Effect of Number of Nodes and Storage Duration of Vine Cuttings on Growth, Yield and Yield Components of Sweet Potato (Ipomoea batatas L.) at Jimma, Southwest Ethiopia

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Abstract
Information regarding cutting characteristics for the establishment and successful sweet potato production in the study area is scarce. The optimum number of nodes used for planting material and the effect of storage duration of vine cuttings have not yet been established. The objective of the study was to identify the optimum number of nodes and storage duration of vine cuttings that improve the yield and yield components of sweet potato in Jimma area. Sweet potato cultivar, Awassa-83 was used for the experiment. A 3×4 factorial treatment structure in a randomized complete block design (RCBD), with three replications was used. Effect of different node numbers (5-nodes, 7-nodes and 9-nodes) and storage duration of vine cuttings (immediate planting, planting after 2-days storage, planting after 4-days storage and planting after 6-days storage) on the growth and yield parameters was studied at Jimma University research site. The result revealed significant interaction in the number of main stems, aboveground biomass yields (q/h), number of marketable tubers per hill, number of unmarketable tubers per hill, marketable tuber yields (q/h), unmarketable tuber yields (q/h), total tuber yields (q/h) and the harvest index. Statistically both 2 and 4-days storage duration of vine cuttings gave significantly higher marketable tubers than immediate planting and 6-days storage duration of vine cuttings under shade. 9-node numbers per cutting gave significantly higher total tuber numbers than 5 and 7-node numbers. The total tuber yield of sweet potato was highly significant and positively associated with marketable tuber numbers (r=0.65**), total number of tubers (r=0.50**) and marketable tuber yield (r=0.99**). This also showed that, total tuber yield favored by marketable tuber numbers, total number of tubers and marketable tuber yield. The presence of high marketable tuber number and yield contributes much to the total yield because of increase in individual tuber size and weight. The correlation of marketable tubers per hill was significantly and positively associated with number of main stems (r=0.39*) and above ground biomass yield (r= 0.47**). This shows that marketable tuber numbers favored by main stem numbers and above ground biomass yield. When stem number increases, the plant canopy and associated leaf area increases leading to more carbon assimilation to the optimum level. Based on the results farmers are advised to use 9-node numbers per cutting with planting of vine cuttings after 2 days of storage duration to maximize their marketable and total tuber yields. Hence, studies involving various sweet potato genotypes on multi-locations for a number of years would generate sufficient information that enables appropriate recommendations to be made.
Keywords: Sweet potato; Storage duration; Node number; Internodes; Vine cutting; tuber yield

1. Introduction

Sweet potato (*Ipomoea batatas L.*) is a dicotyledonous plant that belongs to the family *Convolvulaceae* (*Tortoe,* 2010). It is grown as a starchy food crop throughout the tropical, sub tropical and frost-free temperate climate zones in the world (ICAR, 2007). Sweet potato is among the world's most important versatile and underutilized food crop grown generally for its storage roots (Tortoe, 2010). It is a short cycle crop usually matures three up to four months (Anyaegbunam *et al*., 2008) and may be grown two or three times in a year (Okonkwo, 2002).

Sweet potato is the seventh among all food crops worldwide from the point of view of total production, thirteenth in value of production and fifth in caloric contribution to human diet (Bouwkamp, 1985; Tortoe, 2010). Among the tuber crops grown in the world, sweet potato ranks second after cassava Ray and Ravi (2005). China accounts for the highest sweet potato production in the world, followed by Uganda and Nigeria (FAO, 2004). In that order, The crop can be considered very important in promoting nutritional security particularly in agriculturally backward areas with poor soils (Srinivas, 2009). Sweet potato is an important crop worldwide which is cultivated in more than 110 countries on an estimated area of 8.5 million ha. The annual global production of sweet potato is estimated at 106.5 million metric tons of which 15% is from East and Central Africa. Nine African countries namely Uganda, Nigeria, Tanzania, Angola, Burundi, Mozambique, Madagascar, Rwanda and Ethiopia are among the top 15 sweet potato producers in the world. The other six are China, Indonesia, Vietnam, India, USA and Japan (FAOSTAT, 2010).

Based on CSO report of 1993/94 the national average yield of sweet potato in Ethiopia was 7 tons per hectare. However, previous 2006 and 2007 research result of Adami Tulu Agricultural Research Center (ATARC) reported the yield up to 37.1 tons per hectare from improved varieties. The crop is planted using vine cuttings for production. Utilizing the vines as planting material give the farmers the opportunity to use all storage roots for consumption or for sale. The length or the number of nodes per cutting of the vine cuttings varies from farmer to farmer and from location to location (Belehu, 2003). 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 disease (Onwueme, 1978; Phills & Hill, 1984). By propagating with vine cuttings the entire tuber harvest can be saved for consumption or marketing instead of reserving some of it for planting purposes and vine cuttings yield better than sprouts, and produce roots of more uniform size and shape.

There are conflicting results regarding the optimum length of vine cuttings. Onwueme (1978) indicated that tuber yield tends to increase with increase in the length of the vine cuttings used, and recommended a length of about 30 cm (9-node numbers per cutting). Cuttings longer than 30 cm tend to be wasteful of planting material, while much shorter cuttings established slower, and gave poorer yields. Ravindran & Mohankumar (1982) and Bautista & Vega (1991) also recommended that 20 to 40 cm long vine cuttings should be used for better storage root yield. Hall (1986) found that 40 to 45 cm cuttings produced higher total marketable root yield than 20 to 25 cm cuttings.

