CHAPTER 6

EFFECT OF CUTTING CHARACTERISTICS ON YIELD AND YIELD COMPONENTS OF SWEET POTATO

6.1 ABSTRACT

Appropriate plant establishment techniques are essential for successful crop growth and yield. Cutting characteristics are important factors that may affect yield and yield components. Effect of cultivar (Kudadie, Bareda and Awasa-83), planting position (horizontal and vertical), type of planting material (terminal vine cuttings with and without leaves) and cutting length (20, 25 and 30 cm) on the number and yield of storage roots were studied in Ethiopia at Awasa and Melkassa. The objective of the study was to identify cutting characteristics for better plant establishment and consequently for higher storage root yields. Cultivar Kudadie had the highest total and marketable storage root yield and cultivar Awasa-83 the lowest, at both locations.

The horizontal method of planting resulted in the highest total and marketable storage root yield at both locations. The planting position x type of planting material interaction was highly significant for total storage root number. The combination of horizontal planting and cuttings with leaves gave the highest total number of storage roots.

The cutting length (20, 25 and 30 cm) did not affect storage root number and yield, except for the number and yield of small storage roots. The 30 cm vine cuttings produced the highest number of small storage roots per unit area and the highest small storage root yield at both locations.

Generally storage root numbers tended to increase when the leaves were retained on the cuttings. Cuttings with leaves also produced the highest total and marketable storage root yield at Awasa. At Melkassa only the yield of small storage roots were higher when cuttings with leaves were planted.

6.2 INTRODUCTION

Sweet potato is one of the most important carbohydrate staples in Ethiopia. According to a survey by the Ministry of Agriculture Southern Regional Bureau (1999) a significant segment of the population depend primarily on sweet potato for their food supply. Its cultivation is estimated to cover an area of about 52,000 hectares in the southern region. In traditional farming systems, sweet potato planting material can be difficult and costly to obtain during the dry season. In general, the crop is planted using vine cuttings. Utilizing the vines as planting material give the farmers the opportunity to use all storage roots for consumption or for sale.

The terminal portion of sweet potato vine is reputed to be superior to the middle and basal portions for plant establishment and root yield. The majority of sweet potato farmers use cuttings with leaves. In Ethiopia sweet potato farmers using oxen to prepare the land prefer horizontal planting to vertical planting of cuttings. However, other resource poor farmers who are cultivating their crop manually prefer planting at an angle of 45^{o}. The length of the vine cuttings varies from farmer to farmer and from location to location. There is no clear evidence whether the presence of leaves on the cuttings affects crop establishment and yield. Furthermore it needs to be established whether different cultivars require different lengths of cuttings and different positions of planting for best results.

There have been attempts to increase yield of sweet potato through modifications in cutting characteristics. Various propagation materials can be used to establish the crop. Sweet potato is normally propagated vegetatively by vine cuttings. However, in areas where production can not be carried on continuously and vines are unavailable for planting, root sprouts and storage root pieces are used for propagation. Vigorous and healthy storage roots from the previous crop are bedded and the sprouts are used as propagating material. Ikemoto (1971) reported that tubers for bedding should weigh from 20 to 50 g, and should be planted 3 cm deep. This method is generally used in temperate and subtropical regions (Steinbauer & Kushman, 1971 and Edmond & Ammerman, 1971).

Vine cuttings are better planting material in tropical regions than sprouts from tubers for several reasons. Firstly, plants derived from vine cuttings are free from soil-born diseases (Onwueme, 1978; Phills & Hill, 1984). Secondly, 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. Thirdly, vine cuttings yield better than sprouts, and produce roots of more uniform size and shape. Cuttings from the shoot apex are considered better planting material than basal and middle vine cuttings (Shanmugavelu *et al*., 1972; Godfrey-Sam-Aggrey, 1974; Eronico *et al*., 1981; Villanueva, Jr., 1985; Choudhury *et al*., 1986; Villamayor, Jr & Perez, 1988; Balasurya, 1991; Schultheis & Cantliffe, 1994). Compared to cuttings from middle and basal portions, apical shoot cuttings grow more vigorously and produce larger storage root yields. Where the planting material is in short supply, middle and basal portions of the vine cuttings can be used, but with a decrease in expected yield (Degras, 1969).

There are conflicting results regarding the optimum length of vine cuttings. Onwueme (1978) indicated that tuber yield tend to increase with increase in the length of the vine cuttings used, and recommended a length of about 30 cm. Cuttings longer than 30 cm tend to be wasteful of planting material, while much shorter cuttings established slower, and gave poorer yields. Godfrey-Sam-Aggrey (1974), Shanmugavelu *et al.* (1972), Tanaka & Sekioka (1976), 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.

Chen & Allison (1982) reported that horizontal planting increased sweet potato yield. Storage root yield was significantly higher in plants from vine cuttings with leaves than in plants from cuttings without leaves (Ravindran & Mohankumar, 1982, 1989).

Information regarding cutting characteristics for the establishment of sweet potato in Ethiopia is scarce. Therefore experiments were conducted in two locations (Melkassa and Awasa) to compare and quantify the effects of cultivar, planting material, planting position and cutting length on the storage root yield. The objectives of the study were:

- to better understand cutting characteristics required for successful crop establishment and crop productivity in Ethiopia;
- to determine whether cultivars differ in terms of the required cutting characteristics;
- to identify the best cutting characteristic combinations for optimum storage root yield; and

- to identify differences in storage root yield using different cultivars and cutting characteristics at different locations.

6.3 MATERIALS AND METHODS

Soil and climate: Melkassa

Melkassa Research Centre, Ethiopia, is located at Lat. 8^o 24' N and Long. 39^o 12' E, at an altitude of 1550 masl, on the flat plains. The Centre is in a drought-prone cropping area. The monthly rainfall, evaporation and mean daily minimum and maximum temperatures for the year 2001 are shown in Figure 6.1a. The long term (1977 to 2001) meteorological data of the Centre indicates that the mean maximum temperature is 28.6° C and the mean minimum temperature is 13.8° C. The long-term average annual rainfall is 811 mm (March to October). May is the month with the highest average maximum temperature (30.9°C), whilst October is the month with the lowest average minimum temperature (11.8°C). Temperatures for the 2001 cropping season at Melkassa were similar to the 25-year trend, but rainfall was higher than normal. During the five months of the growing season (April to August 2001) precipitation totaled 648 mm, compared to the 25-year average of 537 mm for the same period. (Appendix, Table A6.1).

