2022-08

Effects of Intra Row Spacing On Growth and Yield Of Orange-Fleshed Sweet Potato (Ipomoea Batatas L.) Varieties In Bahir Dar, Amhara Region , Ethiopia

Alebachew Maru

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM

Effects of Intra Row Spacing on Growth and Yield of Orange-Fleshed Sweet Potato (*Ipomoea batatas* L.) Varieties in Bahir Dar , Amhara Region , Ethiopia

M.Sc. Thesis Research

By

Alebachew Maru

August 2022

Bahir Dar, Ethiopia

BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM

Effects of Intra Row Spacing on Growth and Yield of Orange-Fleshed Sweet Potato (*Ipomoea batatas* L.) Varieties in Bahir Dar , Amhara Region , Ethiopia

M.Sc. Thesis Research

By

Alebachew Maru

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (M.Sc.) IN ''HORTICULTURE''

August 2022

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by **Mr. Alebachew Maru** entitled **"Effects of Intra-Row Spacing on Growth and Yield of Orange-Fleshed Sweet Potato** *(Ipocioea botatas* L.) **Varieties in Bahir Dar, Amhara Region, Ethiopia".** We hereby certify that, the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Horticulture.

Board of Examiners

Semagn Asredie (PhD) ____________ 19/08/2022

Name of External Examiner — Signature — Date

Baye Berihun (PhD) ____________ 19/08/2022

Name of Internal Examiner — Signature — Date

Abaynew Jenber (PhD) ____________ 19/08/2022

Name of Chairman — Signature — Date

DECLARATION

This is to certify that this thesis entitled "**Effects of Intra-Row Spacing on Growth and Yield of Orange-Fleshed Sweet Potato (*Ipomoea batatas* L.) Varieties in Bahir Dar, Amhara Region, Ethiopia**" submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in "Horticulture" to Department Graduate Council of Horticulture, Bahir Dar University, by **Mr. Alebachew Maru** (BDU1300324) is an authentic work carried out by him under our guidance. The matter embodied in this thesis work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

MSc. Candidate: **Alebachew Maru** ______________ 19/08/2022

Name | Signature | Date

Advisor:

Mr.Tadele Yeshiwas ______________ 19/08/2022

Name | Signature | Date

ACKNOWLEDGEMENTS

First and foremost, I would like to praise and glorify the supreme Almighty God for providing me the strength and patience that I required to complete the study. I would also like to express my deepest and heartfelt gratitude as well as my most sincere appreciation to my advisor Mr. Tadele Yeshiwas for his suggestions and comments from the initial concept development to the final thesis write-up.

I have no word to express my unbound love for my dear wife, Melkam Addisu; my children, Eyoas Alebachew and Simon Alebachew; mother, Mrs. Simegne Ale; younger sister, Hana Maru and brother, Yibekal Melkamu for their encouragement throughout the study.

I would like to thank Mr. Atena Abebe and Mr. Ayechew Teshager for providing me computer for thesis write-up. Next, my gratitude goes to my dear friends, Mr. Fasikaw Belay and Mr. Tesfahun Belay and my instructor, Dr. Melkamu Alemayehu for their guidance and commenting my thesis.

Last but not least, I would like to convey my cordial thanks to Staffs of Woramit Horticulture Research and Training Subcenter for providing me research site and all the necessary inputs to my research.

DEDICATION

This thesis work is dedicated in loving memory of my father, Mr. Maru Mazengia and my mother, Mrs. Beletu Kassie and my best friend, Engineer Habtamu Taye.

ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CIP	International Potato Center
CRCT	Crop Science and Research Department
CSA	Central Statistical Agency
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistical Data
LSD	Least Significant Difference
m.a.s.l	Meter above sea level
MoA	Ministry of Agriculture
OFSP	Orange –Fleshed Sweet Potato
RAC	Reaching Agents of Change
RCBD	Randomized Complete Block Design
SNNPR	Southern Nations, Nationalities and Peoples' Region

Effects of Intra-Row Spacing on Growth and Yield of Orange-Fleshed Sweet Potato (*Ipomoea batatas* L.) Varieties in Bahir Dar, Amhara Region, Ethiopia

By:

Alebachew Maru

Advisors: Mr. Tadele Yeshiwas (Asst.Prof)

ABSTRACT

Orange fleshed sweet potato is an important food and nutrition security crop in Ethiopia. However, its productivity is low (8 t ha^{-1}) due to the use of low-yielding variety and inappropriate plant spacing., a field experiment was conducted at Wormait Horticulture research and training center at Bahir Dar during the 2021 rainy season with the objective of determining the effect of varieties and intra row spacing on the productivity of the crop. The treatments consisted of three intra row spacing (20, 30 and 40 cm) and four varieties (Alamura, Dilla, Kulfo and Birtukanie). The experiment was laid out ina Randomized Complete Block Design in a factorial arrangement with three replications. Growth and yield parameters of sweet potato were collected using standard procedgures and analysied using SAS 9.4. The results of ANOVA analysis showed that the interaction effect of varieties and intra row spacing had significantly affected most of the parameters studied except surivavte rate, number of branch per plant and unmarketable yield which were significantly affected by main effects of varieties and intra row spacing. Highest (171.7 cm) and lowest (61.5 cm) vine lengths were recorded from treatment combination of Dilla variety with 40 cm intra row spacing and Kulfo variety with 20 cm intra row spacing, respectively. The highest number of storage roots per plant (9.2) and storage root length (25.6 cm) were obtained from the treatment combination of Alamura variety with 30 cm intra row spacing.. Treatment combination of Birtukanie variety with 30 cm intra row spacing generated the highest marketable yield (22.8 t ha^{-1}), net benefit (397,855.3 ETB ha^{-1}) with acceptable MRR (408.4%), which can be recommended for profitable production of sweet potato in the study area and areas with similar agro-ecologies. As the study was conducted at one location for a single season, repetition of the study across different representative agro-ecologies and seasons is also recommended.

Keywords:Variety, Plant density, Storage root

TABLE OF CONTENTS

THESIS APPROVAL SHEET iii
DECLARATION iii
ACKNOWLEDGEMENTS iv
DEDICATION vi
ABBREVIATIONS AND ACRONYMS vii
ABSTRACT viii
LIST OF TABLES xi
LIST OF FIGURE xii
LIST OF APPENDIX TABLES xiii
LIST OF APPENDIX FIGURES xv
Chapter 1. INTRODUCTION 1
1.1Background and Justification 1
1.2 Statement of the Problem 2
1.3 Objectives 3
1.3.1 General objective 3
1.3.2 Specific objectives 3
Chapter 2. LITERATURE REVIEW 4
2.1 Description of Sweet potato 4
2.2 Nutritional and Economical Importance of Oragnge Fleshed Sweet potato 5
2.3. Environmental and Edaphic Requirement of Sweet potato 6
2.4 Effect of Intra Row Spacing on Growth and Yield of Orange Fleshed Sweet Potato 7
2.5 Growth and Yield of Orange fleshed Sweet Potato Varieties 8
2.6 The Interaction Effect of Intra Row Spacing and Varieties on the Growth and Yield of Orange fleshed Sweet Potato 9
Chapter 3. MATERIALS AND METHODS 10
3.1 Description of Experimental Materials 11
3.2 Experimental Treatments and Design 12
3.3 Experimental Procedures and Management of the Experimental Plants 13
3.4 Data Collection 13
3.4.1 Phenological parameters 13

3.4.2 Growth parameters 14
3.4.3 Yield and Yield Components 14
3.5 Data Analysis 15
3.6 Partial Budget Analysis 15
Chapter 4. RESULTS AND DISCUSSION 17
4.1 Effects of Intra row Spacing and Varieties on Phenological Parameters of Orange Fleshed Sweet Potato 17
4.1.1 Survival rate 17
4.1.2 Days to physiological maturity 18
4.1.3 Vine length 19
4.1.4 Number of branches per plant 21
4.2 Effects of Intra row Spacing on the Yield Components of Orange Fleshed Sweet Potato Varieties 22
4.2.1 Number of storage roots per plant 22
4.2.2 Storage root length 23
4.2.3 Storage root diameter 24
4.2.4 Aboveground fresh weight 25
4.2.5 Storage root weight 25
4.3 Effects of Intra row Spacing on the Yield of Orange Fleshed Sweet Potato Varieties 26
4.3.1 Marketable storage root yield 26
4.3.2 Unmarketable yield 27
4.3.3 Total yield 29
4.4 Relationships of Growth and Yield parameters of Sweet potato as Influenced by variety and Intra Row Spacing 31
4.5 Partial Budget Analysis 32
Chapter 5. CONCLUSION AND RECOMMENDATIONS 35
5.1. Conclusion 35
5.2. Recommendations 36
REFERENCES 37
APPENDICES 46
BIOGRAPHY 65

LIST OF TABLES

Table		Page
3.1.	Description of the four orange fleshed sweet potato varieties used as experimental materials	12
3.2.	Treatment combinations used in the study	13
4.1.	Interaction effect of variety and intra row spacing on vine length of Sweet Potato	18
4.2.	Main effects of Varsity and Intra Row Spacing on number of branch per plant Sweet Potato	19
4.3.	Interaction effect of variety and intra row spacing on yield components of sweet Potato	23
4.4.	Main effect of variety and intra row spacing on unmarketable yield of sweet potato	25
4.5.	Interaction effect of variety and intra row spacing on marketable and total yield of Sweet Potato	27
4.6.	Relationships of growth and yield parameters of Sweet potato, grown at Woramit Kebele as influenced by varieties and intra row spacing	28
4.7.	Partial budget analysis of Sweet Potato as affected by varieties and intra row spacing in Woramit Kebele during the 2021 rainy season	30
4.8	Dominance and Marginal Rate of Return analysis of Sweet potato as affected by varieties and intra row spacing in Woramit kebele during the 2021 rainy season	31

LIST OF FIGURE

Figure	Page
3.1. Map of the study area	11

LIST OF APPENDIX TABLES

Appendix Table		Page
1.	Main effect of variety and intra row spacing on days to physiological maturity of Orange fleshed Sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season	47
2.	Main effect of variety and intra row spacing on vine length of Orange fleshed Sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season	48
3.	Main effect of variety and intra row spacing on number of storage roots per orange fleshed sweet potato plant at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season	49
4.	Main effect of variety and intra row spacing on storage root length of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season	50
5.	Main effect of variety and intra row spacing on storage root weight of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season	51
6.	Main effect of variety and intra row spacing on storage root diameter of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season	52
7.	Main effect of variety and intra row spacing on above ground fresh weight of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season	53
8.	Main effect of variety and intra row spacing on marketable yield of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season	54
9.	Main effect of variety and intra row spacing on above total yield of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021	55

LIST OF APPENDIX TABLES (CONTINUED)

10.	Analysis of variance for survival rate	56
11.	Analysis of variance for days to physiological maturity	56
12.	Analysis of variance for vine length	56
13.	Analysis of variance for number of branches per plant	57
14.	Analysis of variance for number of storage roots per plant	57
15.	Analysis of variance for storage root length	57
16.	Analysis of variance for storage root diameter	57
17.	Analysis of variance for above ground fresh weight	58
18.	Analysis of variance for storage rootweight	58
19.	Analysis of variance for marketable yield	58
20.	Analysis of variance for unmarketable yield	59
21.	Analysis of variance for total yield	59

LIST OF APPENDIX FIGURES

Appendix Figure		Page
1.	Picture taken during land preparation in 2021 growing season in Woramit Horticulture Research and Training sub center	59
2.	Picture taken during planting materials preparation in 2021 growing season in Woramit Horticulture Research and Training sub center	60
3.	Picture taken during planting in 2021 growing season in Woramit Horticulture Research and Training sub center	61
4.	Picture taken during data collection during 2021 growing season in Woramit Horticulture Research and Training sub center.	62
5.	Scare crow used to deter animals during 2021 growing season in Woramit Horticulture Research and Training sub center	63
6.	Picture taken during 2021 growing season in Woramit Horticulture Research and Training sub center.	64

Chapter 1. INTRODUCTION

1.1 Background and Justification

Ethiopia has highest potential for root and tuber crop production than any country in Africa. This can be explained by the fact that the country has abundant natural resources and favorable agro-ecological conditions that are suitable for the production of root and tuber crops. Root and tubers contribute a major share of traditional food system in Ethiopia (EIAR, 2015). The principal root and tuber crops in Ethiopia include Enset, Potato, Taro, Yams, Anchote, Cassava, Tannia and Sweet potato. Sweet potato (*Ipomoea batatas* L.) is grown for its tuberous storage roots for food security and income generation. It has large, starchy, sweet-tasting and tuberous roots (Fekadu Gurumu, 2019).