In Melkassa and Hawassa the three cutting lengths of Hwassa-83 cultivar (20 cm considered 5-node numbers, 25 cm considered 6-node numbers and 30 cm considered 9-node numbers) did not differ in total, marketable, medium, large, under size and over size storage root yields. The 30 cm cuttings (9-node numbers per cutting) resulted in highest yields of small storage roots than the 20cm cuttings (5-node numbers per cutting) and 25 cm cuttings (6-node numbers per cutting). There were no significant yield differences of small storage roots between the 20 cm and 25 cm cuttings (Belehu, 2003). Choudhury (1979) obtained more tuberous roots using cuttings from top portion of the vines with four nodes. The terminal vine cuttings were also reported to give higher yield than cutting made from the middle portion of the vine irrespective to the number of nodes in cutting. suitable planting material ensures proper growth, optimum plant stand and tuberization which ultimately influenced the yield of crop. The different vine parts used as planting material influence the growth, and yield of sweet potato to a great extent.

Yield of sweet potato could be improved by the use of good planting materials. The most common method of sweet potato propagation is by the use of vine cuttings (Edmond, 1971). In many places, farmers use any length of cuttings which are available or convenient to handle. Some farmers use short cuttings for planting just because they are easy for handling or in order to economize the planting materials. Others also take very long cuttings, fold them several times and insert them in the soil. In other places, after harvesting the previous crop, the vines left on the field to grow again without any organized propagation (Amoah, 1997). Vine cuttings stored under shade in the main field for 3 days produced plants with highest marketable root yield followed by 4 days old cuttings (Hammett, 1983). Cut vines with intact leaves are stored under shade for two days prior to planting in the main field to promote better root initiation, easy establishment of vines and higher root yield (Ravindran and Mohankumar, 1989; Biswal, 2008).

Storing of vines for a long time caused failure of establishment in the field due to drying. Planting of sweet potato vine cuttings is preferably done as soon as possible, after they are selected and cut. However, this may not always be possible, for instance, when it is too hot, when the field is not ready yet, labor for planting may be scarce, or due to any other reasons. Cuttings can be kept for a maximum of seven days, before losing condition that leads to large reduction in storage root yield. Storing vine cuttings for 1 - 3 days does not affect the final yield (SASHA, 2009). In order to preserve the food reserves in the stem, most of the leaves on the cuttings should be removed, leaving only a few leaves at the tip. Then the cuttings are tied in small bundles with their bases covered with a wet cloth or sack. The bundles are kept in a cool and shady place. Alternatively, may be partially buried in a narrow trench under the shed of a tree with the vines spread out along the trench, with two-thirds of the vines under the soil surface.

During the storage period, roots may develop at the base of the cuttings. This is called “pre-sprouting.” The cuttings should then be carefully planted with the roots. Storing the vine cuttings hardens them, that is, they become tougher and more resistant to the “shock” of planting. Establishment is faster when vine cuttings are pre-sprouted. However, there is no yield advantage from this practice (SASHA, 2009). Information regarding cutting characteristics for the establishment and successful sweet potato production in Southwestern Ethiopia is scarce. The optimum and suitable number of nodes per cutting used for planting material and the effect of vine cuttings stored under shade in the main field after preparing have not yet been standardized and therefore’ this experiment is expected to fill the gap. Hence, this experiment was designed with the objective: To identify the optimum number of nodes per cuttings and storage duration of vine cuttings that improve the yield and yield components of sweet potato in Jimma area.

2. Materials and Methods

2.1. Description of the Experimental Site

The experiment was conducted under rain-fed condition from June 2014 to February 2015 at Jimma University College of Agriculture and Veterinary Medicine, research site. The site is located at 7°42”N latitude and

36°50"E longitude with a distance of 356 km away from Addis Ababa, with an altitude of 1710 meters above sea level (m.a.s.l.). Abera (2011) reported the mean annual rainfall, relative humidity and temperature of the study area is1250- 1500 mm, 91% and 11.8 to 26.8°C, respectively. The dominant soils of the area are Nitisol and Cambisol with favorable physical property for agricultural practices and well recognized as the most productive soils in Ethiopia (Mesfin, 1998).

2.2 Experimental Materials

Sweet potato cultivar, Awassa-83 was used for the experiment. Cuttings of the various node numbers were prepared from plants which were grown in the field for 3-4 months. 240 pieces each containing 5-node, 7-node and 9-node cuttings were taken from the middle portion of healthy vines. The cuttings were left under shade for 2, 4 and 6-days to accelerate root initiation.

2.3. Treatments and Experimental Design

The experiment was laid out as a randomized complete block design in a 3×4 factorial arrangement and replicated three times. The treatments were three different numbers of nodes (5, 7 and 9) and four storage duration of vine cuttings under shade (control (immediate planting), planting after 2-days storage, planting after 4-days storage, planting after 6-days storage. There were 12 treatment combinations and 36 plots. The treatments were randomly assigned to each plot. The rows were spaced 0.6 m apart and cuttings in the row was space 0.3 m (60 cm × 30 cm). Each plot consisted of 4 rows and each row contained 5 cuttings. Each plot with each row accommodating 20 plants. Data was taken from the two center row of 6 plants. The gross plot size was 3.6m^2 and net harvest area was 1.08 m^2.

2.4 Crop Field Management

The leaves were stripped off from the vines leaving two leaves at the upper portion. The cuttings were inserted into the soil inclined at an angle of 45^0 with half of the length buried in the soil with the nodes pointing upwards. Weeding was done for the first 6-weeks after planting. Rodent attack on some of the exposed tubers was controlled by periodic earthning-up of all ridges. Prior to harvesting, the field was watered for 2-days to facilitate easy digging in order to limit bruising of tubers. Harvesting was done manually after which the tubers is washed and packed for record.

