root length was recorded for apical vine cutting portions and basal cutting portions respectively. Similarly, the widest (8.6 cm) and narrowest (5.3 cm) storage root diameter was recorded from apical and basal cutting portion respectively (Table 9). This could be due to fast crop establishment from the apical vine cuttings, unlike the older and fibrous basal cuttings. This result is similar to Netsai *et al*. (2019) who reported that apical stem cutting had generated the longest storage roots as compared to middle and basal cuttings. Root diameter and length tend to increase due to the fact that vine cuttings from apical shoots grow more vigorously and produce large storage roots compared with cuttings from middle and basal portions (Tewe *et al* ., 2003). This result in lines with Essifie *et al*. (2016) who reported earlier establishment and increase in circumference of roots produced from apical portion over the middle and basal portion. Basal cutting also developed fewer and shorter roots as compared to apical and middle cuttings. This might contribute to the reduction in storage root diameter due to limited water and nutrient uptake. Belehu (2003) also stipulated that basal cutting has a poor root establishment.

Regarding the varietal differences, variety Kabode produce significant (P<0.05) longest (21.4cm) storage root over Alamura, Hawssa-09 and Awassa-83 varieties. The shortest storage root (17.8 cm) length was recorded from variety Awassa-83. On the other hand storage diameter was widest for variety Hawassa-09. The remaining three varieties showed statistically similar storage root diameter (Table 9). The reason might be due to genetic difference between varieties in response of root emergence and growth. The corroborates the findings of Naskar (1987) who reported significant difference among sweetpotato varieties for yield attributes such as number of root per plot, root length and mean root diameter. In addition, Deslegn *et al*. (2015) also reported variations among sweetpotato genotypes for yield and other desirable trait. In case of dry matter contant, Awassa-83 produced highest root dry matter content (17.3 %) followed by variety Kabode, while the lowest root dry matter content (8.6 %) recorded by variety Hawassa-09 (Table

9). This result is in agreement with the findings of Woolfe (1992) who concluded that dry matter content depends on varietal response. Tsegaye *et al.* (2007) also reported significant difference in dry matter content for sweetpotato genotypes. Many other studies also support varietal difference for sweetpotato root dry mater content (Fongod *et al.,* 2012; Ali *et al*., 2015).

4.3. Root yield correlations to phonological, crop growth parameters and Yield and Yield Components

Correlation coefficient (r) was computed for the 20 response variables considered for the evaluation sweetpotato varietal differences to the different seed vines cutting portions. The correlation results identified the association of individual phonological and crop growth parameters to yield and yield related traits. Except few parameters relations, many parameter measurements in this study were either positively or negatively and significantly correlated with each other (Figure 8).