Sweet potato is an important root crop globally, and ranked Africa's second most important staple root crop after cassava (FAOSTAT, 2014; Wassu Mohammed *et al*., 2015). It is not only a staple food, but it is also an important industrial raw material for animal feed and alcohol production in different countries. In Africa, sweet potato is increasingly becoming an important economic crop due to its potential of alleviating poverty, reducing night blindness (using orange-flesh varieties), and improving the nutritional status of the rural poor in an inexpensive and sustainable way (FAO, 2004).

The fresh roots can be boiled or roasted as well as processed into pure to use in a range of products including breads, chapattis, cakes, juices, porridge *etc*. The fresh roots can be cut into small pieces, sundried, and kept as food stock, which can be rehydrated and eaten or made into flour. In some countries, sweet potato roots are processed to produce starch, noodles, candy, pink to black cloth dyes and fermented to make alcohol. In China, sweet potato starch production has become an important cottage industry. Moreover, sweet potato mainly organge fleshed sweet potato (OFSP) has high nutritive value and contains carbohydates, protein, fat, fiberm, vitamin A and C and minerals. Further more, the leaves can be used as food for humans and animals (CIP, 2018).

Sweet potato is the seventh most important food crop and second most important storage root crop in the world after Irish potato with an annual production of 124 million tons produced on 9 million hectares of land (FAOSTAT, 2021). In Africa, sweet potato is the second most important root crop after cassava with the production of 12.6 million tons produced on 2.9 million hectares (FAOSTAT, 2020). Its production is concentrated in the East African countries around Lake Victoria (Echodu *et al.*, 2019).

Sweet potato is widely grown in south, south western and eastern parts of Ethiopia by small scale farmers. It is one of the most important root crops produced in Ethiopia and occupied about 53,499 hectares of land with a total annual production of 1.85 million tons with average national yield of 8 tons ha^{-1} (CSA, 2018) which is low compared to the world average of about 14.8 ton ha^{-1}). Moreover, the quality of the roots produced in Ethiopia is low (Fekadu Gurumu, 2019). The major causes of this low yield and quality are inappropriate agronomic practices including inappropriate varieties, inappropriate plant density, rates of fertilizers,soil fertility depletion and pests (Tesfaye Tadesse *et al*., 2011) .

As indicated in the above paragraphs, several researchers found the influence of plant density and use of impro ved varieties on growth and yield of sweet potato. Hence, this study was initiated with the objective of determining the optimum intra row spacing for economical production of orange-fleshed sweet potato varieties in the study.

1.2 Statement of the Problem

Sweet potato is mainly produced in South Nations Nationalities and Peoples Region in Ethiopia. but in , Amhara Region is not the major producer of the crop. On the other hand, the region is suffering from nutrition security where nutritous root crops like orange fleshed sweet potato is not common. In recent years, however, Bureau Agriculture and Amhara agricultural research institute are trying to introduce sweet potato to the lowland parts of the region. Accordingly, Sirinka and Adet agricultural reaserch centers have been conducting variety evaluation and yield performance experiments on this crop and released some varieties so far.

Studies towards optimization of agronomic practices like intra row spacing of sweet potato in Amhara region are lacking. Sweet potato in the region is produced using the blanket recommended intra row and inter row spacing of 30 and 60 cm, respectively (Fekadu Gurumu, 2019), without considering the environmental conditions and the variety used. Implementing appropriate agronomic practices can increase sweet poato yield up to 64.4 t ha^{-1} (Abdissa Teshome *et al*., 2011).

The demand for sweet potato in the region is also in increasing trend (Selina Wamucii, 2022). Increasing the production and productivity of sweet potato is therefore necessary to alivate shortage and seasonal supply of the crop and nutrition insecurity in the region. The ultimate goal of the present study is therefore to increase production and productivity by determining the optimum intra row spacing of of sweet potato varieties.

1.3 Objectives

1.3.1 General objective

- The general objective of the study was to contribute for enhanced production and productivity of orange fleshed sweet potato through determining the optimum plant population and best performing variety in the study area.

1.3.2 Specific objectives

The specific objectives of the study were to

- Evaluate the effects of intra row spacing and variety on growth and yield of orange fleshed sweet potato.
- Identify the optimum intra row spacing and best performing variety for economical production of orange fleshed sweet potato in the study area.

Chapter 2. LITERATURE REVIEW

2.1 Description of Sweet potato

Sweet potato (*Ipomoea batatas* L.) 2n=6x=90 is a perennial plant cultivated as an annual crop. It is a dicotyledonous plant and belongs to the morning glory family (Convolvulaceae) (Troung *et al*., 2011; Fekadu Gurumu, 2019). Most sweet potato cultivars are self-incompatible where seeds produced through self pollination are difficult to germinate.

Sweet potato is commonly propagated vegetatively by stem or vine cuttings. The root system of sweet potato is divided into storage, fibrous and pencil roots and lateral roots. The most important functional differences between these root types are their capacity for storage root initiation in specific region of the thick roots (Wilson, 1982; Kays, 1985). According to Agata (1982), the storage root formation starts about 30 to 35 days after planting and root dry weight increases linearly until harvest.

The stem of sweet potato is called vine. The vine is a long thin stem that trail on the surface of the soil, which can produce roots at the nodes. The length of the vine varies and ranges from 1to 6m.The stem is circular or slightly angular and it is predominantly green in color based on the length of their vines. sweet potato genotypes are classified as erect, bushy and intermediate, or spreading (Yen, 1974; Kays, 1985).

Sweet potato has internodes and these Internodes length is highly variable, ranging from a few centimeters up to 10 cm in length. Planting density has a pronounced effect on the internodes length as well as on vine length (Somda andKays, 1990a).

Sweet potato branching is cultivar dependent and branches are vary in number and length. Normally, sweet potato plants produce three types of branches, primary, secondary and tertiary, at different periods of growth. The total number of branches varies between 3 and 20 among cultivars. Spacing, photoperiod, soil moisture and nutrient supply influence the branching intensity in sweet potato plant (Sasaki *et al*., 1993).

The leaves of sweet potato occur spirally on the stem. The total number of leaves per plant varies from 60 to 300 (Somda *et al*., 1991). The number of leaves per plant increases with decreasing plant density (Somda and Kays, 1990b), increasing irrigation (Indira and Kabeerathumma, 1990; Holwerda and Ekanayake, 1991; Nair and Nair, 1995), and N application (Nair and Nair, 1995).

Sweet potato petiole length varies widely with genotypes and may range from approximately 9 to 33 cm. The petiole retains the ability to grow in a curved or twisted manner to expose the lamina to maximum light. In the early stages of development of the canopy petiole length is at its minimum, but towards the middle and latter part of the growing season petiole length increases substantially with an increase in canopy size (Yen, 1974).The flowers of sweet potato are born solitarily or on cymosely inflorescences that grow vertically upward from the leaf axis, each flower has five united sepals, and five petals joined to form a funnel-shaped corolla tube. This tube is purplish in color and is the most conspicuous part of the flower. Each flower opens before dawn on a particular day, stays open for a few hours, then closes and wilts before noon the same day. Pollination is by insects, particularly by bees and the physiology of the sweet potato flower is complex. Due to these features seed production is difficult (Purseglove, 1972; Onwueme, 1978). According to (Purseglove, 1972 and Onwueme,1978) in sweet potato a false septum, formed during fruit development, have no viable seeds and the testa is very hard and almost impermeable to water and oxygen and germination of seeds is difficult to use as a planting materials rather than using the stem part or vines what we call asexual propagation.

2.2 Nutritional and Economical Importance of Oragnge Fleshed Sweet potato

Sweet potato is a rich source of carbohydrates and dietary fibers. Especially orange-fleshed sweet potato (OFSP) contains β-carotene, a precursor of vitamin A, and its leaves are rich in proteins. The roots also contain vitamins C, B complex, and E as well as potassium, calcium, and iron. Purple-fleshed sweet potatoes contain anthocyanin that has antioxidant and anti-cancer properties (RAC, 2012).. According to Collins (1984), Sweet potato preparation varies with respect to location and the purpose for which it is been used but in Ethiopia, roots are boiled unpeeled or roasted unpeeled, or less commonly, the sweet potato is boiled or fried with other vegetables or root crops.

Sweet potato serves as important crop for both domestic and industrial purposes. According to Collins (1984), The storage roots are used as staple food and to feed animals. In some part of the world, the crop is made into flour, which is cooked for human consumption the crop is used as raw material for industrial purposes as a starch source and for alcohol production. It is also used in the baking industries sand the preparation of adhesives, textile and paper sizing. It has agricultural advantages such that high yield, Low labor requirement, low cost, low risk and directly benefit the poor people through improving their incomes and nutritional status.

2.3. Environmental and Edaphic Requirement of Sweet potato

Sweet potato is widely grown between 40°N to 40° S latitudes and at altitudes as high as 2500 m above sea level near the equator (Hahn and Hozyo, 1984). They grow best where the average temperature is 24°C (Kay, 1973). At temperatures below 10°C growth is severely retarded. The crop is damaged by frost, and this restricts the cultivation of sweet potato in the temperate regions to areas with a minimum frost-free period of 4 to 6 months. Even where the frost-free period is sufficiently long, it is still essential that temperatures should be relatively high during much of the growing period. In the tropics, yield declines with increasing altitude as do the number of roots and the proportion of roots that are marketable. Increasing altitude also delays maturity (Negeve *et al.,* 1992).

Sekioka (1964) reported yields to be 5 to 6 times higher at 25/20°C than at 15/13°C (day/night), and higher at a soil temperature of 30°C than 15°C. On the other hand, Young (1961) found that high night temperatures, by increasing carbon loss through respiration, are deleterious with yield substantially lower at 29/29°C than at 29/20°C. Seasonal plantings in north-western Argentina suggest that flower and seed production are best with daily maximum temperatures between 23 to 24°C and minimum temperatures between 13 to 19°C (Folquer, 1974). In Puerto Rico, flowering in a greenhouse did not occur above 27°C (Campbell *et al.,* 1963).

Sweet potato performs best in regions with an annual rainfall of 750-1000 mm, with about 500 mm falling during the growing season. The timing and distribution of moisture supply as well as the amount affect yields. The crop is intolerant of water deficit during the first six weeks of planting and during storage root initiation. Hahn and Hozyo (1984) suggested that at other times it may have tolerance to drought. Sweet potato is intolerant to water logging, particularly during storage root initiation (Wilson, 1982; Hahn and Hozyo, 1984). Sweet potato grows best on sandy-loam soils and does poorly on clay soils. Good drainage is essential since the crop cannot withstand water logging. Where the water table is high, the crop is planted on mounds or ridges (Kay, 1973).

Soil with high bulk density or poor aeration tends to retard storage root formation and result in reduced yield (Watanabe *et al.*, 1968). Wet soil conditions at harvest lead to an increase in storage root rot and 6 adversely affect yields, storage life, nutritional and baking quality (Hahn and Hozyo, 1984). Sweet potato is often considered as a crop associated with poor soils. This is probably because it is well suited to sandy soils that are often infertile, and because storage root yields are sometimes depressed in very fertile or heavily fertilized soils. Nevertheless, good yields can be obtained only under conditions of high, but balanced, nutrition (Watanabe *et al*, *1968*).

2.4 Effect of Intra Row Spacing on Growth and Yield of Orange Fleshed Sweet Potato

Plant population refers to the number of plants per unit area and is important in root and tuber crop production since it has an influence on growth and yield of storage root. The planting density in sweet potato affects some of the important plant traits such as total yield, storage root size and quality (Belehu Tariku, 2003; Ogbologwung *et al.* 2016) and Mulken Demilie *et al.*, 2019).

According to Struik (2007) the yield of storage roots per hectare decreased with the increased plant spacing while reduction of plant spacing increased the hectare yield, while decreased the yield per plant. However, increasing planting space increased the proportion of large-sized storage roots. The plants having the widest spacing, produces the maximum weight of storage roots per hill and the highest yield of storage roots were also obtained from the closest spacing and the lowest was in the widest spacing.. Similarly, Berga and Caeser, (1990) and Alvin *et al.* (2007) reported the increased storage root yield per unit area while decreasing the yield per plant.

According to Muluken Demilie (2019), who conducted research at Middle Awash valley, weet potato needs optimum spacing (spatial arrangement) which enables growers to produce high quality storage roots yield. There was a difference in yield, storage root size and uniformity with various intra spacing. Varieties gave better yield at closer spacing of between rows and between plants. He has reported that closer plant spacing recorded the higher marketable yield with increased the yields of the most desired grade size storage root and the greatest monetary return. Marketable storage root yield was significantly reduced when plant spacing increased where the highest marketable storage root yield was obtained at closer spacing and the lowest yield at a wider plant spacing.