The pre-experimental soil chemical and physical characteristics are presented in Table 6.1. The soil is volcanic in origin. The texture is mainly silt clay loam with 40% silt, 32% sand and 28% clay. The pH is in the range of 7.3. Accordingly, the soil can be characterized as alkaline. The organic carbon content of 1.29% and the total nitrogen content of 1.08% are rated as moderately low and low in tropical soil standards. The available P is generally too low to afford sustainable crop production. Cation exchange capacity (CEC) determined by NH_4OAC solution at pH 7 is relatively high, ranging from 25.2 to 28.4 c mol kg^{-1}. The dominant exchange cations present are calcium and magnesium.

Table 6.1 Soil chemical and physical properties at Melkassa and Awasa experimental sites

	Melkassa	Awasa
pH (in H_2O 1:2.5)	7.3	6.62
Organic Carbon %	1.29	2.32
Total N %	0.15	0.22
CEC (cmol kg^{-1})	25.2-28.4	25.5-26.3
P (ppm)	7.06	35.80
Ca (m.e./100g)	17.52	20.19
Mg (m.e./100g)	3.33	4.32
K (m.e./100g)	2.00	3.75
Na (m.e./100g)	0.67	1.35
Sand (%)	32.0	28.5
Silt (%)	40.0	43.5
Clay (%)	28.0	28.0
Texture class	Silt Clay Loam	Silt Clay Loam

* Source: Eylachew Zewdie Ethiopian Agricultural Research Organization, National Soils Laboratory Research Center, Addis Ababa, Ethiopia. (This table is from this source)

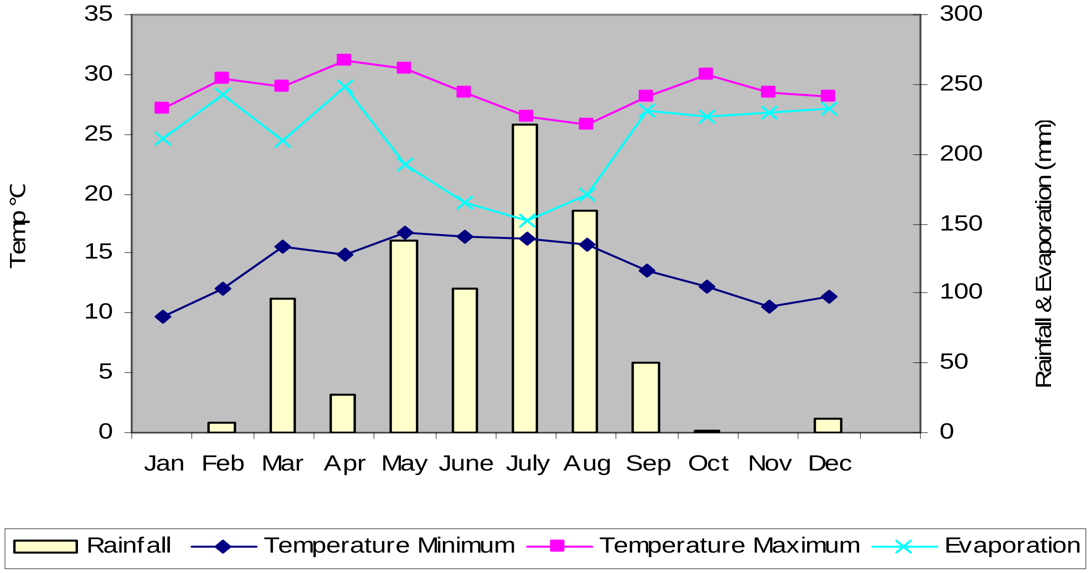

Figure 6.1a Meteorological data for Melkassa Research Centre showing daily mean maximum and minimum temperatures, evaporation and rainfall in 2001.

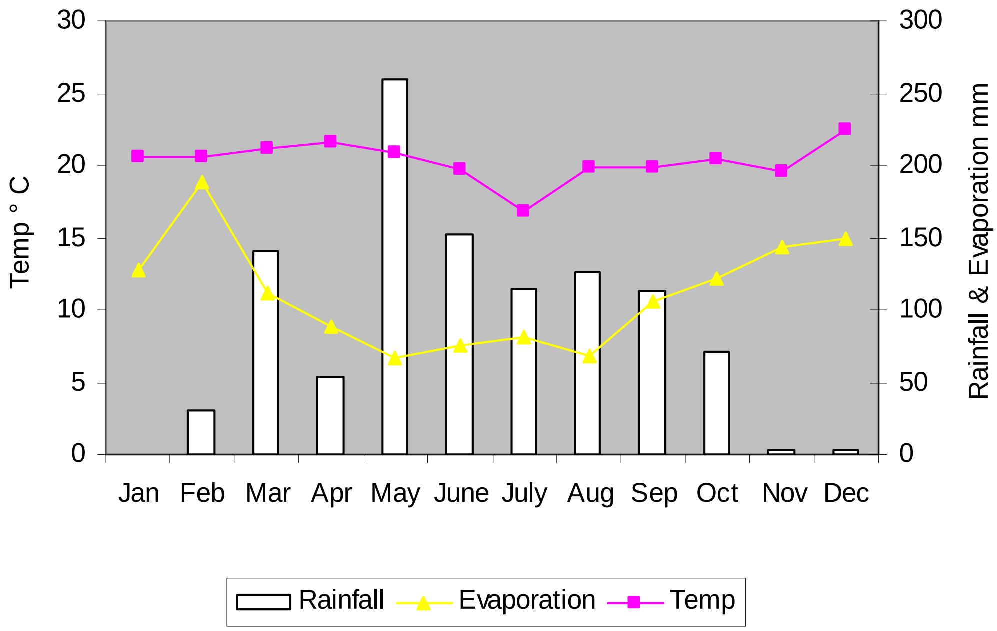

Figure 6.1b Metereological data for Awasa Research Centre showing daily mean temperatures, evaporation and rainfall in 2001

Soil and climate: Awasa

Awasa Research Centre, Ethiopia, is located at Lat. 07^o 04' N and Long. 38^o 31' E, at an altitude of 1700 masl, in the middle of the Rift Valley. The monthly rainfall, evaporation and mean daily temperature for the year 2001 are shown in Figure 6.1b. According to the long-term (1972 to 2001) meteorological data of the Centre, the mean maximum temperature is 26.6° C and the mean minimum temperature is 12.5° C. The long-term average annual rainfall is 1055 mm, fairly evenly distributed throughout the rainy season (May to October). May is the month with the highest average daily temperature (26.5° C), whilst July is the month with the lowest mean daily temperature (16.8° C). Temperature and rainfall for the 2001 cropping season at Awasa were similar to the 30-year trend. During the five months of the growing season (June to October 2001), precipitation totaled 577mm, which is the same as the 30-year average (Appendix, Table A6.2).

