EVALUATION OF ANCHOTE (*Coccinia abyssinica* (Lam.) Cong) ACCESSIONS FOR THEIR GROWTH AND YIELD PERFORMANCES UNDER DIFFERENT ALTITUDES IN SIDAMA REGION

MSc. THESIS

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OCTOBER, 2023

EVALUATION OF ANCHOTE (*Coccinia abyssinica* (Lam.) Cong) ACCESSIONS FOR THEIR GROWTH AND YIELD PERFORMANCES UNDER THREE DIFFERENT ALTITUDES IN SIDAMA REGION

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A THESIS SUBMITTED TO THE SCHOOL OF PLANT AND HORTICULTURAL SCIENCE, COLLEGE OF AGRICULTURE, SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN PLANT AND HORTICULTURAL SCIENCES (SPECIALIZATION: HORTICULTURE)

OCTOBER, 2023

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

ADVISORS'APPROVAL SHEET

(Submission Sheet – 1)

This is to certify that the thesis entitled **Evaluation of anchote (*Coccinia abyssinica,* (lam.) cong) accessions for their growth and yield performances under three different altitudes in Sidama region** submitted in partial fulfillment of the requirements for the degree of **Masters of Sciences** with specialization in Horticulture Graduate Program of the School of **Plant and Horticultural Sciences**, College of Agriculture, and has been carried out by **Nejat Ali**, under my supervision and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the course of this investigation has been well acknowledged. Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Dereje Haile (PhD) ____________________ __________________

Name of major advisor Signature Date

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EXAMINERS‟ APPROVAL SHEET-1

(Submission Sheet-2)

We, the undersigned, members of the Board of Examiners of the final open defense by Nejat Ali have read and evaluated her thesis entitled Evaluation of anchote (*Coccinia abyssinica*, (lam.) cong) accessions for their growth and yield performances under three different altitudes in Sidama region and examined the candidate. This is, therefore to certify that thesis has been accepted in partial fulfillment of the requirements for the Master's degree in Horticulture.

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Name of Major Advisor	Signature	Date
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Final approval and acceptance of the thesis is contingent up on the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School of Graduate Committee (DGC/SGC) of the candidate's School.

DECLARATION

I seriously declare that this MSc thesis is an original report of my work and that has not been submitted to any other institutions anywhere for the award of any academic degree, diploma or certificate. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others. This thesis is submitted in partial fulfillment of the requirements for MSc. degree at Hawassa University and deposited in Hawassa University library and is made available to users under the rules of the library.

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Place: College of Agriculture, Hawassa University, Hawassa

Date of Submission: _________________________________

ACKNOWLEDGEMENTS

Above all, I would like to say alhamdulillah for everything Happens in my life. My deepest gratitude extends to my major Advisor, Dr. Dereje Haile for his continuous guidance and support during the experimental period. I sincerely appreciate him for his; permanent availability, providing required materials during data collection, scientific guidance, comment and motivated me willing to work with my schedule.

I am very grateful to Dr. Meseret Tesema, for evaluating my final research proposal and for her valuable comment. I would like to acknowledge Mr. Zerihun Teshome for his invaluable guidance for my site selection and for his help in planting time. I am very grateful to field workers in all three sites from planting to harvesting. My thank also for my friend Markos Samuel for his suggestion and help from day one.

I also wish to express my thanks to all members of Hawassa University College of Agriculture, soil laboratory especially Mr. Bishri Muhammed who helped me during soil analysis and scientific guidance. Most importantly, I wish to thank my mother, Jemila Hussein, my three sisters and my beloved husband for their Golden advice, spiritual support, and endless motivation from my childhood to now which helped me to keep on going on numerous occasions. I am grateful to Ethiopian ministry of education and Hawassa University for giving me the opportunity to attend Master ‘s program. I also want to thank sweet potato-anchote thematic research project at Hawassa University for the financial support. Finally, I want to send my warm gratitude to all individuals out there always wishing to see accomplishment in my academic aspect.

LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
CEC	Cation exchange capacity
LSD	Least significance difference
pH	Potential hydrogen
RCBD	Randomized complete block design
SAS	Statistical analysis software
masl	Meter above sea level
HU	Hawassa university

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES IN APPENDIX

LIST OF FIGURES IN APPENDIX

Evaluation of anchote (*coccinia abyssinica* (lam.) cong) accessions for their growth and yield performances under three different altitudes in Sidama region

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ABSTRACT

Among the most important root and tuber crops, anchote is one of the potential crops produced in the western and south-western parts of Ethiopia. It serves as a food, cultural, social, and economic crop for the producers. Due to limited research coverage and less attention to determining the growth and yield performance of anchote accessions, the production of anchote has not spread to other parts of Ethiopia. Therefore, the study was conducted to evaluate the growth and yield responses of anchote accession grown at different altitudes in the Sidama region of Ethiopia from June to November 2021. Nine anchote accessions (Gimbi, Jimate, Degaga Didhessa, Jimma Arjo, Ale, Sheka, Sibu Sire1, Sibu Sire2, and Sibu Sire3) were sow in three locations representing different altitudes (1305 masl, 1835 masl, and 2504 masl). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Growth and yield data were collected following standard procedures. The results revealed that phenological parameters and growth performances (leaf area, leaf number, vine length, above-ground fresh and dry biomass) were significantly influenced by the main factors of accession, location, and their interactions. Days to 50% of flowering were affected by the main factors (accession and location), and vine number was affected only by location. The highest (92%) and lowest (58.7%) emergence percentages were obtained from Sheka accession at mid-altitude and Sibu Sire1 at Bilate, respectively. The largest (597.3 g) and the minimum (6.2 g) above-ground fresh biomass per plant were produced by accession Sibu Sire1 under Leku and accession Gimbi under Hula, respectively. The maximum (62.1 g) and minimum (33.6 g) above-ground dry biomass were produced by accession Ale under Leku and accession Jimate under Bilate. In the case of yield, yield-related parameters (root weight and diameter, total biomass weight, root yield, and underground dry root weight) of anchote accessions were significantly affected by accessions, location, and their interaction. Root number per plant was affected by accessions and location. Root diameter was affected only by accession. The highest storage root weight (522.3g) and total biomass (847 g) per plant were obtained from Degaga Didhessa anchote accession under Hula location. Whereas, the lowest storage root weight (94.6 gm) and total biomass (153 gm) were also recorded from Sibu Sire3 under Hula conditions. The highest yield (59.6 t/h)) was obtained from the anchote accession of Degaga Didhessa at the Leku location. The significantly lowest yield (12.3 t/h)) was recorded from Gimbi Anchote accessions under Bilate. Anchote accessions evaluated in this study showed a differential response to different locations that represented different altitudes. We recommended accessions of Degaga Didhessa, Sheka, and Sibu Sire1 that produced better storage root yield, high underground dry biomass content, root weight, and dry matter content across three locations that indicated good performance and adaptation. Those accessions that we recommend are suggested to be produced by farmers in the areas of Bilate, Leku, and Hula and related conditions in the Sidama region.

Keywords, *Accession, Altitudes, Anchote, Location Morphology*

1. INTRODUCTION

The root and tuber crop sub-sector play an important role in the overall employment and income generation of the poor farm communities, in the Western and Southwestern regions of Ethiopia (Desta, 2011). The food potential of root and tuber crops have not yet been fully exploited and utilized despite their significant contributions towards food security, income generation, provision of food energy and resource base conservation (Gebremedhin *et al.*, 2008). There are many root and tuber crops that supported millions of populations as a food and feeds, sources of income in Ethiopia. Among the list Potato, Sweet potato, anchote, Taro, Yam and many others are included (Desta, 2011).

Anchote (*Coccinia abysinica* (Lam.)) Cogn), is an annual trailing vine belonging to the Cucurbitaceae family, best known and grown principally for its tuberous root even though its tender leaves are also widely used as food (Abera, 1995). The genus Coccinia consists up of 30 species of which about 10 species occur in Ethiopia; however, only one species (Coccinia abyssinica) is cultivated for human consumption (Endashaw, 2007). The name 'anchote' is derived from Afan Oromo, a native language spoken by the Oromo nationalities in Ethiopia, and refers to the edible tuber of the cultivated races of *Coccinia abyssinica*. It is also known by different vernacular names at different places and tribe such as 'ushushe' in Walaita, 'shushe' in Dawero and 'ajo' in Kaffa (Amsalu *et al.*, 2008). However, its cultivation as a root crop is common in Wollega, Iluababor, Jimma, Kaffa, and Sidama (Amare, 1973), it is not well known in other parts of Ethiopia and the world.

Anchote is endemic root crop of Ethiopia and the unique characteristics of the plant is the edibility of its different parts such as its tuber, leaf, and fruit which makes the plant ideal as potential food security crop even though the root is the most economic concern in most growing areas of Ethiopia. (Amare 1973; Endashaw 2007; Desta 2011). Roots of anchote are a good source of vitamins, minerals protein, potassium, iron and calcium compared to other root crops (Girma and Dereje, 2015, Beruk et al., 2015, Desta, 2011). Therefore, it can be used as a strategic crop to alleviate protein deficiency in areas of nutrition with low protein source (Amsalu *et al.*, 2008). In addition to its nutritional importance, anchote is a cultural and medicinal crop widely used in growing areas (Amare, 2003). According to Abera (1995), juice of anchote root is used to treat cancer, tuberculosis, skin eruptions and gonorrhea by traditional medicine practitioners of Ethiopia. Tubers of anchote are boiled and prepared with local butter. Finely prepared local anchote dish can be served during special ceremonies like wedding, betrothals, circumcision, birthdays, the finding of the True Cross (*Meskel*) and New Year holidays. Tubers of wild anchote are not edible although widely used for animal fattening in West Wollega areas (Desta, 2011). The fruits are edible; fruits of the cultivated anchote are not normally eaten by most growers even though missioners in Wollega consume the unmatured tender fruits (Amare, 2003).

Anchote grows in areas with altitudes ranging from 1300 to 2800 masl with sporadic distribution (Amare 1973). It prefers soil pH of 4.5 to 7.5, mean minimum and maximum temperature of 12°C and 28°C and rain fall ranging from 800 mm to 2000 mm/year (references). The storage root yield of anchote on research field range 42 -76 ton per hectare, as compared to other root and tuber crops yield its high (Mengesha D, et al.,2012). Based on climate, altitude and soils, Westpal (1974) classified the country into many agro ecological regions between which two regions have special connections with anchote. The south eastern part of the Ethiopian highlands: these areas are situated at altitude of 1800 masl. and have Afisols as a major soil type. They receive 950-1500 mm average annual rainfall. The south western part of the Ethiopian highlands including Wollega, Illubabor and Jimma has oxisols, ultisols and vertisols as major soil types. The southwestern part of the Ethiopian/Oromia highlands is situated at 1500-2400 masl. and receives an annual rainfall about 1500mm to over 2000 mm per year.

Ethiopia is divided into 18 major and 58 sub agro-ecological zones which are endowed with suitable climatic and edaphic conditions for quality and quantity production of various kinds of root and tuber crops, including anchote (EIAR, 2008).

Anchote production in Ethiopia have different constraints. Absence of well evaluated accessions for agronomic performance, absence of information on suitable planting time for each altitude, lack of planting materials, absences of released varieties having wider adaptation and with high yield and other merits, lack of awareness of the crop on production practices, nutritional benefits and utilization in non-growing areas of the country etc. could be mentioned as a bottle neck for the under- development of anchote in Ethiopia (Desta, 2011). In addition, anchote production and productivity is affected by Agroecological conditions and other factors like pests (Hora et al., 1995). Moreover, productivity and production of anchote tubers and seed could be linked low soil fertilities and attacks by wild animals like monkeys, porcupines**,** rodents, wild pigs and others (References). Anchote demands high soil fertility which is rich in organic matter, nitrogen and phosphorus for vigorous growth of the vegetative and tubers parts (Tufa *et al.,* 2017). *Coccinia abyssinica* is not seriously attacked by disease and pests, but fruit decay result prematurely due to certain kind of wasp and fruit fly (Yambo & Feyissa 2013). It has been noticed that anchote is also affected by fungal diseases like powdery mildew and rust diseases (Personal communication). Rust diseases are one of the devastating diseases of anchote which attached leaf and resulting in shriveled roots (unpublished data).