Table 1. Number of treatments

No. of treatments	Treatment description
1	5-nodes per cutting × Immediate planting (control)
2	5-nodes per cutting × 2-days storage vine cuttings under shade
3	5-nodes per cutting × 4-days storage vine cuttings under shade
4	5-nodes per cutting × 6-days storage vine cuttings under shade
5	7-nodes per cutting × Immediately planting (control)
6	7-nodes per cutting × 2-days storage vine cuttings under shade
7	7-nodes per cutting × 4-days storage vine cuttings under shade
8	7-nodes per cutting × 6-days storage vine cuttings under shade
9	9-nodes per cutting × Immediately planting (control)
10	9-nodes per cutting × 2-days storage vine cuttings under shade
11	9-nodes per cutting × 4-days storage vine cuttings under shade
12	9-nodes per cutting × 6-days storage vine cuttings under shade

2.5 Data Collected

The sweet potato plants used as stock plants were allowed to grow for 175 days (almost six months) while monitoring growth and harvesting the vines at the specified stages of growth. The parameters studied included:

1. **Total Weight of Fresh Tuber Yield (TWFTY) (q/h):** The total fresh yield of tuberous roots were determined by combining the weights of the marketable and the unmarketable tuberous root fresh yields.
2. **Weight of Marketable Tuber Yield (WMTY) (q/h):** The marketable fresh yields of tuberous roots were determined by weighing the afore-mentioned tuberous root categories separately.
3. **Weight of Unmarketable Tuber Yield (WUMTY) (q/h):** The unmarketable fresh yields of tuberous roots were determined by weighing the afore-mentioned tuberous root number categories separately (Mohammed *et al*., 2011)
4. **Total Number of Tubers Per Hill (TNT)**: At the final harvesting, all plants from the net plot area were harvested. The number of unmarketable tuberous roots was determined by counting the number of tuberous roots having the weight of less than 100 g as well as those that were blemished. Similarly, the number of marketable tuberous roots was determined by counting those having the weight of more than 100 g. The number of total tuberous roots was determined by adding up the values of the two tuberous root categories. This method is most

probably similar with they are used by (Mohammed *et al*., 2011).

5. Number of Marketable Tubers Per Hill (NMT): The marketable tubers per hill were judged by tuber size, length, shape, cleanness, free from diseases and pests. Similarly, the marketable tuberous roots was determined by counting those having the weight of more than 100 g.

6. Number of Unmarketable Tuber Per Hill (NUMT): The number of unmarketable tuber root were determined by counting the number of tuberous roots having the weight of less than 100 g as well as those that were blemished, attacked by rodents, diseases and pests.

7. Average Tuber Length (TL): The average length of tuberous roots was measured from each harvest plot.

8. Tuber Dry Matter Content (TDMC) (%): The dry matter content was determined by drying in an oven at 70°C-80°C during 24 hrs to constant weight. The amount of dried pulp of sweet potato tuberous roots from hundred (100) gram of fresh pulp of sweet potato tuberous roots was weighed. The dry matter content was expressed as follows:

Dry matter content = 100 * (W 2 /W 1)

Where,

W 2 = the weight of dried pulp of tuberous root

W 1 = the weight of fresh pulp of tuberous root

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9. The Number of Main Stems (NMS): The actual count of primary branches at harvest time

10. Number of Nodes (NN): It was taken at harvest from the main stem

11. Length of Internodes (IL): It was taken at harvest from the center of main stem

12. Plant Height (PH): The length of plant was measured from the ground level to the tip of the plant from the number of main branches randomly at harvest

13. Aboveground Biomass Yield (ABY) (q/h): The fresh aboveground biomass yield per hectare at harvest.

14. Harvest index (%) $= \frac{WFSR}{WFSR+ABY} \times 100$

Where,

WFSR= weight of fresh storage roots

ABY= aboveground biomass yield

Linear model of RCBD

$$Y_{ij}=\mu+\tau_i+\beta j+\varepsilon_{ij}$$

where : Y_{ij} is the jth observation of the ith treatment

μ is the population mean,

τ_i is the treatment effect of the ith treatment,

βj is the rep effect of the jth, replicate, and

ε_{ij} is the random error.

2.6. Statistical Analysis

After having test of normality of variances for each parameters studied, data were subjected to analysis of variance using statistical software package SAS version 9.2 at 95% confidence interval. The differences between treatment means were compared using Least Significant Difference (LSD) at 5% level of significance. Simple correlation coefficients were carried out among growth, yield and yield components.

3. Results and Discussion

3.1 Growth Parameters

3.1.1 Number of main stems

Analysis of variance showed that number of main stem was significantly ($p<0.05$) influenced by the number of nodes per cutting. Similarly storage duration of vine cuttings and the interaction effect of number of nodes per cutting with storage duration of vine cuttings were also highly significantly ($p<0.01$) influenced the number of main stems.

The combination of all main effects of node numbers with 6-days storage duration of vine cuttings and 7 and 9-node numbers with 2-days storage duration of vine cuttings were significantly difference from the interaction of all the main effect of node numbers with immediate planting and 5-node numbers with 2 and 4-days storage duration of vine cuttings (Table 2). Among the interaction effect of all factors of node numbers with 6-days storage duration of vine cuttings and 7 and 9-node numbers with 2-days storage duration of vine cuttings were showed statistically non-significant difference in the number of main stems. This indicates for increasing number of main stems any node numbers need to lay up 2-6-days before planting, and Stored vines were found to be superior to fresh vines in respect of number of main stem.

Table 2. The effect of node number and storage duration of vine cutting on number of main stems

Number of nodes	Days of storage vine cuttings under shade			
	Immediate	2 days	4 days	6days
5	5.72[f]	8.60[ef]	7.77[ef]	11.61[abcd]
7	6.39[ef]	12.99[ab]	9.72[bcde]	12.33[abc]
9	6.94[ef]	12.11[abc]	9.49[cde]	13.66[a]

LSD(0.05) = 1.93, CV(%) = 20.2; CV= coefficient of variation, LSD= least significant difference. Means sharing the same letter in the columns/rows are not significantly different at 5% P level according to LSD test.