Plant density has shown to affect vine length and number of branches per plant of Sweet potato. Levy *et al*. (1985) reported that taller and more branched plants were obtained at the lower densities Jadhav *et al* (1992) and Aydogdu and Acikgoz (1995) also explained that closer spacing increased plant height. In contrast, Osei (1977) noted that increase in plant population did not increase plant height and final yield but reduced the number of branches.

Amato *et al*. (1992) and Loss *et al*. (1998) both reported that high plant densities of sweet potato lead to less number of branches. Ahmad *et al*. (2002) and Caliskan *et al*. (2004) summarized that plant height was gradually shortened with increased plant population and denser plant cultivars produced longer stems due to competition for available resources especially of light that penetrates the plant canopy. Wider inter-row and intra-row spacing also encouraged the number of branches per plant on safflower. Delgado and Yermanos (1975) stated that plant height of sweet potato increased with increased spacing.

2.5 Growth and Yield of Orange fleshed Sweet Potato Varieties

According to Alam *et al.* (2016) and Daniel Markos (2019) different sweet potato varieties responded differently. The yield and yield contributing characters of different sweet potato varieties were varied significantly due to varietal difference. According to the authors, varieties that have genetically longer plants recorded small storage root per plant and smaller storage roots while, high storage root number and storage root weight per plant, highest storage root diameter recorded from plants that are genetically short. Bezawit Mekonnen (2015) reported significant variation between orange fleshed sweet potato (OFSP) varieties for root diameter, number of storage rootous roots per plant, marketable storage root yield and total storage root yield.

Merga Boru *et al* (2018) reported, there were significant differences on performance of different sweet potato varieties on number of storage roots per plant, storage root fresh weight per plant, root dry weight per plant, root length and yield.

2.6 The Interaction Effect of Intra Row Spacing and Varieties on the Growth and Yield of Orange fleshed Sweet Potato

The interaction effects of intra row spacing and varieties on growth and yield components of sweet potato is reported by different researches.

A Study conducted by Muluken Demelle *et al.* (2019) on the effect of plant population and variety on yield and yield related traits of sweet potato under irrigated areas of middle awash valley of Ethiopia revealed the non-significant effect of variety and intra row spacing on marketable storage root yield, unmarketable storage root yield, total storage root yield, green top yield and root number per plant. However, plant population and variety found to have a highly significant effect on average root weight of sweet potato.

According to Damavandi and Asle-Gorgani (2005) report, the number of stems plant^{-1} at maturity, stem and leaf dry weight at maturity, and storage root dry weight compared to shoot dry weight were significant due to cultivar and density. A significant difference has observed among cultivar in plant height, number of branches, leaf area, storage root number and storage root weight. Abong (2010) reported that specific gravity, dry matter content differed significantly among the different potato cultivar. Potato crop growth and storage root yields have been linked to the duration of the growth cycle, which depends on climate, cultivar, and crop management (Kooman *et al.,* 1996). Saluzzo *et al.*(1999) also reported that variety with higher average storage root weight in addition to its late maturity might also be more efficient in dry matter partitioning to storage roots than variety with lower average storage root weight.

Chapter 3. MATERIALS AND METHODS

3.1 Description of the Study Area

The present study was conducted in Woramit Horticulture Research and Training sub-center of Adet Agricultural Research Center during 2021 rainy season. The sub-center is located in north-western part of Bahir Dar town on the shore of Lake Tana. It is geographically located at 11° 35′ 6″ North, 37° 23′ 24″ East (Figure 3.1)**.** The area has an altitude of 1800 meter above sea level. It has warm and humid climate with distinct dry and wet seasons. The mean daily maximum temperature is 29.5 °C in April, while the mean daily minimum temperature is 6.2 °C in January. The area receives a mean annual rainfall of 800 to 1250 mm. According to West Amhara Meteorological Service Agency (unpublished), the area is characterized as tepid moist mild agro-ecology. The soil of experimental site is Nitisol with the pH of 6.4, which is slightly acidic. The soil is clay loam with the textural classification of sand (13%), silt (33%) and clay (54%). It has very low organic matter content (3.9 %). Available phosphorus content is low (6.3 mg/kg). It has medium total nitrogen contents (0.16%) (Amhara design and supervision works, unpublished). Major crops grown in the study area are beetroot, carrot cabbage, tomato, papaya, mango, coffee, haricot bean maize and finger millet (Meneyahl Zegeye, 2021).

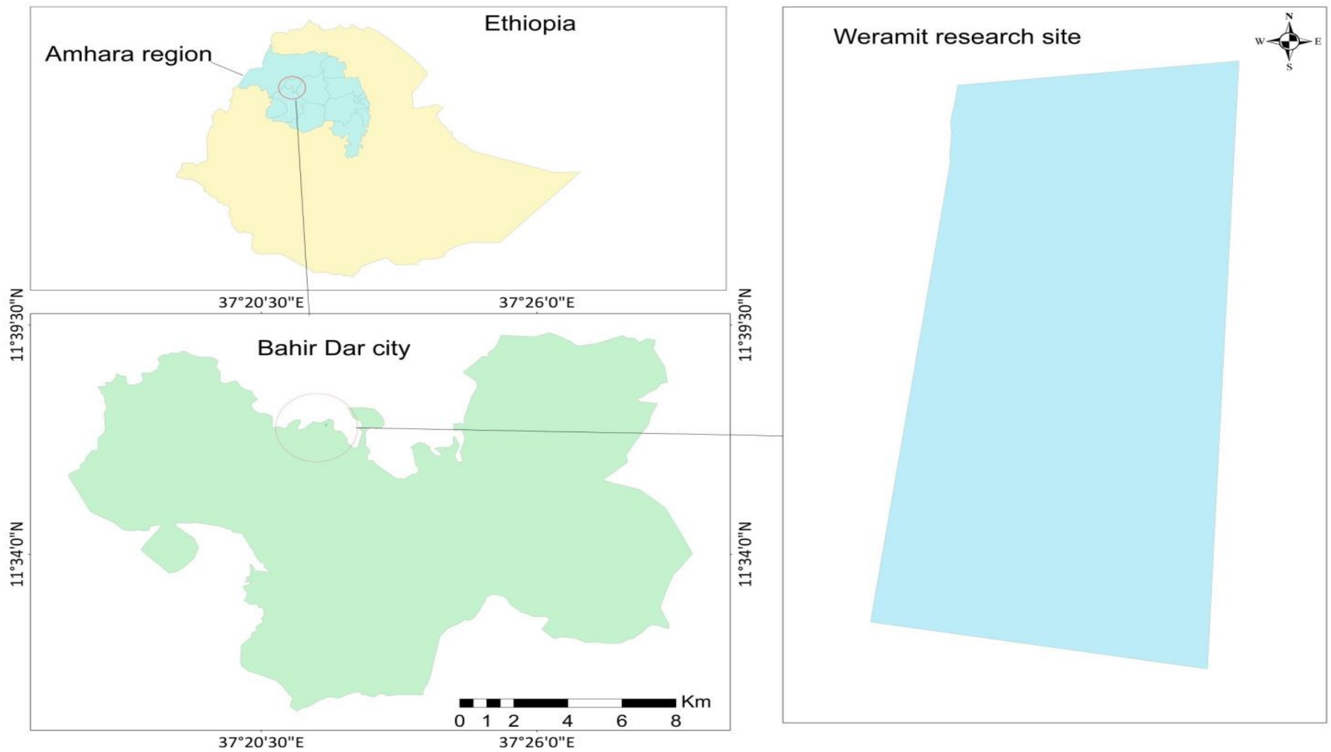

Figure 3.1. Map of the study area

3.1 Description of Experimental Materials

Four orange-fleshed sweet potato varieties (*Alamura*, *Birtukanie*, *Dilla* and *Kulfo*) were used as test crop (Table 3.1). Vine planting materials were obtained from Wormait Horticulture Research and Training Sub-center of Adet Agricultural Research Center. Select vine cuttings from a clean, healthy, vigorous-looking crop, which should be 2 or 3 months old.

Table 3.1. Description of the four orange fleshed sweet potato varieties used as experimental materials

Varieties	Year of release	Breeder/maintainer	Days to Maturity
Alamura	2019	AwARC	150
Dilla	2019	AwARC	150
Kulfo	2005	AwARC	150
Birtukanie	2008	Sirinka ARC/ARARI	150

Note: AwARC= Awasa Agricultural Research Center, ARARI= Amhara Agricultural Research Center Source: Ministry of Agriculture Crop variety registration bulletin (1983-2019).

3.2 Experimental Treatments and Design

The experiment consisted of 12 treatments with the factorial combination of four orange-fleshed sweet potato varieties (*Alamura*, *Dilla*, *Kulfo* and *Birtukanie*) and three intra-row spacing (20, 30 and 40 cm) (Table 3.2). The experiment was laid out in Randomized Complete Block Design (RCBD) in factorial arrangemet with three replications. The gross size of each plot was 6.72 m^2 (2.4m × 2.8m) accommodated four rows with 14, 9 and 7 plants per row for the intra row spacing of 20, 30 and 40 cm, respectively. The net plot area of each treatment was 2.88 m^2 (1.2 m × 2.4 m), 2.64 m^2 (1.2 × 2.2.) and 2.4 m^2 (1.2 × 2.0) for 20, 30 and 40 cm intra row spacings respectively. The recommended inter row spacing of 60 cm was maintained for all plots. The blocks were separated with a 1.5 m open space while the plots within a block were separated by a 1 m open space as walking distance for field management. The outer single rows at both sides of the plot and one plant at both ends of the rows were considered as border plants.

Table 3.2 Treatment combinations used in the study

Treatments	Intra Row Spacing (cm)	Planting density (plants/ha)	Varieties	Intra Row Spacing × Varieties
T1	S1 (20)	83,333		S1×V1
T2	S2 (30)	55,555	*Alamura* (V1)	S2×V1
T3	S3 (40)	41,666		S3×V1
T4	S1 (20)	83,333		S1×V2
T5	S2 (30)	55,555	*Dilla* (V2)	S2×V2
T6	S3 (40)	41,666		S3×V2
T7	S1 (20)	83,333		S1×V3
T8	S2 (30)	55,555	*Kulfo* (V3)	S2×V3
T9	S3 (40)	41,666		S3×V3
T10	S1 (20)	83,333	*Birtukanie*(V4)	S1×V4
T11	S2 (30)	55,555		S2×V4
T12	S3 (40)	41,666		S3×V4

Note: S = Spacing; V= Variety

3.3 Experimental Procedures and Management of the Experimental Plants

Land preparation was ploughed 4 times using oxen plow. It was also disked and harrowed until being very loose soil. Planting ridges were prepared mannualy, which is generally recommended for sweet potato planting in Ethiopia (Fekadu Gurumu and Tesfaye Tadesse, 2016). The orange fleshed sweet potato vines with 30 cm long having three internodes were prepared from the top plant by excluding the succulent part (CRC, 2005; Daniel Markos *et al.*, 2016 and Fekadu Gurumu *et al.*, 2016). Vines were planted in July 2nd at 45° slant angle on the prepared ridge. Two third parts of the vine were covered by the soil (CRCT, 2005; Fekadu Gurumu and Tesfaye Tadesse, 2016).

NPS fertilizer at the rate of 100 kg ha^{-1} was applied uniformly for all treatments after 15 days of planting. Similarly, urea fertilizer at the rate of 150 kg ha^{-1} was applied uniformly for all treatments after 21 days of planting in ring placement method as recommended by MoA (2016) and Getachew Etana *et al*. (2020). All other agronomic management practices including hoeing, hearthening up and plant protection (weeding, insect, disease *etc*.) were done uniformly for all treatments according to the recommendation.

3.4 Data Collection

3.4.1 Phenological parameters

Survival Rate (%): surivaval rate of vines were calculated as a ratio of number of vines that sprouted new leaf to total number of vines planted and multiplied by 100%. It was recorded when 50% of the vine cuttings in a plot sprouted as indicated by CIP, AVRDC and IPGRI (1991).

$$\text{Survival rate (\%)} = \frac{\text{Number of Survivied vines}}{\text{Total number of planted vines}} \times 100$$

Days to physiologicam maturity (days): the number of days elapsed from planting to the time when 90% of the plant population in each plot turned yellow or senesced and the storage roots reached maturity as shown by cracking of the soil above the storage root as indicated by Stathers *et al.* (2018).

3.4.2 Growth parameters

Vine length (cm): vine lengths of five randomly taken plants grown in the net plot area were measured from the base to the tip of the main shoot of the plants right at physiological maturity and the average value was computed as indicated by Alex (2015) and Awoke Mensa *et al.* *(*2019).

Number of branches per plant (count): the number of branches (primary, secondary and tertiary) of five randomly taken plants grown in the net plot area were counted physiological maturity and the average value was computed as indicated by Shalini *et al*. (2021).