Anchote widely grown in Wollega, Illubabor, Jimma, Southern Nations and Nationalities under traditional managed cropping systems. It is commonly planted in home gardens by small scale farmers and produce roots and/or tuber in underground part. The important nature of this crops is drought resistant, can stay in the soil until it is required for consumption or sale, has high carbohydrate and other nutritional contents which are important food stuffs, produced under traditional management system with farmers knowledge and practices, and relatively less susceptible to insect and disease pests (Yambo & Feyissa 2013). It occurs in many parts of Ethiopia including the western, southern and northern parts with sporadic distribution (Abera and Gudeta, 2007).

Its production and consumption are not as such known in many parts of the county due to limited research coverage and lower attention on anchote evaluation for agronomic and food quality attributes (Amare, 1973). Because practices of cultivation and utilization of anchote has been passing from generation to generation through oral tradition with very little recorded information (Gemeda, 2000). According to Abera (1995), anchote has little chance of exposure to research and development in the past due to lack of literature on it. Though it is reported that anchote had been grown in southern part of Ethiopia, it is not known by many farmers and users as important source of food and feed and production are limited to only western parts of the country. Previously two studies have been conducted at Hawassa University research site to evaluate the performance of anchote accession (Girma and Dereje, 2015, Dereje Unpublished). The authors reported that anchote has good yield performances and provides good nutrients comparable to yield and nutrients of another root crops. The previous study has evaluated it at the university campus and has recommended it for further evaluation and promotion. There was no previous study that has introduced anchote accessions into different agro ecologies in the Sidama region and we thought introducing the accessions of this new crop for adaptation trial and further evaluation of their performances could enhance farmers' food security and income sources in the future. Accordingly, different anchote accessions previously collected from the producing areas of the country was evaluated for their variability in quantitative and qualitative traits of agronomic performance under different location.

2. OBJECTIVE OF THE STUDY

General objective

- To evaluate performance of anchote (*Coccinia abyssinica* (Lam.)) Cogn) accessions at three different altitudes in Sidama region.

Specific objectives

- To compare growth and yield performance of nine anchote accessions across different altitudes.
- To identify better performing accessions under each location/altitude.

3. LITERATURE REVIEW

3.1. Taxonomy

Anchote belongs to the Cucurbitaceae family. The Cucurbitaceae are mostly prostrate or climbing herbaceous annuals comprising about 90 genera and 700 species that are further commonly characterized by having five angled stems and coiled tendrils (Austin & Brendan, 2008). The leaves are alternate and usually palmately five lobed or divided; stipules are absent (Phan, 1999). According to Abera (1995) under the genus Coccinia there are 30 species of which ten are reported to be occurring in Ethiopia. The species recorded in Flora of Ethiopia since 1995 include: *Coccinia abyssinica* (Lam.) Cogn., *C. adoensis* (Hochst. Ex. A. Rich.) Cogn.), *C. grandis* (L.) Voigh (Syn. *C. indica* Wight and Arn.), *C. megarrhiza*, C. Jeffrey and *C. schliebenni* Harms. The remaining three species have not so far been described and named.

3.2. Center origin and domestication

Anchote is indigenous root crop of Ethiopia and domesticated in Western, Southwestern and Southern parts of the country (Abera, 1995). It is widely domesticated in these areas as nutritional, medicinal and cultural crop. Practices of cultivation and utilization of anchote has been passing from generation to generation through oral tradition with very little recorded information. Women farmers have great role in domestication and culture of anchote.

3.3. Importance of anchote

Root and tuber crops such as potato, sweet potato, enset, anchote, Oromo dinich, taro and yam is widely cultivated in South and Southwestern parts of Ethiopia. They are adapted to various marginal growing conditions; and if properly managed and utilized, can play a key role in supporting rural livelihoods and in addressing food shortage in many parts of the country (Asfaw, 1997). Most of these tuber and root crops are drought tolerant and are appreciated by farmers as food during famine. They can also provide income opportunities for local communities involved in agricultural practices of the crops and diversify farmers' incomes as well. Despite their importance however such crops happen to be neglected. Since the species have very restricted habitats and agro-ecological zones which are attached to the culture and tradition of the ethnic groups in West and Southern parts of Ethiopia, their mismanagement can cause significant damages that may lead to their extinction (Yeshitila, 2007). According to Weyessa (2009) anchote is produced on hectares 440.75 and 440 in East and West Wollega zones in 1998/99 cropping season with 20 and 10 tons of root yield per hectare respectively.

Anchote is endemic root crop of Ethiopia and it is a unique root crop in its uses and the parts consumed. All parts of anchote: root, leaves and the immature fruit are consumed even though the root is the most economic concern in most growing areas of Ethiopia. In addition, to its nutritional importance, anchote is a cultural and medicinal crop widely used in growing areas (Amare, 2003). According to Abera (1995), juice of anchote root is used to treat cancer, tuberculosis, skin eruptions and gonorrhea by traditional medicine practitioners of Ethiopia. The consumable parts: root, leaf, and fruit are rich in protein, calcium, iron, and potassium and it can be used as a useful crop to fight malnutrition. According to Koller (2008) other Coccinia groups such as *grandis* and *indica* are also widely used to treat gonorrhea, asthma, skin eruptions, diabetes and eye diseases and they are rich in calcium, potassium, iron and protein. A farmer in Western parts of Wollega usually plants 400 to 600 square meters of anchote, mainly for home consumption (Amare, 2003).

3.4. Nutritional composition of anchote

Nutrition is the science of foods, the nutrients, and other substances therein, their action, interaction and balance in relationship to health and diseases; the processes by which the organism ingests, digests, absorbs, transports, and utilizes nutrients and disposes of their end products. In addition, nutrition is concerned with social, economic, cultural, and psychological implications of food and eating. According to Tairo *et al*. (2008), different parts of sweet potato; root, leaves and vines are consumable as human food and animal feed. There is also a wider variability in nutritional composition among different genotypes of root crops (Gasura *et al*., 2008).

The nutritional composition of anchote is comparable with other food crops in the amount of energy and fat content (Table 1). However, anchote root contains much higher amount of protein than other root and tuber crops and its higher calcium content makes it preferable for children, youth, aged persons, and those suffering from bone fracture and displaced joints (Abera, 1995). There was no any information so far on nutritional composition of anchote leaf and fruit.

3.5. Anchote characteristics

Runner growth habit is the characteristics of cucurbits (Nagy, 2005 and Clausen, 2009) including the *Coccinia* group such as *Coccinia grandis*, *Coccinia indica* and others. Anchote has a runner growth habit with a trailing vine which needs support for successful fruit development when the seeds are needed for future planting. The germination type of cucurbits is epigeal and the cotyledon shape is broad kidney (Deyo and Malley, 2008). The type of germination of anchote seed is not identified so far. It starts to develop flowers after two and half months of planting when the vines start to cover the ground. Stripped fruits develop at the base of each node on the vine alternatively similar to the leaf arrangement. Anchote is the only crop grouped in to two plant groups; root crop and cucurbit family. In addition, it could be distinguished in its consumable parts from cucurbits and root crops. All parts of anchote are consumable as human food and animal feed but root is the most economic consumable part as human food and fruit in other cucurbit families except for the genus *Coccinia*.

Leaf characteristics

Characteristics of anchote leaves; color, shape, arrangement and general outline has not been characterized so far. Cucurbit's foliage color ranges from deep green, yellowish green, light green to dark purple (Diez *et al*., 2005).

Vine characteristics

Anchote is a trailing annual vine with hardy creeper or soil surface runner, but able to climb where there are supports (Abera, 1995). No work has been done on the morphological characteristics of anchote vine.

Flower characteristics

The understanding of both the reproductive biology and the regulation of the sexual expression of cucurbit flowers makes crop management easier and can improve fruit yield and quality (Valdir *et al*., 2010). The floral nature and reproductive biology of anchote has not been identified and characterized so far. Self-fertilization in sweet potato is rare, because it has a high degree of self-incompatibility. Similarly, it may be difficult to obtain seed from crosses between certain parents, because cross incompatibility also occurs (Wilson *et al*., 1989). According to Condon and Gilbert (1988), some cucurbits develop separate male and female flowers. Male flowers develop first, and are easily distinguished as a plain flower on a long stem, having only stamens; female flowers form large ovaries, which look like small fruit.

After the first female flowers are pollinated, the vines develop both male and female flowers. Some melons, many squashes, and all cucumbers cross-pollinate with one another. During the initial stages of flower development, male flowers develop profusely and get drop after a week, then after the perfect flowers develop. This condition is also partly exhibited in cucurbit types; Gurania and Psiguria, that individual vines undergo two kinds of sex change (Condon and Gilbert, 1988). According to Gallagher (2002), in contrary of the cucurbit's floral nature; monoecious, muskmelons are bisexual and they are highly self-pollinated plants. Thus, as of muskmelons, regardless of its most family members' floral morphology and pollination nature, anchote is a highly self-pollinated plant with perfect flowers.

Fruit characteristics

Cucurbita *spp*. is collectively ranked among the ten leading vegetable crops worldwide. Winter squash populations show great diversity in morphological characteristics, particularly fruit length, fruit diameter, fruit shape, fruit brightness, skin thickness, flesh thickness and color (Balkaya *et al*., 2009). Most cucurbit families develop stripped fruits with different shapes and colors. Even though anchote plant develops fruits, the phenotypic and nutritional traits and its potentials has not been studied and characterized so far.

Anchote seed characteristics

Cucurbit seeds are variable in size, shape and structure, traits which are used in family classification (Nerson, 2007). Most seed production in the *Cucurbitaceae* is directed for propagation. However, in some parts of the world cucurbit seeds; mainly watermelons and squash is produced and consumed as snack food, because their nutritive values are high (Nadaan and Lal 1984; Sharma et al., 1986). For example, melon seeds may be served as nutritive additives to pasta dishes (Kaur et al., 1988), and those of a wild watermelon ancestor can be used as a source of protein for human food and animal feed (Sawaya *et al*., 1986). The morphological and nutritional traits and importance of anchote seed are not characterized and the potential is not known yet.

Anchote storage root characteristics

Anchote is a tuberous root crop with diversified potentials for food, animal feed, medicinal and starch production (Desta, 2007 unpublished). Even though anchote is categorized in to Cucurbitaceae family, its most economical part is tuberous root.

3.6. Ecology and cultivation of anchote

The crop seems to have a wider ecological adaptation as it grows well in 'Qolla', 'Weinadega' and 'Dega' (Amh.), the traditional agro-ecological zones of Ethiopia based on relative altitudinal ranges; 500-1500 m, 1500-2300 m and 2300-3200 m above sea level, respectively (Zemede Asfaw, 1997). But there is almost no research information on the ecological adaptation of the crop. In the growing regions, very fertile soils in homestead areas are used for anchote cultivation. The information on other soil types is lacking. According to Abera Hora (1995), southwestern parts of Ethiopia with oxisol, ultisol and vertisol soil types, altitudinal range of 1500-2400 masl, receiving an annual rain fall of about 1500 mm to over 2000 mm might be suitable for anchote. But, on the contrary, he also found anchote growing in areas outside the indicated ecological limits. According to Holstein and Norbert (2011), Coccinia species can grow on lateritic soils (i.e., red tropical soils), and are distributed in semi-arid, wood-lands and forest habitats of Sub-Saharan Africa.

Tubers vary in shape depending on environmental conditions, but generally spherical or elongated at maturity. Almost all activities associated to anchote culture are done by women (Abera Hora, 1995). Land preparation, sowing, weeding, staking, harvesting, processing, storing and marketing are mainly accomplished by women, and usually, home gardens are used for anchote growing. Pests such as porcupines, wild pigs, and wart hogs hunt anchote tubers. The vicinity of anchote plots to home area helps family members and guarding dogs in protection. Parasites of fungal, bacterial, viral, and/or nematode origin and insect pests may also attack the aerial and/or underground parts of the plant.

Anchote can be propagated both vegetatively and by seeds. In the vegetative propagation, high quality tubers that might have been obtained from market or any other source, can be planted and used as seed sources during the next growing season. Some tubers may also be left in soil for regrowth as ‘guboo’ (Oro.) for the coming season. But, the commonest way of anchote propagation is via seeds. Mature red/yellow fruits are collected and seeds extracted. The seeds are stored in safe area and used during the coming season. Sowing is by broadcasting, although sowing in line may increase tuber quality (Abera Hora, 1995). Staking may be essential to increase fruit number, and thereby seed production. Fencing may also be important to protect the aerial parts of anchote from devastation by domestic animals such as sheep, goats, donkeys, and the like.

