EFFECT OF NUMBER OF AXILLARY BUDS ON STEM CUTTINGS OF SWEET POTATO (*IPOMOEA BATATAS*) CV. 'BLESBOK' PRODUCTIVITY USING SACK GARDENING TECHNOLOGY

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DECLARATION

I, Lebogang Rejoice Moitsi, declare that the mini-dissertation hereby submitted to the University of Limpopo, for the degree Master of Science in Horticulture has not been submitted previously by me or anybody for a degree at this or any other university. Also, this is my work in design and in execution, and related materials contained herein had been duly acknowledged.

Candidate: Lebogang Rejoice Moitsi	Signature	Date

DEDICATION

I dedicate this to my beloved mother (Moitsi Amanda Mamoitsi), my supportive sister (Moitsi Valentia Refilwe) and my loving grandmother (Moitsi Mmangwako Raisibe).

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ABSTRACT

Worldwide, water scarcity, land degradation and unavailability of agricultural lands have posed serious threats on food security and income generation. Hunger, micronutrient deficiencies and starvation are likely to go up in Africa due to increasing urbanisation and rise in global food prices. As a result, it is important to identify innovative vegetable growing-based strategies, which can increase access to food by utilising the limited space available in rural and urban areas. Therefore, sack gardening technology could be a solution to both the lack of arable land and water scarcity in urban and rural areas. The objective of the study was to determine whether axillary bud number will have an effect on agronomic parameters and yield of sweet potato cv. 'Blesbok' produced using the sack gardening technology. Treatments, namely, 1, 2, 3, 4, and 5 number of axillary buds per stem cutting, were arranged in randomised complete block design, with 10 replicates. One bud (1) was used as a control. Different stem cuttings measuring from 10 to 30 cm long with approximately one (1) to six (6) axillary buds were collected from mature sweet potato plantation at a certified nursery from cv. 'Blesbok'. A total of eight (8) stem cuttings were planted in sacks consisting of growing media mixture of steam pasteurised loam soil and compost (3:1 v/v), 4 on top side of the sack and the remaining four on the side-holes of the sack. Insect pests were scouted and monitored weekly, while diseases were managed using spraying programmes as in commercial sweet potato production systems. Two weeks after transplanting, each plant was fertilised with 5 g nitrogen (N), phosphorus (P), and potassium (K) 2:3:2 (26) + 0.5%

Zinc (Zn) + 5% sulphur (S) and 5% calcium (Ca). Number of axillary buds had significant effects on vine length, fresh shoot mass, number of shoots and dry shoot mass contributing 59%, 58%, 45% and 58% in total treatment variation (TTV), respectively, whereas axillary bud numbers had no significant effects on fresh tuberous root mass, chlorophyll content, vine stem diameter, tuberous root diameter, tuberous root length, dry tuberous root mass and number of tuberous roots. Relative to control (one bud), two (2), three (3), four (4), five (5) number of axillary buds decreased vine length, fresh shoot mass and dry shoot mass by 8-37, 30-55 and 26-55%, respectively. However, relative to control (one bud), number of axillary buds increased number of shoots by 8-17%. The quadratic relationship models were explained by 95, 92, 96 and 98% of vine length (VL), number of shoots (NS), fresh shoot mass (FSM) and dry shoot mass (DSM), respectively. In conclusion, findings of the study demonstrated that a single (1) or two (2) axillary bud(s) on stem cuttings of sweet potato CV. ‘Blesbok’ showed better results for both yield and growth parameters as compared to three (3), four (4) and five (5) buds.

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

Worldwide, water scarcity, land degradation and unavailability of agricultural lands have posed serious threats on food security and income generation (Njenga and Karanja, 2013). This resulted in a drastic decline in agricultural production, especially in areas where land and access to agricultural inputs is limited. The problem of water scarcity appears to be increasing as cities and industries compete with agriculture for the use of water (Njenga and Karanja, 2013). The issue of land scarcity is complicated by the fact that population and business industry growth often take place in prime agricultural areas (Asamoah, 2010). Many farming communities often experience a decline in agricultural productivity due to lack of access to farming land (Crush *et al*., 2011). As more land is lost, it becomes more difficult to produce the amount of food needed to feed the growing human population (Nyarko, 2015). As a result, issues of food security, hunger and poverty as well as ways of addressing them, continue to be of great concern.

According to FAO (2008), the issue of limited space for agricultural production across the world continues to increase due to rapid urbanization. As urbanization takes place, the population of urban poor also continues to rise along with its levels of food insecurity. Furthermore, millions of hectares are lost each year when agricultural land is converted and used for highways, factories and other urban needs (Crush *et al*., 2011). The share of the global population expected to live in cities is projected to grow by around 2.5 billion people by 2050 (Cohen, 2003). Such growth often results in a permanent loss of arable land. However, urbanization can also drive many environmental issues and problems such as climate change, environmental pollution and loss of agricultural productivity (Grimm *et al*., 2008; Faulkner, 2004; McDonald, 2008). South Africa is one of the most urbanized countries in Africa (Ramaswami *et al*., 2016). According to McDonald (2008), 63% of South Africans are already living in urban areas and the statistics is expected to rise up to 71% by the year 2030, resulting in an increase in demand on basic infrastructure requirements. South African experienced an increase in level of urbanization in the past ten years, with an increase in urban population of 67.37% in 2020 (Tiando *et al*., 2021). In other countries like China, the level of urbanization in 2010 had increased when compared to the previous year 2000, with the urban population experiencing 16.47% growth over the ten-year period (Zhao *et al*., 2008).

Vegetables are a rich source of vitamins and minerals that contribute towards the dietary demands of human health (Uusiku *et al*., 2010). Low vegetable productivity has a pronounced negative impact on development of involved livelihoods and income generation. Aiken (2013) reported that food insecurity, hunger, micronutrient deficiencies and starvation are likely to go up in Africa due to increasing urbanization and rise in global food prices. In addition, hundreds of millions of people in both developed and developing countries consume less nutritious vegetables compared to the recommended daily intake (FAO, 2008). As a result, many households are infected with deficiency related diseases associated with inadequate intake of minerals, essential amino acids, poor quality fat and vitamin. According to Black *et al*. (2008), millions of children under the age of five are suffering from stunting as a result of malnutrition and chronic undernutrition.

People who practice traditional livelihoods that place modest demands on the land, such as small-scale farming and forestry, are being isolated by governments and economic actors pursuing commercial resource development and intensive agricultural production (McDonald, 2008). Moreover, vegetation production in many areas is threatened by land degradation that has resulted from excess chemical application on the soil and soil nutrient depletion (Gerber *et al*., 2014).

Sweet potato (*Ipomoea batatas L*.) is an economically important food security crop globally and it is mainly cultivated both by commercial and subsistence small-scale farmers (Nyarko, 2015). Sweet potato is considered as a stable food crop in many developing countries such as Africa, Asia and southern America (Gurmu *et al*., 2015). Although sweet potato is an underrated popular vegetable, it is considered an important food source in global food security research (Iese *et al*., 2018). The crop plays an important role in the food systems of southern African countries and its importance is rising as an attractive income generator (Gurmu *et al*., 2015). Sweet potato is an important source of carbohydrates, vitamins A and C, fiber, iron and it provides a healthy diet for millions of people across the country (Gurmu *et al*., 2015). However, major farmers lose 20–98% of their sweet potato yields due to a range of factors including drought, disease and limited land area needed for cultivation. The total sweet potato production in South

Africa was estimated at 73945.00 tons in 2017 and 88000. 00 tons in 2019, which are much less than the potential production (FAOSTAT, 2019). As a result, households consume lower nutritious vegetables like sweet potato than recommended.