3.4.3 Yield and Yield Components

Number of storage roots per plant (count): number of storage roots of five randomly taken plants grown in the net plot area was counted at harvest and the average values were computed and used for analysis as indicated by Bezawit Mekonnen (2015).

Storage root length (cm): lengths of storage roots of five randomly taken plants grown in the net plot area were measured from the distal to the proximal end of storage roots at harvesting by using tape meter and the average value was worked out as indicated by Ogbologwung (2016) and Merga Boru (2018)**.**

Storage root diameter (cm): diameters of storage roots of five randomly taken plants grown in the net plot area were measured from mid-section of the root, where diameter is maximum, using vernier caliper and the average value was worked out as indicated by Bezawit Mekonnen (2015) ; Alam *et al.* (2016) and Daniel Markos (2019).

Storage root weight (g): weight of storage roots were measured, from the five randomly taken plants grown in the net plot area, after removing of soil from the storage roots and average weight of storage roots were worked out as indicated by Sunita Koodi (2016).

Aboveground fresh weight (t ha^{-1}): weights of above ground parts of sweet potato plants grown in the net plot area were measured using beam balance and converted to t ha^{-1} as indicated by Alex (2015).

Marketable yield (t ha^{-1}): the weights of clean and uninfected storage roots harvested from the net plot area and having the weights at the ranges of 100 g to 500 g were measured using beam balance and converted to t ha^{-1} as indicated by Bezawit Mekonnen (2015).

Unmarketable yield (t ha^{-1}): storage roots that are infested, under sized (<100 g), oversized (>500g) and mechanically damaged are considered as unmarketable as indicated by Bezawit Mekonnen (2015). Such storage roots harvested from the net plot area were measured using beam balance and converted to t ha^{-1}.

Total storage root yield (t ha^{-1}): total storage root yield was recorded by summation of marketable and unmarketable storage root yields.

3.5 Data Analysis

The collected data were subjected to Statistical Analysis of Variance (ANOVA) using Statistical Analysis System (SAS) version 9.4 (SAS institute, 2018). Mean separations were conducted using Least Significant Difference (LSD) depending on ANOVA results as indicated by Gomez and Gomez (1984). Simple correlations between parameters were computed (Gomez and Gomez, 1984).

3.6 Partial Budget Analysis

To determine economically profitable treatment(s), partial budget analysis was performed following the CIMMYT (1988) methodology. The gross benefit (GB) was obatined by multiplying storage root yields by corresponding price at Bahir Dar market price at the time of harvest. Costs of labor for planting and management and planting material were considered as variable costs that vary with the treatments. Costs were estimated based on the surrounding market prices. Net benefits (NB) were obtained by deducting TVC from GB at hectare basis.

Dominance analysis was done to exclude the dominated treatments for further analysis where treatments were ranked in ascending order of the total variable costs (TVC). Any treatments that have net benefits less or equal to the previous treatment will be dominated and removed from further analysis. Marginal rate of return (%) was estimated as the percentage ratio of the change in net NB to change in TVC. Those treatments having MRR value more than the minimum acceptable level (100%) was considered for comparison.

Chapter 4. RESULTS AND DISCUSSION

4.1 Effects of Intra row Spacing and Varieties on Phenological Parameters of Orange Fleshed Sweet Potato

4.1.1 Survival rate

The analysis of variance revealed that the main effect of variety and its interaction with intra row spacing did not significantly (P>0.05) influence survival rate of oragnge fleshed sweet potato. However, the main effect of variety highly significantly (P<0.01) influenced survival rate of orange fleshed sweet potato plant (Appendix Table 10).

In the intra row spacing, the survival rate ranged from 97.25-98.83%, which are statisticaly similar (Table 4.1). The highest survival rate (100%) was obtained from *Birtukanie and Dilla* varietis, while the lowest survival rate (92%) was recorded from *Kulfo* variety (Table 4.1). This present result is in line with the findings of Kabir *et al.* (2007) ,Martha Mebrhatu (2014) and Haileslassie Gebremeskel *et al.* (2018) who reported Kulfo variety had the lowest survival rate and delayed days to establishment as compared to other genotypes.

Table 4.1. Main effects of variety and intra row spacing on survival rate of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Survival Rate (%)
Alamura	98.79a
Dilla	100a
Kulfo	92.89b
Birtukanie	100a
SL	**
LSD (0.05)	3.66
CV (%)	3.83
SE±	0.74
Intra row Spacing (cm)	
20	97.66
30	97.25
40	98.83
SL	ns
CV (%)	3.83
SE±	0.74

Where, ** = highly significant (P < 0.01); ns=non-significant (P > 0.05); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different.

4.1.2 Days to physiological maturity

The analysis of variance revealed that the main effect of variety and intra row sapcing and interaction highly significantly (P<0.01) and significantly (P<0.05) influenced days to physiological maturity of orange fleshed sweet potato plant respectively (Appendix Table 11). The highest days to physiological maturity (162.3) was obtained from variety *Dilla* and the lowest days to physiological maturity (143.6) was obtained from variety *Kulfo.* Variety *Dilla* was late to reach physiological maturity while variety *Kulfo* matured earlier by 18.7, 12.7 and 9.2 days as compared to *Dilla*, *Alamura* and *Birtukanie* respectively (Appendix Table 1). This result is in line with the works of Wogayehu Worku (2005) who reported significant variation in days to physiological maturity among varieties. Moreover, the highest (156) and lowest (151.3) days to physiological maturity were obtained from the widest (40 cm) and closest (20 cm) intra row spacing (Appendix Table 1). This might be due to intra specific completion for resources in closest spacing and their biological clock forces them to mature earlier as compared to plants spaced at widest intra row sapcing (40 cm). In regards to the interaction effect, The highest days to physiological maturity (164) was obtained from *Dilla* variety planted with widest intra row spacing of 40 cm. While, the lowest days to physiological maturity (140.3) was recorded from *Kulfo* variety planted with the closest intra row spacing of 20 cm (Table 4.2).

Table 4.2. Interaction effect of variety and intra row spacing on days to physiological maturity analysis of Orange fleshed Sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Intra row spacing (cm)	Variety	Days to physiological maturity (days)
20	*Alamura*	154.33dde
	Dilla	160.83b
	Kulfo	140.33i
	Birtukanie	150f
30	*Alamura*	157.33c
	Dilla	162.16ab
	Kulfo	144h
	Birtukanie	152.66e
40	*Alamura*	157.33c
	Dilla	164a
	Kulfo	146.67g
	Birtukanie	156c
SL		**
LSD (0.05)		2.18
CV (%)		0.82
SE±		1.2

Where, ** = highly significant (P < 0.01); CV = coefficient of variance; SE = Standard Error; LSD = least significant difference; SL= significance level; means followed by the same letter(s) in columns are not significantly different.

4.2. Effects of Intra row Spacing and varieties on Growth Parameters of Orange Fleshed Sweet Potato

4.1.3 Vine length

The analysis of variance revealed that the main and interaction effects of varieties and intra row spacing highly significantly (P < 0.01) influenced the vine length of Orange fleshed sweet potato (Appendix Table 12). Variety *Dilla* had longest vine (150.7 cm) while variety *Kulfo* had the shortest vine length (65.2 cm). Moreover, highest (117.1 cm) and lowest value (95.6 cm) for vine length were obtained under widest (40 cm) and medium (30 cm) intra row spacing respectively (Appendix Table 2). In regards to the interaction effect, the longest vine (171.7 cm) was obtained from *Dilla* variety planted with widest intra row spacing of 40 cm. While, the shortest vine (61.5 cm) was recorded from *Kulfo* variety planted with narrowest intra row spacing of 20 cm (Table 4.1).

Vine length varies with cultivar and ranges from about 1 m to 6 m which is associated with the genetic makeup of the varieties. Similarly, internodes length is also highly variable based on the variety and ranging from a few centimeters up to 1 m in length as indicated by (Solomon Ali *et al.*, 2015). The results of the present study are in agreement with the report of Rana *et al.* (1993) who found significant differences in vine length of sweet potato varieties. According to Somda and kays, (1990a), planting density has a pronounced effect on the internodes length as well as on vine length, which is associated with the computition of the plants for resources like water, nutrient, light and space. Consistent with the results of the present study, Sultana and Siddique (1991) reported that wider spaced sweet potato plants recorded taller plants than closer spaced plants. Similarly, Levy *et al.* (1986) reported that plant height and number of branches per plant were significantly influenced by sweet potato plant density where taller and more branched plants were obtained at the lower densities. \In contrast to the present stuudy, Osei (1990); Jadhav *et al.* (1994); Aydogdu and Acikgoz (1995); Awoke Mensa *et al. (*2019) and Shalini *et al.* (2021) noted that increase in plant population did not increase plant height and reduced the number of branches.

Table 4.1. Interaction effect of variety and intra row spacing on vine length of OFSP at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Intra row spacing (cm)	Variety	Vine length (cm)
20	*Alamura*	115.3d
	Dilla	146.7b
	Kulfo	65ef
	Birtukanie	81.3e
30	*Alamura*	70.9ef
	Dilla	133.7bc
	Kulfo	69ef
	Birtukanie	108.8d
40	*Alamura*	113d
	Dilla	171.7a
	Kulfo	61.5f
	Birtukanie	122.3cd
SL		**
LSD (0.05)		17.7
CV (%)		10
SE±		5.9

Where, ** = highly significant (P < 0.01); CV = coefficient of variance; SE = Standard Error; LSD = least significant difference; SL= significance level; means followed by the same letter(s) in columns are not significantly different .

4.1.4 Number of branches per plant

The analysis of variance revealed that the main effect of intra row spacing and its interaction effect with variety did not influence number of braches of sweet potato significantly ($P > 0.05$). However, the main effect of variety highly significantly influenced number of branches per sweet potato plant (Appendix Table 13). In the intra row spacing, the number of branches ranged from 11.8 to 13.7, which are statisticaly similar (Table 4.2). The highest number of branches per sweet potato plant (19.9) was obtained from *Kulfo* variety, while the lowest number (9) was recorded from *Birtukanie* variety (Table 4.2). The difference in number of branches among varieties might be due to the genotypic differences. The results of the present study are in agreement with the findings of Miheret Hendebo (2011) and Martha Mebratu (2014) where sweet potato varieties differ with the number of branches. According to the authors, *Kulfo* variety of sweet potato recorded the highest average number of branches compared to *Birtukanie* and Awassa-83.

Table 4.2. Main effects of variety and intra row spacing on number of branch per plant of OFSP at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Number of branches per plant
Alamura	9.3b
Dilla	11b
Kulfo	19.9a
Birtukanie	9b
SL	**
LSD (0.05)	2.6
CV (%)	21.9
SE±	0.8
Intra row Spacing (cm)	
20	11.8
30	11.6
40	13.7
SL	Ns
CV (%)	21.9
SE±	0.8

Where, ** = highly significant ($P < 0.01$); ns=non-significant ($P > 0.05$); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different.

4.2 Effects of Intra row Spacing on the Yield Components of Orange Fleshed Sweet Potato Varieties

4.2.1 Number of storage roots per plant

The analysis of variance revealed that the main effects of varieties and its interaction with intra row spacing highly significantly ($P < 0.01$) influenced number of storage roots per plant of Orange fleshed Sweet potato. However, the main effect of intra row spacing did not influence number of storage roots per plant of Sweetp potato significantly ($P > 0.05$) (Appendix Table 14). In the intra row spacing, the number of storage roots per plant ranged from 5.3 to 5.7, which are statisticaly similar. The highest number of storage roots per plant (6.8) was obtained from *Alamura* variety, while the lowest number (4.2) was recorded from *Kulfo* variety (Appendix Table 3). In regard to the intreaction effect, the highest number of storage roots per plant (9.2) was obtained from variety *Alamura* planted with 30 cm intra row spacing. While the lowest Number of storage roots per plant (3.8) was recorded from variety *Birtukaanie* planted with 30 cm intra row spacing (Table 4.3).

The result of the present study indicating significant effect of intra row spacing on number of storage root, was also acknowledged by Abdissa *et al*. (2011) who reported that intra row spacing spacing of 45 cm gave significantly maximum number of storage root (5.1) per vine which was followed by intra row spacing 30 cm (3.0). Maximum number of storage root per vine might be due to the more land area available per plant. It showed that closer spacing produced comparatively less number of storage roots.

In regard to the varieties, The result of the present study indicating significant difference among varieties for storage root number were acknowledged by Martha Mebratu (2014). However, this result is not in line with the finding of Bezawit Mekonen (2015) who reported non-significant difference among the five sweet potato varieties tested for number of storage rootous roots per plant. Even though the number of storage rootous roots per plant were not significantly different among the five OFSP varieties, the highest mean number of storage rootous roots per plant (6.27) was recorded lowest mean number of storage rootous roots per plant (4.9) were recorded. The difference perceived among the OFSP varieties in number of storage rootous roots per plant could be attributed to the differences in their genotypic composition.