3.7. Production and productivity

Anchote is usually cultivated in rainy season (April to January) which depending on agroecological zones takes four to five months to mature to consumable or marketable root size, which makes anchote a short season crop. The yield of anchote varies in different soil types and agro-ecological zones. For instance, one annual report of 2004/5 production season shows that anchote crop was produced nearly on 3,000 hectares of land in West Wollega Zone which yielded a total of 25,000 tons of tuber (Anonymous, 2011). However, maximum tuber yield (76.45 t/ha) was obtained in Ebantu agroecological condition (Daba Mengash *et al.*, 2012) under experimental condition and even more (80 t/ha) yield was obtained on vertisol soil type at Debre-Ziet Agricultural Research Center (Desta Fekadu, 2010)

3.8. Adaptation

Abera (1995) and Amare (1973) stated that anchote is cultivated in areas between 1300 to 2800 meters above sea level with 762 to 1016 mm rainfall. According to Amare (1973) and Desta, (2011), anchote is a potential dry land crop and suitable to be produced in arid areas. It occurs in many parts of Ethiopia including the western, southern and northern parts (Amare, 1973). It is believed that there are many accessions with potential yields in all growing areas. However, its production and consumption are not as such known in many parts of the county as there were no work done on anchote evaluation for agronomic and food quality attributes (Amare, 1973).

3.9. Effect of growth environments on growth performances of anchote plant

Phonological, growth performances and yield of anchote has been studied in some parts of Ethiopia and the effect of different growth environments on these parameters has been documented (Tilahun *et al*., 2014, Dasta, 2011, Daba *et al.*, 2012). Those authors reported that the growing environments had affected the yield and growth performances of anchote accession. The different agroecological factors such as temperature, altitude, rainfall, soil type, growing season and others significantly affected the growth performances of anchote accessions. These factors cause variation in hormonal balance, cell division rate, photosynthesis rate and other physiology parameters (Chauhan et al., 2005). Mostly altitude and accession type have impact on anchote growth performance (Daba *et al*. 2011). The differences in responses between accessions with regards to yield and growth performances could be due to the difference in genetic makeup of the tested accessions and also perhaps due differences/variation in Growth environments (temperature, solar radiation, rainfall, and soil type) of the location where studies were conducted. on high altitude the photosynthesis rate is high; this photosynthesis rate initiates or facilitate the growth rate of the plant. As a result, the yield and all yield components of the plant relative to low land.

3.9.1. Effect of environments on anchote seed germination

According to Daba *et al*., (2012) anchote seeds sown at mid altitudes (1710 masl) germinate earlier than the one sown at earlier emergence of anchote seeds was observed under Jimma condition (1710 masl) compared to that of Ebantu (2100 masl). Such difference might be due to variation of the two locations in terms of average temperature among other factors. Jimma condition had comparatively higher mean average temperature (18.8°C) as compared to that of Ebantu (16.8°C). After emergence, the number of seedlings was not affected by location; as a result, almost, all seedlings survived in both locations. As a result, the stand count at emergence was statistically similar with the emergence percentage of the same accession among all the accessions. This shows that anchote seedling can adapt in different environmental conditions after germination and have the capacity to tolerate different environmental conditions after emergence.

Germination percentages of anchote varied with growth environmental and accessions. Anchote seeds germinated within 9-12 days after planting with the average of nine days on Bishoftu area 1860 masl (Desta, 2011).

3.9.2. Effect of environments on anchote vine number and vine length per plant

Location under which anchote has grown affected the vine length and number. For example, the highest vine number (3.06 m) was obtained from plants established at Ebentu, Eastern Wollega, Oromia Region (2100 masl) compared to Jimma (1710 masl) which measured vine length of 2.4 m. With respect of vine number, the highest recorded were 6.23 m and 3.34 from Ebantu and Jimma respectively (Daba *et al*., 2012). In another study, highest vine length 3. 32 and highest vine number 4 were recorded (Tillahun, 2014). This indicates that both accessions and environment in which the plant has grown affects the vine length and number of anchote.

3.9.3. Effect of environments on anchote leaf area and leave number

Growing area and accession type have influence in anchote leaf area and leaves number. For instance, the highest leaf area (86.5 cm^2) and the largest leaves number (31.23) was obtained from anchote plant that planted at Ebatu (2100 masl) compared to Jimma (1710 masl) which measured leaf area (68.3cm^2) and leaves number (28.34) (Daba *et al*., 2012). In another study that was conducted at Debre Zeit Agricultural Research Center (DZARC) Research Site (1860 masl) the highest leaf area obtained was 174 cm^2.

3.9.4. Effect of environment on anchote fruit number

Growing area and accession type have influence on anchote fruit number. The experiment that conducted in Bako Agricultural Research Center (BARC) Its elevation is 1560m.a.s.l. done by (Tillahun, 2014) result shows different accession type have different fruit number 1 to 10.

3.9.5. Effect of environments on anchote total biomass

The total biomass of anchote had greater variation among the accessions and location; this may be due to the growth response of accessions with the environments. From the experiment that done by (Daba *et al.,* 2012) significant differences were observed ($p<0.05$) among the accessions and environments with regard to total biomass. The highest total biomass weight (19.13 kg) was produced under Ebantu condition. On the other hand, the smallest weight (9.53 kg) was recorded under Jimma condition.

3.9.6. Effect of environments on anchote storage root number, root diameter and yield

Abera (1995) reported that a farmer in Western parts of Wollega usually allocate 400 to 600 square meters of land for anchote production mainly for home consumption. Its productivity shows a discrepancy based on genotypes, soil fertility level, location and cultural practices used. Under farmers condition it can yield 20 - 30 t ha^{-1} (Abera, 1995; BARC, 2004).

According to (Desta, 2011) study in at Bishofu (1860 masl) the highest yield obtained was 76.4 tha-1). In the experiment output that conducted at Bako Agricultural Research Center (BARC), Oromia, Ethiopia Its elevation is 1560m.a.s.l and worked by (Tilahun *et al*., 2014) the highest storage root yield and root diameter was 65.2$tha^{-1}$and 8.89cm respectively. The average root yield per plant in this site was 0.20 to 0.53 kg,

The storage root yield has varied between location and accession studied. According to Daba, et al., 2012, the high storage root yield, storage root number per plant and storage root diameter was obtained in high altitude areas at Ebantu district than Jimma district (1710m.a.s.l). The authros reported significantly the highest total storage root yield (76.45 t ha-1) and 58.3 tha^{-1}. were obtained under Ebantu and Jimma condition respectively. In root number per plant, the highest number (3.03) was obtained from Ebantu and roots number of was 2.46. was recorded from Jimma. In the cause of root diameter, the largest diameter in Ebantu was 55 mm and the largest diameter in Jimma was 36.5 mm.

4. MATERIALS AND METHODS

4.1. Description of the study areas

The field study was conducted at three locations (Fig 1) namely Hula, Leku and Bilate in Sidama region that represent three altitudes from June, 2021 to November, 2021. Experimental locations selected at Bilate, Leku and Hula represented low (1330 masl), mid (1835 masl) and high (2504 masl). altitude.

Bilate is located in south part of Ethiopia in the region of south nation nationality people region at 350 km south from Addis, the capital city of Ethiopia. It is located at approximate geographic coordinate of latitude $6^0$49'20.3''N and longitude of $38^0$05'16.1''E and at altitude of 1330 masl. It receives annual rainfall of 876 mm and minimum and maximum temperature of 17 ^{0}C and 30 ^{0}C respectively. The major soil texture that represents the study area is Sandy clay loam.

Leku (Shebedino) is located in south part of Ethiopia in the region of Sidama at 302 km south from Addis Abeba, the capital city of Ethiopia. It is positioned at 1835 masl and located at latitude 6°52′34″N and longitude of 38°28′49″E. It receives an annual rainfall of 1095 mm and minimum and maximum temperature 15.7 ^{0}C and 29.2 ^{0}C respectively. The major soil texture of that represent the study area is clay.

Hagereselam (Hula) is located in southern part of Ethiopia in the region of Sidama at 370 km south from Addis, the capital city of Ethiopia. It located at approximate geographic coordinate of latitude $6^0$29'17.3''N and longitude of $38^0$31'28.9''E and at altitude of 2504 masl. It receives an annual rainfall of 1642 mm and minimum and maximum temperature 5 ^{0}C and 21 ^{0}C respectively. The major soil texture of that represent the study area are clay.

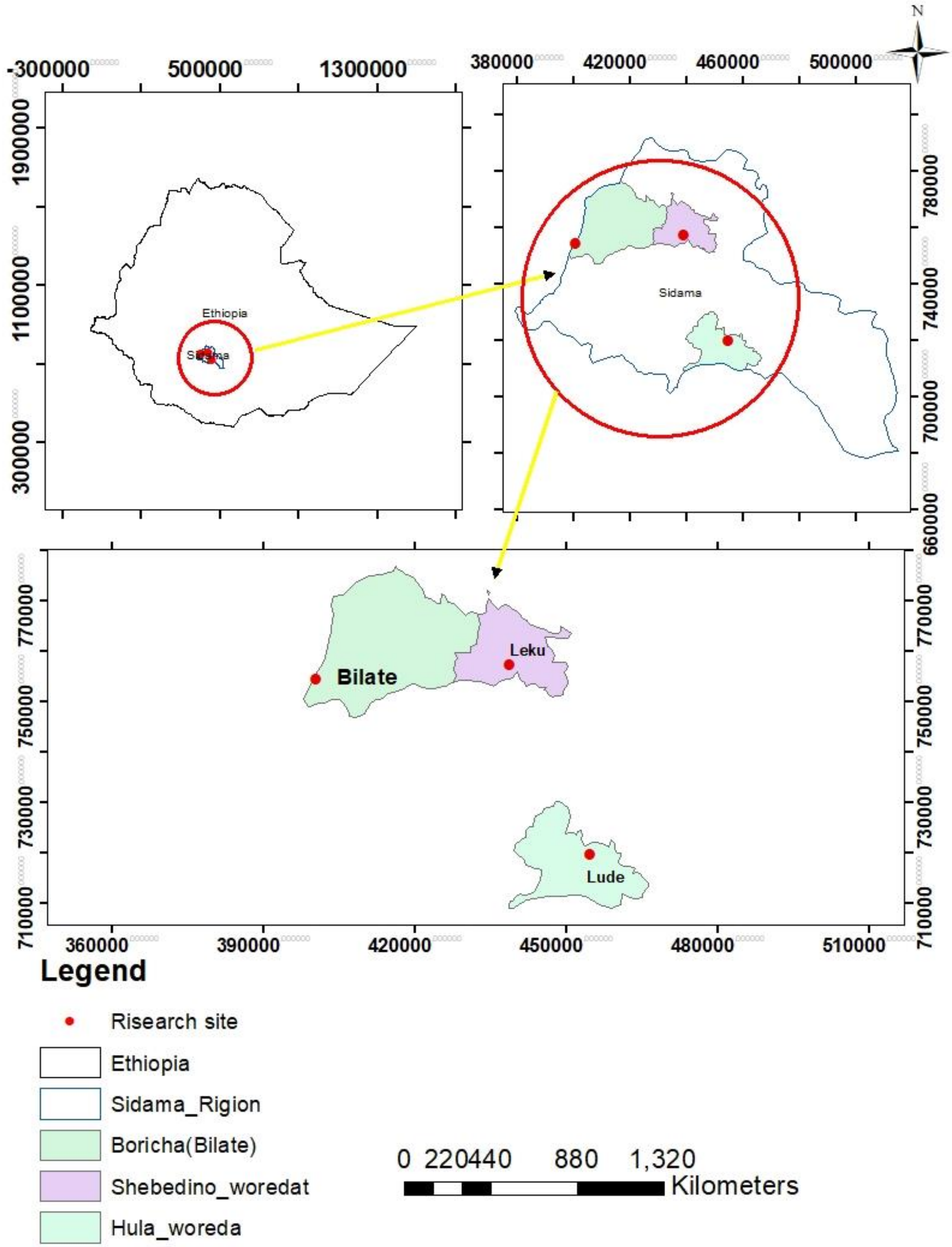

Figure 1. Map of the study areas

Table 1. Monthly air temperature and rain fall of the three experimental sites during the period from June to November, 2021.