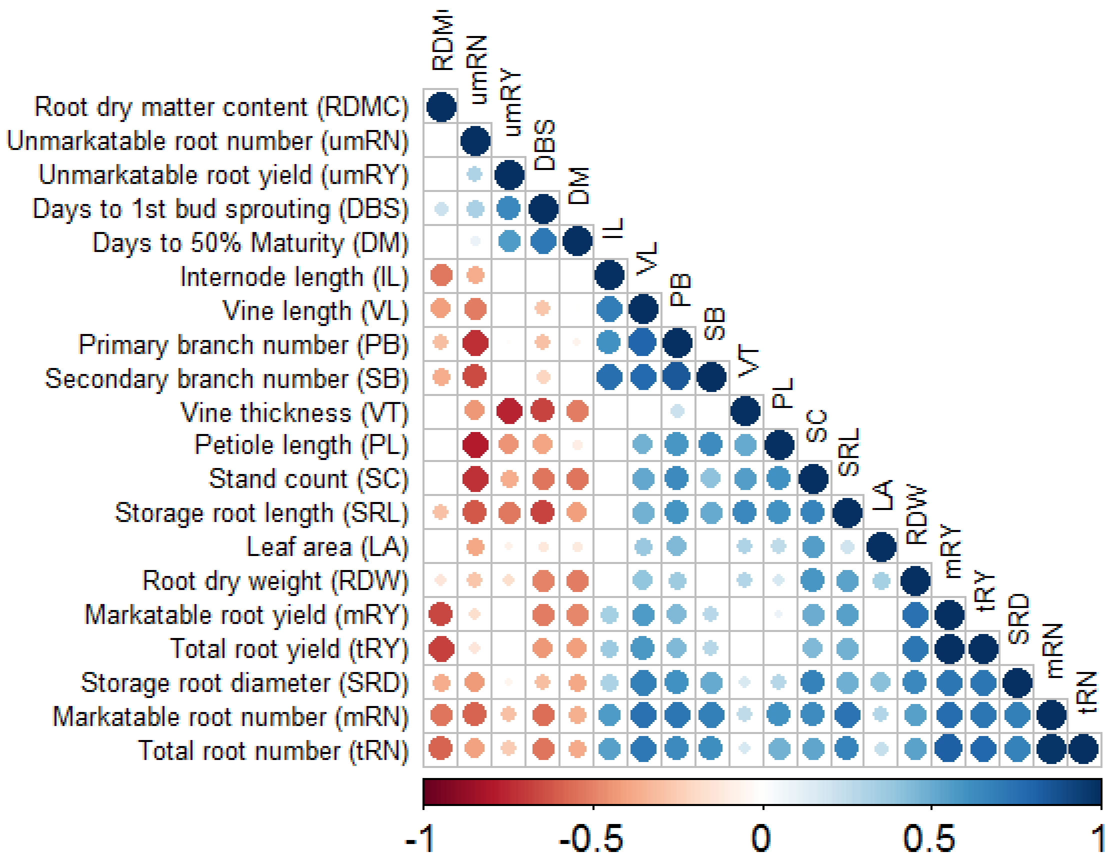


Figure 8 Correlogram of Pearson's correlations coefficients for the 20 response parameters considered for the evaluation sweetpotato varieties and different vine cutting portions

Blue color and red indicate positive and negative significant respectively and white colors indicate non-significant correlations and the dot sizes and color intensity refer to the strength of the correlation.

Important root yield parameters such as total root yield (tRY) and marketable root yield (mRY) as well as total root number (tRN) and marketable root number (mRY) were positively and significantly correlated with crop stand count (SC) and most growth parameters including internode length (IL), vine length (VL), branch numbers but the magnitude correlation is smaller for petiole length (PL) and vine thickness (VT). On the other hand, significant and negative correlations to the yield and yield components were observed from phonological traits such as days to maturity (DM) and days to first bud sprouting (DBS) implying that early bud sprouting and crop maturity have not favored for higher root yields. Expectedly, the higher the unmarketable root yield (umRY) and unmarketable root number (umRN), the lower the total and marketable yield as indicated in negative and significant correlations.

Over all the highest positive and significant correlation (r = 0.99) was observed between total root yield (tRY) and marketable root yield (mRY) followed by (r = 0.98) between total root number (tRN) and marketable root number (mRY). On the other hand, the most contrasting and significant correlation (r = - 0.78) was observed between, unmarketable root number (umRY) and petiole length (PL) followed by (r = - 0.77) unmarketable root yield (umRY) and vine thickness (VT). Comparable results of correlations, particularly between root yield parameters such root number and root mass each estimated as total, marketable and unmarketable were reported from previous studies (Gedamu *et al*., 2010; Tesfaye, 2006).

5. SUMMARY AND CONCLUSIONS

The overall objective of the present study was to assess sweetpotato seed systems and evaluate varietal productivity differences as affected by seed vine catting portions combining survey and designed field experiments. The sweetpotato production in Sidama mainly occurs in smallholder settings in ≈ 0.15 ha farm size areas under variable socio-demographic and socio-economic contexts.

Over the course of the survey, seed system networks were mapped, key actors in seed network were identified, the vine types and varieties used for production of sweetpotato in the Sidama areas were determined.

- Farmer's access seed-vines from multiple sources including own-saving, purchasing, institutional donations, exchanges with relatives and fellow farmer friends across the community, but they heavily rely on their own stocks and on immediate circle of relatives and friends.
- From the four sweetpotato varieties (Awassa-83, Hawassa-09, Kulfo, and Local) that were under cultivation and recorded in the four surveyed *Kebeles*, the Local variety (50% of the households) dominated the production systems.
- It was concluded that sweetpotato production is constrained severely by limited access to good quality and quantity of seed-vines and diseases. If seed-vines available to choose, farmers consider various characteristics of sweetpotato planting materials for selection as seed-vine *viz* plant parts (roots and vines), mother plant age and cutting portions (apical, middle and basal), and opt for vines from middle cutting portion from medium aged mother plant.