The result of this experiment indicating highest number of storage roots per plant from *Alamura* variety is not in line with the result of Martha Mebratu (2014) who reported number of storage roots per plant from *Kulfo* variety.

4.2.2 Storage root length

The analysis of variance revealed that both the main and interaction effects of varieties and intra row spacing highly significantly ($P < 0.01$) influenced the storage root length of sweet potato plants (Appendix Table 15). Variety *Alamura* had longest root (23 cm) while variety *Birtukanie* had the shortest root (15.5cm). Similarly, increasing the intra row spacing increased root length. Accordingly, the highest (20.7 cm) and lowest (16.4 cm) storage root length was obtained from widest (40 cm) and closest intra row spacing (20 cm) respectively. In regards to the interaction effect, the highest storage root length (25.6 cm) was obtained from variety *Alamura* planted at 30 cm intra row spacing. On the other hand, the lowest storage root length (12.4 cm) was recorded from *Birtukanie* variety planted at 20 cm intra row spacing (Table 4.3).

The differences in root length among varieties observed in the present study could be due to the characters of the cultivars. In this regard, Jilani *et al.* (2009) found difference among cultivars in storage root length due to genetic inheritance. As indicated in the present study, increasing plant density significantly and linearly decreased storage rootous root length, which is obviously associated with resource compitition. In line with the present study, Teshome Alemu *et al.* (2011) Thus,reported longest storage rootous roots from sparsest planting density while shortest were obtained from the highest planting density.

4.2.3 Storage root diameter

The analysis of variance revealed that both the main and interaction effects of varieties and intra row spacing influenced the storage root diameter of sweet potato plants highly significantly ($P < 0.01$) (Appendix Table 16). Variety *Kulfo* had highest diameter (8.6 cm) while variety *Alamura* had the lowest diameter (5.7 cm). Moreover, highest (7 cm) and lowest (6.1 cm) diameter were obtained under medium (30 cm) and closest (20 cm) intra row spacing respectively. In regards to the interaction effect ,the highest storage root diameter (9.8 cm) was obtained from *Kulfo* variety planted with 40 cm intra row spacing. While the lowest storage root diameter (4.9cm) was recorded from *Alamura* variety planted with 40 cm intra row spacing (Table 4.3).

The diference in treatments for storage root diameter might be due to genotypic differences among cultivars used in the experiment. Similar results were also reported by Teshome *et al*. (2011) who indicated the significant effect of planting density on storage root diameter of sweet potato varieties.

4.2.4 Aboveground fresh weight

The analysis of variance revealed that both the main and interaction effects of varieties and intra row spacing highly significantly ($P < 0.01$) influenced the aboveground fresh weight of sweet potato plants (Appendix Table 17). Variety *Birtukanie* had the highest aboveground fresh weight (19.2 t ha^{-1}) while variety *Kulfo* had the lowest aboveground fresh weight (9.2 t ha^{-1}). Moreover, highest (16.2 t ha^{-1}) and lowest (9.8 t ha^{-1}) aboveground fresh weight were obtained under medium (30 cm) and closest (20 cm) intra row spacing respectively. In regards to the interaction effect, the highest aboveground fresh weight (26.4 t ha^{-1}) was obtained from *Birtukanie* variety planted with 30 cm intra row spacing. While the lowest above ground fresh weight (7.2 t ha^{-1}) was recorded from *Kulfo* variety planted with 40 cm intra row spacing (Table 4.3). In line with the finding of the present study, Awoke Mensa (2022) reported asignificant variation ($P < 0.05$) between varieties for stand count at harvest and yield of top green parts per plot (fresh weight in kg) and highly significant variation ($P < 0.01$) between varieties for yield and other yield related characters.

4.2.5 Storage root weight

The analysis of variance revealed that the main effect of variety and its interaction effect with variety highly significantly ($P < 0.01$) influenced storage root weight of sweet potato. While, the main effect of intra row spacing significantly ($P<0.05$). influenced storage root weight of sweet potato plant (Appendix Table 18). Variety *Kulfo* had the highest storage root weight (490 g) while variety *Dilla* had the lowest storage root weight (281.3 g). Similarly, increasing intra row spacing increased storage root weight of sweet potato. Accordingly, highest (383.2 g) and lowest value (339.4 g) for storage root weight were obtained under widest (40 cm) and closet (20 cm) intra row spacing respectively. In regards to the interaction effect, the highest storage root weight (603.3 g) was obtained from *Kulfo* variety planted with 40 cm intra row spacing. While the lowest storage root weight (267 g) was recorded from *Dilla* variety planted with 20 cm intra row spacing (Table 4.3).

The result of the present study indicating significant effect of varieties and intra row spacing might be due to genetic difference and higher sink (storage root) development at widest spacing as a result of lesser intra specific competition for growth factors. The present finding is in line with the works of Muluken Demilie *et al.* (2019), who reported significant interaction effect of varieties and intra row spacing on storage root weight of sweet potato.

Table 4.3. Interaction effect of variety and intra row spacing on yield components of sweet Potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Intra row spacing (cm)	Variety	NSRPP	SRL	SRD	AFW	SRW
20	*Alamura*	5bcde	18.4bcd	5.9bcd	9.8ef	294ef
	Dilla	4.8cde	19bc	5.7cd	10.6ef	267f
	Kulfo	4.5cde	16d	7.1b	7.6f	420.7bc
	Birtukanie	8.3a	12.4e	5.8cd	11.4def	376.3bcd
30	*Alamura*	9.2a	25.6a	6.2bc	11.3def	306def
	Dilla	5.7bc	18.7bc	6.4bc	14.1de	280.7ef
	Kulfo	4.1de	20.6b	9.4a	12.9de	446b
	Birtukanie	3.8e	16.7cd	6.1bcd	26.5a	326.7def
40	*Alamura*	6.3b	25a	4.9d	15.8cd	284ef
	Dilla	5.2bcde	19.9b	6.7bc	20.5b	296.3ef
	Kulfo	4.2de	20.6b	9.8a	7.2f	603.3a
	Birtukanie	5.4bcd	17.3cd	6.6bc	19.9bc	349.3cde
SL		**	**	**	**	**
LSD (0.05)		1.4	2.5	1.2	4.5	77.5
CV (%)		15.9	7.9	10.2	19.6	12.3
SE±		0.3	0.6	0.3	1.0	16.9

Where, ** = highly significant (P < 0.01); CV = coefficient of variance; SE = Standard Error; LSD = least significant difference; SL = significance level; NSRPP=Number of Storage Roots Per Plant; SRL=Storage Root Length; SRW=Storage root Weight; SRD=Storage Root Diameter; AFW= Aboveground Fresh Weight; means followed by the same letter(s) in columns are not significantly different.

4.3 Effects of Intra row Spacing on the Yield of Orange Fleshed Sweet Potato Varieties

4.3.1 Marketable storage root yield

Marketable yield is the ultimate goal of any crop production system aimed at increasing the economic yield. It is the end product of all metabolic processes of crop plants over the growing season. The analysis of variance revealed that both the main effect of variety and its interaction effect with intra row spacing highly significantly (P < 0.01) and the main effect of intra row spacing significantly influenced the marketable yield of sweet potato plants (Appendix Table

19). Variety *Birtukanie* provided the highest marketable yield (21.3 t ha^{-1}); while, variety *Kulfo* provided the lowest marketable yield (6.2 t ha^{-1}) which might be attributed to establsiment problem of the variety having the lowest survival rate as compared to the other varieties tested. Moreover, highest (16.5 t ha^{-1}) and lowest value (14.3 t ha^{-1}) for marketable yield were obtained under medium (30 cm) and widest (40 cm) intra row spacing respectively. In regards to the interaction effect, the highest marketable yield (22.8 t ha^{-1}) was obtained from *Birtukanie* variety planted at 30 cm intra row spacing while the lowest marketable yield (5.3 t ha^{-1}) was recorded from *Kulfo* variety planted at 40 cm intra row spacing (Table 4.5).

The differences in marketable root storage root yield observed in the present study could be attributed to the genetic variations among the OFSP varieties in partitioning photosynthates, which were also acknowledged by Nedunchezhiyan *et al*. (2007). Marketable yield increased up to medium intra row spacing (30 cm) used, accommodating 55,555 plants ha^{-1} and slightly decreased at the highest intra row spacing (40 cm), accommodating 41,666 plants ha^{-1} and lowest intra row spacing(20) accomudate 83333 plants ha^{-1}. This present result, indicating highest marketable yield at medium intra row spacing spacing (30 cm), were acknowledged by Barry *et al.* (1990) who reported that medium planting desnity helped for efficient utilization of the available resources leading to higher marketable yield.

4.3.2 Unmarketable yield

The analysis of variance revealed that the main effect of variety highly significantly ($P < 0.01$) and that of intra row spacing significantly ($P < 0.05$) influenced unmarketable yield of sweet potato plants. However, interaction effect of variety and intra row spacing did not significantly ($P > 0.05$) influenced unmarketable yield of sweet potato plants (Appendix Table 20). Accordingly, the highest unmarketable yield (3.8 t ha^{-1}) was obtained from *Dilla* and the lowest unmarketable yield (0.8 t ha^{-1}) was obtained from *Kulfo* variety (Table 4.4). Moreover, highest (2.4 t ha^{-1}) and lowest (1.9 t ha^{-1}) unmarketable yield were obtained under widest (40 cm) and medium (30 cm) intra row spacing respectively.

Variety *Kulfo* produced relatively less unmarketable roots than the other cultivars, which might be due its genetic makeup. These results are in agreement with observation of Geleta (2009) who reported treatment that resulted in induction of the highest number of shoots also produced higher proportion of unmarketable sweet potato storage root yield.

In the present study, relatively higher values for unmarketable yield were recorded from highest and lowest intra row spacing used. This might be due to intraspecific competition at highest planting density leading to undersized storage roots and efficient utilization of the available resources at lowest planting density. This result is not in line with the findings of Nwankwo *et al*. (2012) and Bezawit Mekonen (2015) non-significant difference for unmarketable storage rootous root yield among different spacing used. The plant grown under wider spacing received more nutrients, light and moisture around each plant surrounding compared to plants of closer spacing, which is probably not suitable market preference than to closer spacing.The variation in nonmarketable yield of the genotypes may be due to adaptability,and inherent ability of sweet potato genotypes in producing unmarketable storage roots.

Table 4.4. Main effect of variety and intra row spacing on unmarketable yield of sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Unmarketable Yield (t ha^{-1})
Alamura	2.6b
Dilla	3.8a
Kulfo	0.9d
Birtukanie	1.7c
SL	**
LSD (0.05)	0.53
CV (%)	24.1
SE±	0.2
Intra row Spacing (cm)	
20	2.3ab
30	1.9b
40	2.5a
SL	*
LSD (0.05)	0.46
CV (%)	24.1
SE±	0.2

Where, **= highly significant; * = significant ($p < 0.05$); CV = Coefficient of variance; SE = Standard error; LSD= least significant difference; SL= significance level. Means followed by the same letter(s) in the same column are not significantly different.

4.3.3 Total yield

The analysis of variance revealed that the main effect of variety and its interaction with intra row spacing highly significantly ($P < 0.01$) influenced total yield of organge fleshed sweetpotato. However, the main effect of intra row spacing did not significantly ($P > 0.05$) influence total yield of sweet potato plants (Appendix Table 21). Variety *Birtukanie* provided the highest total yield (23 t ha^{-1}) while variety *Kulfo* yielded the lowest total yield (7.1 t ha^{-1}). In the intra row spacing, total yield ranged from 16.7-18.5, which are statisticaly similar. In regards to the interaction effect, the highest total yield (24.5 t ha^{-1}) was obtained from *Birtukanie* variety planted with 30 cm intra row spacing and the lowest total yield (6.4 t ha^{-1}) was obtained from *Kulfo* variety planted with 40 cm (Table 4.5). The genetic potential of *Birtukanie* variety and optimum plant population for better utilization of the available resources could have attributed to the highest storage rootous root yield than any other treatment combinations. This present result was also acknowledged by Birhanu Amare *et al*. (2014); Martha Mebrhatu (2014); Wariboko and Ogidi (2014) who reported significant differences in total storage rootous root yield among varieties in their experiment.