The pre-experimental soil chemical and physical characteristics are presented in Table 6.1. The soil is volcanic in origin. The texture is mainly silt clay loam with 43.5%, silt, 28.5% sand and 28% clay. The pH is in the range of 6.62 to 6.64. Accordingly the soil can be characterized as slightly acidic (Asefa Zeleke, Kelsa Kena & Desta Goshu, unpublished data, 1995*). The organic carbon content of 2.32% and total nitrogen content of 0.22% both can be rated as moderately low. The available P is moderately high for sustaining crop production. The cation exchange capacity (CEC) determined by NH_4OAC at pH 7 is relatively high at 26.3 meq/100g soil. The dominant exchange cations present are calcium and magnesium.

* Southern Agricultural Research Institute. Awasa Agricultural Research Center, Natural Resource Section, Awasa, Ethiopia.

Experimental design and treatments

At both Melkassa and Awasa, a 3x2x2x3 factorial experiment in a randomized complete block design with four replications was planted. Treatments applied were three cultivars (Awasa-83, Bareda and Kudadie), two types of planting material (terminal vine cuttings with and without leaves), two types of orientation of cuttings (vertical and horizontal) and three cutting length (20, 25 and 30 cm). For both vertical and horizontal planting two thirds of the cutting length were planted under the soil surface while the remaining one third was left above the soil. The 20 cm cuttings of Awasa-83 consisted of 6 nodes, Bareda of 4 nodes, and Kudadie of 8 nodes. The 25 cm cuttings of Awasa-83 consisted of 7 nodes, Bareda 5 nodes, and Kudadie 9 nodes. The 30 cm cuttings of Awasa-83 consisted of 9 nodes, Bareda 6 nodes, and Kudadie 11 nodes. Planting depth for vertically oriented cuttings ranged from 13cm for the 20 cm cuttings to 20cm for the 30 cm cuttings. In the case of the horizontal planting cuttings were placed 7 to 10 cm below the soil surface with the top one-third above the soil surface. The cultivars represented different maturity groups. Awasa-83 is a late maturing white-fleshed cultivar with a recommended growing period of more than 150 days. Bareda is an intermediate maturing cream-fleshed cultivar with a recommended growing period ranging from 120 to 135, days and Kudadie is an early maturing carrot-fleshed cultivar with a recommended growing period ranging from 90 to 105 days. All three cultivars are nationally released in Ethiopia.

The experiments were planted on 30 March 2001 at Melkassa and 31 May 2001 at Awasa. At Awasa the experiment was conducted under rain-fed conditions. At Melkassa the rain was supplemented by furrow irrigation. At each site there were 144 plots, each plot consisting of five rows of 3 m with 0.6 m between rows. Each row contained 10 cuttings spaced 0.3 m apart.

In the case of the 30 cm cuttings this arrangement resulted in the cuttings being placed end to end for the horizontal planting position. The planting density was 55,555 cuttings per hectare. The two border rows were disregarded and the three central rows were harvested. This resulted in a net plot size of 4.32 m^2.

Data recorded

The experiments were harvested 150 days after planting and the tubers were separated into the standard sizes of small, medium and large (marketable yield) and total yield. Tubers with a weight of less than 100g were grouped as undersize, with a weight ranging between 100g to 200g as small, with a weight ranging between 200g to 350g as medium, with a weight ranging between 350g to 500g as large and with a weight of greater than 500g as oversize. The undersize and the oversize tubers were categorized as unmarketable.

The experimental data were subjected to standard analyses of variance using the General Linear Model (GLM) procedure in the Statistical Analysis System (SAS, 1989) programme to determine the effect of main factors and the interaction between them. Differences at the $P \leq 0.05$ level were used as a test of significance and means were separated using Tukey's t-test. The trials at the two sites were analysed separately.

6.4 RESULTS AND DISCUSSION

Melkassa experiment

Tuber numbers

The mean number of small, medium, large, (marketable), undersize, oversize and total storage roots of the three cultivars at Melkassa is presented in Table 6.2. Cultivar Kudadie produced the highest number of total, marketable, small, medium, large, undersize, and oversize storage roots, and Awasa-83 the lowest. The small storage roots accounted for 19.6% of the total number of storage roots per unit area, medium storage roots for 15.8%, large storage roots for 15.5%, undersize storage roots for 42.6% and oversize storage roots for 6.3%. The highest proportion of the total root number was obtained from undersize storage roots.

The two planting positions (vertical and horizontal) differed significantly in number of medium, large, and oversize storage roots. The storage root numbers of all grades tended to increase with horizontally planted vine cuttings compared to a vertical planting position. Planting the cuttings in a horizontal position increased the number of medium storage roots by 17% and the number of large storage roots by 39%.

The two types of planting material (terminal cuttings with and without leaves) differed in the number of small, undersize and total storage roots produced. Vine cuttings with leaves significantly increased the number of small storage roots by 36% and the number of undersize storage roots by 18%.

The three vine cutting lengths did not differ in number of medium, large, undersize, oversize and total storage roots per unit area. The 30 cm cuttings produced significantly more small storage roots than the 20 cm cuttings.

A number of significant interactions were observed. The cultivar x type of planting material interaction on total root number is illustrated in Figure 6.2, showing differences in total storage root number of the cultivars when the vines were planted with and without leaves. Cuttings of cultivar Kudadie with leaves resulted in a higher number of storage roots than cuttings without leaves. In the case of cultivars Bareda and Awasa-83 the number of roots were not affected by the presence or absence of leaves. This conflicting result between cultivars may be indicating that the effect of presence or absence of leaves on storage root number is cultivar dependent. It is interesting to note that the presence of leaves on the cuttings resulted in the formation of even more storage roots in the prolific tuberizing Kudadie, but the presence of leaves had no effect on the storage roots of Awasa-83 and Bareda. The exact scientific explanation for this phenomenon remains unclear.

The type of planting material x planting position interaction on total storage root number is illustrated in Figure 6.3. Horizontally planted cuttings with leaves produced more roots than the horizontally planted cuttings without leaves, In the case of vertically planted cuttings the number of roots were not affected by the presence or absence of leaves.