Sweetpotato seed systems assessment survey provided the above useful insights in delineation of currently operating seed-vine system in the study area. We recommend multi-stakeholder discussion in order to co-design resilient system that can supply required quantity of quality seed vines in studied areas. Community seed bank associations, supported by research and development institutes such as research centers and universities could be key entry points for development of functional seed systems for sweetpotato and other clonal crops. Farmers playing central roles in seed exchange networks occupying linking position for distribution of vines should be capacitated and engaged in farmer's field research units and farmer's field demonstrations schools. Such interventions have to consider the socio-demographic and socio-economic variability of sweetpotato production contexts in Sidama region.

The field experiment was conducted after soliciting information on vine cutting portions used by farmers in Sidama area in the survey part. The vine-cutting portions (apical, middle and basal) used by the farmers were investigated for their effect on 20 quantitative response variables including phonological, growth as well as yield and yield components of sweetpotato roots on four selected varieties (Awassa-83, Hawassa-09, Kabode and Alamura).

From the 20 examined sweetpotato plant parameters, about 3 leaf area (cm^2), marketable storage root yield (ton/ha) and storage root dry weight (g) were significantly affected by vine cutting portions and varietal interaction effects. The remaining 17 parameters including Days to 1st bud sprouting (DBS), stand count (SC), Days to 50% maturity (DM), primary branch number (PB), secondary branch number (SB), internode length (IL), petiole length (PL), vine thickness (VT), vine length (VL), storage root length (SRL), storage root diameter (SRD), marketable root number (mRN), unmarketable root number (umRN), total root number (tRN), unmarketable root yield (umRY), total root yield (tRY) and root dry matter content (RDMC) showed significant difference either for cutting portion, varietal difference or both main effects.

Crops established from apical cutting portion performed very well for 16 parameters that showed significant main effect differences. The apical vine portion with yield of 38.5 ton/ha roots produced almost twice as high as basal cutting portion (19.8 tone/ha). Comparing the highest total marketable root yield (Hawassa-09 from apical vine cutting) and lowest marketable root yield, (Awassa-83 from basal vine cutting), taking vines from older basal portion instead of the tender terminal regions of vines had decreased total marketable root yield by 51.43 %.

Overall, in scenarios of ample seed-vines, for all the four varieties, apical portion of vine cutting provide superior yields, but for other varieties such as Hawassa-09 and Kabode middle cutting portions are also equally productive. Variety Hawasa-09 out-performed the other three varieties for yield and yield component traits including total root yield (49.6 ton/ha), total root number and marketable root number. However, other varieties such as Alamura were significantly late maturing.

Eventually, the results should be taken with caution as the study is limited only to four varieties from 29 released varieties that are deemed available for sweetpotato farming communities of Ethiopia. Given the fact that, seed-vines are not luxurious resources, we recommend evaluation of more number varieties accompanied by genotype X environment interaction multi-locations experiments for evaluation of vine cutting portion for use as planting materials. In addition comparative evaluation of economic costs of accessing different vine cutting portions as well as improved varieties over local varieties should be investigated.

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7. APPENDIX

Appendix 1: Questionnaires

Questionnaire for studying assessment of sweetpotato seed systems Sidama, Ethiopia

I General information

Interviewer name: ____________________ Date of interview __________________number _______Woreda________________________Kebele____________

PART I. Socio-demographic and socio-economic characteristics

Name of household head____________________________

1. Sex of Household head 1= Male 2 = Female

2. Age of HHH, in year's _______________

3. Educational level head of HH 1=None (illiterate) 2=read and write 3=Primary (1-4 4=Junior (5-8) 5=Secondary (9-10) 6=Tertiary (11-12)

4. Marital Status of the HH 1.Single 2.Married 3.Divorced 4.Widowed 5.Others

5. HH size ____________________

PART II Sweetpotato farming

6. How many total landholdings do you own?_________

7. What is the size of your Sweet potato farming land? ___________________

8. How many years of experience do you have in Agriculture? _______________________

9. How long have you been cultivating sweetpotato farming____________________?

10. A.Total quantity of sweetpotato seed actually planted this last season quantity of sweet potato seed actually planted this last season? _______________

B.How much seed do you plant this season? _______________________

11. Is the sweet potato coverage increasing or decreasing? 1 Increasing 2 Decreasing

3 NOT Changed

12. What is the reason for sweetpotato production trends increasing or decreasing?

1 =Lack of land 2. = Disease 3 =lack of planting material.