Table 4.5. Interaction effect of variety and intra row spacing on marketable and total yield of Sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Intra row spacing (cm)	Variety	Marketable yield (t ha^{-1})	Total yield (t ha^{-1})
20	*Alamura*	19.4b	22.6abc
	Dilla	13.6c	17.7d
	Kulfo	6.3d	7e
	Birtukanie	19.2b	20.7bcd
30	*Alamura*	22.3ab	24.4ab
	Dilla	14c	17.1d
	Kulfo	7d	7.9e
	Birtukanie	22.8a	24.5a
40	*Alamura*	14.6c	17d
	Dilla	15.5c	19.8cd
	Kulfo	5.3d	6.4e
	Birtukanie	21.9ab	23.9ab
SL		**	**
LSD (0.05)		3.2	3.7
CV (%)		13	13.1
SE±		1.0	1.1

Where, ** = highly significant ($P < 0.01$); CV = coefficient of variance; SE = Standard Error; LSD = least significant difference; SL= significance level; means followed by the same letter(s) in columns are not significantly different.

4.4 Relationships of Growth and Yield parameters of Sweet potato as Influenced by variety and Intra Row Spacing

The relationships between growth, yield components and yield of sweet potato as influenced by varieties and intra row spacing are presented in Table 4.6. Marketable yield had a highly significant ($P < 0.01$) and positive correlation with vine length (r=0.33**), number of storage roots per plant (r=0.45**), number of branches per plant (r=0.82**), length (r=0.55**), diameter (r=0.59**) and weight (r=0.54**) of storage root, aboveground fresh weight (r=0.5**) total yield (r=0.99). However, unmarketable yield was significantly ($P<0.05$) and negatively correlated withmarketable yield (r=-0.35*).

The correlation analysis indicates that any improvement in positively correlated parameters of sweet potato such as vine length, number of storage roots per plant, number of branch per plant, length, diameter and weight of storage root, aboveground fresh weight and total yield.

Contribute to increment in marketable yield of sweet potato while negatively correlated parameters showed that marketable yield was increased as parameters like unmarketable yield decreased. The present result indicating positive association between marketable yield and growth and yield related traits of sweet potato were previously acknowledged by Martha Mebrhatu (2014).

Table 4.6. Relationships of growth and yield parameters of Sweet potato, grown at Woramit Horticulture Research and Training Sub-center, as influenced by varieties and intra row spacing

	VL	NBPP	NSRPP	SRL	STW	SRD	AFW	MY	UNMY	TY
VL	1									
NBPP	-0.49**	1								
NSRPP	-0.11ns	-0.40*	1							
SRL	-0.02ns	0.07ns	0.19ns	1						
STW	-0.60**	0.65**	-0.25ns	-0.10ns	1					
SRG	-0.47**	0.76**	-0.37*	0.07ns	0.69**	1				
AFW	0.47**	-0.35*	-0.15ns	-0.08ns	-0.35ns	-0.25ns	1			
MY	0.33**	0.82**	0.45**	0.55**	0.54**	0.59**	0.50**	1		
UNMY	0.85**	-0.46**	0.10ns	0.18ns	-0.63**	-0.42*	0.21ns	-0.35*	1	
TY	0.46**	0.84**	0.44**	-0.01ns	-0.61**	-0.62**	0.50**	0.99**	0.50**	1

Where, **= highly significant (P < 0.01), *= significant (P < 0.05), ns= not significant, VL= vine length; NBPP=Number of Branches Per Plant; NSRPP=Number of Storage Roots Per Plant; SRL=Storage Root Length; STW=Storage Storage root Weight; SRG=Storage Root Diameter; AFW= Aboveground Fresh Weight; MY=Marketable Yield; UNMY=Unmarketable Yield; TY=Total Yield.

4.5 Partial Budget Analysis

Partial budget analysis was done based on procedures described by CIMMYT (1988). Costs of labor and planting material were considered as variable costs that vary with the treatments. Accordingly, the highest net benefit (397,855.3 ETB ha^{-1}) was recorded from *Birtukanie* variety planted at 30 cm intra row spacing followed by *Alamura* variety planted at 30 cm intra row spacing (394,255.3 ETB ha^{-1}). On the other hand, the lowest net benefit (86,041.8 ETB ha^{-1}) was obtained from *Kulfo* variety planted at 40 cm intra row spacing (Table 4.7). The only and acceptrable marginal rate of return (MRR) was recorded from *Birtukanie* variety planted at 30 cm intra row spacing with the value of 408.4% which indicates that investing one Ethiopian Total Birr (ETB) on the treatment combination of *Birtukanie* variety and 30 cm intra row spacing enables the growers to obtain a return of 4.08 ETB $ha^{-1.}$

$$MRR = \frac{\Delta \text{NB}}{\Delta \text{TVC}}$$

Where, MRR: Mariginal rate of return

ΔNB: change in net benefit

ΔTVC: change in total variable cost

Table 4.7. Partial budget analysis of Sweet Potato as affected by varieties and intra row spacing at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

TRT	AMY (t ha^{-1})	RMY (ETB ha^{-1})	Labour cost (ETB ha^{-1})	VCC (ETB ha^{-1})	TVC (ETB ha-1)	GB (ETB ha-1)	NB (ETB ha^{-1})
A×20	17.46	349200	2000	16417	18417	349200	330783
A×30	20.34	406800	1500	11044.7	12544.7	406800	394255.3
A×40	13.14	262800	1000	8358.2	9358.2	262800	253441.8
D×20	12.24	244800	2000	16417	18417	244800	226383
D×30	12.6	252000	1500	11044.7	12544.7	252000	239455.3
D×40	13.95	279000	1000	8358.2	9358.2	279000	269641.8
K×20	5.67	113400	2000	16417	18417	113400	94983
K×30	6.3	126000	1500	11044.7	12544.7	126000	113455.3
K×40	4.77	95400	1000	8358.2	9358.2	95400	86041.8
B×20	17.28	345600	2000	16417	18417	345600	327183
B×30	20.52	410400	1500	11044.7	12544.7	410400	397855.3
B×40	19.71	394200	1000	8358.2	9358.2	394200	384841.8

Where, TRT= treatment, AMY =adjusted marketable yield, RMY= revenue from marketable yield, GB = gross benefit, VCC= vine cutting cost; TVC =total variable cost, NB=net benefit, ETB =Ethiopian total birr, A= *Alamura*, D= *Dilla*, K= *Kulfo*, B= *Birtukanie*; Cost of vine cutting= 20 cents per vine, price of sweet potato storage root= 20 ETB kg^{-1}; Labor cost = 100 ETB per man per day.

Table 4.8. Dominance and Marginal Rate of Return analysis of Sweet potato as affected by varieties and intra row spacing in Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

TRT	TVC	NB	DA	MRR (%)
A×40	9358.2	253441.8	D	
D×40	9358.2	269641.8	D	
K×40	9358.2	86041.8	D	
B×40	9358.2	384841.8		
A×30	12544.7	394255.3	D	
D×30	12544.7	239455.3	D	
K×30	12544.7	113455.3	D	
B×30	12544.7	397855.3		408.4
A×20	18417	330783	D	
D×20	18417	226383	D	
K×20	18417	94983	D	
B×20	18417	327183	D	

Where, TRT= treatment, TVC =total variable cost, NB=net benefit, MRR= marginal rate of return, ETB =Ethiopian total birr, DA= dominance analysis, D= dominated A= *Alamura*, D= *Dilla*, K= *Kulfo*, B= *Birtukanie.*

Chapter 5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Variety and intra row spacing are one of the most important agronomic practices that influence the growth and yield of Orange fleshed Sweet poato. Based on the results of the present study, number of storage roots per plant, length and diameter of storage rootous roots, aboveground fresh weight, and storage root weight, marketable and total yield were significantly affected by the interaction effect of variety and intra row spacing, whereas vine length and unmarketable yield were affected by main effects of variety and intra row spacing. while, number of branch per plant was influenced by the main effect of variety highly significantly.

Birtukanie and *Dilla* varieties had 100% survival rate while *Kulfo* variety had the lowest survival rate (92%) and delayed days to establishment as compared to other genotypes. Variety *Dilla* took the highest number of days to reach physiological maturity while variety *Kulfo* matured earlier than the other cultivars. The longest vine length (171.7 cm) was recorded at the widest intra row spacing (40 cm) and *Dilla* variety treatment combination and the shortest vine length (61.5 cm) was observed at the narrowest intra row spacing (20 cm) with *Kulfo* variety. However, *Kulfo* cultivar showed the highest number of branches (19.9) compared to *Dilla* (11), *Alamura* (9.3) and *Birtukanie* varieties (9).

The highest number of storage roots per plant and storage root length were obtained from *Alamura* variety planted with medium intra row spacing used (30 cm). Furthermore, the treatment combination of *Kulfo* variety and widest intra row spacing (40 cm) had the highest storage root diameter and storage root weight. However, it resulted in lowest aboveground fresh weight, marketable and total yield. Whereas, *Birtukanie* variety planted with medium intra row spacing used (30 cm) yield the highest values for aboveground fresh weight and total yield.

The marketable yield was found to be positively correlated with growth, yield attributes and yield of organe fleshed sweet potato except unmarketable yield. The partial budget analysis has shown that the treatment combination of *Birtukanie* variety and 30 cm intra row spacing provided the highest net benefit (397,855.3 ETB ha^{-1}) with highest and acceptable MRR (408.4%).

5.2. Recommendations

Based on the results of the present work, planting *Birtukanie* variety at 30 cm intra row spacing recorded the highest marketable yield (22.8 t ha^{-1}), net benefit (397,855.3 ETB ha^{-1}) and acceptable MRR (408.4%) of sweet potato, which can be recommended for the economical production of the crop in the study area and areas with similar agro-ecology. However, since the results are limited to one growing season and single location, it is also recommended to repeat the study across different seasons and locations.

REFERENCES

Abdissa Teshom., Amenti Chali, Kasaye Tolessa , Fisiha Tadesse and Geremew Awas. 2011. Yield and Yield Components of Sweet Potato as Influenced by Plant Density: In Adami Tulu Jido Kombolcha District, Central Rift Valley of Ethiopia. AJEA.1 (2): 40-48.

Abong G. (2010). Evaluation of selected Kenyan potato cultivars for processing into potato crisps. Agriculture and Biology Journal of North America 1: 886-893

Agata W. and Takeda T. 1982. Studies on dry matter production of sweet potato plants. The characteristics of dry matter and yield production under field conditions. *J. Fac. Agric. Kyushu Univ*. 27, 65. *Sweet potato products: A natural resource for the tropics*, p. 80-126.

Selina Wamucii. 2022. *Ethiopian sweetpotato price*. Retrieved from https://www.selinawamucii.com/insights/prices/ethiopia/sweet-potatoes/. Accesed on 19 August 2022.

Alam M. , Rana Z. and Islam S. 2016. Comparison of the proximate composition, total carotenoids and total polyphenol content of nine orange-fleshed sweet potato varieties grown in Bangladesh. *Foods*, *5*(3), 64.

Alex B. 2015. *Growth, yield and quality factors of sweet potato (Ipomoea batatas (L.) Lam) as affected by seedbed type and fertilizer application. M.Sc thesis. Thesis.*Kwame Nkrumah University of Science and Technology, Kumasi.

Alvin, J.B., Mitchell, P.D., Copas, M.E. and, Drilias, M.J. 2007. Evaluations of the Effect of Density were on Potato Yield and Tuber Size Distribution. Crop Science, 47:2462-2472.

Assefa Tofu, Teshome Anshebo, Engida Tsegaye and Tesfaye. Tadesse. 2007. Summary of progress on orange-fleshed sweet potato research and development in Ethiopia in *Proceedings of the 13th ISTRC Symposium*, 728 –731.

Belehu Tariku 2003. Effect of planting density and Cultivar on yield and yield components of sweet potato in Ethiopia. University of Pretoria etd. Chapter 8.

Berga L. and K. Caeser. 1990. Relationships between numbers of main stems and yield components of potato (Solanum tuberosum L) as influenced by different day length. Potato Res. 33: 257-267.

Bezawit Mekonnen, Solomon Tulu and Jima Nego. 2015. Evaluation of Orange Fleshed Sweet Potato (*Ipomoea batatas* L.) Varieties for Yield and Yield Contributing Parameters in the Humid Tropics of Southwestern Ethiopia .J. Plant.Sci. *10* (5): 191-199, 2015 ISSN 1816-4951 / DOI: 10.3923/jps.2015.191.199.

Birhanu Amare, Fetien Abay,Yemane Tsehaye. 2014. Evaluation of sweet potato (*Ipomea batata* L.) varieties for total storage root yield in south and south east zones of Tigray, Ethiopia. *Am. J. Trade Policy*, 3(1): 74-78.

Campbell, G., T. Hernandez, and J. Miller, 1963. The effect of temperature, photoperiod and other related treatments on flowering in Ipomoea batatas. Proc. Am. Soc. Hort. Sci., 83: 618- 62.

CIP (International Potato Centre) (2018). Improving the livelihoods of small-scale sweet potato farmers in central Uganda through a crop post-harvest-based innovation system. Validation of storage technologies for sweet potato storage roots.

CIP, AVRDC and IPGR.1991. *Descriptor for sweet potato*. Huaman Z. Editor. Internatiional board for plant genetic resources, Rome, Italy.