Based on the issue of low productivity and rise in population rates, it is necessary to find ways that will lead to more production of nutritious vegetable such as sweet potato. In order to achieve that, there is a need to identify innovative vegetable growing-based strategies which can increase access to food by utilizing the limited space available in rural and urban areas. Therefore, sack gardening technology could provide a solution to both limited arable land and water scarcity in urban and rural areas. Sack gardening is regarded as an inexpensive but high-yielding form of urban agriculture where the cultivation of crops takes place in large sacks filled with soil (Sullivan *et al*., 2015). Sack gardening technology can be utilized under limited space available in rural, urban and semi-urban areas for the production of nutritious agricultural crops (Gallaher *et al*., 2013). Apart from ensuring food security, sack gardening technology has been proved to be economically viable and has improved living standard of many families (Essilfie *et al*., 2016). Many disadvantaged household individuals find it difficult to practice farming due to limited or unavailable land for production. In such cases, the use of sack gardening technology to increase access to food as well as generate income from crop sales could be beneficial. However, farming with tuberous crops like sweet potato using the sack gardening technology could be a challenge as productivity of the crop depends on a number of factors, one of them being the number of axillary buds on the stem cutting for use as planting material. Therefore, the current study focused on assessing the effect of number of axillary buds on stem cuttings of cv. 'Blesbok' sweet potato productivity using sack gardening technology.

1.2 Problem statement

Worldwide, countries are undergoing rapid urbanization with an increase in population rates. Many households often experience a decline in productivity, partly because of limited land needed for agricultural production (Crush *et al*., 2011). In addition, constraints such as water shortages, limited agricultural land and a high cost of agricultural production exacerbate food insecurities (Sekhar, 2007). This necessitates a need for innovative methods which could serve as an alternative means to increase vegetable production and mitigate the problem of food insecurity. Sack gardening technology is an effective way of increasing food security and income generation by utilising limited space in both urban, rural and semi-urban areas (Gallaher *et al*., 2013). Production of nutritional crops such as sweet potato using sack gardening could improve production and increase access to food. To-date, the production of sweet potato using sack gardening technology in South Africa has not been documented. Therefore, the researcher intended to determine the effect of axillary bud number on stem cuttings of sweet potato cv. 'Blesbok' productivity using sack gardening technology.

1.3 Rationale of the study

Sweet potato is a stable food crop in many countries and serves as raw material for many industrial products (Gurmu *et al*., 2015). In South Africa, some rural communities use green leaves from sweet potatoes as relish. According to Van Jaarsveld *et al*. (2006), sweet potatoes are an extremely important source of Vitamin A because they contain high levels of beta-carotene. The crop contains significant amounts of carbohydrates when compared to other starchy crops such as rice, maize and sorghum porridge and it provides almost a balanced diet for the human body (Birt *et al*., 2013). Sweet potatoes contain large amounts of fiber, which have long been known for improving the health of the gut as well as digestion. Sweet potatoes are mostly propagated by stems cuttings or by stimulating the development of axillary and apical buds (Sivparsad and Gubba, 2012). Vegetative propagation through stem cuttings makes the sweet potatoes vine relatively easy to plant and it ensures multiplication of the best stock possible (Mukherjee, 2002). Therefore, sweet potato production by stem cuttings using sacks can ensure a sustainable supply of food and make a major contribution to the food security across the world.

Sack gardening technology has proven to be an effective and inexpensive means of increasing, dietary diversification, food security, income generation and a way for households to be self-reliant (Gallaher *et al*., 2013). Sack gardening technology is very effective since it requires a small space, and it allows households to produce various food varieties of high nutritional value. Many urban poor people who could not afford to practice expensive forms of urban farming can adopt sack gardening technology to increase access to food as well as generate income from selling their produce.

1.4 Purpose of the study

1.4.1 Aim

The aim of this study was the assessment on the effect of number of axillary buds on stem cuttings of sweet potato cv. 'Blesbok' production in sack gardening technology.

1.4.2 Objective

The objective of this study was to determine whether number of axillary buds will have an effect on agronomic parameters and yield of sweet potato cv. 'Blesbok' produced using the sack gardening technology.

1.4.3 Hypothesis

Number of axillary buds will have an effect on agronomic parameters and yield of sweet potato cv. 'Blesbok' produced using the sack gardening technology.

1.5 Reliability, validity and objectivity

The reliability of data was based on statistical analysis of data at the probability level of 10%, objectivity was achieved by ensuring that the findings were discussed on the basis of empirical evidence, in order to eliminate all forms of subjectivity (Leedy and Ormrod, 2005).

1.6 Bias

Bias was reduced through minimising the experimental error by increasing the number of replications on the experiments conducted. The treatments were also randomised within the selected experimental design (Leedy and Ormrod, 2005).

1.7 Significance of the study

Land scarcity because of urbanization put additional restraints on agricultural development, therefore, the adoption of sack gardening technology would increase crop production by utilizing limited space. This study is aimed at assessing the response of agronomic parameters and yield of sweet potato cv. 'Blesbok' to different number of axillary buds grown using sack gardening technology. The data from this study would provide information on sack gardening technology that will ensure household individuals with a steady supply of vegetables, especially in areas where the soil is no longer productive and access to inputs for agricultural production is limited. Based on the decline in sweet potato production and taking into account its high potentiality, it could be important to intensify research efforts to increase its production for the benefit of the producers and consumers to sort out the problem of food insecurity. The production of sweet potato using sack gardening technology will ensure continuous production and make a major contribution to food security. With high unemployment rate and poverty level, household individuals with limited access to land will find sack gardening technology very helpful as it is a technique that minimizes household expenditure while maximizing income.

1.8 Structure of the mini-dissertation

This mini dissertation consists of five chapters. Chapter 1 is general introduction containing the background information, problem statement, purpose of the study, rationale and statistical analysis. Chapter 2 reviewed the work done, and the work not done on the problem statement, whereas the research related to the objective was addressed in Chapter 3. Chapter 4 is summary, significance of the findings, recommendations with respect to future research and with the conclusions that were intended to provide a take home message regarding the current study. The citation and references followed the Harvard style of author-alphabet as approved by the Senate of the University of Limpopo.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Due to industrial development and rapid urbanization that compete for land with agriculture (Zhang *et al*., 2016; Mueller *et al*., 2012), countries continuously loose arable lands. In 2015, reports indicated that the earth had lost a third of its arable lands over the past 40 years (Milman, 2015). In countries with fast economic development, such as China, India, and Africa, much arable land has been converted to industrial use (Cakir *et al*., 2008; Xu *et al*., 2000). Urbanization rates in Africa are almost twice that of the global average, and cities are fast becoming epicentres of the food security challenge in Africa (UNDESA, 2007). The research from the International Fund for Agricultural Development suggests that a large number of households limit their food intake to one or two meals a day (Ahmed *et al*., 2007). Jessica (2018) reported that the average per capital income of sub-Saharan African is approximately three times lower than that of the rest of the world. One of the main sources of income in Africa is agriculture which can easily be impacted by the quality of soil, land shortage and a stable water source (Jessica, 2018).

Worldwide, countries are faced with high food prices, low income, hunger, and food insecurity partly because arable land for agriculture is a limited resource (Liu *et al*., 2017). According to Mabhaudhi *et al*. (2021), South Africa is a water scarce country and ranks as one of the 30 driest countries in the world with an average rainfall of about

40% less than the annual world average rainfall. Currently, approximately one billion people (16% of global population) suffer from chronic hunger as compared to a time when there is more than enough food to feed everyone on the planet (Xu *et al*., 2000). According to Christiaense *et al*. (2012), the Food and Agriculture Organisation of the United Nations (FAO) on the acute food crises in the Sahel region of West Africa, estimated that about 1 million children under the age of five are at risk of severe acute malnutrition. Therefore, with a consistent rising population, more food is needed to sustain life (Thorn *et al*., 2015). This calls for innovative and efficient ways of increasing food security especially in areas where agricultural land is limited. A new form of urban agriculture called sack gardening technology had been reported as one of the innovative cultivation methods that could serve as a solution to address the loss of cultivable land by utilising the limited space around households for production (Essilfie *et al*., 2016). By implementing sack gardening technology in South Africa, food insecurity can be tackled throughout. Sack gardening technology has the potential to contribute to food security within cities and rural areas. The importance of sack gardening technology in general is its limited need for space and water used for irrigation (Dubbeling and Massonneau, 2009). However, information on production of vegetables using sack gardening technology remains limited.