PART III Sweetpotato panting materials

13. What type of sweet potato seed do you used as planting material?

1 Roots 2 Vines

A.If vine which portion of cutting do you use? (if you use two or more encircle so

1 Apical 2 Middle 3 Basal

B. Which of the above portion is best and why is best?

____

____

14. Which age do you use for planting purpose?

1. Youngest 2 medium 3 oldest.

PART IV Sweet potato varieties and Source

15. Which sweet potato varieties have you used?

1 Awassa -83 2 Hawass-09 3Kulfo 4 Local

16. Which of the above variety is preferred by farmers?

1 Awassa -83 2 Hawass-093 Kulfo 4 Local

17. Where did you get sweet potato seed for planting in the last season (2018-2019)?

1= Local market 2 =Research center 3=Farmers 4=NGO 5=From*Woreda* Agriculture office 6=Own farm 7=Relatives

Appendix Table 1 ANOVA for impact of vine cutting portions on crop phenology and establishment

		Mean Square		
Source variation	DF	DFBS	CEC	D50 % M
CP	2	627.028***	751.083***	182.194**
Var	3	207.63***	38.889*	319.741***
CP*Var	6	26.657NS	15.306NS	3.824NS
Error	24	24.778	10.472	21.667

Where DFBS= days to first bud sprouting, CEC=Crop established stand-count and D50 % M=days to 50% maturity *, ** and *** denotes significant at 5, 1 and 0.1% probability level respectively, NS=non-significant

Appendix Table 2 ANOVA for impact of vine cutting portions and varieties on growth parameters

		Mean Square					
Source variation	DF	NPB	NSB	VT	IL	PL	VL
CP	2	11.9353***	125.564***	0.07923***	4.2673***	210.068***	14277.9**
Var	3	1.9447***	69.8***	0.06237***	19.1106***	38.302*	6128.2***
CP*Var	6	0.1508NS	2.271NS	0.00311NS	0.0125NS	3.874NS	502.2NS
Error	24	0.2242	3.702	0.00223	0.2336	10.684	240.3

Where NPB=primary branches number, NSB=secondary branches number, VT=vine thickness, IL= internode length, PL=petiole length and VL= vine length *, ** and *** denotes significant at 5, 1 and 0.1% probability level respectively, NS=non-significant.

Appendix Table 3. ANOVA for main interaction effect of cutting portions and varieties