Collins W. 1984. Progress in development sweetpotato (*Ipomoea batatas* (L) Lam.) cultivars for fuel alcohol production. In: F. Shideler and H. Rincon (eds.) Proc. 6th symp. Int. Soc. Trop. Root Crops, CIP, Lilm, Peru, p 571-575.

CRCT (Crop Science Research Department). 2005. *Available technologies and constraints in technology dissemination*. Awassa, Ethiopia: Crop Science Research Department of SARI.

CSA (Central Statistical Agency). 2016. *Agricultural sample survey Report on area and production of major crops of private peasant holdings*. The FDRE Statistical bulletin, vol 1:584. Addis Ababa, Ethiopia.118pp.

CSA (Central Statistical Agency).2019. *Agricultural sample survey 2018/2019. Report on area and production of major crops*. Central Statistical Agency of Ethiopia.

CSA (Central Statistical Authority). 2011. *Ethiopian agricultural sample enumeration*. Statistical bulletin, 146, Addis Ababa, Ethiopia.

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

Dantata I., Babatunde F., Mustapha S. and Fagam A. 2010. Influence of variety and plant spacing onstorage root size, storage root shape and fresh marketable yield of Sweet potato in Bauchi Nigeria. Biol. and Environ. Sci. J. Tropics, 7(2): 140-144.

Echodu R., Edema H., Wokorach, G., Zawedde C., Otim, G., Luambano, N., Ateka, E. and Asiimwe, T., 2019. Farmers' practices and their knowledge of biotic constraints to sweetpotato production in East Africa. Physiol. Mol. Plant Pathol., 105, pp.3-16.

EHNRI (Ethiopian Health and Nutrition Research Institute). 2010. *Nutrition Baseline Survey 2009/10*. Report for the National Nutrition Program of Ethiopia. AddisAbaba, Ethiopia.

EIAR (Ethiopian Institute of Agricultural Research) (2001). *Blanket recommendation of fertilizer use for all crops*. Addis Ababa, Ethiopia.

Engida Tsegaye, Mihertu Cherinet, Asfaw Kifle, Daniel Mekonen and Tesfaye Tadesse. 2011. Genotype x Environment Interactions and Yield Stability of Orange Fleshed Sweet Potato Varieties Grown in Ethiopia. Tropical Roots and Storage roots in a Changing Climate. A Critical Opportunity for the World. 2 -6 Nov 2009, Lima, Peru.

Ephrem Gebregizhaher. 2015. *Disease Management Practice on Potato* (*Solanum storage rootosum* L.) in Ethiopia. World J. Agric. Res, 8(5):120-127).

Ermias Shonga, Mesele Gurumu, Tesfaye Tadesse, Elias Urga.2013. Review of Entomological Research on Sweet Potato in Ethiopia.JAFS.1(5):83-92.

Etana Gurumu. 2018. *Effect of NPSB blended fertilizer on growth, yield and Quality of orange-fleshed sweet potato* (*Ipomoea batatas* (L.) Lam)) *varieties under Jimma condition, south west Ethiopia (Doctoral dissertation)*,Jimma university, Jimma, Ethiopia .

Ethiopian Institute of Agricultural Research (EIAR). 2015. *The Root and Storage root Crops working group proceedings of the first meeting*. Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization). 2014. Production year book : Food and Agricultural Organization,Rome, Italy.

FAO (Food and Agriculture Organization. 2004. Roots, Storage roots, Plaintains and Bananas in human Nutrition. Food and Agriculture Organization of the United States.

FAOSTAT (Food and Agriculture Organization Statistical Data). 2016. Food and Agriculture Organization of the United Nations. FAO Statistics Division.

FAOSTAT (Food and Agriculture Organization Statistical Data). 2014. Food and Agriculture Organization of the United Nations http://www.fao.org/statistics/en/ (Accessed on 14 November 2020).

Fekadu Gurmu, Shimelis Hussein & Mark L. 2015b.The potential of orange-fleshed sweetpotato to prevent vitamin a deficiency in Africa. Int. J. Vitam. Nutr. Res. 84(1): 65-78

Fekadu Gurmu, Shimelis Hussein &Mark L. 2015a. Diagnostic assessment of sweetpotato production in Ethiopia: constraints, post-harvest handling and farmers' preferences. Res. Crop. 16(1): 104-115.

Fekadu Gurumu, 2019. Sweetpotato Research and Development in Ethiopia: A Comprehensive Review. JACR . 7(7):20-29.

Folquer, F., 1974. Varietal efficiency in the spring production of sweet potato seeds (*Ipomoea batatas* (L.) Lam.). Field Crop Res. 29(5): 88.

Food and Agricultural Organization (FAO). 2011. FAOSTAT annual report. Http//es.wikipedia the encyclopaedia.

Food and Agriculture Organization statistics (FAOSTAT).2014. Agricultural database. /http://faostat.fao.org./ (accessed on June 29, 2016).

Gebiremedihin Kidane, Kebede Abegaz ,Afeworke Mulugeta. and Singh P. 2013. Nutritional analysis of vitamin A enriched bread from orange flesh Sweet potato and locally available wheat flours at Samre Woreda, Northern Ethiopia. *Curr. Res. Nutr. Food Sci.* 1(1): 49-57.

Gomez K.& Gomez A.1984. *Statistical procedures for agricultural research.Second edition*. JWS, New York. Pp 68.

Habtamu Tegen, Wasu Mohammed and Yigzaw Dessalegn, 2015. Physicochemical attributes of Tomato (*Lycopersicon esculentum* Mill.) varieties under Polyhouse and Mulching Conditions. *Med. J. Biosci.*, 1(1), 38-49.

Hahn, S. and Y. Hozyo, 1984. Sweet potato. In: P. Goldsworthy and N. Fisher (eds), The physiology of field crops. New York: JWS. pp. 55 1-567.

Hahn, S.and Y.Hozyo, 1984. Sweet potato. In the physiology of tropical field crops.eds.Goldworthy, P.and N.Fisher, pp.551-558. JWS, Chichester.

Helen Teshome. 2016. A Review on Potato (*Solanum storage rootosum* L.) Production Situations in Ethiopia. Food Science and Quality Management, 57:32-35.

Hotz C., Loechl C., Lubowa A.,Tumwin K, Brauw A.,MeenakshiJ.V., & Gilligan D. 2012. Introduction of beta carotene rich orange fleshedsweetpotato in rural Uganda results in increased vitamin A, intakes among children and women and improved vitamin A status among children. Nutr. J.142(34):1871-1880.

Huaman Z. 1991. IPGRI (International Plant Genetic Resources Institute). *Descriptors of sweet potato*,Rome,Italy. 25-56.

IPGRI (International Plant Genetic Resource Institute).1991.Descriptors for Sweetpotato. Rome, Italy.

Kabir, M., Kabir, M., Jahan, M. and Das, G.. 2004. Yield performance of three aromatic fine rice in a coastal medium high land. Asian J. Plant Sci. 3(5): 561-563.

Kay D.1973. Crop and product digest.Root Crops, Tropical Product Institute, London. pp. 245.

Kays S., Kays S.1997: Sweet potato chemistry in relation to health. Proceedings, International Workshop on Sweet Potato Production System toward the 21st century December 9-10, Miyakonojo, Miyazaki, Japan, p. 231.

Kays S.1985. The physiology of yield in sweet potato. In: J., Bouwkamp, (eds), *Sweet potato products: a natural resource for the tropics*. CRC press, Boca Raton, F1 p. 79-132.

Kooman, P., Fahem, M., Tegera, P. and Haverkort, A. 1996. Effects of climate on different potato genotypes 1. Radiation interception, total and tuber dry matter production. *European Journal of Agronomy*, *5*(3-4), pp.193-205.

Low J., Kinyae P., Gichuki S., Oyunga M. , Hagenimana,V., &Kabira, J. 2009. Combating vitamin A deficiency through the use of sweetpotato.International Potato Center, Lima, Peru.

Manrique K. and M. Hermann. 2000. Effect of GxE Interaction on Root Yield and Betacarotene Content of Selected Sweetpotato (*Ipomoea batatas* (L) Lam.) Varieties and Breeding Clone.

Martha Mebirhatu.2014. *Sweet Potato [Ipomoea Batatas (L.) Lam] Growth and Yield as Affected by Planting Density and Cultivar in Wolaita Soddo, Southern Ethiopia.*Thesis.Haramaya University, Ethiopia.

Ministry of Agriculture 2016. *Crop Production and Protection Packages Manual*. Addis Abeba, Ethiopia.

Muluken Demelie and Abiyot Aragaw. 2015. Genetic Variability of Sweet Potato on Yield and Yield Related Traits at Werer Agricultural Research Center, Ethiopia. Int. J. Agric. Sc. (2): 2348 – 3997.

.

Negeve J., S.Hahn, and J.Bouwkamp, 1992. Effect of altitude and environments on sweet potato yield in Cameroon. Trop. Agricultural. Trinidad, 69: 43-48.

Ogbologwung L. , Okpara D. and Njoku J. 2016. Effect of plant spacing and variety on weed and performance of orange-fleshed sweet potato in humid agro-ecological zone of Nigeria. *UJAS*, *17*(1), 11-20.

Onunka N., G. Antai, Onunka B. and Njoku S. 2011. Effect of Plant Density and Land Race on the Growth and Yield of Sweet potato in Northern Guinea ; Savanna of Nigeria. JASR, 11(1): 164-172.

Onwueme I.1978. *The tropical storage root crops. Yam, Cassava, Sweetpotato and Cocoyams.* New York: JWS.

RAC (Reaching Agents of Change) 2012. *Sweet potato facts and fiction*. CIP, Nairobi. 2 pg. SASHA (Sweet potato Action for Security and Health in Africa) (undated). Facts and figures about sweet potato. 2pg.

Rodriguez-Amaya D. 2001. A Guide to Carotenoid Analysis in Foods.ILSI Human Nutrition Institute, United States of America, Washington DC.

Saluzzo, J., Echeverria, H., Andrade, F. & Huarte, M. (1999). Nitrogen nutrition of potato cultivars differing in maturity. Journal of Agronomy of Crop Science, 183(3), 157–165. https://doi.org/10.1046/j. 1439-037x.1999.00323.x.

Sanginga N. and Mbabu A. 2015. Root and Storage root Crops (Cassava,Yam,Potato and Sweet Potato). Feeding Africa. abdou diouf international conference center. Dakar, Senegal.

Sekioka, H., 1964. *The effect of some environmental factors on the translocation and storage of carbohydrate in the sweet potato, potato and sugar beet: III.* Bulletin of the faculty of Agriculture, Kyushu University, 21: 131-148.

Shahana Sultana and Shahiduzzaman Md. 2016. Effect of plant spacing on the growth and yield of sweet potato cultivars in medium highland condition under AEZ-9 Int. J. Appl. Res.

Singh, N. Singh, R. (2002). Scientific crop production, X pressGraphics, Delhi-28, 1st ed., India sweet potato yield in Cameroon. Trop. Agricultural. Trinidad. 69: 43-48.

Solomon Ali, Wassu Mohammed and Beneberu Shimelis.2015. Agronomic and Physicochemical Evaluation of Sweet Potato [Ipomoea batatas (L.) Lam.] Collections in Ethiopia. Adv Crop Sci Tech, 3(3):230-240.

Stathers, T., Low, J., Mwanga, R., Carey, T., McEwan, M., David., S., Gibson, R., Namanda, S., McEwan, M., Malinga, J., Ackatia-Armah, R., Benjamin, M., Katcher, H., Blakenship, J., Andrade, M., Agili, S., Njoku, J., Sindi, K., Mulongo, G., Tumwegamire, S., Njoku, A., Abidin, E., Mbabu, A., Mkumbira, J., Ogero, K., Rajendran, S., Okello, J., Bechoff, A., Ndyetabula, D., Grant, F., Maru, J., Munyua, H., Mudege, N., (2018). Everything You Ever Wanted to Know About Sweetpotato: Reaching Agents of Change ToT Manual. International Potato Center, Lima, Perú. https://hdl.handle.net/10568/98338 12 vols., 664 p.

Sunita Koodi. 2016. Thesis Master of Science in Agriculture (Horticulture) Department of Horticulture s.k.n. college of agriculture, jobner s.k.n. agriculture university, jobner. 303 - 329.

Tenaw Workayehu. 2001. Sweet potato production Daniel M., Gobeze L. 2016. Sweet Potato Agronomy Research in Ethiopia: Summary of Past Findings and Future Research Directions. Agric. Food Sci., 3(1): 1-11.

Teow C., Truong C., V. McFeeters, Thompson R., R.Pecota, K. and Yencho G. 2007. Antioxidant activities, phenolic and β-carotene contents of sweet potato genotypes with varying flesh colours. Food Chem. 103:829–838.