	Bilate		Leku		Hula	
Month	Average T°c	Ave RF (mm)	Average T°c	Ave RF (mm)	Average T°c	Ave RF (mm)
Jun	22.3	117.0	21.2	203.8	12.75	158.3
July	21.5	133.3	21.1	218.3	11.6	257.5
Aug	21.9	164.3	21.2	250.3	10.45	166.4
Sept	22.6	63.0	21	150.0	12.8	229.4
Oct	23.3	57.0	20.9	145.3	12.75	255.3
Nov	23.75	72.0	20.65	160.8	13.85	114.1

Source: Ethiopian National Meteorology Agency, Hawassa center, 2021. This has been rounded up to the nearest tenth.

Table 2. Mean annual rainfall and temperature of the three experimental sites.

Locations	Longitude	Latitude	Altitudes(m)	Average Rainfalls(mm)	Average T°c
Bilate	$38^0$05'16.1"E	$6^0$49'20.3"N	1330 m	876 mm	23.5°c
Leku	$38^0$28'49.2"E	$6^0$52'34.5"N	1835 m	1,095 mm	22.4°c
Hula	$38^0$31'28.9"E	$6^0$29'17.3"N	2504 m	1642 mm	13°c

Source: National Meteorology Agency, Hawassa center

4.2. Experimental materials

For this experiment we use seeds of nine anchote accessions (Table 3) which were collected previously from anchote producing farmers in different location, multiplied at Hawassa University and kindly provided.

Table 3. Description of anchote accessions used for the experiment.

No	**Anchote accessions** (Name represent district /specific location where accession were collected)	**Zones where they collected**
1	Gimbi	West Wollega
2	Jimate	East Wollega
3	Degaga Didhessa	‘’
4	Jimma Arjo	‘’
5	Ale	Illu Ababor
6	Sheka	South west Ethiopia
7	Sibu Sire 1	East Wollega
8	Sibu Sire 2	East Wollega
9	Sibu Sire 3	East Wollega

4.3. Experimental design and treatment combination

The design was randomized complete block (RCBD) with three replications. The plot size was $4m^2$ (2 m * 2 m), having 5 rows. The spacing between rows and between plants within row was 40 and 20 cm respectively. The plots were 0.6 m apart from each other, and spacing between replications was 1m.

4.4.Experimental procedure

The experimental lands were ploughed, harrowed and seed beds are prepared before planting at the three locations. Two seeds per spot were sown on well-prepared beds at 5 cm depth in the soil and later thinned to one plant per spot after one month of planting. Sowing was done at the onset of rain when each location gains enough moisture for good germination of seeds. Sowing was done in June, 2021 for all location in one day interval (day one Leku, day two, Bilate and day three Hula). Before planting, representative soil samples were collected from each experimental site as described under section 4.5 for physical and chemical analysis.

Weeding was done two times using manual method at four and eight weeks after planting. Fertilizer was applied as Diammonium phosphate (DAP) and urea at the rate of 46 kg ha^{-1} N and 20 kg ha^{-1} P_2O_5 (Girma and Gudeta, 2007). All recommended rate of Diphosphorus pentoxide (P_2O_5) and nitrogen was applied after one month of planting date. The experiment was conducted under rainfed condition. Harvesting was done five months after planting in November, 2021 when more than 90% of the plants in a plot showed physiological maturity index such as basil leaf yellowing and leaf drop (Daba *et.al.* 2012).

4.5. Experimental soil sampling and analysis

Soil analyses for specific parameters relevant to the current study were carried out at Hawassa University College of Agriculture, soil laboratory. Representative samples from surface soil (0-20 cm depth), were collected randomly from the entire experimental field by using Auger sampler in a zigzag pattern before planting and composited into one sample at each location. The soil samples were dried and grounded to pass through 0.2 mm sieve before laboratory analysis, and the samples were analyzed for parameters relevant to the study at Hawassa University College of Agriculture, soil laboratory. Soil textural class (sand, silt and clay), soil pH, EC, total N, available P, CEC and organic carbon were determined as per the following laboratory procedure. The soil pH values were determined in soil water suspension 1:2.5 using glass electrode pH meters Jackson (1967). Determination of particle size distribution (texture) was carried out hydrometrically following the methodology of Day (1965) Soil organic carbon (OC) was determined using the Walkley and Black wet oxidation method (Walkley's and Black, 1934), and soil total nitrogen by the Kjeldahl as described by Dewis and Freitas (1970), and cation exchange capacity (CEC) by saturating the soil with a neutral ammonium acetate method (Chapman, 1965). Available phosphorus was determined using the sodium bicarbonate solution extraction method, and the quantity was measured using a spectrophotometer as defined by way of Olsen et al., (1954). The chemical and physical properties of the soil before planting are presented in Table 5.

4.6. Data collections

Different yield and growth performance parameters were collected from ten randomly selected plants from the three middle rows of the five rows per plot of each treatment/accession. Different qualitative and quantitative parameters were used for evaluating anchote performance.

4.6.1. Phenological data

Emergence percentage: The emergence percentage was calculated after 20 days of sowing by counting the numbers of seeds that emerged from each plot and dividing it by the total number of seeds sown.

Days to 50% flowering: The day 50% flowering was determined by counting number of days from flower forming until 50% of plants in the plot had at least one open flower.

4.6.2. Growth and morphological data

Vine number per plant: Number of vines per single hill were counted from the five randomly selected plants at the maturity or at five months of sowing.

Vine length per plant (cm): Vine length was measured from base to tip of the plant (m) from five randomly selected plants from interior rows at the maturity of the plant or at five months of sowing.

Leaves number per plant: The total number of leaves per plant was counted from five randomly selected plants in each plot and average number was calculated.

Leaf area per plant (cm^2): Leaf area was record by using a scientific leaf area meter (Area Meter AM 200-002 ADC Bioscientific Ltd). Leaf area was measured from the middle parts of the plant by selecting 20 leaves at random from each plot and then average was done at full maturity stage from five sampled plants.

Above ground biomass per plant (g): was obtained by measuring above ground biological yield from five sample plants by using sensitive balance from each plot at harvest stage**.**

Dry above ground biomass per plant (g): 200 grams fresh weight samples from total above ground biological yield taken and then chopped in to small pieces. The sample was exposed to sunlight to loss moisture and finally dried in microwave oven at 75℃ for 48 hours before the dry weight was measured in gram**.**

4.6.3. Yield and yield related parameters

Root number per plant the average number of storage roots per single plant was determined by counting roots obtained from the five randomly taken plants from each plot.

Storage root diameter per plant (mm): Diameter of the roots measured using caliper from five randomly selected storage roots that contain small, medium and large size from each plot and average root diameter was calculated.

Storage root length per plant (cm): The length of roots was measured at the middle of root from the five randomly select storage roots and then the average was taken from each plot.

Storage root weight per plant (g): Storage roots weight per plant was measured by randomly taking roots from five sample plants.

Fresh root yield per hectare (ton): The total root yield was measured in tons per hectare from the sample plants to the overall plots.

Dry underground biomass per plant (g): Representative sub-samples were taken from the middle part of the fresh tubers from each accession and sliced into pieces, 200 g was put in paper bag and was dried in an oven until a constant dry weight achieved.

Dry matter content (%): Representative sub-samples were taken from the middle part of the fresh tubers from each accession and sliced into pieces, 200 g was put in paper bag and was dried in an oven until a constant dry weight achieved.

The dry matter content was then calculated according to the formula**:**

DMC= $\frac{\mathrm{TDWR}}{\mathrm{TFWR}} X100$

Where; DMC =dry matter content, TDWR = total dry weight storage root, TFWR = total fresh weight storage root (Lamaro, 2020).

Total biomass per plant (g): was obtained by measuring the total above and below ground biological yield from each plot at harvest.

4.7. Data Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) using statistical analysis system SAS software version 9.2 (SAS Institute 2008). To evaluate the interaction effect combined analysis was done considering locations and accessions as two factors. The means were separate by using the Least Significant Differences (LSD) test at 5% level of significance. Pearson correlation analysis was used to define the relationship between variables.

5. RESULTS AND DISCUSSION

Nine different anchote accessions were tested for yield and yield components performances at three different locations representing varying altitudes. To this effect, all yield and yield component parameters data were collected from the field experiment of nine anchote accessions at three locations to evaluate the accessions performance and effect of altitudes on yield and yield related parameters and tested for analysis of variances to determine variations of yield and yield related parameters among the accessions, different altitudes and the interaction effect of accessions and altitudes and the results are presented and discussed in the following sections.

Physical and chemical properties of the soil in experimental fields

An analysis result of soil physical and chemical properties is presented in (Table 4). It revealed that the soil texture of Bilate (1305 masl), Leku (1835 masl) and Hula (2504 masl) is represented by Sandy clay loam, clay and clay loamy respectively. The pH of the soil was 5 (Table 5) which was strongly acidic (Tekalign, 1991). The organic carbon content and the total nitrogen content are rated as moderately low and low in tropical soil standards (Table 5). This low value of soil pH could be due to loss of base forming cations down the soil profiles through leaching and drain to streams in runoff (Nigussie and Kissi, 2012).

Bilate (low altitude) have a higher pH, accordingly, the soil can be characterized as alkaline, higher available potassium, higher and electro conductivity. The organic carbon concentration of the all three-study location (Hula (2504 masl), Leku (1835 masl) and Bilate (1305 masl)) was 1.29%, 1.01% and 1.48% respectively (Table 5). According to Landon (2014) the categories for the organic carbon content of soils are: Very low (< 2%), low (2- 4), medium (4 - 10), high (> 10). Thus, the organic carbon content of the soil of all three locations is rated as low. Total nitrogen value of the three (Hula (2504 masl), Leku (1835 masl) and Bilate (1305 masl)) experimental site soils was (0.13, 0.09 and 0.11) respectively (Table 5). According to Ethio SIS (2014) TN content <0.1, 0.1-0.15, 0.15-0.3, 0.3-0.5, and >0.5 is rated as very low, low, medium, high and very high, respectively.

The optimum total nitrogen level needed for crop production under most soils of Ethiopia is reported to be <0.2 % according to Ethio SIS (2013). Due to this total nitrogen amendment is important at study area. Available K content of the all three (higher, mid and lower altitude) experimental site was 8.98 mg kg^{-1}, 11.33 mg kg^{-1}, 24.93 mg kg^{-1} respectively (Table 5). According to Bray (1995) when the range of potassium in Bray method is <55 $mgkg^{-1}$, 55-210 $mgkg^{-1}$, 210-280 $mgkg^{-1}$, 280-500 $mgkg^{-1}$ and >500 $mgkg^{-1}$, it is rated as very low, low, medium, high and very high, respectively. Ethio SIS (2014) suggest that healthy levels of potassium in soil range from 40 -80 $mgkg^{-1}$.

The CEC of the all three (Hula (2504 masl), Leku (1835 masl) and Bilate (1305 masl)) experimental site was 39.8 cmol kg^{-1}, 22.68 cmol kg^{-1} and 18.78 cmol kg^{-1} respectively (Table 5). Landon, *et al*. (1991) reported that soils having CEC of >40, 25-40, 15-25, 5-15, < 5 cmol kg^{-1} are categorized as very high, high, medium, low and very low, respectively. According to the result obtained from soil laboratory, the value of CEC was in high range in Hula and Leku while medium range in the Bilate. Finally, difference in soil properties and rain fall significantly affects plant growth Lestari *et al*., (2019).

Table5. Physical and chemical properties of the soils of experimental sites of each location before-planting.

Properties	Bilate	Leku	Hula
Sand (%)	57.12	31.12	33.12
Silt (%)	20	24.72	18.72
Clay (%)	22.16	44.16	48.16
Textural class	Sandy clay loam	Clay	Clay loam
Organic carbon (%)	1.29	1.01	1.48
pH	7.6	6.1	5.1
Total nitrogen (%)	0.09	0.11	0.13
Available phosphorus (mg/kg)	24.93	11.34	8.98
EC (dS/m)	0.023	0.01	0.02
CEC (Cmol/ kg)	18.7	22.6	39.8

5.1. Phenological data

5.1.1. Emergency percentage and Days to 50% Flowering

Emergency percentage of anchote was significantly ($p<0.001$) influenced by accession, location and their interactions (between location and accession) (Appendix Table 2). The highest (92%) and lowest (58.7%) emergence percentage was obtained from Sheka accession at Leku and Sibu Sire1 at Bilate location respectively (Table 6). Good average seed emergency percentage and early emergence were observed under Leku location than other locations. This difference may be due to variation in rainfall, temperature, soil and others factor across three locations. Leku have comparatively medium average temperature (20^{o}c) compared to other location. The variation observed for emergence percentage in this study were in agreement with the earlier findings of Daba et al. (2012) who reported high temperature area had high emergency percentage than low temperature area.