3.1.2 Plant height

The main effect of number of nodes per cutting, storage duration of vine cuttings under shade as well as their interaction effect were non- significant in plant height, this might be due to the same variety. Numerically the main effects of 9-node numbers per cutting and 6-days storage duration of vine cuttings under shade recorded the highest plant heights, but statistical result showed that all factors have similar height (Table 3).

Table 3. Effect of node numbers and storage duration of vine cuttings on plant height

Number of nodes per cutting	Plant Height (cm)
5	86.02
7	82.76
9	88.46
LSD(5%)	17.69
Storage duration of vine cuttings under shade	
Immediate	78.64
2	85.17
4	80.68
6	98.49
LSD(5%)	20.43
CV(%)	24.49

LSD= least significant difference; CV= coefficient of variation.

3.1.3. Number of nodes to the main stem

Neither the main effects of number of nodes per cutting and storage duration of vine cuttings nor their interaction were significant in number of nodes taken from the main stem of sweet potato. This may be due to similar plant height and variety. Both the main effects did not observed significant differences in number of nodes (Table 4).

Table 4. Effect of node numbers and storage duration of vine cuttings on number of nodes

Number of nodes per cutting	Number of Nodes
5	33.52
7	32.27
9	33.15
LSD(5%)	2.27
Storage duration of vine cuttings under shade	
Immediate	32.23
2	32.71
4	32.86
6	32.33
LSD(5%)	2.62
CV(%)	8.18

LSD= least significant difference; CV= coefficient of variation.

3.1.4. Length of internodes

Neither the main effects of number of nodes per cutting and storage duration of vine cuttings nor their interaction were significant in internodes' length of sweet potato. Similar result with the plant height, numerically the main effect of 9-node numbers per cutting and 6-days storage duration of vine cuttings under shade were recorded the highest internodes length, but statistically they are not different each other (Table 5).

Table 5. Effect of node numbers and storage duration of vine cuttings on internodes length

Number of nodes per cutting	Internodes Length (cm)
5	4.91
7	4.87
9	4.94
LSD(5%)	0.82
Storage duration of vine cuttings under shade	
Immediate	4.74
2	4.83
4	4.85
6	5.20
LSD(5%)	0.95
CV(%)	20.06

LSD= least significant difference; CV= coefficient of variation.

3.1.5. Aboveground biomass yield

Main effects of storage duration of vine cuttings (p<0.01), the number of nodes per cutting and their interaction effects showed a significant (p<0.05) difference in the aboveground biomass yield. There was a general trend towards increase aboveground biomass yield with increase number of nodes per cutting. This result is agreement with Amoah (1997), who reported that, in the pattern of above ground biomass yield, probably because increasing above ground biomass yield resulted in the production of more stem numbers and branches.

As far as storage duration of vine cuttings under shade is concerned, statistically 2, 4 and 6-days storage duration of vine cuttings were showed none significant difference in the aboveground biomass yield. Generally the aboveground biomass yield was relatively increase with increase the storage duration of vine cuttings and also decrease the aboveground biomass yield with planting fresh vine cuttings. This finding also most probably similar with the result of main stem numbers. Because the presence of high main stem numbers contributes much to the total above ground biomass yield due to increase in individual size and weight of the plant. as well as the interaction effect of all node numbers with immediate planting were showed statistically significant difference from the interaction of all node numbers with 6-days storage duration of vine cuttings and 9-node numbers with 2 and 4-days storage duration (Table 6).

Table 6. Effect of node numbers and storage duration of vine cuttings on aboveground biomass yield(q/h)

Number of nodes	Days of storage vine cuttings under shade			
	Immediate	2 days	4 days	6 days
5	425.0^{d}	577.1^{bcd}	576.1^{bcd}	771.0^{ab}
7	452.1^{d}	757.2^{abc}	670.4^{abcd}	808.3^{ab}
9	481.4^{cd}	839.3^{ab}	794.9^{ab}	908.5^{a}

LSD(5%)= 165.47; CV(%)= 25.63; LSD= least significant difference; CV= coefficient of variation. Means sharing the same letter in the columns/rows are not significantly different at 5% P level according to LSD test.

3.2 Yield Parameters

3.2.1 Number of marketable tubers per hill

The main effect of number of nodes per cutting and storage duration of vine cuttings under shade showed highly significant ($p \leq 0.01$) in number of tubers per hill. The number of marketable tubers was screened by tuber size, length, cleanliness from rodents, diseases and pests. In a general trend towards shorter cuttings establish more slowly and result in lower yield. In the 7 and 5-node numbers of cuttings, there were relatively fewer nodes than 9-node numbers per cutting to serve as points for their initiation; hence, relatively only few marketable tubers were produced from 5-node numbers per cutting. This agrees with the report made by Amoah (1997) Who observed that more node numbers per cutting, more marketable tubers were initiation.

There was highly significant difference in storage duration of vine cuttings under shade, statistically both 2 and 4-days storage duration of vine cuttings gave significantly higher marketable tubers than immediate planting and 6-days storage duration of vine cuttings under shade. This is due to the highest time of storage duration and delayed tuber initiation and bulking. Mukhopadhyay *et al*. (1990) observed that Storing of vines for a long time caused failure of establishment in the field due to drying. Stored vines were also found to be superior to fresh vines in respect of leaf area index (LAI), crop growth rate (CGR), root bulking rate, number of roots per plant and root and vine yields in trials conducted at Kalyani in West Bengal, India. Cut vines with intact leaves are stored under shade for two days prior to planting in the main field to promote better root initiation, easy establishment of vines and higher root yield (Ravindran and Mohankumar, 1989, Biswal, 2008). This result also most probably conformity with the finding of (Hammett, 1983, Maniyam, Gangadharan and Susantha (2012), vine cuttings stored for 3 days produced plants with highest marketable root yield followed by 4-days old cuttings.