Terefe Belehu and Geleta Legese. 1994. Agronomic Studies on Sweet potato. In: proceedings of the Second national Horticultural workshop in Ethiopia, 1-3 Dec.1992. Addis Ababa, Ethiopia.

Teshome Abdissa, Amenti Chali, Kassaye Tolessa, Fiseha Tadese and Geremew Awas, 2011. Yield and yield components of sweet potato as influenced by plant density: In Adami Tulu Jido Kombolcha District, Central Rift Valley of Ethiopia. *AJEA.* 1(2): 40-48.

Troung V., Avula R., Pecota K. and Yencho C. 2011. Sweetpotatoes. In: Sinha, N. (ed.) Handbook of vegetables and vegetable processing. New Jersey: Wiley Blackwell.

Tsegaye Demssie, Ahmed Ali, Yared Mekonen, Jemal Haider, Meleaku Umeta. 2010. *Magnitude and distribution of vitamin A deficiency in Ethiopia*. Ethiopian Health and Nutrition Research Institute, Addis Ababa.*Food Nutrition Bulletin.* 31(2): 234-241.

Wassu Mohammed, Solomon Ali, Beneberu Shimelis and Simret Burga. 2015. Genetic Diversity of Local and Introduced Sweet Potato (*Ipomoea batatas* (L.) Lam.) Collections for Agro Physicochemical Attributes in Ethiopia. J. Sci. Technol., *4(1): 09-19.*

Watanabe, K., K. Ozaki, and T. Yashiki, 1968. Effect of soil air composition and soil bulk density on the growth of sweet potato. Proc. Crop Sci. Soc. Jpn., 37: 65-69.

Wilson L.1982. Storage rootization in sweetpotato (*Ipomoea batatas* (L.) Lam). In: Proceeding of the First International sweet potato symposium, Tainan, Taiwan, AVRDC, p. 79-94.

Wogayehu Woku, 2005. Evaluation of common bean (Phaseolus vulgaris L.) varieties intercropped with maize (Zea mays L.) for double cropping at Alemaya and Hirna areas, Eastern Ethiopia. M.Sc. Thesis Presented to Haramaya University. Haramaya, Ethiopia.

Woolfe J. 1992. *Sweet Potato an Untapped Food Resource*. Cambridge University Press, Cambridge, United Kingdom.

Yen D.1974. *The sweet potato and Oceania; An essay in Ethno botany*. Honolulu, Hawaii; Bishop Museum press.

Young, C., 1961. Effect of thermoperiodism on storage root formation in Ipomoea batatas under controlled conditions. Plant Physiol., 36: 380-384.

APPENDICES

Appendix Table 1. Main effect of variety and intra row spacing on days to physiological maturity of Orange fleshed Sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Days to physiological maturity (days)
Alamura	156b
Dilla	162.3a
Kulfo	143.6d
Birtukanie	152.8c
SL	**
LSD (0.05)	1.0
CV (%)	4.3
SE±	3.4
Intra row Spacing (cm)	
20	151.3c
30	154b
40	156a
SL	**
LSD (0.05)	0.92
CV (%)	0.84
SE±	3.4

Where, ** = highly significant ($P < 0.01$); ns=non-significant ($P > 0.05$); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different

Appendix Table 2. Main effect of variety and intra row spacing on vine length of Orange fleshed Sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Vine length (cm)
Alamura	99.7b
Dilla	150.6a
Kulfo	65.1c
Birtukanie	104.1b
SL	**
LSD (0.05)	10
CV (%)	9.8
SE±	
Intra row Spacing (cm)	
20	102b
30	95.5b
40	117.1a
SL	**
CV (%)	9.8
SE±	

Where, ** = highly significant ($P < 0.01$); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different.

Appendix Table 3. Main effect of variety and intra row spacing on number of storage roots per orange fleshed sweet potato plant at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Storage roots per plant
Alamura	6.9a
Dilla	5.3b
Kulfo	4.3c
Birtukanie	5.9b
SL	**
LSD (0.05)	0.87
CV (%)	15.9
SE±	0.79
Intra row Spacing (cm)	
20	5.7
30	5.7
40	5.3
SL	ns
CV (%)	15.9
SE±	0.79

Where, ** = highly significant ($P < 0.01$); ns=non-significant ($P > 0.05$); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different

Appendix Table 4. Main effect of variety and intra row spacing on storage root length of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Storage root length (cm)
Alamura	23a
Dilla	19.2b
Kulfo	19b
Birtukanie	15.5c
SL	**
LSD (0.05)	1.49
CV (%)	7.9
SE±	2.34
Intra row Spacing (cm)	
20	16.5b
30	20.4a
40	20.7a
SL	**
LSD (0.05)	1.29
CV (%)	7.9
SE±	2.34

Where, ** = highly significant (P < 0.01); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different.

Appendix Table 5. Main effect of variety and intra row spacing on storage root weight of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Storage root weight (g)
Alamura	294.8c
Dilla	281.3c
Kulfo	490a
Birtukanie	350.8b
SL	**
LSD (0.05)	42.6
CV (%)	12.2
SE±	1.8
Intra row Spacing (cm)	
20	339.5b
30	399.2b
40	383.3a
SL	*
LSD (0.05)	36.9
CV (%)	12.2
SE±	1.8

Where, ** = highly significant (P < 0.01); *= significant (P<0.05); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different.

Appendix Table 6. Main effect of variety and intra row spacing on storage root diameter of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Storage root diameter (cm)
Alamura	5.7b
Dilla	6.3b
Kulfo	8.7a
Birtukanie	6.2b
SL	**
LSD (0.05)	0.7
CV (%)	10.1
SE±	0.46
Intra row Spacing (cm)	
20	6.8b
30	7.0a
40	6.9a
SL	**
LSD (0.05)	0.57
CV (%)	10.1
SE±	0.5

Where, ** = highly significant (P < 0.01); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different.

Appendix Table 7. Main effect of variety and intra row spacing on above ground fresh weight of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Above ground fresh (t ha^{-1})
Alamura	12.3c
Dilla	15b
Kulfo	9.2d
Birtukanie	19.3a
SL	**
LSD (0.05)	2.7
CV (%)	19.5
SE±	7.5
Intra row Spacing (cm)	
20	9.8b
30	16.2b
40	15.9a
SL	**
LSD (0.05)	2.3
CV (%)	19.5
SE±	7.5

Where, ** = highly significant (P < 0.01); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different.

Appendix Table 8. Main effect of variety and intra row spacing on marketable yield of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Marketable yield (t ha^{-1})
Alamura	18.8b
Dilla	14.4c
Kulfo	6.2d
Birtukanie	21.3a
SL	**
LSD (0.05)	1.93
CV (%)	13
SE±	3.9
Intra row Spacing (cm)	
20	14.7b
30	14.5a
40	14.3b
SL	*
LSD (0.05)	1.7
CV (%)	13
SE±	3.9

Where, ** = highly significant (P < 0.01); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different.

Appendix Table 9. Main effect of variety and intra row spacing on above total yield of orange fleshed sweet potato at Woramit Horticulture Research and Training Sub-center during the 2021 rainy season

Variety	Total yield (t ha^{-1})
Alamura	21.3a
Dilla	18.2b
Kulfo	7.2c
Birtukanie	23a
SL	**
LSD (0.05)	2.2
CV (%)	13.1
SE$\pm$	5.2
Intra row Spacing (cm)	
20	16.9
30	18.5
40	16.8
SL	ns
CV (%)	13.1
SE$\pm$	5.3

Where, ** = highly significant ($P < 0.01$); ns=non-significant ($P > 0.05$); CV = coefficient of variance; SE = Standard Error; LSD=least significant difference; means followed with the same letter(s) within the same column are not significantly different

Appendix Table 10. Analysis of variance for Survival rate

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	7.8	0.6	0.6	ns
Variety	3	104.1	7.4	0.0013	**
Intra row Spacing	2	8.0	0.6	0.6	ns
Interaction	6	7.3	0.5	0.8	ns
Error	22	14			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table 11. Analysis of variance for days to maturity

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	7.2	6.1	0.007	**
Variety	3	548.3	465.7	<0.001	**
Intra row Spacing	2	64.7	54.9	<0.001	**
Interaction	6	3.1	2.7	0.04	*
Error	22	1.2			

Where, **= highly significant (P < 0.01); *=significant (P<0.05); DF = Degree of freedom; SL= significance level

Appendix Table 12. Analysis of variance for vine length

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	161.4	1.5	0.24	ns
Variety	3	11099.8	104.6	<0.01	**
Intra row Spacing	2	1466.9	13.8	<0.01	**
Interaction	6	959.7	9	<0.01	**
Error	22	106			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table 13. Analysis of variance for number of branch per plant

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	15.9	2.1	0.1361	ns
Variety	3	235.5	32.2	<0.01	**
Intra row Spacing	2	15.8	2.2	0.1383	ns
Interaction	6	5.1	0.7	0.6513	ns
Error	22	8			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table 14. Analysis of variance for number of storage roots per plant

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	0.12	0.15	0.86	ns
Variety	3	10.45	13.14	<0.01	**
Intra row Spacing	2	0.68	0.86	0.44	ns
Interaction	6	9.70	12.21	<0.01	**
Error	22	0.74			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table 15. Analysis of variance for storage root length

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	1.8	0.75	0.48	ns
Variety	3	84.9	36.21	<0.01	**
Intra row Spacing	2	67.4	28.76	<0.01	**
Interaction	6	8.2	3.49	<0.01	**
Error	22	2.3			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table16. Analysis of variance for storage root diameter

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	1.8	1.9	0.16	ns
Variety	3	47.2	33.8	<0.01	**
Intra row Spacing	2	5.8	6.2	<0.01	**
Interaction	6	10.1	3.6	<0.01	**
Error	22	0.46			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table 17. Analysis of variance for aboveground fresh weight

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	4.9	0.66	0.53	ns
Variety	3	163.1	21.78	<0.01	**
Intra row Spacing	2	153.9	20.55	<0.01	**
Interaction	6	50.9	6.81	<0.01	**
Error	22	7.5			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table 18. Analysis of variance for storage root weight

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	4496.8	2.37	0.12	ns
Variety	3	81882.2	43.14	<0.01	**
Intra row Spacing	2	7586.9	4.00	0.03	*
Interaction	6	8221.9	4.33	<0.01	**
Error	22	1897.9			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table 19. Analysis of variance for marketable yield

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	1.6	0.39	0.68	ns
Variety	3	392.3	100.36	<0.01	**
Intra row Spacing	2	17.2	4.39	0.03	*
Interaction	6	14.6	3.72	<0.01	**
Error	22	3.9			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table 20. Analysis of variance for unmarketbale yield

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	0.16	0.55	0.58	ns
Variety	3	14.07	47.43	<0.01	**
Intra row Spacing	2	0.76	2.56	0.09	ns
Interaction	6	0.48	1.62	0.18	ns
Error	22	0.29			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Table 21. Analysis of variance for total yield

Source	DF	Mean Square	F-Value	Pr>F	SL
Replication	2	1.5	0.29	0.75	ns
Variety	3	460.9	87.88	<0.01	**
Intra row Spacing	2	10.7	2.04	0.15	ns
Interaction	6	18	3.44	0.01	**
Error	22	5.2			

Where, **= highly significant (P < 0.01); ns=Non-significant (P>0.05); DF = Degree of freedom; SL= significance level

Appendix Figure 1. Picture taken during land preparation in 2021 growing season in Woramit Horticulture Research and Training sub center.

Appendix Figure 2. Picture taken during Planting Materials preparation in 2021 growing season in Woramit Horticulture Research and Training sub center.

Appendix Figure 3. Picture taken during Planting 2021 growing season in Woramit Horticulture Research and Training sub center.

Appendix Figure 4. Picture taken during data collection during 2021 growing season in Woramit Horticulture Research and Training sub center.

Appendix Figure 5. Scare crow used to deter animals during 2021 growing season in Woramit Horticulture Research and Training sub center.

Appendix Figure 6. Picture taken during 2021 growing season in Woramit Horticulture Research and Training sub center.

BIOGRAPHY

The author, Alebachew Maru, was born in January 30, 1985 in Bahir Dar city of Amhara region, Ethiopia. He attended his elementary and junior education at Teyema primary school from 1992-2000. He completed secondary and preparatory education at Ghion Secondary and Preparatory School from 2001-2002. In 2004, he joined Burie Agricultural ATVET College and graduated with Diploma in Plant sciences in 2006. Then he was hired as crop development and protection expert at Bahir Dar city administration in 2007 and served till 2014.then he joined Wollo University in 2015 and graduated with Bachelor of Science in Plant Sciences in 2018. Later he joined Bahir Dar University self-sponsored and pursued his Master of Science study since 2021.