2.2 Sweet potato production

2.2.1 Origin

Sweet potato (*Ipomoea batatas L*.) is originated from tropical Central America and it belongs to the Convolvulaceae family, which is preferable known as the morning glory family (Iese *et al*., 2018). It is grown for its edible tuberous root or for its ornamental shaped green to purple leaves. Sweet potato is among the world's most important and multipurpose food crops (Bovell-Benjamin, 2007) and ranking seventh among the most important food crops (Iese *et al*., 2018). About 8 million hectares of the world's agricultural land were used to grow sweet potato, and over 95% of the world's sweet potato output was from developing countries (Srinivas, 2009). In many parts of Africa, the crop is grown as a staple food and it is efficient in the production of carbohydrates, proteins, vitamins and cash income per unit area of land (Magagula *et al*., 2010). Sweet potato is considered an important staple food and has been consumed and cultivated for more than 5000 years (Bovell-Benjamin, 2007).

2.2.2 Addressing food security

Sweet potato plays an important role in ensuring food security and income generation for disadvantaged local communities (Manners and van Etten, 2018). It is an important food and vegetable crop in most developing countries where it was ranked seventh economically after rice (*Oryza sativa*), wheat (*Triticum aestivum*) and maize (*Zea mays*) (Mukhopadhyay *et al*., 2011). In Africa, sweet potato is an important economic crop due to its potential of alleviating poverty and improving the nutritional status of the rural poor in a sustainable way (Low *et al*., 2009). From the perspective of food security, sweet potato is an excellent crop as it often survives where staple crops fail. It contributes to food availability by providing high output per unit of land and can produce on marginal soils (Adeyonu *et al*., 2019). Sweet potato can be used to eradicate poverty and it is grown in developing countries, often by small-scale, subsistence farmers and in home gardens (Mukhopadhyay *et al*., 2011). According to Mukhopadhyay *et al*. (2011), sweet potato production can create sustainable income generation opportunities for small farmers due to its profitability, low production costs due to low input requirements and the potential for high yields. It provides poor households with access to cheap food and prevent hunger during periods of food shortage (Mwanga and Ssemakula, 2011). Sweet potatoes can be easily produced by smallholder farmers, are high yielding and requires less management. According to De-Brauw *et al*. (2017), sweet potato can grow non-seasonally and many households sell the crop to obtain income to purchase other food to diversify their diet. According to FAOSTAT (2012), about 115 countries produced 108,274,685 tons of sweet potatoes with Africa contributing up to 14% of global production which amounted 14,441,099 tons in 2010. Despite its many benefits, sweet potato is characterized by a low production, yield and tuber quality across the world. Sweet potato production in South Africa was just above 54 300 tons but dropped by 14% in 2006 and the production volumes was found to be the lowest in a ten-year period. As of 2018, South Africa's sweet potato production output notably grew by 16.5% relative to 2017 production output (Scott, 2021).

2.2.3 Cultivation

Although sweet potato can be cultivated by seed, conventionally and traditionally it is propagated using stem cutting fragments of 20-30 cm long with 3-5 nodes (Low *et al*., 2009). According to Ming-fu (2011), utilizing the vine cuttings as planting material give the farmers an opportunity to use all storage roots for consumption or for sale. Vine cuttings are better planting material in tropical regions than sprouts from tubers for several reasons. Plants derived from vine cuttings are free from soil-borne diseases (Onwueme, 1978). By propagating with vine cuttings, farmers can be able to save the entire tuber harvest for consumption instead of reserving some for planting purposes. Low *et al*. (2009) reported that there is shortage of planting material in Sub-Sahara Africa because nurseries owned by smallholder farmers are small and most of them are located at small backyard spaces. However, in South Africa, there are not many commercial sources of planting material for the gardeners and small-scale farmers. Plants derived from vine cuttings have a shorter growth period, free from soil-borne disease and yield better than sprouts and produce roots of more uniform sizes (Alizadeh *et al*., 2010). Sweet potato planting time is mainly determined by the climate of a location. The crop can easily be damaged by light frost and the plants require high temperatures for a period of 4 to 5 months to yield well (Mukhopadhyay *et al*., 2011).

2.2.4 Utilization and nutritional value

Worldwide, sweet potato provides significant quantities of carbohydrates compared to other staple foods. Apart from simple starches, sweet potatoes are rich in complex carbohydrates, dietary fibre, beta carotene, vitamin C, and vitamin B6. According to Islam *et al*. (2003), sweet potato is used as food, as livestock feed and for starch as well as alcohol production. The crop is also used in baking industries and tuberous roots are cooked together with other ingredients in various dishes or stored for later use as boiled vegetable (Islam *et al*., 2003). In some part of the world, the crop is processed into flour, which is cooked or baked for human consumption. Consumers accepted and utilized sweet potato leaves as food through modified and culturally acceptable traditional recipes (Laurie and Van Heerden, 2012). Medicinally, sweet potato leaves are an essential mineral rich vegetable containing chlorogenic acid which is a remedy for obesity suppression in humans (Kathabwalika *et al.,* 2013).

2.3 Sack gardening technology

Sack gardening technology is a form of container gardening that can be practised in densely populated areas where a garden plot is usually not available for most parts of the local population (Pearson *et al*., 2010). Sack gardening technology involves planting various crops into the top and sides of large plastic sacks filled with soil, which allows people to plant a larger number of plants in areas where soil is no longer productive. It is proved to be an effective way to grow food in regions with drought as well as areas prone to flooding, in rural communities and in urban areas (Tixier and De Bon, 2006).

2.3.1 Utilization

Sack gardening technology continues to grow in popularity as an alternative method for crop production under limited space. Like other forms of urban gardens that can be found worldwide such a roof gardens, it contributes towards nutrition of many households by providing vegetables, herbs, and staples (Whittinghill, 2012). The sack gardening technology creates income to poor households and can be used in any climate change due to its adaptability (Tixier and De Bon, 2006). Generally, vegetables from the sack gardening technology are used for immediate consumption or they are sold, thereby increasing a household’s access to cash for other needs and for education (Maina, 2010). Compared to a traditional field-based farm, sack gardening technology require fewer resources in every category such as less space, less water, and less labour (Essilfie *et al*., 2016).

In addition to its benefits, sack gardening technology allows farmers to use readily available materials to grow their crops such as broken basins and stones (Hatloy *et al*.,1999). According to Gallaher *et al*. (2013), sacks are prepared by filling a 50 to 90 kg sack with soil and a column of rocks in the middle to improve water filtration. The rocks release micronutrients into the soil, including boron, cobalt copper, iron, manganese, molybdenum, chlorine and zinc are all essential for high yields and healthy plant growth. The sacks are naturally placed near the owner's house where they are easily accessible for maintenance and monitoring (Radice, 2005). One sack which can contain 50 seedlings saves about 7 m^2 of land for other purpose (Hossain and Akter, 2015). In addition, sack gardening technology allows a freer flow of water to the roots and retains moisture more efficiently than traditional methods. Sack gardening technology is also easy to manage when it comes to watering the crop variety and weeding (Catherine, 2007). WinklerPrins and Souza (2005) reported that, this method is an efficient water management venture as the sacks are tailored to ensure that there is no water waste, thus ensuring all plants are well watered. Generally, maintenance of the plants is easy as weeds rarely grow on the sacks (Harriet, 2017). According to Anita (2019), sack gardening technology ensures space management, soil management and high-quality production with low cost.