Statistically the combination between all main effect of node numbers with 2 and 4-days storage duration of vine cuttings under shade were gave significantly the highest number of marketable tubers per hill and the combination between all main effect of node numbers per cutting with immediate planting and 6-days storage duration of vine cuttings under shade were gave significantly the lowest number of marketable tubers per hill (Table 7).

Table 7. The effect of node numbers and storage duration of vine cuttings on number of marketable tubers per hill

Number of nodes	Days of storage vine cuttings under shade			
	immediate	2 days	4 days	6days
5	2.35[d]	2.96[abc]	2.98[abc]	2.37[d]
7	2.45[d]	2.96[abc]	3.11[ab]	2.56[d]
9	2.56[d]	3.33[a]	3.11[ab]	2.58[d]

LSD(5%)= 0.37; CV(%)= 8.05; LSD= Least significant difference; CV= coefficient of variation. Means sharing the same letter in the columns/rows are not significantly different at 5% P level according to LSD.

3.2.2 Number of unmarketable tubers per hill

The main effect of storage duration and the interaction with number of nodes showed highly significant ($p<0.01$) difference in number of unmarketable tubers. Both immediate planting and 6-days storage produced significantly higher unmarketable tuber numbers per hill than 2 and 4-days storage duration of vine cuttings under shade. This is probably due to the lack of timely initiation and drying of node numbers per cutting. Mukhopadhyay *et al*. (1990) observed that storing of vines for a long time caused failure of establishment in the field due to drying and Stored vines in a short day were found to be superior to fresh vines.

The interaction effect between all the main factor of 5, 7 and 9-node numbers per cutting with immediate and 6-days storage duration of vine cuttings under shade were recorded significantly the highest number of unmarketable tubers per hill and significantly lowest result recorded for all node numbers per cutting for 2 and 4-days storage duration of vine cuttings under shade (Table 8). The number of unmarketable tuber per hill was not significantly affected by the node numbers per cutting .

Table 8. The effect of node numbers and storage duration of vine cuttings on number of unmarketable tubers per hill

Number of nodes	Days of storage vine cuttings under shade			
	immediate	2 days	4 days	6days
5	0.87[ab]	0.37[d]	0.54[cd]	0.89[ab]
7	0.77[ab]	0.55[cd]	0.48[cd]	0.98[ab]
9	0.96[ab]	0.55[cd]	0.53[cd]	1.07[a]

LSD(5%)= 0.29; CV(%)= 24.76; LSD= least significant difference; CV= coefficient of variation. Means sharing the same letter in the columns/rows are not significantly different at 5% P level according to LSD test.

3.2.3 Total number of tubers per hill

The main effects of storage duration and number of nodes showed highly significantly ($p\leq0.01$) influenced the total number of tubers. 9-node numbers per cutting gave significantly higher total tuber numbers than the 7 and 5-node cuttings (Table 9). This is probably due to delayed tuber initiation in the 7 and 5-node cuttings also shorter cuttings establish more slowly and result in lower yields (Amoah, 1997). In the 7 and 5-node cuttings, there were relatively fewer nodes to serve as points for their initiation; hence, only few tubers were produced. The difference between 5- and 7-node cuttings was not significant although the total number of tubers in the 7-node cuttings were slightly higher than those in the 5-node cuttings. This agrees with the report made by Amoah (1997) probably because with more node numbers per cutting, more tubers were initiated. Immediate planting and 4-days storage duration of vine cuttings under shade was showed significant difference in the total number of tubers per hill. This might be due to the proper storage duration of the vine cuttings. Among 2, 4 and 6-days storage duration of vine cuttings were not statistically difference. Similarly, among Immediate planting, 2, and 6-days storage duration also not observed significant differences.

Table 9. The effect of node numbers and storage duration of vine cuttings on total number of tubers per hill

Number of nodes per cutting	Number of total tubers per hill
5	3.35[b]
7	3.43[b]
9	3.70[a]
LSD(5%)	0.23
Storage duration of vine cuttings under shade	
Immediate	3.30[b]
2	3.57[ab]
4	3.58[a]
6	3.52[ab]
LSD(5%)	0.27
CV(%)	8.08

LSD= least significant difference; CV= coefficient of variation. Means sharing the same letter in the column are not significantly different at 5% P level according to LSD test.

3.2.4 Marketable tuber yield

The main effect of number of nodes and storage duration of vine cuttings under shade as well as the interaction effects were showed significantly ($p < 0.01$) affected in marketable tuber yields. The marketable fresh yields of tuberous roots were determined by weighing the afore-mentioned tuberous root categories separately.

Hall (1986) reported that total marketable root yield of cultivar "Red Jewel" was significantly greater with 40 to 45 cm than 20 to 25 cm cuttings. Other authors (Shanmugavelu *et al.,* 1972; Tanka & Sekioka, 1976; Chen & Allison, 1982; Ravindren & mohankumar, 1982; Sunchez *et al*., 1982; Bautista & Vega, 1991) reported that cuttings of intermediate lengths (40 cm) produced better storage root yields than longer cuttings. The literature reflects conducting results on the effect of length of sweet potato cuttings on yield. This result agrees with the report made by Amoah (1997) the highest node number gave the highest tuber yield. This also in line with the report made by Belehu (2003) the three cutting lengths of Hawassa83 cultivars 20cm (5-nodes), 25cm (6- nodes) and 30cm (9-nodes) did not significant difference in the storage marketable tuber yields. Cuttings of greater length than 30cm (9-nodes) tend to be wasteful of planting material, while much shorter cuttings establish more slowly and result in lower yield. It should be noted that longer cuttings are more difficult to handle, transport and planting. In general it can be concluded that cutting lengths or node numbers do affect marketable storage tuber yield much, and therefore farmers can not follow local planting practices.