Table 6. The interaction effect of accessions and altitudes on emergency percentage of anchote at.

Location/Altitude	Accessions	EMPR
Bilate (1330 masl)	Sibu Sire2	63.6^{hij}
	Jimate	65^{hi}
	Ale	60^{jk}
	Jimma Arjo	60.3^{ijk}
	Sibu Sire1	58.6^{k}
	Sheka	79.3^{cde}
	Degaga Didhessa	74^{f}
	Sibu Sire3	66^{h}
	Gimbi	65^{h}
Leku (1835m.a.s.l)	Sibu Sire2	71.3^{f}
	Jimate	746^{ef}
	Ale	83.6^{bc}
	Jimma Arjo	64.3^{hij}
	Sibu Sire1	96^{b}
	Sheka	92^{a}
	Degaga Didhessa	72.6^{f}
	Sibu Sire3	80^{cd}
	Gimbi	71f^{g}
Hula (2504 masl)	Sibu Sire2	71^{fg}
	Jimate	66.3^{gh}
	Ale	75.3^{def}
	Jimma Arjo	60.3^{ijk}
	Sibu Sire1	80.6^{c}
	Sheka	82.3^{bc}
	Degaga Didhessa	72.6^{f}
	Sibu Sire3	75.3^{def}
	Gimbi	62^{hijk}
LSD		4.34
CV		4.02

Means with different letter on the table are statistically significant at P-values < 0.001 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

Similarly, days to 50% flowering of anchote was significantly ($p<0.001$) influenced by accession and location. Interactions between location and accession had no significant influence on days to 50% flowering of anchote (Appendix Table 2). The significantly highest (108.5) and the lowest (102.4) days to flowering was recorded from Sheka and Sibu Sire2 accession respectively (Table 7).

In the case of location flowering of anchote accessions that planted under Hula location (2504 masl), Leku (1835m.a.s.l) and Bilate (1330 masl) need 127-137.67, 95-102 and 82-90 days respectively. Variation in flowering date observed in this experiment was due to either the accession's genetic variation or location that is attributed to climate factor and growth period duration. 50% flowering date increase with increasing altitude because it dependent on environmental gradient such as decreasing soil temperature, nutrient composition and diversity along the increasing elevation (pellerin et at.,2012)

In this study flower drops observed mostly may be due to accessions genetic makeup or altitudes effect that's means natural drop, most flower drops happen due to a lack of pollination, If the soil is infertile doesn't have enough nutrients to support or soil type and Temperature fluctuations, such as those above, greatly affect plant blooms. In addition to flower drop during high temperature, cooler temperatures following blossom set can also lead to blossoms falling off. Insufficient light, whether it's too much or too little, can also contribute to flowers dropping off plants. Some fruits developed also fall off its may be due to genetic makeup, natural drop, hormonal effect, gravity force (Gravity is a force that attracts a body towards the center of the earth so it leads fruit detach from the plant), high and low temperature, an unsatisfactory watering regime whether the is getting too little or too much water, lack of or incomplete pollination, self-regulating tactic that a fruit tree employs when it does not have enough resources to ripen all of its fruit. Fruit set and flowering obtained from this study contradicted with the finding of Desta (2011) who reported anchote flowering and fruit set number.

Table 7. The effects of accession and altitudes on days to 50% flowering date of Anchote.

Accession	**Parameters**
	Days to 50% Flowering
Gimbi	102.4[c]
Jimate	106.1[ab]
Degaga Didhessa	105.7[abc]
Jimma Arjo	103.3[bc]
Ale	107.0[a]
Sheka	108.5[a]
Sibu Sire1	103.1b[c]
Sibu Sire2	108.4[a]
Sibu Sire3	106.5[ab]
LSD (0.05%)	**3.55**
CV	**3.55**
	Altitude
Bilate	87.37[c]
Leku	97.00[b]
Hula	132.74[a]
LSD (0.05%)	2.05
CV	3.55

Means with different letter on the table are statistically significant at P-values < 0.01 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

5.2. Morphological and growth parameters

5.2.1. Leaves number and leaf area per plant

Leaves number of anchote was very high significantly ($p<0.001$) influenced by accession, location and by their interaction (Appendix Table 1). The largest average number of leaves was recorded from accession Jimate (96) and it was statistically on par with accession Ale (95.7) and Jimma Arjo (95.3) that planted under Bilate location. (Table 8). The minimum leaf number (35.6) was recorded from Jimma Arjo anchote accession that planted at Hula conditions. This shows that majority of anchote accessions poorly responded under Hula condition than Leku and Bilate condition with regard to growth parameters. This is in line with previous findings which have reported great variability in the performance of the accessions at different locations, illustrating strong accessions by the environment effect (Ortiz et al., 2007; Daba et al., 2012).

This variability shows variations of genetic makeup among the accessions and resulted in variations in yield differences. The leaf number was also expected to be one of the parameters that positively influence the physiological process of plants thereby increase dry matter accumulation in plant systems. Therefore, one might assume that the greater the number of leaves in a field, the better interception of sunlight and the higher the tuberous root yield and vice versa.

Leaf area of anchote was very high significantly ($p<0.001$) influenced by accession, location and also by their interaction (Appendix Table 1). The largest average leaf area was produced from anchote accession Gimbi (75 cm^2) under Bilate location. The Smallest leaf area (26 cm^2) was recorded from accession Gimbi that planted at Hula location. The range of the area was wider (26 cm^2 to 75 cm^2) among the accessions (Table 8). This result indicated low altitude anchote plant had broad or high leaves area relative to high altitude area and presence of genetic variability among accessions evaluated and interaction of accessions with the environment resulting in different genetic response. Leaf area is contributed for high dry matter accumulation and production of assimilate through their effect on photosynthesis. Girma and Hailu (2007) also reported production of dry matter depends on the conversion of radiant energy into carbohydrate through the process of photosynthesis which takes place in the leaves. The greater area of leaves in a field, the better interception of sunlight and the higher the tuberous root yield and vice versa. This study finding is in agreement with reports in yam (Beford et al., 2001) and in potato (Showemimo, 2007) that high yielding varieties tended to be broad leaves than low yielding varieties as the case of this study. The variation in leaf area may also be attributed to variation in genetic makeup and adaptability of these accessions to different environmental conditions and this may be due to physiological process variations among the accessions. Similarly, it was explained by other study that the variation in leaf area and other parameters in different varieties at different locations may also be belonging to varying genetic makeup, soil and environmental adaptability (Ahemd et al., 2008; Daba et al., 2012).

For most of the accession leaf area decrease with increasing altitudes level (Table 8) these results illustrate that plants can adapt to the environmental changes that accompany high altitude by decreasing leaf area and increasing life thickness mesophyll tissue thickness and stomata density.

Table 8. The interaction effect of accessions and altitudes on leaf area (cm^2) and leaves number of Anchote.

Location/Altitudes	Accessions	LN	LA
Bilate (1330 masl)	Sibu Sire2	93.0^{ab}	65.5^{b}
	Jimate	96.0^{a}	47.7^{fghi}
	Ale	95.6^{a}	60.1^{bc}
	Jimma Arjo	95.3^{a}	66.0^{ab}
	Sibu Sire1	73.0^{cde}	58.8^{bcd}
	Sheka	56.3^{fgh}	65.7^{b}
	Degaga Didhessa	60.0^{efg}	44.5^{ghij}
	Sibu Sire3	79.0^{bc}	65.4^{b}
	Gimbi	39.3^{ij}	75.1^{a}
Leku (1835 masl)	Sibu Sire2	36.6^{ij}	48.6^{efgh}
	Jimate	55.6^{fgh}	54.6^{cdef}
	Ale	37.3^{ij}	57.2^{bcde}
	Jimma Arjo	43.3^{hij}	52.6^{cdefg}
	Sibu Sire1	46.6^{ghij}	42.3^{hijk}
	Sheka	62.3^{def}	49.6^{defgh}
	Degaga Didhessa	51.0^{fghi}	58.0^{bcde}
	Sibu Sire3	36.0^{j}	54.^{5cdef}
	Gimbi	39.2^{ij}	48.7^{efgh}
Hula (2504 masl)	Sibu Sire2	77.0^{cd}	45.3^{fghi}
	Jimate	45.3^{ghij}	29.7l^{mn}
	Ale	49.3^{fghij}	34.0^{klmn}
	Jimma Arjo	35.6^{j}	28.^{5mn}
	Sibu Sire1	54.6^{fgh}	29.3^{mn}
	Sheka	46.6^{ghij}	39.1^{ijkl}
	Degaga Didhessa	50.3^{fghij}	35.6^{jklm}
	Sibu Sire3	39.3^{ij}	31.2^{lmn}
	Gimbi	47.0^{ghij}	26.0^{n}
LSD		14.9	9.37
CV		16.03	11.75

Means with different letter on the table are statistically significant at P-values < 0.01 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

5.2.2. Vine length and vine number per plant

Vine length of anchote was significantly ($p<0.01$) influenced by accession, location and also by their interaction (Appendix Table 1). The longest average vine length (4.5 m) was produced by Sheka accession planted altitudes of 1305 masl (Bilate), Whereas the smallest vine length (0.92 m) was recorded from accession Gimbi planted at Hula (2504masl) (table 9). These variations may be attributed to variations in genetics make up of accessions and/or due to environmental condition. Vine length decreased with increasing altitudes because of some environmental effect such as air pressure, soil temperature and others which in turn cause variation in hormonal balance and cell division rate (Chauhan *et al*.,2005). Daba et al. (2012) also obtained different vine length among the different anchote accessions and attributed the variations is because of different genetic makeup of accessions.

Table 5. The interaction effect of accessions and altitudes on vine length (cm) of Anchote.

Location/Altitudes	Accessions	VL
Bilate/ (1330 masl)	Sibu Sire2	3.09^{bcde}
	Jimate	3.68^{ab}
	Ale	1.91^{fghi}
	Jimma Arjo	3.38^{bc}
	Sibu Sire1	3.64^{ab}
	Sheka	4.50^{a}
	Degaga Didhessa	3.29^{bcde}
	Sibu Sire3	3.76^{ab}
	Gimbi	4.32^{a}
Leku (1835 masl)	Sibu Sire2	2.47^{def}
	Jimate	3.31^{bcd}
	Ale	2.41^{efg}
	Jimma Arjo	2.07^{fgh}
	Sibu Sire1	2.57^{cdef}
	Sheka	2.09^{fgh}
	Degaga Didhessa	2.70^{cdef}
	Sibu Sire3	2.60^{cdef}
	Gimbi	2.46^{def}
Hula (2504 masl)	Sibu Sire2	1.17^{ij}
	Jimate	1.25^{hij}
	Ale	1.20^{hij}
	Jimma Arjo	1.09^{ij}
	Sibu Sire1	1.00^{j}
	Sheka	1.57^{ghij}
	Degaga Didhessa	1.33^{hij}
	Sibu Sire3	1.14^{ij}
	Gimbi	0.92^{j}
LSD		0.89
CV		22.73

Means with different letter on the table are statistically significant at P-values < 0.01 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

Vine number was significantly ($p<0.05$) influenced only by location (Appendix Table 1). The largest vine number (2.68) recorded under Leku while the smallest vine number (1.7) was obtained under Hula location (Table 10). The variations observed on these parameters among the sites may be owing to variations in soil properties especially pH and fertility status of the location conditioned by the temperature variation or solar radiation. This is confirming similar finding of great variability in the performance of the Anchote accessions at different locations and attributed the variation to the difference in soil and temperature of the experimental locations (Daba et al., 2012).