According to Binns and Lynch (1998), the most appropriate crops for sack gardening technology are leafy vegetables due to their ability to grow after the leaves have been harvested. Sack gardening technology has the ability to produce crops such as spinach, lettuce (*Lactuca sativa*), beets (*Beta vulgaris*), arugula (*Eruca vesicaria*), potatoes (*Solanum tuberosum*), carrots (*Daucus carota*) and onions (*Allium cepa*). Most farmers practiced the use of sack gardening technology by growing kale (*Brassica oleracea*) and Swiss chard (*Beta vulgaris*) since seedlings are easily purchased at local markets (Karanja and Njenga, 2011). According to Karanja and Njenga (2011), the majority of farmers grow a combination of four crops in their sack gardens: kale, Swiss chard, onions, and coriander (*Coriandrum sativum*). A small number of farmers also reported planting pumpkin, (*Cucurbita spp*.), tomatoes (*Solanum lycopersicum*), garden huckleberry (*Solanum scabrum*), malabar spinach (*Basella alba*), and jute mallow (*Corchorus spp*.). Al-Kodmany (2018) reported that growing superfoods like kale, spinach and root crops filled otherwise poor diets with vitamins and other nutrients. Not only does sack gardening technology impact the economy, but families are able to have access to a stable food source (Francis, 2000).

2.3.2 Productivity

The adoption of sack gardening technology had been a success at improving household food security and improving local income earning potential (Pearson *et al*., 2010). Numerous studies reported that sack gardening technology can provide a sustainable source of vegetables both in rural and in urban areas (Binns and Lynch, 1998; Crush *et al*., 2011). Vegetable produced from the sack gardening technology provide an average of four meals per household in a week and an additional average weekly income generated by selling yields (Pascal and Mwende, 2009). Heuvelink and Gonzalez-Real (2007) assessed growth of tomatoes in bags, where results showed growth to be equally as successful if not better than growth in ground beds. Also, results indicated that four cultivars of tomatoes under greenhouse tested in sacks, produced a yield ranging from

8.21 kg to 8.85 kg per plant (Heuvelink and Gonzalez-Real, 2007). In tomato study conducted by Okoth (2016), similar results were obtained where high yield was obtained as compared to open traditional farming.

Hatloy *et al*. (1999) observed average yield of 28 tomatoes per tree with the sack gardening technology as compared to 15 tomatoes per tree in the open fields. Peprah *et al*. (2014) reported that many farmers practicing sack gardening technology have indicated that the technology was successful while having the ability to generated higher yields and with reduced amount of water than open farming. Masimba (2014) observed that sack gardening technology allows individuals to harvest high yield of potatoes as compared to the traditional way of growing potatoes on the ground. Also, the study reported that each sack of potato plant produced approximately 30 kgs when harvested (Masimba, 2014).

2.3.3 Challenges

Although the sack gardening technology had been proven to be one of the effective innovative strategies for improving food security in areas where land for agricultural farming is scanty, several ongoing challenges, which include pest and diseases, accessing fertile soil and irrigation water were experienced (Mwangi, 1995). Studies had demonstrated that the technology was successfully adopted in Africa where agriculture faces distinctly different challenges (Foeken and Owuor, 2008; Memon and Lee-Smith 1993). Household individuals that need to engage in sack gardening technology, also requires access to materials and inputs, which includes sacks, seeds, soil, manure and water (Herforth, 2010). Some challenges experienced were labour problems especially in filling the sacks, land degradation when soil was collected in the forests and yet some experienced water availability problems (Masvodza and Mpuwei, 2015).

Generally, finding good fertile soil suitable for sack gardens could be an obstacle and could result in poor outcome of sack gardening projects (Nowak and Ujereh, 2004). Farmers obtained their soil from a variety of sources, including open fields near their house, old construction sites, the railroad and old dumpsites (Njeru, 2006 In cases where the necessary resources, for example good soil, are not available, the community members may have to buy soil, which resulted in additional costs (Pascal and Mwende, 2009). Gallaher *et al*. (2013) reported difficulties in obtaining good soil for planting both in rural and urban areas. Villavicencio (2009) reported that in areas that are frequently flooded, sack gardeners had to collect enough soil to avoid rainy season. In some cases, soil hardening was reported which resulted in negative effect on the roots and yield set (Masvodza and Mpuwei, 2015). Gallaher *et al*. (2013) reported that soil collected from dumpsites were more likely to have high levels of heavy metal contamination (cadmium (Cd), and lead (Pb)). In urban environments, pollution of air, soil and water is very common due to heavy industrial production facilities and insufficient waste treatment (Angelone and Udovic, 2014; Njeru, 2006).

Some farmers experienced a challenge in accessing water as some areas lack reliable water supply systems (Memon and Lee-Smith 1993). Some sacks shrunken during the dry periods as a result of lack of water (Freeman, 1991). Furthermore, many farmers turn to sewer water to irrigate their crops resulting in heavy metal and bacterial contamination on crops (Foeken, 2006). Most households purchase water at a cost of three to four dollars for 20 litres for them to irrigate crops (Villavicencio, 2009). Therefore, purchasing water was challenging for poor household who live on less than two dollars a day (Njenga *et al*., 2010). As a result, poor maintenance of sacks was reported due to increased costs and efforts required to obtain water during frequent water shortages, (Hovorka, *et al* 2006).

In a potato study conducted by Masvodza and Mapuwei (2015), the observation indicated that around 25% of farmers experienced much lower yields of potatoes per sack than expected. These low yields were reported as a result of lack of technical knowledge, inputs issues, soil and media issues (Hossain *et al*., 2008). Furthermore, farmers experienced an issue of low temperatures that resulted in extension of normal harvesting period in sacks as compared to field-produced potatoes. Also, it was reported that inexperienced farmers faced storage difficulties due to short tubers storage, thus downgrading market value resulting in more losses (Masvodza and Mpuwei, 2015). Some specialists reported lot of shading from trees resulting in tall and highly vegetative plants which delay or reduce yield (Manzira, 2012). Pests and diseases were also discovered as one of the biggest challenges in sack gardening as crops in a sack are planted close together (Villavicencio, 2009). In some cases, drying and yellowing of leaves were discovered as a sign of disease infection. Also, white flies and snails were reported especially in areas where sacks are placed near other plants or bushes (Jackel, 2006).

In general, several farmers have faced challenges due to lack of knowledge on particular aspects of sack gardening technology (Villavicencio, 2009).

2.3.4 Addressing food security

Basically, the sack gardening technology is commonly practiced in many African countries like Kenya, Ghana, Nigeria, Zambia and Zimbabwe (Gibbon, 1992). With an increasing issue of starvation deaths, diseases and poverty (Jha, 2002), it is now more important to understand the contributions of sack gardening technology to household livelihood strategies and food security. Sack gardening technology has been reported to be inexpensive and a simple way to produce nutritious foods, combating the issue of food insecurity in areas throughout Africa (Peprah *et al*., 2014). Many households are now practising this technology to save on the purchase of vegetables as it allows them to grow vegetables they would otherwise struggle to purchase (Aiken, 2013). According to Rembiałkowska (2010), a growing sack can take a maximum of five cabbages (*Brassica oleracea*) while in its actual position on the ground, only one cabbage can be grown. Also, a space that can be occupied by two collard greens (*Brassica oleracea var. viridis*) seedlings planted the conventional way, can be occupied by one sack that can hold up to 15 pieces of collard green (Wavinya, 2020). When sacks are arranged on balconies, one can pile the sacks vertically and still get big harvests for the family from the tiniest spaces (Iynet, 2019).