Statistically the interaction of all main effects of node numbers with immediate planting did not showed significant difference. The interaction of 9-node numbers with 2-days storage duration were observed significantly gave the highest marketable yields as compare as from the interaction of 5 and 7-node numbers with 2-days storage duration. Among the interaction of all the main effects of node numbers with 6-days storage duration of vine cuttings did not showed significant difference. But the combination between all the main effects of node numbers with 2-days storage duration of vine cuttings and 6-days storage duration of vine cuttings were observed significant difference in the marketable tuber yields (Table 10).

Table 10. Effect of node numbers and storage duration of vine cuttings on marketable tuber yield(q/h)

Number of nodes	Days of storage vine cuttings under shade			
	immediate	2 days	4 days	6days
5	573.02[cde]	678.20[bc]	558.39[cde]	430.86[e]
7	612.99[bcd]	678.52[bc]	610.30[bcd]	431.29[e]
9	653.85[bcd]	834.37[a]	737.12[ab]	500.98[de]

LSD(5%)= 154.35; CV(%)= 15.06; LSD= least significant difference; CV= coefficient of variation. Means sharing the same letter in the columns/rows are not significantly different at 5% P level according to LSD test.

3.2.5 Unmarketable tuber yield (q/h)

The main effect of storage duration of vine cuttings and the interaction effect were showed highly significant ($p \leq 0.01$) difference in unmarketable tuber yields. But The unmarketable tuber yields was not significantly affected by the main effect of node numbers.

Both the interaction between all the main effect of 5, 7 and 9-node numbers per cutting with 6-days storage duration of vine cuttings under shade and 9-node numbers with immediate planting were significantly and relatively more unmarketable tuber yields produced (Table 11). In most case the unmarketable was consistently lower in 2 and 4-days storage for 7 and 9-nodes. The combination of all the main effects of node numbers with 2 and 4-days storage duration of vine cuttings and main effect of 5 and 7-node numbers with immediate planting did not observed significant difference and gave lowest unmarketable tuber yields. The finding showed that Comparatively for fresh storage root yields long time storage duration system of vine cuttings under shade was not necessary. Mukhopadhyay *et al*., (1990) observed that storing of vines for a long time caused failure of establishment in the field due to drying.

Table 11. The effect of node numbers and storage duration of vine cuttings on unmarketable tuber yields(q/h)

Number of nodes	Days of storage vine cuttings under shade			
	Immediate	2 days	4 days	6days
5	22.76^{cd}	12.19^{cd}	22.26^{cd}	37.25^{ab}
7	22.00^{cd}	20.58^{cd}	22.52^{cd}	38.79^{ab}
9	37.28^{ab}	22.65^{cd}	21.63^{cd}	44.07^{a}

LSD(5%)= 14.47; CV(%)= 31.09; LSD= least significant difference; CV= coefficient of variation. Means sharing the same letter in the columns/rows are not significantly different at 5% P level according to LSD test.

3.2.6 Total tuber yields

Both the main effect of number of nodes and Storage duration of vine cuttings under shade, as well as the combination effect were showed highly significantly ($p < 0.01$) affected the total storage tuber yields. Yield increase due to increasing node number might be due to the fact that with increasing node number, more nodes were buried and so there were more points for tuber initiation. Due to early rapid growth in higher node number cuttings, tuber infiltration and bulking began earlier than in lower node number cuttings which translated into higher tuber yield in the higher node number cuttings. Enyi (1973) observed that tuber yield in yam is dependent on the amount, rate and duration of assimilates translocated to the tubers.

The combination between the 9-node numbers with 2 and 4-days storage duration of vine cuttings under shade and the interaction between 7-node numbers with 2-days storage duration of vine cuttings under shade were statistically did not show significant difference in the result of total tuber yields. But the above combinations were observed significant differences from the interaction of 5 and 7-node numbers with 6-days storage duration of vine cuttings. In general this result indicated that most of the interactions did not observed significant differences (Table 12).

Table 12. The effect of node numbers and storage duration of vine cuttings on total tuber yields(q/h)

Number of nodes	Days of storage vine cuttings under shade			
	immediate	2 days	4 days	6days
5	602.39^{bcde}	690.39^{bc}	584.65^{cde}	465.11^{e}
7	634.99^{bc}	699.10^{abc}	632.83^{bcd}	470.08^{de}
9	691.13^{bc}	857.52^{a}	758.75^{ab}	545.05^{cde}

LSD(5%)= 163.11; CV(%)= 15.22; LSD= least significant difference; CV= coefficient of variation, means sharing the same letter in the columns/rows are not significantly different at 5% P level according to LSD test.

3.2.7 Average Tuber length

The main effect of storage duration was significantly ($p \leq 0.01$) affected the average tuber lengths. 2-days storage showed the shortest tuber lengths than the other storage. Immediate planting, 4-days storage duration of vine cuttings under shade and 6-days storage duration were statistically not significant. But, both the main effect of number of nodes per cutting and the interaction effect didn't show significant difference in tuber lengths of sweet potato (Table 13).

Table 2. Effect of node numbers and storage duration of vine cuttings on tuber length

Storage duration of vine cuttings under shade	Average tuber length(cm)
(immediate planting)	20.66^{a}
2-days	16.67^{b}
4-days	20.77^{a}
6-days	21.31^{a}
LSD(5%)	2.91
CV(%)	15.06

LSD= least significant difference; CV= coefficient of variation. Means sharing the same letter in the column are not significantly different at 5% P level according to LSD test.