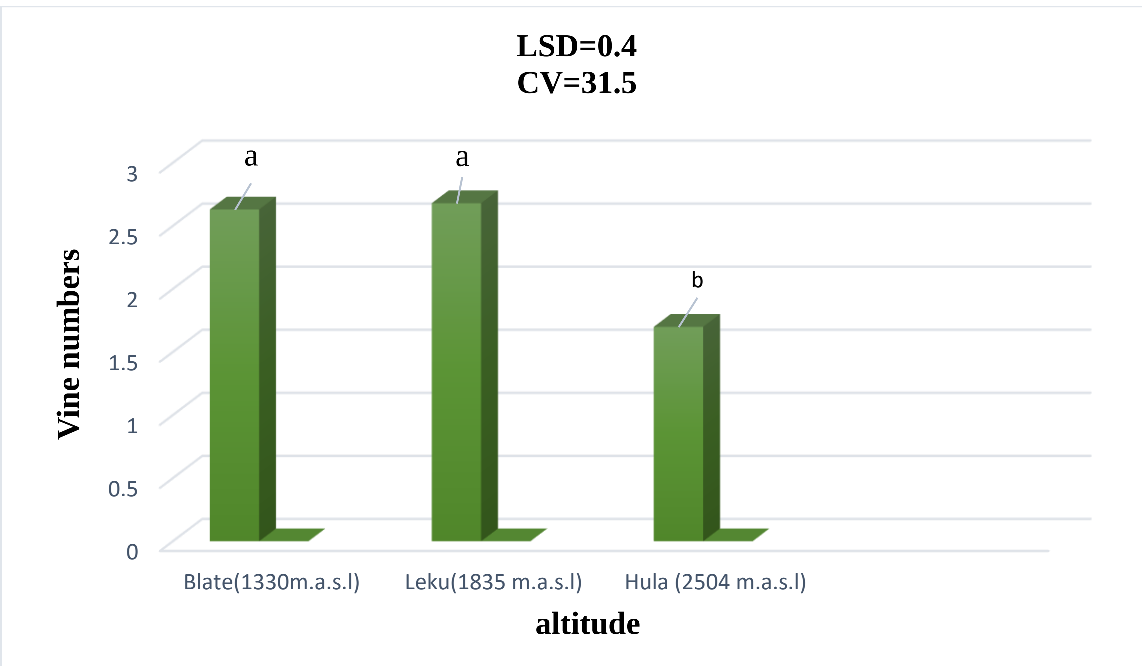

Figure 2. The effects of altitudes on vine number of Anchote. The same letter(s) on the bars are not significantly different at P –value ≤ 0.01.

5.2.3. Above ground fresh and dry biomass

Analysis of variances revealed that accession, location and their interaction had significant difference ($p<0.01$) on above ground fresh and dry biomass (Appendix Table 2). The largest above ground fresh biomass (613.3 g) was produced by accession Sibu Sire2 that planted under low altitude (Bilate). Minimum Above ground fresh biomass (6.2 g) was produced from accession Gimbi that planted under Hula location (table 10). The results also revealed that high altitude (location) has high above ground biomass than low altitude (location) because of some environmental condition such as air pressure, sun light, temperature and so on. warmer temperature (soil temperature) may decrease root biomass and increase foliage (above ground fresh biomass.

The highest above ground dry biomass (62.1 g) was obtained from accession Ale that planted under Leku and the minimum above ground dry biomass (33.6 g) was obtained from accession Jimate under Bilate location (table 10). This suggesting presence of variations among the accessions in moisture content. The above ground fresh and dry biomass variation observed in this study were corroborating with the other study findings of Tilahun (2012) who reported the significant difference among 49 Anchote accessions on above ground fresh and dry biomass yield of Anchote.

Table 10. The interaction effect of accessions and altitudes on above ground fresh (g) and dry biomass (g) of Anchote.

Altitudes	Accessions	AGFB (g)	AGDB (g)
Bilate	Sibu Sire2	613.3[a]	40.9[hijk]
	Jimate	347.6[fg]	33.6[l]
	Ale	290.6[gh]	40.4[hijkl]
	Jimma Arjo	424.6d[ef]	48.2[defg]
	Sibu Sire1	527.6[abc]	39.3[ijkl]
	Sheka	348.6[fg]	51.3[cdef]
	Degaga Didhessa	388.3[ef]	43[ghij]
	Sibu Sire3	418[def]	42.9[ghij]
	Gimbi	403[def]	34.6[kl]
Leku	Sibu Sire2	540.6[ab]	54.3[cd]
	Jimate	442[cde]	46.3[efgh]
	Ale	447[de]	62.1[a]
	Jimma Arjo	368.6[efg]	61.6[ab]
	Sibu Sire1	597.3[a]	37.9[jkl]
	Sheka	476[bcd]	44[ghij]
	Degaga Didhessa	352.3[fg]	55[bc]
	Sibu Sire3	571.3[a]	43.4[ghij]
	Gimbi	298.6[gh]	53.1[cde]
Hula	Sibu Sire2	111[i]	48.6[cdefg]
	Jimate	89.6[ij]	45.9[fghi]
	Ale	123.3[i]	42.3[ghij]
	Jimma Arjo	53.3[ij]	46f[ghi]
	Sibu Sire1	84.6[ij]	44.5[ghij]
	Sheka	98[i]	44.5f[ghij]
	Degaga Didhessa	259[h]	40.9[hijk]
	Sibu Sire3	65.6[ij]	44.5[ghij]
	Gimbi	6.17[j]	45.1[fghi]
LSD		86.3	6.82
CV		16.27	9.10

Means with different letter on the table are statistically significant at P-values < 0.01 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

The overall performance of growth parameters of anchote accessions were poor at Hula condition ascribing to poor soil fertility associated with pH of the soil resulting in low availability of essential nutrient for crop. Higher elevations always experience lower air pressure. This lower air pressure can influence plant life in many ways: Plants need carbon dioxide to grow, and lower air density and atmospheric pressure at high altitude produces lower carbon dioxide levels and a slower transpiration rate. Slow transpiration and limited caron dioxide slow dawn the rate of photosynthesis and plant vegetative growth. Low temperature at high altitudes limits plant growth and nutrient supply. Plants are unable to absorb the required amount of nutrients for growth. Nutrient content of soil tends to significantly decrease with increasing elevation. Temperature and rainfall affect the intensity of leaching and the weathering of soil minerals. On the other hand, this may happen due to low temperature. Low temperature affects several aspects of plant growth and development viz., plant survival rate cell division, photosynthesis, water transport and enzyme production.

Another possible reason for variation in above ground fresh and dry biomass among anchote accessions at different location may also attributing to variation in genetic makeup of the accessions on utilizing and assimilating nutrient and convert to dry matter which was also discussed by Tilahun (2012).

Accordingly, the significantly highest performance of growth parameters of anchote accessions were obtained under Bilate location or low altitude might be due to sandy clay loam soil suitability, high temperature and higher air pressure of the site as compared to Leku and Hula which was suitable for normal growing of the crop as discussed and reported by Daba et al. (2012).

5.3. Yield and yield related parameters

5.3.1. Storage root weight and total biomass

The analysis of variances revealed that storage root weight and total biomass per plant of anchote were significantly ($P < 0.01$) affected by accessions, location and their interaction between location and accession (Appendix Table 3, 4). The significantly highest storage root weight (522.3g) and total biomass (847 g) were obtained from Degaga Didhessa anchote accessions planted at high altitude/Hula/ conditions (Table 11). Whereas, the significantly lowest storage root weight (94.6 g) and total biomass (153 gm) per plant were also recorded from Sibu Sire3 accession planted under Hula location. signifying presence of great variation among the accessions under the Hula than the other location. The total biomass and storage root weight of anchote had shown great variation among the accessions under the Hula than the other location, which may be due to the growth response of accessions differently with the environments. This finding was in conformity with other study (Nagy, 2007) who explained that plant gained weight may differ in varieties due to environmental conditions which in turn cause variations in hormonal balance and cell division rate. The other reason may also be presence of genetic variability conditioned by environment resulting in different genetic response to storage root weight. This result concurred with study result on yam (Belford et al., 2001) and in potato (Showemimo, 2007) significant variations between accessions and environmental component interaction indicated wide differences between the environments and differential genotypic behavior in the environment. From this experiment we obtained maximum root weight 1053gram weight from Degaga Didhessa accession under Hula location.

Table 11. The interaction effect of accessions and altitudes on root weight (g) and total biomass weight (g) of Anchote per plant at harvesting.

Locations/Altitudes	Accessions	RW(g)	TBM(g)
Bilate (1330 masl)	Sibu Sire2	210.3^{efghi}	653.6^{b}
	Jimate	198.3^{fghij}	552.6^{bcdefg}
	Ale	132.3^{jkl}	423^{fghi}
	Jimma Arjo	183.6^{ghij}	628.3^{b}
	Sibu Sire1	179.6^{hij}	428^{efgh}
	Sheka	249.6^{defg}	579.6^{bcd}
	Degaga Didhessa	210.6^{efghi}	565.6^{bcde}
	Sibu Sire3	245.3^{efgh}	570^{bcde}
	Gimbi	95.6^{l}	482.3^{cdefgh}
Leku (1835 masl)	Sibu Sire2	254.3^{def}	476^{cdefgh}
	Jimate	203.3^{fghi}	479.3^{cdefgh}
	Ale	396.3^{b}	576.6^{bcd}
	Jimma Arjo	380.3^{bc}	600^{bc}
	Sibu Sire1	180.6^{hij}	457^{defgh}
	Sheka	353.3^{bc}	615^{bc}
	Degaga Didhessa	275.6^{de}	571.3^{bcd}
	Sibu Sire3	316^{cd}	560.6^{bcdef}
	Gimbi	216.8^{efghi}	416^{ghi}
Hula (2504 masl)	Sibu Sire2	102^{kl}	204.6^{j}
	Jimate	254.3^{def}	280.6^{ij}
	Ale	264^{def}	445.3^{defgh}
	Jimma Arjo	252.6^{def}	483^{cdefgh}
	Sibu Sire1	100^{kl}	184.6^{j}
	Sheka	178^{ij}	403^{hi}
	Degaga Didhessa	522.3^{a}	847^{a}
	Sibu Sire3	94.6^{l}	153.6^{j}
	Gimbi	165^{ijk}	254.6^{j}
LSD		**66.4**	**142.6**
CV		**17.64**	**18.23**

Means with different letter on the table are statistically significant at P-values < 0.01 based on the LSD (Least significance difference) comparison method CV=coefficient of variance.

5.3.2. Root length and root number

The analysis of variance for storage root length of anchote was significantly ($p \leq 0.05$) influenced by only accession. location and interactions between location and accessions had no significant effect on storage root length (Appendix Table 3). The significantly highest (11.5 cm) and smallest (8.1 cm) storage root length was obtained from accessions Sheka and Gimbi respectively (Figure 3). It indicated presences of genetic variations among the Anchote accessions as was also discussed and reported by Tilahun (2012). Similarly, the variation of root length among Anchote accessions observed was concurrent with the work of Desta (2011) in 36 Anchote accessions. Enhanced root growth could have enhanced the ability of plants to access nutrients. Increments of root length facilitates more nutrient reserve exploitation as compared to potato and sweet potato and resulted in high dry matter storage. Usually, Anchote root grows downwards in to the soil and never requires ridging or mound making as compared to most other root and tuber crops.

The analysis of variance for root number was significantly ($p \leq 0.01$) influenced by main factors (location and accessions). Interaction between location and accession had no significant effect on storage root number (Appendix Table 3). The highst (1.33) and smallest (1.06) root numbers was obtained from accession Jimate and accession Sibu Sire3 respectively. Based on altitudes, longest (1.43) and smallest (1.07) storage root number was recorded from location Hula and Leku respectivly(table 12). This might be the effect of genetic and altitude related factors (soil type, temperature and rain fall).