According to Pascal and Mwende (2009), about 80% of crop production from sack gardening technology is self-consumed, contributing to the diversification of family diets, and enables the reduction of the family budget share dedicated to food purchases. Also, it is said that sack gardening technology has allowed households to maintain and improve their nutritional status without having to cut back on other expenses such as health and education (Pascal and Mwende, 2009). Many poor households sell vegetables from their sacks informally to their neighbours, whereas others sell them more formally at vegetable stands in the market (Mireri *et al*., 2007). Households practicing sack gardening technology shared their vegetables as a way of encouraging others to plant their own sack gardens (Mireri *et al*., 2007). In the markets where vegetables are expensive, sack gardening technology allows households to get vegetables throughout the year. For some farmers, sack gardening technology has been beneficial because it has provided them with additional income (Memon and Lee-Smith,1993). The money earned is used to buy a variety of things, including water for their plants and other household items.

In general, sack gardening technology ensures that the family saves instead of going to the market to buy food, thus boosting the economy. The prices of vegetables are getting increasingly higher due to the fact that some vegetables must be transported from one province to another (Memon and Lee-Smith, 1993). Therefore, vegetables produced from sack gardening technology can reduce the amount of money spent on buying from supermarkets.

2.4 Work not done on the research problem

Many studies reported the benefits of utilising sack gardening technology under limited space, especially in densely populated areas. Studies also reported on the production of leafy vegetables such as spinach, pumpkin and amaranth, as well as other tuber crops like potatoes using sack gardening technology. However, currently, no work has been documented on sweet potato production in sacks, especially investigating on the number of axillary buds per vine stem cuttings using the sack gardening technology.

CHAPTER 3

EFFECT OF AXILLARY BUD NUMBER ON STEM CUTTINGS OF SWEET POTATO CV. 'BLESBOK' PRODUCTIVITY USING SACK GARDENING TECHNOLOGY

3.1 Introduction

Worldwide, the issue of land scarcity and food insecurity continues to be a great concern as population and business industry growth often take place in prime agricultural areas (Asamoah, 2010). According to UN-HABITAT (2008), African cities are facing enormous problems as more than half of all residents live in overcrowded areas and are likely to experience malnutrition. Hundreds of millions of rural and urban dwellers face undernutrition today due to unavailability of land needed to produce food (Asamoah, 2010). As a result, the challenge of achieving an increase in crop production to satisfy the dietary needs and preferences of the growing human population is urgent (Godfray, 2014).

Innovative methods which can utilise the limited space available in rural, urban and semi- urban areas for the production of nutritious agricultural crops are required. Therefore, a form of urban agriculture called the sack gardening technology was developed and tested, whereby various vegetables can be grown on limited space utilising sacks (Karanja and Njenga, 2011). Sack gardening technology takes up less space than small-scale gardens. It is a simple technology, which can help households to grow fresh produce on very small spaces.

Production of sweet potato cultivars in sacks can provide rural, urban and semi-urban families with the required nutrition in their diet. However, vegetative propagation using stem cuttings with a certain number of axillary buds had been a challenge in determining the suitable number of axillary buds that will result in productive production of sweet potatoes edible roots under limited space of production. Therefore, the aim of this study was to assess the effect of number of axillary buds on stem cuttings of sweet potato cv.
'Blesbok' production using the sack gardening technology.

3.2 Materials and methods

3.2.1 Description of the study site

A field study was conducted at the Green Biotechnologies Research Centre of Excellence, University of Limpopo, Limpopo Province, South Africa (23°53'10"S, 29°44'15"E) from January to April in 2021. The location has summer (November-January) rainfall with mean annual rainfall of less than 500 mm, whereas maximum/minimum temperatures average 38 /5°C.

3.2.2 Treatments and research design

Five treatments namely, 1, 2, 3, 4 and 5 axillary buds per sweet potato cv. 'Blesbok' stem cuttings, were arranged in a randomised complete block design (RCBD), with 10 replications (n = 50). One (1) bud was used as a control.

3.2.3 Procedures and preparations

Plant material preparation: Mature sweet potato vines obtained from a certified nursery were multiplied by planting tuberous roots inside 20cm plastic pots to generate fresh stem cuttings using steam pasteurized loam soil and Hygromix (3:1 v/v), under greenhouse conditions. After six weeks, different stem cuttings measuring from 10 to 30 cm long with one (1) to five (5) axillary buds were excised from the vines and transplanted into seedling tray consisting of Hyggromix to generate roots (Figure 3.1). After 20 days when stem cuttings had developed adventitious roots, they were hardened for five days and ready for transplanting into the sacks.

Growing sacks preparation and planting: Fifty (50) kg new mealie-meal sacks containing 40 kg growing media mixture of steam pasteurised loam soil and compost (3:1 v/v) were prepared (Figure 3.2). The sack was perforated with 4 alternating holes on the sides. A total of eight (8) stem cuttings representing treatments were planted, 4 on the top side of the sack and the remaining four on the side-holes of the sack. For ease of drainage and water distribution during irrigation within the sack, a central tunnel of about 5 cm diameter filled with stones was made during sack filling with growing media (FAO, 2009). Plants were irrigated twice a week to field capacity or when the moisture content reached below 50%. The soil moisture sensor was used to estimate the amount of water in the soil. Insect pests were scouted and monitored weekly, and diseases were managed using spraying programmes as in commercial sweet potato production systems. Two weeks after transplanting, each sack with stem cuttings received 5 g NPK 2:3:2 (26) + 0.5% Zn + 5% S and 5% Ca fertilizer.

Figure 3.1 Preparation of sweet potato cv. 'Blesbok' stem cuttings using seedling trays.

Figure 3.2 Growing sacks with sweet potato stem cuttings soon after transplanting.

Figure 3.3 Sweet potato cv. 'Blesbok' stem cuttings at 90 days after planting using sack gardening technology.

3.2.4 Data collection

At 90 days after transplanting the stem cuttings (Figure 3.3), vine length was measured from the surface to the tip of the flag leaf. Chlorophyll content on three matured healthy leaves per plant was measured using chlorophyll meter (Minolta Spad-502, Osaka).
Stems were severed at the soil surface and vine stem diameter (VSD) was measured at 5 cm above the severed end using vernier caliper. Shoots were counted per plant and weighed for fresh shoot mass (FSM). Fresh shoots were later dried using oven dryer at 70°C for 72 h and weighed for dry shoot mass (DRM). Root systems were removed from the soil, immersed in water to remove soil particles, blotted dry and number of tuberous roots (NTR) were counted per plant. Tuberous root length (TRL) was measured` and tuberous root diameter (TRD) were also measured using vernier caliper. Tuberous roots (Figure 3.4) were weighed for fresh tuberous root mass (FTRM) and later dried in an air-forced oven at 70°C for 72 h to obtain dry tuberous root mass (DTRM).

Figure 3.4 Harvested Sweet potato cv. 'Blesbok' tubers at 90 days after planting using sack gardening technology.

3.2.5 Data analysis

Data were subjected to analysis of variance (ANOVA) using the Statistix 10.0. When the treatments were significant at the probability level of 5% and 10%, the degrees of freedom and their associated sum of squares were partitioned (Appendix 3.1, 3.5, 3.7, 3.10) to determine the percentage contribution of sources of variation to TTV among the treatment means. Mean separation was achieved using Fisher's Least Significant Difference Test. The variable with significant treatment means were further subjected to lines of the best fit. Unless otherwise stated, only treatment means significant at the probability level of 5% and 10% were discussed.

3.3 Results

Number of axillary buds had significant (P≤ 0.05) effects on vine length contributing 59% in TTV, respectively (Table 3.1, Appendices 3.5). number of axillary buds had significant (P≤ 0.05) effect on fresh shoot mass, number of shoots and dry shoot mass contributing 58%, 45% and 58% in TTV, respectively (Table 3.1, Appendices 3.1, 3.7, 3.10). However, number of axillary buds had no significant (P≤ 0.05 or 0.10) effects on fresh tuberous root mass, chlorophyll content, vine stem diameter, number of tuberous roots, tuberous root diameter, tuberous root length, dry tuberous root mass (Table 3.1).