A number of significant higher order interactions were observed. The cultivar x cutting length x type of planting material x orientation of cutting interaction on medium and large roots was significant. The 25 cm cuttings with leaves planted horizontally was found the best combination for Kudadie to produce the highest number of storage roots (85.6 m $^{-2}$). For Bareda the combination that produced the highest number (39.5 roots m $^{-2}$) was 30 cm cutting planted horizontally without leaves. In the case of Awasa-83 to produce the highest number (17.6 roots m $^{-2}$) the best combination was found to be both 20 and 25 cm cuttings with leaves planted horizontally (Appendix Table A6.3).

Table 6.2 Effect of cultivar, position of planting, type of planting material and length of cuttings on storage root numbers m^{-2} at Melkassa

Treatment		Storage root number m $^{-2}$						
		Total	Marketable	Small	Medium	Large	Undersize	Oversize
Cultivar	**Awasa-83**	14.8	9.1	3.2	3.0	2.9	4.5	1.1
	Bareda	24.6	12.2	4.2	3.8	4.2	9.6	2.3
	Kudadie	56.0	27.1	11.2	8.3	7.6	26.4	2.6
	LSD_T	4.54	2.44	1.28	0.94	0.92	2.30	0.63
Planting position	**Vertical**	33.5	14.8	6.1	4.6	4.1	13.4	1.6
	Horizontal	29.8	17.5	6.4	5.4	5.7	13.6	2.4
	LSD_T	3.7	1.99	1.05	0.77	0.75	1.88	0.52
Terminal cuttings	**without leaves**	29.5	15.0	5.3	4.8	5.0	12.4	2.0
	with leaves	33.8	17.3	7.2	5.2	4.9	14.6	1.98
	LSD_T	3.7	1.99	1.05	0.80	0.75	1.88	0.52
Cutting length	**20cm**	29.7	14.6	5.0	4.9	4.7	12.9	2.3
	25cm	32.3	16.8	6.3	5.2	5.3	13.7	1.8
	30cm	32.9	16.9	7.3	4.9	4.8	14.0	2.0
	LSD_T	4.50	2.44	1.54	0.94	0.92	2.30	0.76
MEAN		31.7	16.14	6.2	5.0	4.9	13.5	2.0
CV%		35.4	37.3	51.1	46.3	46.4	42.1	77.5

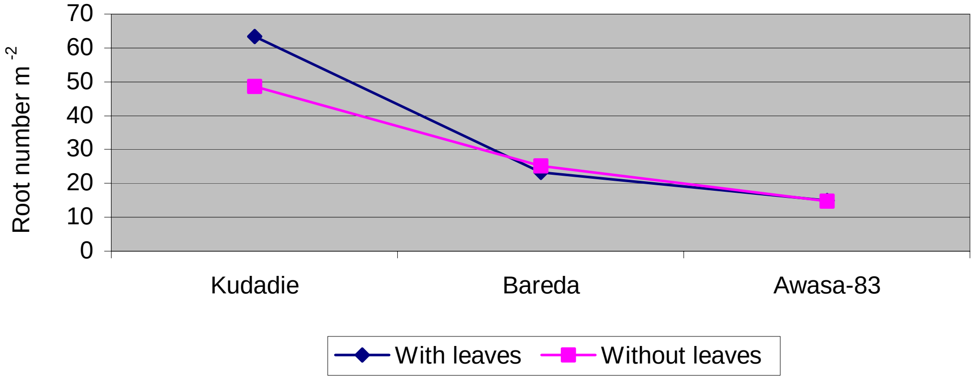

Figure 6. 2 Interaction between cultivar and type of planting material on total storage root number at Melkassa

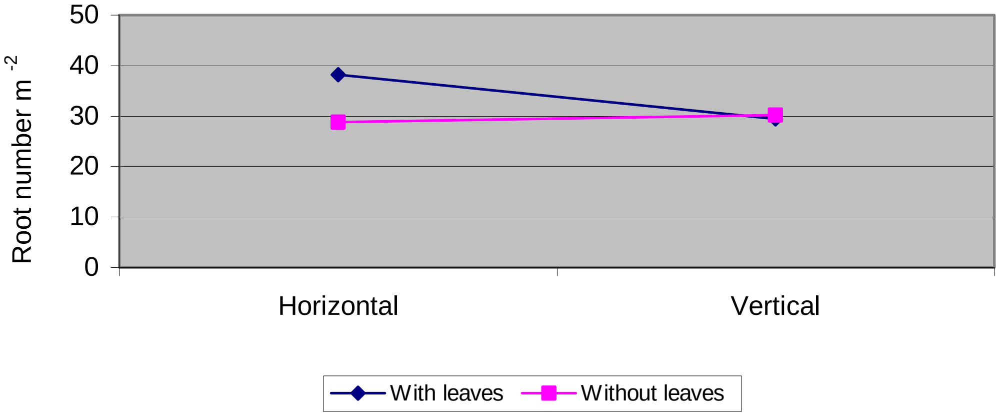

Figure 6.3 Interaction between type of planting material and planting position on total storage root number at Melkassa

Storage root yield

The mean yield of small, medium, large, and total storage roots of the three cultivars at Melkassa is presented in Table 6.3.

The three sweet potato cultivars differed significantly in total, small, medium and large fresh root yields. Cultivar Kudadie produced the highest total root yield (138.7t ha $^{-1}$) and Awasa-83 (49.5t ha $^{-1}$) the lowest. On average small storage roots accounted for 10% of the total storage root yield per hectare, medium storage roots for 16%, and large storage roots for 32% of the total storage root yield. The highest portion of the marketable yield of the three cultivars was obtained from the large storage roots and the lowest from the small roots.

The two planting positions (vertical and horizontal) differed in total, medium, large and marketable storage root yield. Horizontal planting produced the highest root yield (111.3t ha $^{-1}$) and vertical planting (77.4t ha $^{-1}$) the lowest. Planting cuttings in a horizontal position increased total storage root yield by 44%, small storage root yield by 11%, medium storage root yield by 25%, large storage root yield by 37%, and marketable storage root yield by 29% compared to the vertical planting position. Hall (1986) reported that U.S. # 1 root yield from 20 to 25 cm ‘Red Jewel’ cuttings was increased when they were oriented vertically compared to cuttings oriented horizontally. Orientation did not influence the U.S. # 1 root yield from 40 to 45 cm ‘Red Jewel” cuttings. Allison & Chen (1980) and Chen & Allison (1982) reported that horizontal planting increased sweet potato yield compared to vertical planting. Contradictory to this Du Plooy, (1989) reported no significant differences in yield between vertical and horizontal orientation of cuttings of three cultivars using cuttings of 30 cm length, planted with either three or five nodes underground. Malcolm (1992) also reported no significant differences in yield between the vertically and horizontally planted cuttings using two cultivars and four cutting lengths.