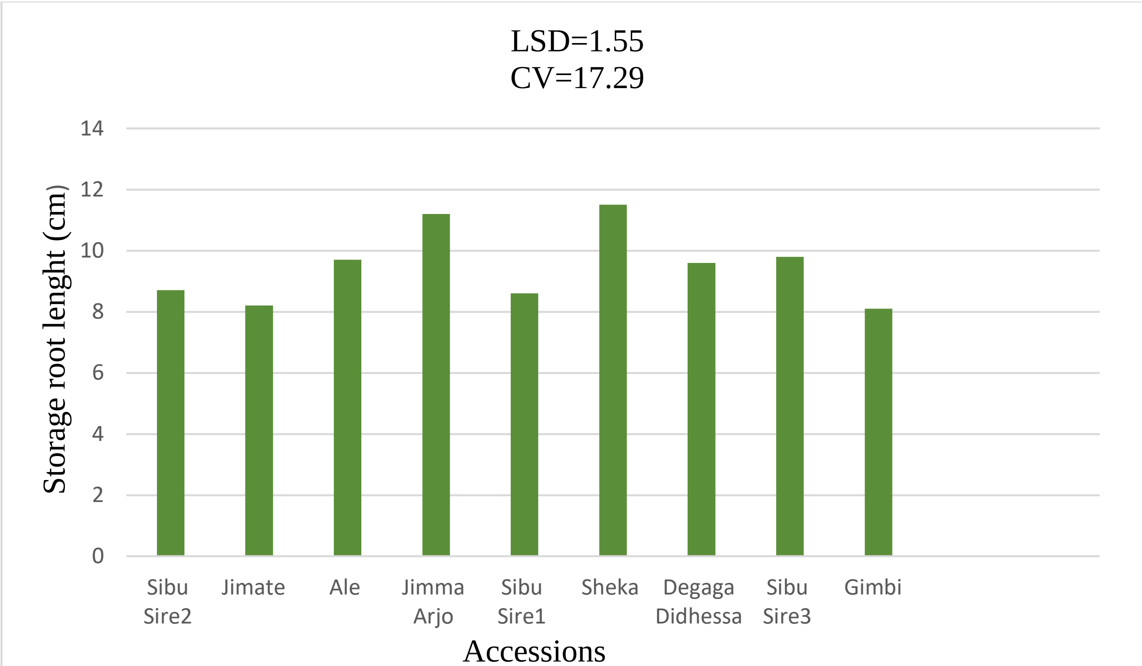

Figure 4. The effect of accessions on root length (cm) of anchote Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

Table 12. The effect of accessions and altitude on root number of anchote.

Accession	RN
Gimbi	1.11[bc]
Jimate	1.33[a]
Degaga Didhessa	1.1[bc]
Jimma Arjo	1.08[c]
Ale	1.28[ab]
Sheka	1.28[ab]
Sibu Sire1	1.2[abc]
Sibu Sire2	1.06[c]
Sibu Sire3	1.25[abc]
LSD (0.05%)	**0.19**
CV	**17.22**
	Altitude
Bilate	1.14[b]
Leku	1.07[b]
Hula	1.43[a]
LSD (0.05%)	0.11
CV	17.22

Means with different letter on the table are statistically significant at P-values < 0.01 based on the LSD (Least significance difference) comparison method CV=coefficient of variance

5.3.3. Root diameter and underground dry weight

The storage root diameter and underground dry weight of anchote were significantly ($p \leq 0.001$) influenced by location and accession and the interaction effect of the two main factors (Appendix Table 3, 4). The highest storage root diameter (78.8 mm) was obtained from Degaga Didhessa anchote accession under Leku locations (Table 13). Whereas, the lowest storage root diameter (36.5 mm) was obtained from Gimbi anchote accession under Bilate location. The diameter of storage roots varied due to the growth pattern of the plant which was influenced by genotypic characteristics as well as adaptation capacity to the environments. Shamilo (2021) stated that storage root diameter was highly significantly affected by variety and altitudes. Habibur *et al*. (2015) who reported that diameter of storage root varied from variety to variety. According to Chipungu *et al*. (1999) and Nedunchezhiyan *et al*. (2010), storage root size, and number of storage root per plant are strongly related to storage root yield and these are highly affected by changes in environmental conditions.

With regard to underground root dry weight, the significantly highest (65.6 g) underground root dry weight was recorded from Sibu Sire1 under Leku conditions (Table 13). Whereas, the significantly lowest (43.3 g) underground root dry weight was obtained from Sheka under Bilate location. This result might be due to variety growth performance based on altitudinal soil variation (Table 5). The current result is in agreement with the finding of the Belehu (2003) who reported the highest dry weight of the storage root from crop planted at medium temperature regime and lowest value was from the plants grown at below 20 ^{0}C. Delowar and Hakim (2014) and Rahman *et al.* (2015) reported that dry weight of storage roots depends on the varietal performance to the particular soil and environments.

Table 13. The interaction effect of accessions and altitudes on root diameter (mm) and underground dry root weight (g) of Anchote.

Locations/Altitudes	Accessions	RD	UGDW
Bilate (1330 masl)	Sibu Sire2	51.1^{ghij}	47.3^{hijk}
	Jimate	61.5^{cdefg}	46^{jk}
	Ale	47.2^{ijkl}	45.6^{jk}
	Jimma Arjo	67^{bcde}	45^{jk}
	Sibu Sire1	61.3^{defg}	49^{ghij}
	Sheka	49.4^{hijk}	43.3^{k}
	Degaga Didhessa	68.3^{abcde}	46.6^{ijk}
	Sibu Sire3	54.9^{fghi}	55.3^{bcd}
	Gimbi	36.5^{l}	45.6^{jk}
Leku (1835 masl)	Sibu Sire2	50.8^{ghij}	59^{b}
	Jimate	65.7^{bcdef}	52^{defg}
	Ale	64.4^{cdef}	50.6^{efghi}
	Jimma Arjo	75.8^{ab}	50.6^{efghi}
	Sibu Sire1	67.6^{bcde}	65.6^{a}
	Sheka	71.8^{abcd}	51^{efgh}
	Degaga Didhessa	78.8^{a}	52.3^{defg}
	Sibu Sire3	68.6^{abcde}	57.6^{bc}
	Gimbi	59.2^{efgh}	53^{defg}
Hula (2504 masl)	Sibu Sire2	51^{ghij}	54.6^{cde}
	Jimate	50.6^{ghij}	58^{bc}
	Ale	45.6^{ijkl}	50.3^{fghi}
	Jimma Arjo	49.6^{hijk}	50.6^{efghi}
	Sibu Sire1	39.6^{kl}	55.3^{bcd}
	Sheka	42^{jkl}	50.6^{efghi}
	Degaga Didhessa	72.3^{abc}	58^{bc}
	Sibu Sire3	43^{jkl}	50.6^{efghi}
	Gimbi	51.3^{ghij}	54^{cdef}
LSD		**10.9**	**4.09**
CV		**11.65**	**4.83**

Means with different letter on the table are statistically significant at P-values < 0.001 based on the LSD (Least significance difference) comparison method CV=coefficient of variance.

5.3.4. Storage root yield and dry matter content

The analysis of variances revealed that storage root yield of anchote accessions were significantly ($P < 0.001$) affected by accessions, location and their interaction between location and accession (Appendix Table 4). The significantly highest yield (59.6 t h^{-1}) was obtained from anchote accession Degaga Didhessa planted at mid altitude /Leku location. Whereas the significantly lowest yield (12.3 t h^{-1}) was recorded from anchote accessions Gimbi planted at low altitudes/ Bilate location (Table 14). The comparable total root yield was obtained by Daba et al. (2012) who reported the total average root yield of 55.7 t h^{-1} and 63.2 t h^{-1} at Jima and Ebantu respectively. However, the current study root yield was much lower than the average root yield 70 t h^{-1} reported by Desta (2011). Such variations might be attributed to the variations in accession type, genetic makeup, soil fertility status and properties among the locations.

The variation observed attributed to variation in genetic makeup of the accessions and variability in climatic and soil factors among the different location resulted in different dry matter accumulation and yield among the environment and tested accessions. Daba et al. (2012) also attributing underground dry weight and root yield variation of anchote accessions at different locations observed to genetic variability and climatic and soil factor.

The analysis of variances revealed that storage root dry matter content of anchote accessions were significantly ($P < 0.001$) affected by accessions, altitudes and their interaction (Appendix Table 4). The significantly highest yield (32.8) was obtained from Sibu Sire1 anchote accession planted at mid altitude /Leku location. Whereas the significantly lowest yield (21.7) was recorded from anchote accessions Gimbi planted at low altitudes/ Bilate location (Table 14). dry matter production and partitioning pattern in anchote accessions is not known so far (Desta, 2011).

According to the result, the root yield and root dry matter (%) were directly proportional to each other in that higher root yielding accessions also had higher percentage of root dry matter and the low root yielding ones had lowest values of dry matter. The result of this experiment was concurrent with the work of Desta (2011) in 36 Anchote accessions.

Table 14. The interaction effect of accessions and altitudes on root yield (ton) and dry matter content (%) of Anchote per hectare.

Locations/Altitudes	Accessions	DMC (%)	YIELD (ton)
Bilate (1330 masl)	Sibu Sire2	23.7^{hijk}	30^{def}
	Jimate	23^{jk}	24.6^{efghi}
	Ale	22.8^{jk}	17.6^{ijk}
	Jimma Arjo	22.5^{jk}	21.6^{fghij}
	Sibu Sire1	24.5^{ghij}	20^{ghijk}
	Sheka	21.7^{k}	28.3^{defg}
	Degaga Didhessa	23.3^{ijk}	27^{defgh}
	Sibu Sire3	27.7^{bcd}	27.6^{defgh}
	Gimbi	22.8^{jk}	12.3^{k}
Leku (1835 masl)	Sibu Sire2	29.5 ^{b}	29.3^{def}
	Jimate	26 ^{defg}	29^{def}
	Ale	25.3 ^{efghi}	46.6^{b}
	Jimma Arjo	25.3^{efghi}	45.6^{b}
	Sibu Sire1	32.8^{a}	32^{cde}
	Sheka	25.5^{efgh}	47.3^{b}
	Degaga Didhessa	26.2^{defg}	59.6^{a}
	Sibu Sire3	28.8^{bc}	40^{bc}
	Gimbi	26.5^{defg}	25^{efghi}
Hula (2504 masl)	Sibu Sire2	27.3 ^{cde}	22.6^{fghij}
	Jimate	29B^{c}	22.3^{fghij}
	Ale	25.2^{fghi}	35^{cd}
	Jimma Arjo	25.3 ^{efghi}	21.6^{fghij}
	Sibu Sire1	27.7^{bcd}	19.6^{hijk}
	Sheka	25.3^{efghi}	26.6^{defgh}
	Degaga Didhessa	29.0^{bc}	44^{b}
	Sibu Sire3	25.3^{efghi}	24^{efghi}
	Gimbi	27^{cdef}	15^{jk}
LSD		**2.05**	**8.47**
CV		**4.84**	**17.57**

Means with different letter on the table are statistically significant at P-values < 0.05 based on the LSD (Least significance difference) comparison method CV=coefficient of variance.

The overall anchote yield and yield components varied among the accessions and locations. The variation in yield observed among the locations may be attributed to weather or climatic factors and the duration of growing periods as was also mentioned and discussed by Daba et al. (2012). From this study all the storage root yield produced from all location were highly marketable because there was no physical damage and disease that affect economic part of anchote, also there was no over and under sized roots. The recorded average size root size diameter range was 36.67 mm to 78.86 mm which was in the range of average size for anchote Dasta (2011) and Daba et al., (2012). As a result, all total yield were marketable even though there were slight variation among accession and location.

Study on sweet potato has shown that greater plant growth and dry matter accumulation could be expected at high altitude locations in the tropics (Behera et al., 2010). This study is also in line with Manrique and Hermann, (2000) who reported significant difference in response of root yield and root diameter of sweet potato among genotypes across locations. The variation in root yield may be also due to climatic or soil factor differences among locations, especially during the root growing period. The water stress during critical periods of root growing have been resulted in low root yield and quality defects in Anchote. The wider variability in root revealed in Anchote accessions at different locations is in agreement with the root traits diversity exhibited in dry mater and root yield variability of sweet potato germplasm collection from Tanzania (Elameen et al., 2011).

5.4. Correlation analysis

The correlation values explained the association between different parameters and clearly indicated the magnitude of their relationships. Correlation analysis indicated that, yield and yield related parameters have strong and non-significant positive and negative relation (Table 15).

Anchote total biomass had positive correlation with leaves number, leaf area, vine number, above ground fresh biomass and root number and also have negative correlation with flowering date emergency percentage, above ground dry biomass and root number.

Anchote yield had positive correlation with most parameters except leaves number, root number and underground weight. Root weight and root diameter had strong correlation with yield. Underground dry weight had negative correlation with leaves number, leaf area, vine length and it had strong positive correlation with yield and slight correlation with other parameters.

Correlation analysis indicated that Anchote yield had positive correlation with most parameters except leaves number, root number and underground weight. Underground dry weight had negative correlation with leaves number, leaf area, vine length and it had strong positive correlation with yield and slight correlation with other parameters.