Relative to the control, stem cuttings with two, three, four and five number of axillary buds, decreased VL by 8%, 13%, 18% and 37%, respectively (Table 3.2). The same trend was observed in FSM and DSM. Relative to the control, stem cuttings with 2, 3, 4 and 5 number of axillary buds, reduced FSM by 30%, 45%, 45% and 55%, respectively (Table 3.2). Similarly, stem cuttings with 2, 3, 4 and 5 number of axillary buds, diminished DSM by 26%, 38%, 44% and 55%, respectively (Table 3.2). In contrast, relative to the control, sweet potato stem cuttings with 2, 3, 4 and 5 number of axillary buds increase the NS by 0%, 8%, 15% and 17%, respectively (Table 3.2).

Plant parameters over increasing number of axillary buds exhibited negative and positive quadratic relationships (Figure 3.5). Vine length and NS of the stem cuttings (y-axis), when regressed against the number of axillary buds (x-axis), exhibited quadratic relationships, which demonstrated a strong positive correlation of 95% and 92%, respectively (Figure 3.5). However, FSM and DSM when regressed over the number of axillary buds (x-axis), exhibited quadratic relationships, which demonstrated a strong negative correlation of 96% and 98%, respectively (Figure 3.5).

Table 3.1 Mean sum of squares for fresh shoot mass (FSM), fresh tuberous root mass (FTRM), chlorophyll content (CC), vine stem diameter (VSD), vine length (VL), number of tuberous roots (NTR), number of shoots (NS), tuberous root diameter (TRD), tuberous root length (TRL), dry shoot mass (DSM) and dry tuberous root mass (DTRM) on stem cuttings of sweet potato cv. 'Blesbok' productivity using sack gardening technology.

Source		FSM		FTRM		CC		VSD		VL		NTR	
	DF	MSS	%	MSS	%	MSS	%	MSS	%	MSS	%	MSS	%
Replication	9	8773.2	17	19476.4	17	76.44	23	5.00	38	1516.95	19	13.15	23
Treatment	4	29449.0	58*	61546.7	56^{ns}	86.26	26^{ns}	4.67	35^{ns}	4790.82	59**	29.23	51^{ns}
Error	36	12833.5	25	29649.1	28	172.62	51	3.53	27	1813.46	22	15.05	26
Total	49	51055.7	100	110672.2	100	335.31	100	13.20	100	8111.23	100	57.43	100

Source		NS		TRD		TRL		DSM		DTRM	
	DF	MSS	%	MSS	%	MSS	%	MSS	%	MSS	%
Replication	9	3.49	36	116.66	35	24.13	24	196.96	16	1055.06	20
Treatment	4	4.27	45*	105.70	32^{ns}	50.84	51^{ns}	736.66	58*	2787.47	53^{ns}
Error	36	1.82	19	110.39	33	25.27	25	325.09	26	1406.84	26
Total	49	9.58	100	332.75	100	100.23	100	1258.71	100	5249.37	100

ns = non-significant at P ≥ 0.05; * slightly significant at P ≤ 0.10, ** = significant at P≤0.05.

Table 3.2 Relative impact of vine length (VL), fresh shoot mass (FSM), dry shoot mass (DSM) and number of shoots (NS) to different number

Axillary bud number	VL (cm)		FSM (g)		DSM (g)		NS	
	Variable	RI (%)^{z}	Variable	RI (%)	Variable	RI (%)	Variable	RI(%)

of axillary buds of sweet potato cv. 'Blesbok' stem cuttings grown using sack gardening technology (n = 50).

1	123.96[a] ± 11.35	–	245.09[ay] ± 64.18	_	39.730[a] ± 9.67	_	4.1000[ab] ± 0.59	_
2	113.1036[b] ± 12.88	–8	169.3916[b] ± 24.08	–30	29.5296[b] ± 3.57	–26	4.1026[b] ± 0.43	0
3	108.1012[a] ± 18.74	–13	133.731[ab] ± 28.35	–45	24.2451[ab] ± 4.91	–38	4.5000[ab] ± 0.48	8
4	101.91[ab] ± 2.5550	–18	134.65[b] ± 15.76	–45	22.030[b] ± 3.04	–44	4.722[a] ± 0.44	15
5	77.98[b] ± 8.56	–37	109.27[b] ± 16.50	–55	18.000[b] ± 3.16	–55	4.8000[a] ± 0.42	17

[y] Column means ± SE (Standard error) followed by the same letter were not different ($P \leq 0.10$) according to Fisher's Least significant Difference test.

[z] Relative impact = [(treatment/control – 1) × 100].

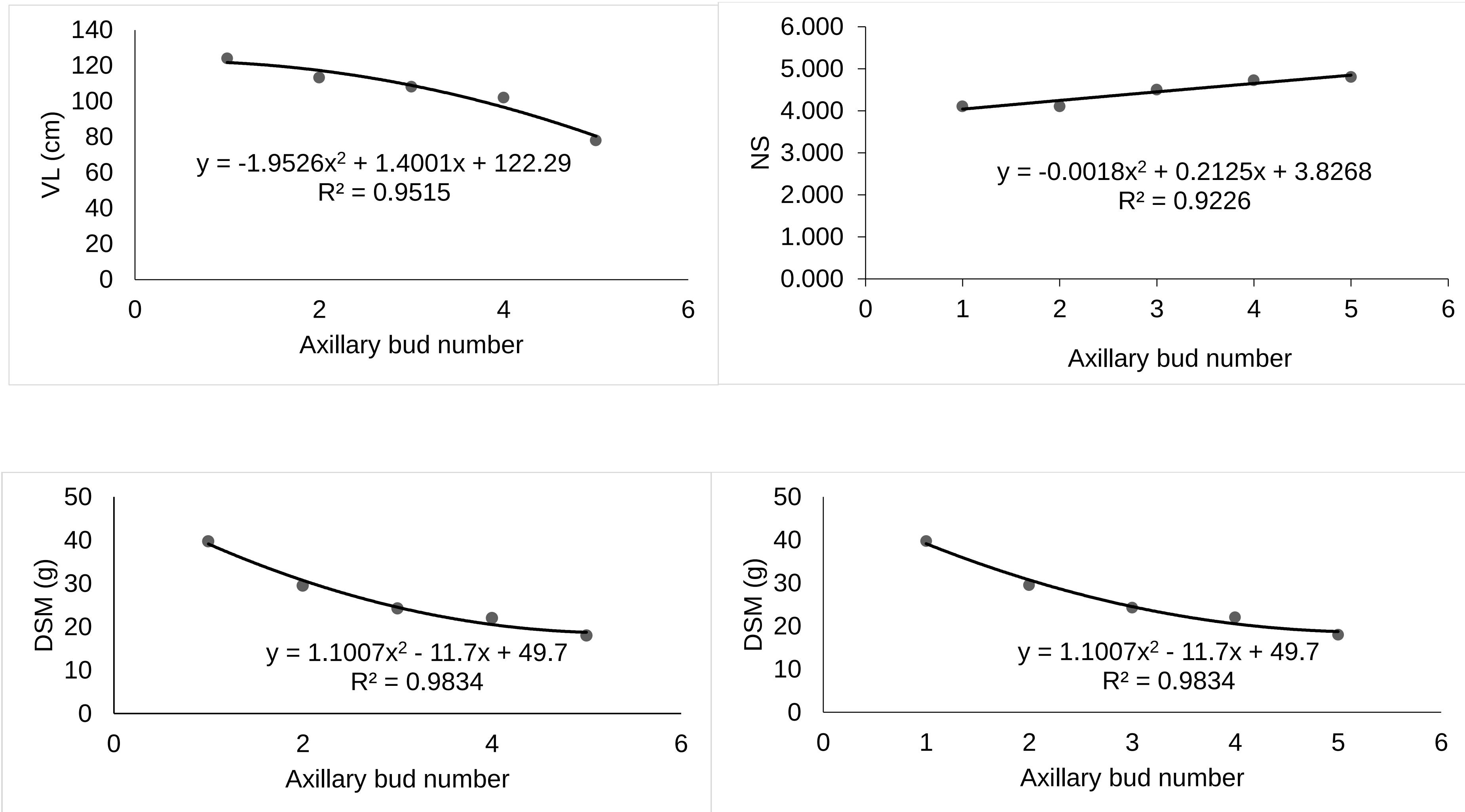

Figure 3.5 Response of vine length (cm), fresh shoot mass (g), number of shoots and dry shoot mass (g) to number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings (n = 50).