The two types of planting material (terminal cuttings with and without leaves) did not differ in fresh storage root yield except for the small storage roots. The cuttings with leaves increased the yield of small storage root by 24%. Ravindran & Mohankumar (1982, 1989) reported that storage root yield was higher in plants from cuttings with foliage compared to plants from cuttings without foliage.

The three cutting lengths (20, 25 and 30 cm) did not differ in the yield of medium, large and marketable storage roots. The 30 cm cuttings resulted in a higher yield of small storage roots than the 20 cm cuttings. There were no significant yield differences between the 25 cm and the 30 cm cuttings. Using cuttings of 23, 31, 46, and 61 cm lengths folded into two equal parts with 5 cm of the blind ends inserted in the soil Godfrey-Sam-Aggrey (1974), reported that 46 and 61 cm long cuttings produced significantly better yields. Hall (1986) also 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; Tanaka & Sekioka, 1976; Chen & Allison, 1982; Ravindran & Mohankumar, 1982; Sanchez *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 contradicting results on the effect of length of sweet potato cuttings on yield. It should be noted that longer cuttings are more difficult to handle, transport and plant. Cuttings of greater length than 30 cm tend to be wasteful of planting material, while much shorter cuttings establish more slowly and result in lower yields. In general it can be concluded that cutting length do not affect storage root yield much, and therefore farmers can follow local practices.

Two of the first order interactions were significant, namely the cultivar x planting material interaction and the planting material x planting position interaction. The cultivar x planting material interaction on total fresh root yield is illustrated in Figure 6.4, showing differences in total root yield of cultivars when the cuttings were planted with and without leaves. Cuttings of cultivars Kudadie and Bareda with leaves resulted in a higher total root yield than the cuttings without leaves, while for Awasa-83 the presence or absence of leaves on the cutting had no effect on total root yield.

The type of planting material x planting position interaction on large storage root yield is illustrated in Figure 6.5 showing differences in large storage root yield of horizontally planted cuttings with and without leaves. Horizontally planted cuttings with leaves resulted in higher large storage root yield than the horizontally planted cuttings without leaves, while for vertically planted cuttings the presence or absence of leaves on the cutting had no effect on large storage root yield.

A significant higher order interaction was observed. The cultivar x cutting length x type of planting material x orientation of cutting interaction on small storage root yield was significant. For Kudadie the 30 cm cuttings with leaves, planted horizontally, was found to be the combination to produce the highest yield of 223.4t ha $^{-1}$ (Appendix Table A6.4). For Bareda the highest yield of 189t ha $^{-1}$ was obtained from 20 cm cutting without leaves planted horizontally. In the case of Awasa-83 the 25 cm cuttings without leaves, planted horizontally, produced the highest (67t ha $^{-1}$) storage root yield (Appendix Table A6.4).

Table 6.3 Effect of cultivar, position of planting, type of planting material and length of cuttings on storage root yield at Melkassa

Treatment		Storage root yield t/ha Total	Marketable	Small	Medium	Large	Undersize	Oversize
Cultivar	**Awasa-83**	49.5	32.6	4.9	9.2	18.5	2.2	14.6
	Bareda	94.9	46.1	5.7	11.1	29.3	3.7	44.7
	Kudadie	138.7	85.0	16.4	25.3	43.2	11.4	42.1
	LSD_T	22.2	10.5	2.5	3.3	7.6	1.13	12.7
Planting position	**Vertical**	77.4	47.7	8.6	13.5	25.6	5.6	24.0
	Horizontal	111.3	61.4	9.5	16.9	35.0	5.9	43.7
	LSD_T	15.1	7.1	1.7	2.2	5.2	0.92	10.39
Terminal cuttings	**without leaves**	95.3	55.3	8.1	15.0	32.2	5.6	34.2
	with leaves	93.4	53.8	10.0	15.4	28.4	6.0	33.4
	LSD_T	15.1	7.1	1.7	2.2	5.2	0.92	10.39
Cutting length	**20cm**	97.8	53.7	8.3	14.9	30.4	6.1	37.6
	25cm	86.2	52.8	8.4	15.4	29.1	5.2	28.5
	30cm	99.1	57.1	10.5	15.3	31.4	6.1	35.4
	LSD_T	22.2	10.5	2.1	3.3	7.6	1.13	12.73
MEAN		94.4	54.6	9.0	15.2	30.3	5.79	33.82
CV%		48.5	39.5	57.4	44.4	51.6	48.3	57.33

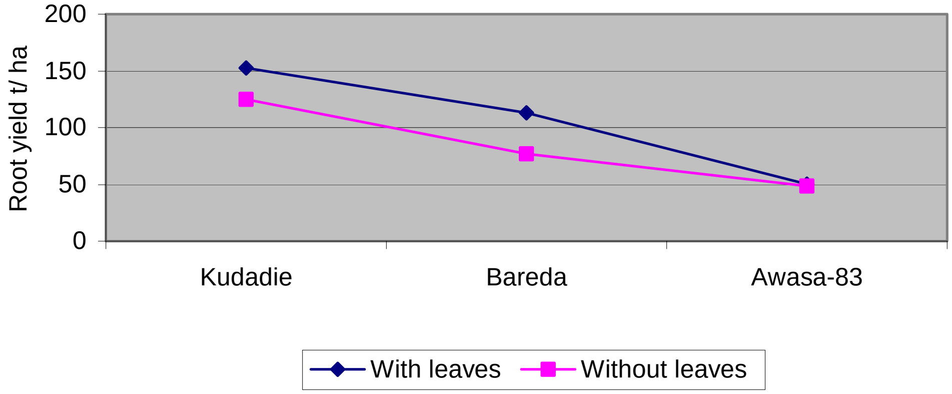

Figure 6.4 Interaction between cultivar and type of planting material on total root yield at Melkassa

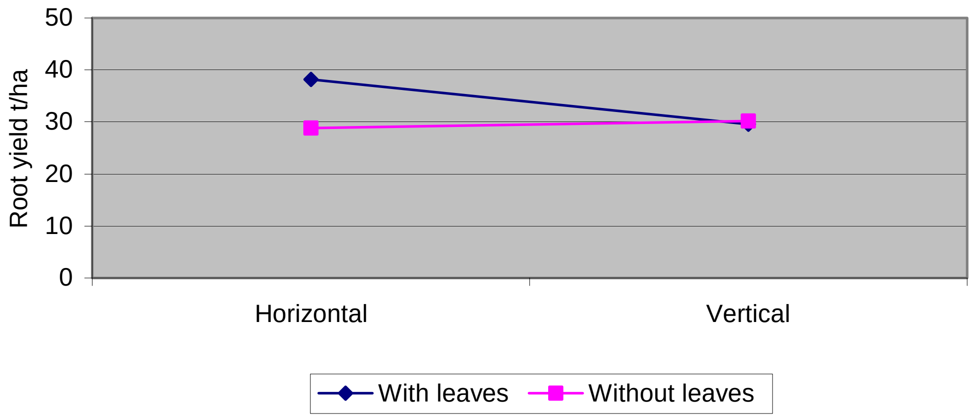

Figure 6.5 Interaction between planting position and type of planting material on large storage root yield at Melkassa