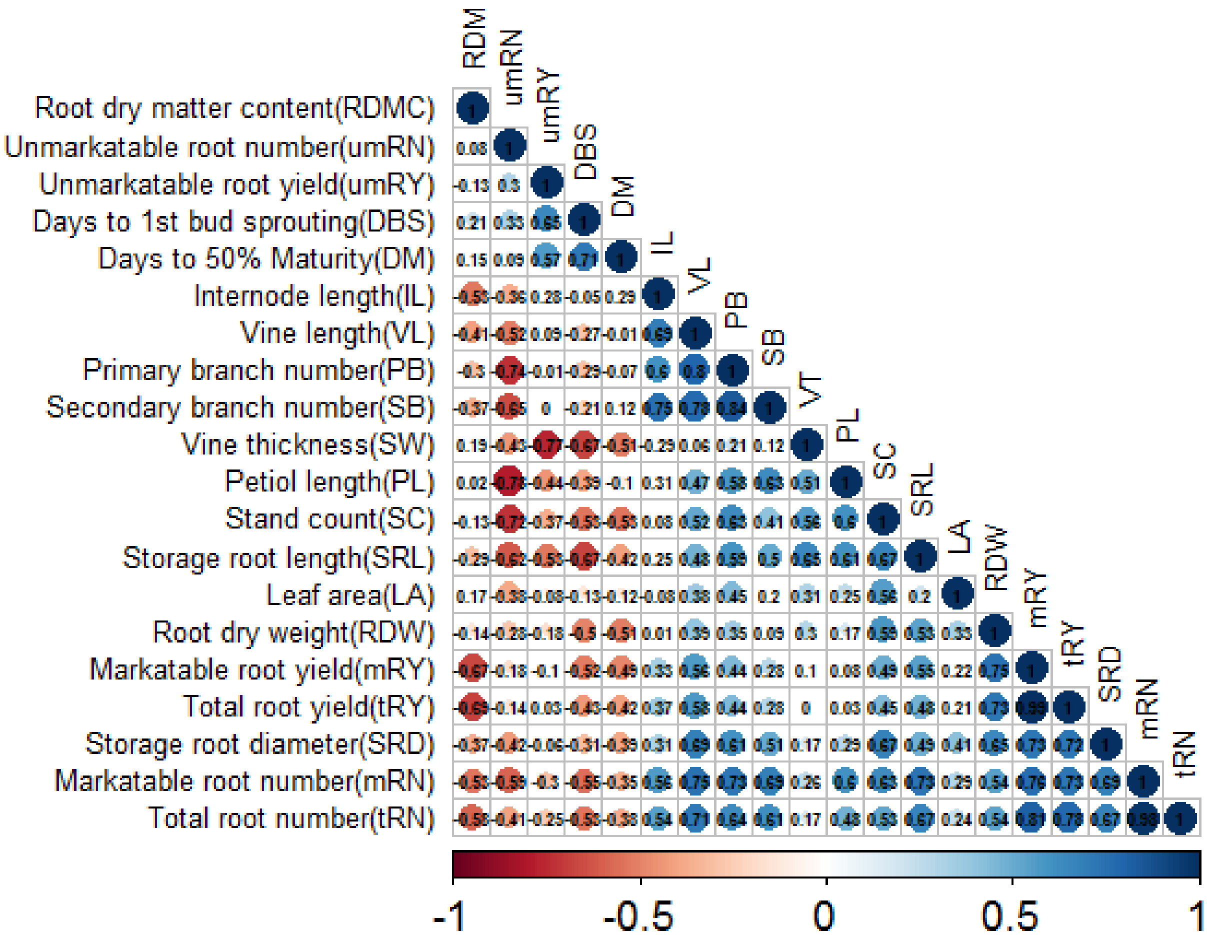
Source variation	DF	Mean Square LA	MRY	RDW
CP	2	34560000***	1290.95**	1714029***
Var	3	46110000***	1594.91**	1152797***
CP*Var	6	6193374***	62.8*	274894*
Error	24	663133	29.38	85798

Where LA= leaf area, MRY=marketable root yield and RDW=root dry weight *, ** and *** denotes significant at 5, 1 and 0.1% probability level respectively, NS=non-significant

Appendix Table 4 Impact of cutting portion and varieties on storage root yield and yield components

		Mean Square							
SV	DF	SRL	SRD	MRN	UMRN	TRN	UMRY	TRY	RDMC
CP	2	222.06**	34.29***	1680.44***	82.86**	1018.69**	13.7***	1045.31**	19.92NS
Var	3	21.03**	9.13*	421.63***	6.07*	483.07***	29.9**	1717.99**	119.22***
CP*Var	6	4.99NS	0.68NS	14.52NS	3.15NS	22.1NS	1.19NS	59.29NS	3.40NS
Error	24	4.33	1.89	20.78	2.14	20.92	0.71	31.94	11.06

Where SRL=storage root length, SDR= storage root diameter, MRN=marketable root number, UMRN =unmarketable root number, TRN= total root number, UMRY =unmarketable root yield, TRN=total root yield and RDMC=root dry matter contant. *, ** and *** denotes significant at 5%, 1% and 0.1% probability level respectively, NS=non-significant



Appendix Figure 1 Numeric values of Correlogram for root yield and yield component correlations to phonological, and crop growth parameters

BIOGRAPHY

The author was born on September 19, 1994 in Gnba hangbre, Siltie Zone, Southern Ethiopia. She attended her elementary and primary schools at Sabola Primary School and followed her secondary school at Hulebrge Preparatory School at Worabe. After successfully passing National University Entrance Examination (NUEE) she joined Diila University College of Agriculture and Natural Resource in 2013 and graduated in July 30, 2016.with the Bachelor of Science (BSC) in Horticulture with award for top performance among female students in the College. She had worked at Diila University as Graduate assistant for one year and joined Hawassa University to pursue MSc study in Plant Sciences (Specialization Horticulture) in 2018.