3.2.8 Harvest index (%)

Storage duration and the interaction effect were significantly ($p \leq 0.01$) affected the harvest index. statistically immediate planting and 6- days storage duration of vine cuttings under shade were showed Significantly difference in harvest index. 2-days and 4-days storage duration of vine cuttings under shade did not show significant difference. Regarded to the interaction effect, the combination between all the main effect of node numbers with immediate planting were observed significantly the lowest harvest index in a percent. This indicates that the fresh tuber storage yield was less than the fresh above biomass yield. This is may be due to the long time storage duration of the vine cuttings not effectively initiated the nodes to the roots. The interaction between all the main effects of node numbers with immediate planting and 5-node numbers with 2 and 4-days storage duration as well as 9-node numbers with 2-days storage duration were observed no significant difference and also indicated that the fresh storage tubers were produced higher yield than the fresh above biomass yield (Table 14).

Table 14. The effect of node numbers and storage duration of vine cuttings on harvest index

Number of nodes	Days of storage vine cuttings under shade			
	immediate	2 days	4 days	6days
5	61.17[a]	55.06[abcd]	50.25[cde]	38.90[f]
7	60.25[ab]	48.46[de]	48.84[de]	36.73[f]
9	59.58[abc]	50.83[bcd]	48.84[de]	38.06[f]

LSD(5%)= 9.55; CV(%)= 11.35; LSD= least significant difference; CV= coefficient of variation, means sharing the same letter in the columns/rows are not significantly different at 5% P level according to LSD test.

3.2.9 Tuber dry matter content

Main effect of number of nodes per cutting showed significant (p<0.05) difference on dry matter content. But the effects of storage duration and their interaction with number of nodes per cutting were not significant (p>0.05) difference. The highest dry matter content (32.04%) was recorded at 7-node numbers per cutting; however, it was not statistically different from 5- node numbers per cutting (31.63%). The lowest dry matter content (30.17%) was recorded at 9-node numbers per cutting (Table 15). There were significant differences in tuber dry weights due to the treatments. However, there was a general trend towards decreasing tuber dry weights with increasing node numbers. This is in line with Amoah (1997) who observes non-significant difference in tuber dry weights due to the treatment. Statistically the main effect of storage duration of vine cuttings under shade and the combination effects did not significantly influenced the result of tuber dry mater contents (Table 15).

Table 35. The effect of node numbers and storage duration of vine cuttings on dry matter

Number of nodes per cutting	Dry matter content (%)
5	31.63[a]
7	32.04[a]
9	30.17[b]
LSD(5%)	1.37
Storage duration of vine cuttings under shade	
Immediate	31.61
2	31.72
4	30.77
6	31.00
LSD(5%)	1.58
CV(%)	5.20

LSD= least significant difference; CV= coefficient of variation. Means sharing the same letter in the column are not significantly different at 5% P level according to LSD test.

3.2.10. Correlation analysis

The correlation of coefficients response variables (Table 16), revealed that the total above ground biomass yield of sweet potato was significantly and positively associated with main stem numbers (r=0.80**), plant height (r=0.61**), total number of nodes (r=0.43**) and inter node lengths (r=0.45**). This shows that total above ground biomass yield favored by main stem numbers, plant height, number of nodes and inter node length. When stem numbers, plant height, and number of nodes and internodes length increases, the plant canopy and associated leaf area increases. The presence of high main stem numbers and plant heights contributes much to the total above ground yield because of the increase in individual size and weight of the plant.

Total tuber numbers of sweet potato was significantly and positively associated with main stem numbers (r = 0.61**), plant height (r = 0.34*), above ground biomass (r = 0.60**) and number of marketable tubers (r = 0.70**). This shows that total tuber numbers favored by main stem numbers, plant height, above ground biomass yield and marketable tubers numbers. When stem number, plant height increases, the plant canopy and associated leaf area increases leading to more carbon assimilation to the optimum level. The presence of high branch numbers and plant heights contributes much to the total above ground yield because of the increase in tuber size and weight. Jarvis (1977) and Wurr (1974) reported in potato a strong relationship between tuber number and stem density, between tuber number distributions in different size grades and stem density. This finding agrees with the work of Zelalem *et al*. (2009) done on Irish potato that Positive and highly significant correlation was obtained between above and underground biomass (r = 0.77**) indicating the existence of close association between them.

Unmarketable tuber yield was significantly and positively associated with main stem numbers (r= 0.38*), plant height (r = 0.45**), node numbers (r = 0.33*) internodes length (r = 0.39**), unmarketable tuber number (r = 83**) and total tuber number (r = 0.34*). According to Hay and Walker (1989), higher crop yield may not be associated with a higher photosynthetic capacity, because over shadowing of canopy affects carbon assimilation and favored for more respiration at the lower side of leaves.

Marketable tuber yield of sweet potato was highly significant and positively associated with marketable tuber numbers (r = 0.67**) and total tuber numbers (r = 0.47**). This could be explained by production of more marketable and total number of tubers resulted in higher marketable tuber yield per hectare. This agrees with the work of Alcoy *et al.*, (1993) weight per storage root was observed to be strongly correlated with weight of marketable roots.

The total tuber yield of sweet potato was highly significant and positively associated with marketable tuber numbers (r = 0.65**), total number of tubers (r = 0.50**) and marketable tuber yield (r = 0.99**). This also showed that, total tuber yield favored by marketable tuber numbers, total number of tubers and marketable tuber yield. The presence of high marketable tuber number and yield contributes much to the total yield because of increase in individual tuber size and weight. This agrees with the work of (Teshome *et al*., 2011).