3.4 Discussion

The use of number of axillary buds in this study as a determinant factor for the successful production and yield of sweet potato cv. ‘Blesbok’ stem cuttings grown using the sack gardening technology showed significant differences on the above ground parameters of the crop, except for the vine stem diameter (cm) and chlorophyll content. No-significant differences were observed on all the below ground parameters tested. Generally, axillary bud commonly known as a lateral bud, is a sprout that develops in the axil of a plant which is the angle formed by the upper side of the stem and an outgrowing leaf or branch (Le Bris *et al*., 2012). Axillary buds have the ability to produce new shoots to promote the growth of the plant and may be specialized by giving rise to either vegetative shoots or reproductive shoots (Costes *et al*., 2014). The use of axillary bud in vegetative propagation has been reported as an alternative way of providing propagation material and generate true-to-parental type progenies (Costes *et al*., 2014). The disturbance or removal of apical dominance under favourable environmental conditions for growth stimulate growth of axillary buds (Ngezahayo, 2014). In many plant species, few axillary buds develops to form branches, as the extent of bud activation is strongly regulated by endogenous and environmental factors surrounding the plant (Chatfield *et al*., 2000). Generally, the development of the axillary bud into a new branch or shoot depends on internal factors such as plant age, position of the bud in the plant, availability of nutrients, competition between plant parts (stem/leaf/petiole/axillary buds). The external factors on which axillary bud growth depends include quality and quantity of light, photoperiod, relative humidity, growing medium and temperature (Luo *et al*., 2019).

In general, axillary buds are the initial sprouts that eventually will give continuity to the plant. In this study, the use of different number of axillary buds had significant effects on vine length, fresh shoot mass, number of shoots and dry shoot mass, among the other tested parameters. Although vine length, fresh shoot mass and dry root mass were reduced with the increase in number of axillary buds, the number of shoots was observed to be reproducing at an increasing rate, relative to the number of axillary buds. Stem cuttings with the highest number of axillary buds had the greatest number of shoots developing from the plants. Similar results were reported by Essilfie *et al*. (2016) on Okumkom variety of sweet potato, where an increase in number of axillary buds significantly affected the number of shoots. Ray *et al*. (2001) also observed an increase in shoot number with an increase in axillary bud number throughout the growth period of sweet potato. An increase in number of shoots might be attributed to the fact that each axillary bud has the potential to develop into a vegetative shoot (Ngezahayo, 2014). Notably, an increase in number of axillary buds increases number of shoots (Le Bris *et al*., 2012), therefore, many shoots are likely to be produced in stem cuttings with multiple axillary buds as compared to those with few numbers of buds. Further observations in this study indicated that, stem cuttings with one and two buds showed a slight decrease in measured plant parameters such as, vine length, fresh shoot mass and dry shoot mass, whereas high reduction was observed in stem cuttings with three, four and five buds. The obtained result, however, contradicts the report of Ray *et al*. (2001) whereby increasing the number of axillary buds increased vine length of sweet potato.

Regarding the below ground parameters, namely, fresh tuberous root mass, tuberous root diameter, tuberous root length, dry tuberous root mass and number of tuberous roots, observation showed no effects as a result of the different number of axillary buds used. The observed findings are in agreement with Essilfie *et al*. (2016), reporting that an increase in number of axillary buds did not significantly affect tuberous root parameters of sweet potato. According to Xue *et al*. (2015), the lack of significant difference observed may be due to the use of different number of axillary buds on stem cuttings, differences in stem part used as planting material, environmental conditions and lack of uniformity in irrigation. Generally, the yield of many crop plants such as sweet potato is influenced by different number of axillary buds present on stem cuttings at planting (Kurangwa *et al*., 2014). Also, the different vine parts (apical, middle and basal) used as planting material has been reported to influence the growth and yield of sweet potato to a great extent (Schuthesis *et al*.,1994).

The sweet potato cultivar type used might also have an influence on the lack of significant response showed by the different number of axillary buds of the stem cuttings used. This might be attributed to the innate characteristics of the sweet potato variety, 'Blesbok' used in this study (Essilfie *et al*., 2016). Generally, 'Blesbok' sweet potatoes are heavy feeders and requires a balanced supply of nutrients (Luo *et al*., 2019). The higher rainfall experienced during early stages of the crop after planting might have resulted in leaching out of nutrients required by the crop. Another interesting factor that could have resulted in the absence of significant effect might also be attributed to the use of same sweet potato variety, 'Blesbok' in this study. According to Schuthesis *et al*. (1994), plants of the same variety can respond similar to different treatments.

Sweet potato yield experienced in the growing sacks might have also been affected by the position of the stem cutting from the parent plant. Apical stem cuttings have been reported to give higher yield than cutting made from the middle portion of the vine, irrespective to the number of nodal buds in cutting (Belehu, 2003). Similarly, studies indicated that apical cutting ensure better rooting establishment and faster shoot growth (Tewe *et al*., 2003; Eronica *et al*., 1981). The faster growth in stem cuttings from the apical portion is because they establish quickly in the soil by initiating more roots and thereby encourage subsequent production of branches than basal and middle obtained stem cuttings (Tewe *et al*., 2003).

According to Schwarz *et al*. (2010), vigorous vegetative growth of the cuttings and their better adaptation to the climatic condition can also result in an increase yield or better performance in various growth parameters. Also, the use of stem cuttings with single axillary bud prevents plants from overcrowding and thus allow for proper air circulation under limited space (Thomas and Hay, 2018). Dry (2000) reported that, fewer branches produced from single, or two buds can allow sunlight to filter down to the lower leaves, moisture can reach the soil, and results in plants receiving more nutrition. Generally, few branches on a limited space can produce ventilated leaves and improved sunlight penetration resulting in high yield (Roy *et al*., 2021).

Generally, the production of sweet potatoes under limited space can be a challenge as the crop is an herbaceous vine bearing alternate leaves, sometimes bushy resulting in shading and overcrowding of branches (DAFF, 2015). In this study, the highest reduction in growth parameters was obtained from stem cuttings with three, four and five number of axillary buds. This might be attributed to shading of shoots inside the sacks due to the limited space that prevented plants from spreading their roots and stems (Harbur and Owen, 2003). Since sweet potato grow horizontally, branches formed on three, four and five buds may have grown closer together resulting in overcrowding and shading of shoots within the sacks. Vance *et al*. (2013) reports that even though many numbers of axillary buds can be left on stem cuttings to obtain balanced growth, it is important to consider that too many buds under limited space can also lead to crowding and problems with shading within the shoots. Overcrowding of plants mostly occurs when the available area per stem cutting is too small to accommodate the shoot growth of the vine (Stefano *et al*., 2010).

Generally, poor yield can result from lack of sunlight, moisture, air circulation and nutrients in a crowded garden (Kliewer and Dokoozlian, 2005). Poor air circulation can lead to an increase of fungal diseases, such as powdery mildew, in an overcrowded garden (Kliewer and Dokoozlian, 2005). Pests, including aphids and mites, can also easily move between plants if there is not enough space for plants to spread. Having more branches in a limited space can also lower leaf temperatures, whereby the photosynthetic rate of the plants can be decreased, resulting in low vine length (Pearcy *et al*., 2005). When plants are too many within a limited space, competition is likely to occur between the plants (Gurevitch *et al*., 1990). As a result, plants tend to compete with each other for soil nutrients, which resulted in increased fertilizer needs. According to Vance *et al*. (2013), increasing the bud number can decrease various plant parameters and this may be attributed to the competition between the shoots in stem cuttings with high bud loads. This is because the more plants there are in a small space, the more quickly the nutrients are used up resulting in nutrient deficiencies (Gurevitch, 1990). Plants suffering from nutrient deficiencies may grow poorly, or they may fail to develop long and strong vine (Thomas and Hay, 2018). Also, when branches are crowded inside the sack, the soil can dry out quickly because too many plants are striving to absorb the necessary moisture from the soil. As a result, water applied from overhead, from irrigation or rain may sometimes have not reached the ground beneath.