Table 15**.** The Pearson Product Moment Correlation Coefficient(r) for yield and yield component

	LN	LA	VN	VL	AGFB	AGDB	RL	RW	RN	RD	TBM	YIELD	UGDW	EMPR	FED
LN	1.00														
LA	0.15	1.00													
VN	0.21	0.51	1.00												
VL	0.38	0.61	0.57	1.00											
AGFB	0.19	0.48	0.47	0.46	1.00										
AGDB	-0.20	-0.08	-0.20	-0.23	-0.04	1.00									
RL	0.18	0.15	0.24	0.08	0.16	0.03	1.00								
RW	0.11	0.20	0.37	0.06	0.22	0.12	0.47	1.00							
RN	-0.12	-0.27	-0.25	-0.31	-0.34	-0.05	-0.13	0.02	1.00						
RD	0.24	0.29	0.46	0.20	0.34	0.09	0.35	0.75	-0.3	1.00					
TBM	0.50	0.55	0.61	0.63	0.57	-0.12	0.38	0.64	-0.2	0.60	1.00				
YIELD	-0.02	0.19	0.30	0.03	0.23	0.19	0.41	0.82	-0.2	0.71	0.48	1.00			
UGDW	-0.2	-0.01	0.01	-0.18	0.12	0.08	0.02	0.22	0.05	0.28	0.08	0.64	1.00		
EMPR	-0.32	-0.21	-0.08	-0.12	0.01	-0.01	0.14	0.09	0.04	0.17	-0.13	0.20	0.18	1.00	
FWD	-0.14	-0.51	-0.41	-0.64	-0.46	0.09	0.09	0.03	0.54	-0.3	-0.52	-0.13	0.10	0.32	1.00

Where, LN=leave number, LA=leaf area, VN=vine number, VL=vine length, AGFB=above ground fresh biomass, AGDM= above ground dry biomass, RL= root length, RW= root weight, RN= root number, RD=root diameter, TBM= total biomass, UGDW= underground dry weight, EMPR= emergency percentage, FWD=flowering date

6. CONCLUSION AND RECOMMENDATION

Anchote is an annual trailing vine belonging to the Cucurbitaceae family best known and grown principally for its tuberous root even though its tender leaves are also widely used as food (Abera, 1995). Root and tuber crops are important in supplying balanced diet in small scale farming communities. Anchote is one of the most important root crops grown in western Ethiopia. Anchote dish is popular among restaurants and groceries as cultural food in the region.

The present study has evaluated anchote accessions under different locations (Bilate, Leku and Hula) using factorial combination of 9 accessions. Data on crop phenology, growth and yield performances were collected and analyzed using SAS software.

Results of this experiment revealed that most parameters such as leave number, leaf area, vine length, above ground fresh biomass, above ground dry biomass, root weight, root diameter, total biomass, underground dry weight, emergency percentage and dry matter content were significantly influenced by location, accession and their interaction. Root number and days to 50% flowering were not influenced by interaction effects. Overall, taking all these above data into consideration we can conclude that different altitudes affect growth, yield and yield related parameters.

The results indicated that there was variation among responses of accession planted under different location. Most of accessions evaluated at Leku performed better on above ground fresh weight, above ground dry weight, emergency percentage, root weight, root diameter, total biomass, underground dry weight, dry matter content and also yield. On the other hand, the highest leaf number, leaf area, vine length above ground fresh biomass were obtained from low land location/Bilate. However, the least root weight, root number, root diameter and yield were obtained from low altitude location or Bilate. The response of accessions is opposite on high land (Hula).

Growth parameters are minimum relative to yield and yield related parameters. Overall, different altitudinal location affects growth, yield and yield related traits of anchote. The result obtained in this study show significant variation, which influenced adaptation of the accession in the three altitudes.

Anchote can adapt and grow in wider agro-ecologies and perform most similarly but needs good cultivation practices and soil fertility but, regarding to location the medium altitude is more productive and showed good anchote performance. The anchote accessions tested in this study showed a differential response to different altitudes. we recommended accession Degaga Didhessa, Sheka and Sibu Sire1 that produced better storage root yield, high underground dry mass, root weight and storage root dry matter content across three locations. It must be noted in mind that this study was conducted on a some anchote accessions under three different altitudes in one season. It may be ideal to recommend the results of this research. Therefore, further replicated trails over two or more seasons in more different locations(altitudes) and accessions with physiological parameters to increase the validity of the finding.

7. REFERENCES

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8. APPENDICES

Appendix table 1. Analysis of variance of leaf number, leaf area, vine length and vine number of anchote accessions.

		Parameters			
Source variation	DF	LN	LA	VN	VL
Location	2	7679***	5419**	8.21**	37.42**
Accession	8	571***	102**	0.45ns	0.71**
Accession*location	16	700***	179**	0.73ns	0.77**
Error		83.69	32.70	0.54	0.29
CV (%)		16.03	11.75	31.54	22.73

*The sign ns, * ** and *** indicates; non-significance different (P>0.05), significance difference (P<0.05), highly significant difference (p<0.01) and very highly significant difference (P<0.001) respectively, LN= leaf number, LA= leaf area, VL=vine length, VN=vine number, and DF= degree of freedom*

Appendix table 2**.** Analysis of variance of above ground fresh biomass, above ground dry biomass, flowering date, and emergency percentage of anchote accessions.

		Parameters			
Source variation	DF	AGFB	AGDB	50%FD	EMPR
Location	2	1034162***	603.05**	15428***	890.25***
Accession	8	32354**	110.71***	46.30**	377.05***
Accession*location	16	21320**	107.01**	25.60ns	84.28***
Error		2777	17.31	14.11	8.24
CV (%)		16.27	9.10	3.55	4.01

*The sign ns, * ** and *** indicates; non-significance different (P>0.05), significance difference (P<0.05), highly significant difference (p<0.01) and very highly significant difference (P<0.001) respectively AGFB=above ground fresh biomass, AGDB= above ground dry biomass, 50%FD=500% flowering date, EMPR= emergency percentage and DF= degree of freedom*

Appendix table 3. Analysis of variance of *root weight, root diameter, root number and root length* of anchote accessions.

		Parameters			
Source variation	DF	RL	RW	RN	RD
Location	2	5.28ns	69294***	0.97***	2210***
Accession	8	13.62***	32023**	0.09**	490***
Accession*location	16	3.71ns	24555**	0.06ns	154***
Error		2.71	1643	0.04	44
CV (%)		17.29	17.64	17.22	11.65

*The sign ns, * ** and *** indicates; non-significance different (P>0.05), significance difference (P<0.05), highly significant difference (p<0.01) and very highly significant difference (P<0.001) respectively RW= root weight RD=root diameter, RN= root number RL=root length and DF= degree of freedom.*

Appendix table 4. Analysis of variance of yield, total biomass and underground dry biomass of anchote accessions.

		Parameters			
Source variation	DF	TBM	DMC	Yield	UGDW
Location	2	272184***	112.8***	2049.15***	451.12***
Accession	8	83132***	18.5***	485.83***	73.73***
Accession*location	16	46647**	8.8***	117.27***	35.24***
Error		7580	1.56	26.75	6.249
CV (%)		18.23	4.84	17.57	4.83

*The sign ** and *** indicates; highly significant difference (p<0.01) and very highly significant difference (P<0.001) respectively yields, TBM= total biomass, UGDW= underground dry biomass and DF= degree of freedom.*

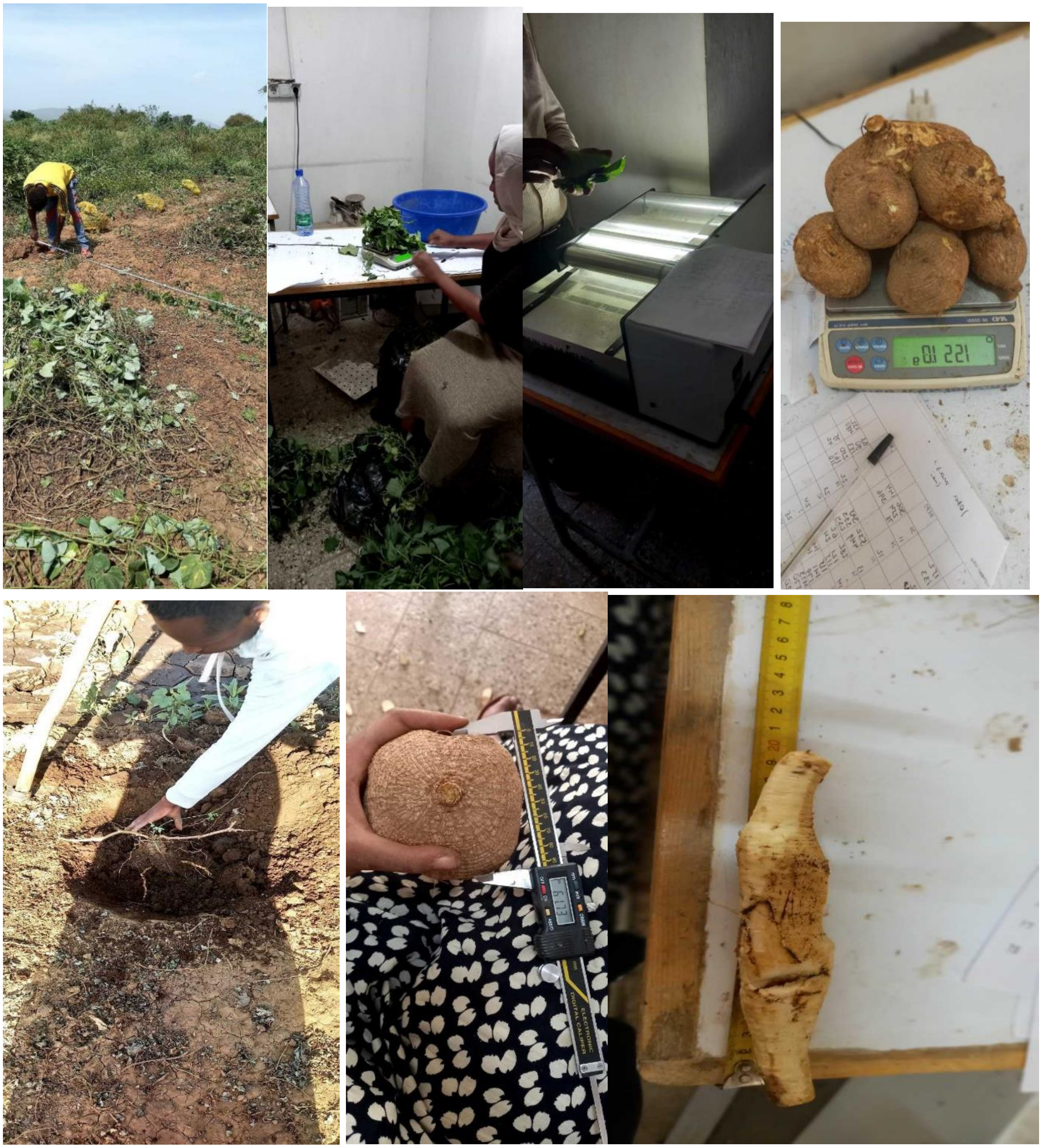
FIGURES IN APPEDICE

Bilate (1330m.a.s.l) Leku (1835m.a.s.l) Hula (2504m.a.s.l)

Appendix figure 1: Land preparation under three locations.

Bilate (1330m.a.s.l) Leku (1835m.a.s.l) Hula (2504m.a.s.l)

Appendix figure 2: Growth performance of achote accessions under three locations



Appendix figure 3: data collection from three location

Bilate (1330m.a.s.l) Leku (1835m.a.s.l) Hula (2504m.a.s.l)

Appendix figure 4: Anchote accessions storage root yield under three locations

BIOGRAPHICAL SKETCH

The author was born on January 25, 1996 GC at Dessie southwollo, Ethiopia. She attends her elementary school at salaysh primary school in kombolcha then she moves to mojo city and attended her secondary and preparatory class at school of excellence secondary and preparatory school. After the completion of Ethiopian Higher Education Entrance Examination (EHEEE) she joined Hawassa university in 2015 to pursue her first Degree and graduated BSc. In horticulture in June 2018. After her graduation, she had worked at Hawassa university as graduated assistant since 2018. After serving 1 year at Hawassa University, she has got a chance to attend her Master's program. In 2019/20 she joined the Graduate program in Horticulture at Hawassa University