Number of marketable tubers per hill was significantly and positively associated with main stem numbers (r = 0.39*) and aboveground biomass yield (r = 0.47**). This shows that marketable tuber numbers favored by main stem numbers and above ground biomass yield. When stem number increases, the plant canopy and associated leaf area increases leading to more carbon assimilation to the optimum level. The presence of high branch numbers contributes much to the total above ground yield because of the increase in tuber size and weight. Jarvis (1977) and Wurr (1974) reported in potato a strong relationship between tuber number and stem density, between tuber number distributions in different size grades and stem density. This finding agrees with the work of Zelalem *et al*. (2009) done on Irish potato that Positive and highly significant correlation was obtained between above and underground biomass (r = 0.77**) indicating the existence of close association between them. However, various research activities done by different scholars (Mortia, 1969; Revindran and Nambisa, 1987; Onwueme and Shinha, 1991), on diversified root and tuber crops indicated that more vegetative growth as the expense of tuber initiation and development for any treatment application that facilitate green top weight (above ground biomass) .

Internodes length was significantly and positively associated with number of main stems (r=0.49**), plant height (r = 0.83**) and number of nodes (r = 0.42*). However, there was a general trend towards increase in number of branches and plant height with increase in node number and internodes length . This agree with the finding of (Amoah, 1997). And also this agrees with the work of (Teshome *et al*., 2011). They observes the internodes length was significantly and positively correlated with the green top.

Harvest index was significantly & negatively associated with number of main stems (r=-0.73**), plant height (r=-0.53*), number of nodes (r=-0.34*), internodes length (r=-0.39*)& aboveground biomass yield (r=-0.83). This a general trend, when the harvest index increases the growth parameter decreases. Number of unmarketable tubers per hill was significantly & negatively associated with number of marketable tubers per hill (r=-0.53*).

Table 16. Correlation analysis among growth, yield and yield components of sweet potato

T	NMS	PH	NN	IL	AGB	NMT	NUMT	TNT	WMTY	WUMTY	TWFTY	TL	TDMC	HI
NMS	1	.553**	.301	.48**	.800**	.38*	.196	.61**	.091	.375*	.124	-.086	-.233	-.739**
PH		1	.75**	.82**	.609**	.136	.214	.33*	.046	.454**	.085	-.009	-.182	-.531**
NN			1	.42*	.432**	.074	.128	.193	.019	.331*	.047	-.007	-.259	-.347*
IL				1	.453**	.171	.125	.303	.109	.391*	.143	.035	-.052	-.398*
AGB					1	.46**	.071	.60**	.259	.310	.289	-.006	-.348*	-.830**
NMT						1	-.537**	.70**	.666**	-.316	.650**	-.320	-.285	-.127
NUMT							1	.224	-.357*	.834**	-.293	.284	-.123	-.214
TNT								1	.468**	.340*	.504**	-.130	-.433**	-.328
WMTY									1	-.234	.997**	-.287	-.105	.272
WUMTY										1	-.154	.155	-.259	-.411*
TWFTY											1	-.278	-.129	.242
TL												1	.165	-.176
TDMC													1	.263
HI														1

Where: NMS= number of main stems ; PH= plant height ; NN= number of nodes; IL= internodes length; AGB= aboveground biomass; NMT = number of marketable tubers; NUMT= number of unmarketable tubers; TNT= total number of tubers; WMTY= weight of marketable tubers yield; WUMTY= weight of unmarketable tubers yield; TWFTY= total weight of fresh tuber yield; TL= tuber length; TDMC= tuber dry matter content; HI= harvest index.
** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

4. Summary and Conclusion

Root and tuber crop in general and sweet potatoes in particular are the crops that need to be cultivated for food security for countries like Ethiopia where population is growing at an alarming rate. In the study area, farmers get lower yield, among the many problems use of inappropriate number of nodes and storage duration of vine cuttings is noted to be one of reasons of low productivity of sweet potato. Though the present study was conducted to investigate the effect of different number of nodes per cutting and storage duration of vine cuttings under shade on yield and yield components of sweet potato. The finding showed significant differences among number of nodes and storage duration of vine cuttings for most yield characters. From the finding of this study it could be concluded that appropriate number of nodes and storage duration of vine cuttings under shade could be practiced to increase the yield and yield components of sweet potato production.

The result of this study suggests that vine cuttings used for sweet potato propagation should have at least nine nodes. Cutting with less than nine nodes did not give high yields. The interaction effect of the treatments were showed significant difference in the following parameters, such as number of main stems, aboveground biomass yields (q/h), number of marketable tubers per hill, number of unmarketable tubers per hill, marketable tuber yields (q/h), unmarketable tuber yields (q/h), total tuber yields (q/h) and the harvest index.

Statistically both 2 and 4-days storage duration of vine cuttings gave significantly higher number of marketable tubers than immediate planting and 6-days storage duration of vine cuttings. Statistically 9-node numbers per cutting was showed significantly higher total tuber numbers per hill. The total above ground biomass yield of sweet potato was significantly and positively associated with main stem numbers (r=0.80**), plant height (r=0.61**), total number of nodes (r=0.43**) and inter node lengths (r=0.45**). The presence of high main stem numbers and plant heights contributes much to the total aboveground biomass yield because of increase in individual size and weight of the plant. In general it can be concluded that storage duration of vine cuttings and node numbers do affect growth, yield and yield components much, and therefore farmers cannot follow local planting practices.

5. Recommendations

The empirical result revealed that most of growth, yield and yield components of sweet potato have statistically significant and had positive impact. The farmers should plant several adaptable cultivars of sweet potato having similar or different number of nodes to spread vine cuttings and get high tuberous yields for ensuring sustained availability of food for humans and fodder for animals.

Based on the present findings, farmers are advised to use a 9 nodded cutting to increase the total tuber numbers per hill. Two - four-days storage duration of vine cuttings shaded under a natural tree with mulching grass was gave significantly higher number of marketable tubers.

This study gave an insight for further study and considerations for the number of nodes per cutting and storage duration of vine cuttings for the sweet potato crop. Hence, further investigations are imperative to determine appropriate number of nodes per cutting and right time of storage of vine cuttings under shade before planting for the increased productivity of both tuberous roots for food and fodder.

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