Awasa experiment

Tuber numbers

The number of marketable, small, medium, large, undersize, oversize and total storage roots of the three cultivars at Awasa is presented in Table 6.4. The three cultivars Awasa-83, Bareda and Kudadie differed significantly in number of small, medium, large, undersize, oversize and total storage roots. At Awasa, as at Melkassa, cultivar Kudadie had the highest number of small, medium, large, marketable, undersize, and total storage roots, and Awasa-83 the lowest. The small and medium storage roots each accounted for 20.9% of the total number of storage roots per unit area, large storage roots 28%, undersize 26% and oversize 4%. The marketable storage roots (small, medium and large storage roots) accounted for 69% of the total storage root number. The highest proportion of the marketable root number was obtained from large storage roots (41%).

Generally the storage root number tended to increase with the horizontal method of planting compared to a vertical planting position, but only the number of large and marketable storage roots increased significantly. The number of large roots was increased by 35% and the marketable roots by 13%.

The terminal cuttings with and without leaves differed in number of storage roots. Cuttings with leaves increased the total number of storage roots by 16%, marketable storage roots by 23%, small storage roots by 46% and medium storage roots by 21%.

The three cutting lengths did not differ in number of storage roots produced per unit area, except for the 30 cm cuttings resulting in significantly more small storage roots than the 25 cm cuttings.

There were significant interactions between cultivar x type of planting material, cultivar x orientation of planting, cutting length x type of planting material, and type of planting material x orientation of planting. The type of planting material x orientation of planting interaction on total root number is illustrated in Figure 6.6. Horizontally planted cuttings with leaves produced more roots than the horizontally planted cuttings without leaves, In the case of vertically planted cuttings the number of roots were not affected by the presence or absence of leaves. It is interesting to note that this interaction is almost identical to the interaction observed at Melkassa (Figure 6.3).

The type of planting material x cutting length interaction on total fresh root number is illustrated in Figure 6.7. Cuttings of 30 cm length with leaves produced more storage roots than the 30 cm cuttings without leaves. In the case of the 20 cm cutting the number of roots were not affected by the presence or absence of leaves. The 30 cm cutting with leaves produced more roots than the 25 cm cuttings with leaves.

A number of significant higher order interactions were observed. The cultivar x type of planting material x orientation of cutting interaction on total storage root number was significant. Cuttings of 20 cm with leaves and vertical planting were found the best combination for Kudadie to produce the highest number (36 m^{-2}) of storage roots. For Bareda the treatment combination to produce the highest number (30.7 m^{-2}) was found to be the 30 cm cuttings without leaves and planted horizontally. In the case of Awasa-83 the combination to produce the highest number (26 roots m^{-2}) was found to be the 30 cm cuttings without leaves and planted horizontally (Appendix Table A6.5).

Table 6.4 Effect of cultivar, position of planting, type of planting material and length of cuttings on storage roots number m^{-2} at Awasa

Treatment		Storage root number m^{-2}						
		Total	**Marketable**	**Small**	**Medium**	**Large**	**Undersize**	**Oversize**
Cultivar	**Aw-83**	18.2	13.5	4.9	4.5	4.1	4.3	0.4
	Bareda	19.6	13.5	3.2	3.9	6.4	5.0	1.1
	Kudadie	28.1	18.9	5.6	5.5	7.8	8.2	1.0
	LSD_T	2.16	1.50	0.81	0.77	1.05	1.32	0.30
Planting position	**Vertical**	21.4	14.3	4.7	4.5	5.2	6.4	0.7
	Horizontal	22.5	16.2	4.4	4.8	7.0	5.3	1.0
	LSD_T	1.76	1.22	0.66	0.63	0.86	1.08	0.25
Terminal cutting	**Without leaves**	20.3	13.7	3.7	4.2	5.8	5.7	0.9
	With leaves	23.6	16.8	5.4	5.1	6.3	6.0	0.7
	LSD_T	1.76	1.22	5.68	0.63	0.86	1.08	0.25
Vine lengths	**20 cm**	21.2	14.6	4.4	4.3	5.9	5.7	0.9
	25 cm	21.3	15.1	4.1	4.5	6.4	5.3	0.9
	30 cm	23.4	16.1	5.2	5.0	5.9	6.6	0.7
	LSD_T	2.16	1.50	0.81	0.77	1.05	1.32	0.30
MEAN		22.0	15.3	4.6	4.6	6.1	5.9	0.8
CV%		24.3	24.2	44.0	41.2	42.7	55.8	91.0

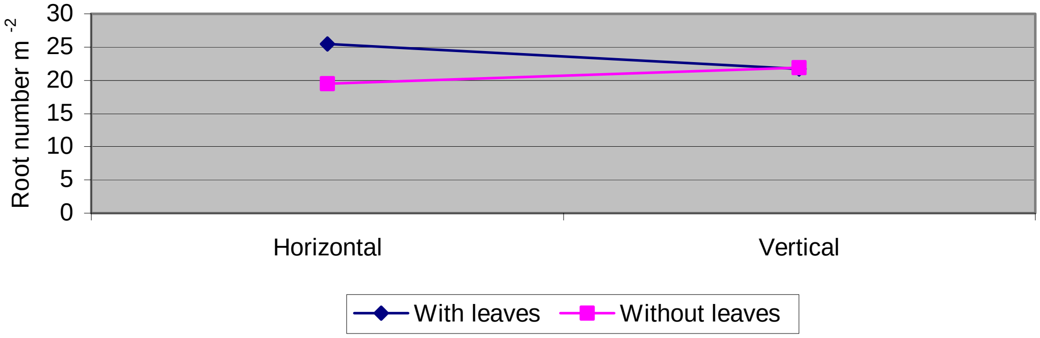

Figure 6.6 Interaction between type of planting material and planting position on total root number at Awasa