3.4.2 Conclusion

The following conclusions were drawn from the study. Number of axillary buds used as treatments significantly affected vine length, fresh shoot mass, dry shoot mass and number of shoots of sweet potato cv. 'Blesbok'. The effect on the above-mentioned plant parameters varied with an increase in number of axillary buds used per stem cutting. The highest number of shoots was obtained in stem cuttings with three, four, and five as compared to one and two buds. In contrast, the highest reduction of plant parameters vine length, fresh shoot mass, dry shoot mass and number of shoots was observed in three, four, five buds as compared to stem cuttings with one and two buds. In this study, stem cuttings with one and two buds gave better results for vine length, fresh shoot mass and dry shoot mass parameter of sweet potato cv. 'Blesbok' when compared with stem cuttings with five number of axillary buds. In conclusion, data from this study confirms that sweet potato yield production under sack gardening can differ depending on the number of axillary buds per cutting. However, this study suggests that more research be conducted to assess the effect of number of axillary buds on different sweet potato cultivars.

CHAPTER 4

SUMMARY, SIGNIFICANCE OF FINDINGS, RECOMMENDATIONS AND CONCLUSIONS

4.1 Summary

The issue of water scarcity and shortage of farmlands on farmers continues to be a greater concern across the world. As a result, finding innovative solutions, which aims at increasing world food production by utilising small space and little amount of water available in rural and urban areas is of great concern. In vegetative propagation, using stem cuttings with a certain number of axillary buds had been a challenge in determining the suitable number of axillary buds that will result in productive production of sweet potatoes edible roots under limited space. This study was conducted to determine the effect of number of axillary buds on stem cuttings of sweet potato cv. 'Blesbok' grown using the sack gardening technology. The results from this study showed that vine length, fresh shoot mass, dry shoot mass decreased with an increase in bud number, whereas number of shoots increased with an increase in number of axillary buds. This study confirms that different number of axillary buds had an effect on the yield and growth of sweet potato cv. 'Blesbok' produced under sack gardening technology. Based on these findings, stem cuttings with one and two number of axillary buds could be used when planting sweet potato cv. 'Blesbok' under sack gardening technology.

4.2 Significance of findings

The current study has provided information on the effect of number of axillary buds on stem cutting of sweet potato cv. 'Blesbok'. The data demonstrated that stem cuttings with one and two number of axillary buds might produce better yield results, which is an indicator of good sweet potato productivity. The results expanded knowledge on number of axillary buds that are suitable for production of sweet potato under sack gardening technology. This valuable information would aid sweet potato industry in the production of sweet potato under limited space. Furthermore, the findings of the research study would contribute to economic growth of the rural parts of South Africa, especially in areas where land needed for crop production is limited.

4.3 Recommendations

The results of this study demonstrated that although one and two buds showed better results, there was a slight decrease in measured growth parameters. Thus, the results from this study suggest that more study should be conducted for validation and better yield potential. In addition, the results from this study showed that stem cuttings with three, four and five buds highly decreased various measured parameters. The highest reduction observed might be attributed to overcrowding of branches due to the limited space inside the sack. As a result, the researcher suggests more research to be conducted using lesser stem cuttings per sack, in order to investigate whether stem cuttings with three, four and five buds would improve the performance of plant growth parameters or not. Furthermore, the absence of significance difference on various plant growth parameters of sweet potato cv. 'Blesbok' has been observed in this study. Based on the lack of significant effect, further research should be done on different sweet potato cultivars to determine the number of axillary buds that would be suitable for production on different varieties under sack gardening technology.

4.4 Conclusions

The current study concluded that different axillary bud affected growth of sweet potato cv. 'Blesbok' under sack gardening technology. The results of this study demonstrated that number of axillary buds had a significant effect on vine length, fresh shoot mass, number of shoots and dry shoot mass of sweet potato cv. 'Blesbok' produced under sack gardening technology. This confirms that number of axillary buds can be considered as one of the factors that influence growth of sweet potato under limited space. Based on current findings, it can be concluded that stem cuttings with one and two buds performed better yield results for the vine length, fresh shoot mass, dry shoot mass growth parameters of sweet potato cv. 'Blesbok'. Also, the data from this study showed that stem cuttings with three, four and five axillary buds had high decrease in growth parameter and found to be inappropriate to be used as planting material. However, the production of sweet potato under sack gardening technology may still require more research before full implementation to avoid setbacks among farmers, in terms of the right number of cuttings per sack, suitable number of axillary buds per stem cutting, water requirements and the potential yield levels.

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LIST OF APPENDICES

Appendix 3.1 Analysis of variance for fresh shoot mass (g) from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P
Replication	9	78959	8773.2		
Treatment	4	117796	29449.0	2.29	0.0781
Error	36	462006	12833.5		
Total	49	658760			

Appendix 3.2 Analysis of variance for fresh tuberous root mass (g) from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P

Replication	9	175288	19476.4		
Treatment	4	246187	61546.7	2.08	0.1043
Error	36	1067368	29649.1		
Total	49	1488842			

Appendix 3.3 Analysis of variance for chlorophyll content from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P
Replication	9	687.93	74.437		
Treatment	4	345.04	86.259	0.50	0.7361
Error	36	6214.24	127.618		
Total	49	7247.22			

Appendix 3.4 Analysis of variance for stem diameter (cm) from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P
Replication	9	45.019	5.00209		
Treatment	4	18.693	4.67321	132	0.2796
Error	36	127.047	3.52907		

Total	49	190.758

Appendix 3.5 Analysis of variance for vine length (cm) from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P
Replication	9	13652.6	1516.95		
Treatment	4	19123.3	4780.82	2.64	0.0498
Error	36	65284.7	1813.46		
Total	49	98060.5			

Appendix 3.6 Analysis of variance for number of tuberous roots from number of axillary buds

of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P
Replication	9	118.420	13.1578		
Treatment	4	116.920	29.2300	1.94	0.1246
Error	36	541.880	15.0522		
Total	49	777.220			

Appendix 3.7 Analysis of variance for number of shoots from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P
Replication	9	31.380	3.48667		
Treatment	4	17.080	4.27000	2.34	0.0737
Error	36	65.720	1.82556		
Total	49	114.180			

Appendix 3.8 Analysis of variance for tuberous root diameter (cm) from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F

Replication	9	1049.95	116.662		
Treatment	4	422.81	105.703	0.96	
Error	36	3974.04	110.390		

Appendix 3.9 Analysis of variance for tuberous root length (cm) from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P
Replication	9	1772.6	196.960		
Treatment	4	2946.6	736.658	2.27	0.0811
Error	36	11703.5	325.098		
Total	49	16422.8			

Appendix 3.10 Analysis of variance for dry shoot mass (g) from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P

Replication	9	1772.6	196.960		
Treatment	4	2946.6	736.658	2.27	0.0811
Error	36	11703.5	325.098		
Total	49	16422.8			

Appendix 3.11 Analysis of variance for dry tuberous root mass (g) from number of axillary buds of sweet potato cv. 'Blesbok' stem cuttings under sack gardening technology (n = 50).

Source	DF	SS	MSS	F	P
Replication	9	9495.6	1055.06		
Treatment	4	11149.9	2787.47	1.98	0.1182
Error	36	50646.3	1406.84		
Total	49	71291.7			