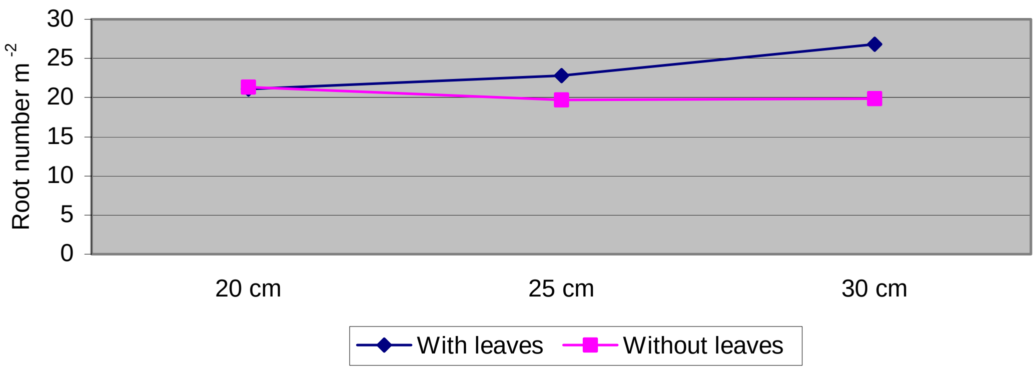

Figure 6.7 Interaction between type of planting material and cutting length on total root number at Awasa

Storage root yield

The yield of total and marketable storage roots of the three sweet potato cultivars at Awasa is presented in Table 6.5. The three cultivars Awasa-83, Bareda and Kudadie differed significantly in total and marketable root yield. Similar to the results of the Melkassa experiment, cultivar Kudadie produced the highest total (76.6t ha^{-1}), marketable (60.8t ha^{-1}), small, medium, large, and undersize fresh root yield, and cultivar Awasa-83 the lowest yield. On average small storage roots accounted for 10% of the total storage root yield per hectare, medium storage roots for 22%, large storage roots for 44%, and marketable storage roots for 77% of the total storage root yield. The highest proportion of both total and marketable storage root yields was obtained from the large storage roots.

The two types of planting positions (vertical and horizontal) differed in total, marketable, large, and oversize storage root yields. Horizontal planting resulted in the highest total, marketable, large and oversize root yields. Planting the cuttings in a horizontal position increased total storage root yield by 27%, marketable storage root yield by 23%, large storage root yield by 34% and oversize storage root yield by 55%, compared to a vertical planting position. Hall (1986) reported that root yield from 20 to 25 cm cuttings was increased when they were oriented vertically compared to the cuttings oriented horizontally. Du Plooy (1989) and Malcolm (1992) found no significant differences in yield between vertical and horizontal orientation of cuttings. Allison & Chen (1980) and Chen &Allison (1982) reported that horizontal planting increased sweet potato yield compared to vertical planting.

The two types of planting material (terminal cuttings with and without leaves) differed in storage root yield. The terminal cuttings planted with leaves produced significantly higher yields of total, marketable, small and medium storage roots per hectare. Planting terminal cuttings with leaves increased the total storage root yield by 12%, marketable storage root yield by 20%, small storage root yield by 52% and medium storage root yield by 22.8% compared to cuttings without leaves. Ravindran & Mohankumar (1982, 1989) also reported that storage root yield was significantly higher in plants from vine cuttings with foliage than in plants from cuttings without foliage.

The three cutting lengths (20 cm, 25 cm and 30 cm) did not differ in total, marketable, medium, large, undersize and oversize storage root yield. The 30 cm cuttings resulted in higher yields of small storage roots than the 20 and 25 cm cuttings. There were no significant yield differences of small storage roots between the 20 and 25cm cuttings. Godfrey-Sam-Aggrey (1974) and Hall (1986) reported that 46 and 61 cm cuttings and cuttings of 40 to 45 cm, respectively produced significantly better yields than shorter cuttings. Other authors (Shanmugavelu *et al.*, 1972; Tanaka & Sekioka, 1976; Chen & Allison, 1982; Ravindran & Mohankumar, 1982; Sanchez *et al*., 1982; Bautista & Vega, 1991) reported that cuttings of 40 cm length produced better storage root yields than longer cuttings.

The cultivar x type of planting material interaction on total root yield is illustrated in Figure 6.7, showing differences in total root yield of cultivars when the cuttings were planted with and without leaves. Bareda cuttings with leaves resulted in a higher total root yield than the cuttings without leaves, while for Kudadie and Awasa-83 the presence or the absence of leaves on the cuttings has no effect on the total root yield.

The type of planting material x cutting length interaction on total storage root yield is illustrated in Figure 6.8. The 25 and 30 cm cutting with leaves produced a higher total root yield than the cuttings without leaves. In the case of 20 cm cutting the presence or the absence of leaves had no effect on the total root yield.

A significant higher order interaction was observed. The cutting length x type of planting material x orientation of cutting interaction on medium and large storage root yield was significant. The 30 cm cuttings without leaves planted horizontally was found to be the best combination for Bareda to produce the highest yield (103.3t ha $^{-1}$) of storage roots. For Awasa-83 the combination that produced the highest yield (63.8t ha $^{-1}$) of total storage roots was found to be 30 cm cuttings without leaves planted horizontally. In the case of Kudadie the highest yield (96.1t ha $^{-1}$) of storage roots was produced from the 20 cm cuttings, with leaves, planted horizontally (Appendix Table A6.6).

At both locations cultivar Kudadie produced the highest storage root yield and Awasa-83 the lowest. Kudadie produced 138.7t ha $^{-1}$ and Awasa-83 49.5t ha $^{-1}$ at Melkassa. At Awasa Kudadie produced 76.6t ha $^{-1}$ and Awasa-83 yielded 46.1t ha $^{-1}$. The total root yield of Kudadie ranged from 109 to 223t ha $^{-1}$ at Melkassa and 48.9 to 96t ha $^{-1}$ at Awasa (Appendix Table 6.4 and 6.6). The total storage root yield of Bareda ranged from 53 to 157.5t ha $^{-1}$ at Melkassa and 44.6 to 103.3t ha $^{-1}$ at Awasa (Appendix Table 6.4 and 6.6). The total root yield of Awasa-83 ranged from 29.6 to 67.4t ha $^{-1}$ at Melkassa and 35.5 to 63.8t ha $^{-1}$ at Awasa

(Appendix Table 6.4 and 6.6). Generally the average storage root yield of the three cultivars was higher at Melkassa than at Awasa.

At both locations cultivar Kudadie produced the highest storage root number and Awasa-83 the lowest. Kudadie produced 56 roots m $^{-2}$ and Awasa-83 produced 14.8 roots m $^{-2}$ at Melkassa (Table 6.2). At Awasa cultivar Kudadie produced 28 roots m $^{-2}$ and Awasa-83 yielded 18 roots m $^{-2}$ (Table 6.4). The total root number of Kudadie ranged from 25 to 85.6 roots m $^{-2}$ at Melkassa and 16.7 to 36 roots m $^{-2}$ at Awasa (Appendix Table 6.3 and 6.5). The total storage root number of Bareda ranged from 19.4 to 39.5 roots m $^{-2}$ at Melkassa and 12 to 33.7 roots m $^{-2}$ at Awasa (Appendix Table 6.3 and 6.5). The total root number of Awasa-83 ranged from 11.5 to 17.6 roots m $^{-2}$ at Melkassa and 14.6 to 26.1 roots m $^{-2}$ at Awasa (Appendix Table 6.3 and 6.5). Except for cultivar Awasa-83, the average storage root numbers of the cultivars were higher at Melkassa than at Awasa. The general trend of cultivars and cutting characteristics on total root yield and total root number are very similar for both locations.

At Melkassa the five months of growing season (April to August 2001) had more precipitation (648 mm) compared to the five months growing season (June to October 2001) of Awasa experiment, which received only (577 mm) Appendix Table A6.1. At Melkassa the crop had not experienced moisture stress since the rain was supplemented with the furrow irrigation.

The Melkassa experiment was planted (30 March 2001) two months earlier than the Awasa experiment, which was planted (31 May 2001) the maximum temperature at Melkassa during the first month of planting was 31^{o}C compared to the maximum temperature of 19.7 ^{o}C at Awasa.

Table 6.5 Effect of cultivar, position of planting, type of planting material and length of cuttings on storage root yields per hectare at Awasa

Treatment		Storage root yield t/ha.						
		Total	Marketable	Small	Medium	large	Undersize	Oversize
Cultivar	**Aw-83**	46.1	38.9	6.7	13.7	18.5	1.7	5.6
	Bareda	67.0	45.8	4.6	12.0	29.2	1.9	19.4
	Kudadie	76.6	60.8	7.6	16.7	36.5	3.4	12.7
	LSD_T	7.0	6.53	1.19	2.28	4.91	0.58	4.46
Planting position	**Vertical**	55.8	43.5	6.2	13.4	23.9	2.4	9.8
	Horizontal	70.8	53.4	6.4	14.8	32.1	2.2	15.2
	LSD_T	5.68	4.45	0.97	1.86	4.0	0.45	3.79
Terminal cutting	**Without leaves**	59.8	44.1	5.0	12.7	26.4	2.2	13.6
	With leaves	66.8	52.8	7.6	15.6	29.6	2.5	11.6
	LSD_T	5.68	4.45	0.94	1.86	4.00	0.47	3.7
Vine lengths	**20 cm**	62.9	46.4	5.9	13.3	27.2	2.3	14.3
	25 cm	64.6	49.2	5.5	13.5	30.1	2.1	13.4
	30 cm	62.3	49.8	7.5	15.5	26.8	2.6	9.8
	LSD_T	6.96	5.45	1.19	2.28	4.91	0.58	4.64
MEAN		63.3	48.5	6.3	14.1	28.0	2.3	12.5
CV%		27.2	27.8	46.6	39.9	43.3	61.4	91.5

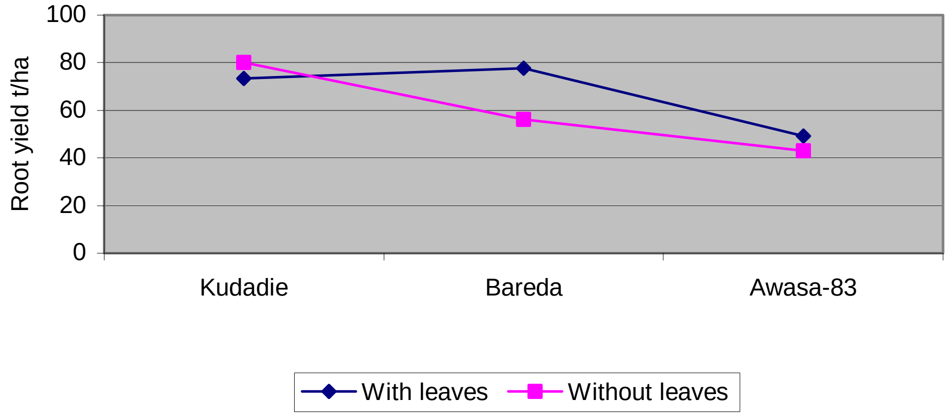

Figure 6.8 Interaction between cultivar and type of planting material on total root yield at Awasa

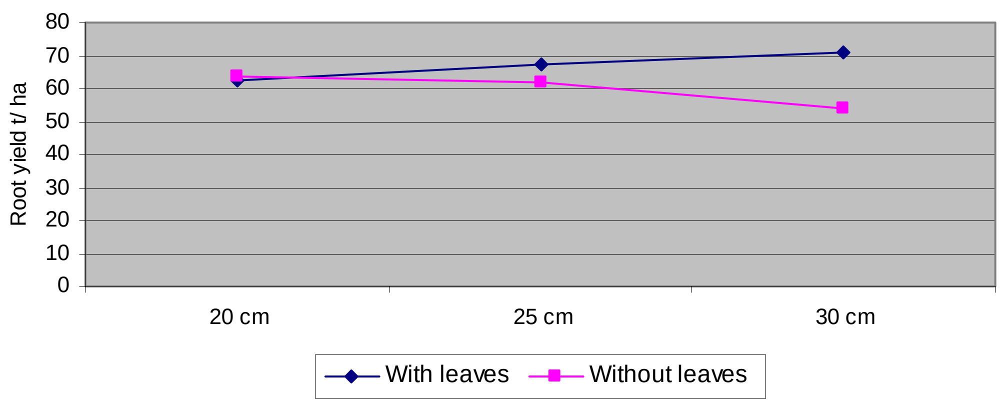

Figure 6.9 Interaction between type of planting material and cutting length on total root yield at Awasa

6.5 CONCLUSION

Although large differences occurred in yield between locations the cultivars and cutting treatments responded similarly at both locations, indicating the reliability of the results.

The cutting treatments did not have a major effect on storage root yield, whether the cuttings were 20, 25 or 30 cm long, planted with or without leaves. Root yields were increased when cuttings were oriented horizontally compared to the cuttings oriented vertically. From these trials and related literature it can be concluded that cutting characteristics *per se* have a relative small effect on storage root yield and farmers can follow local practices within these general guidelines.

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