African Journal of Agricultural Research Vol. 7(7), pp. 1129-1141, 19 February, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.894
ISSN 1991-637X © 2012 Academic Journals

Full Length Research Paper

Effect of planting methods and vine harvesting on shoot and tuberous root yields of sweet potato [*Ipomoea batatas* (L.) Lam.] in the Afar region of Ethiopia

Mohammed Ahmed[1], Nigussie-Dechassa R.[2]* and Bekele Abebie[3]

[1]Afar Pastoral and Agro-Pastoral Research Institute, Samara, Afar, P. O. Box 16, Ethiopia.
[2]Department of Plant Sciences, Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia.
[3]School of Humanities and Natural Sciences, Adama University, P. O. Box 1888, Adama, Ethiopia.

Accepted 13 October, 2011

In the arid pastoralist Afar region of Ethiopia, scarcity of food and fodder owing to recurring droughts is a major problem imperilling livestock and human survival. Therefore, sweet potato production as a dual purpose food-security crop has been steadily increasing in the region. However, there is scarcity of information on agronomic practices that may lead to optimum production of tuberous roots and shoots. Therefore, a field experiment was conducted at Werer Agricultural Research Centre with the objective of evaluating the influence of planting methods and vine harvesting time on yields of tuberous roots and shoots of the crop plant. The treatments consisted of three planting methods (ridge, flat, and sunken), and three vine harvesting times (45, 75 and 105 days after planting including one control treatment without vine harvesting). The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated four times. The results revealed that planting sweet potato on ridges and harvesting the vines 105 days after planting (when about 60% of the growth phase of the plant was completed) led to optimum production of herbage for fodder without compromising yield of tuberous roots.

Key words: Planting method, shoot (vine) yield, tuberous root weight, tuberous root dry matter weight, tuberous root number, vine harvesting.

INTRODUCTION

Sweet potato [*Ipomoea batatas* L. (Lam.)] is an important food security crop grown in many of the poorest regions of the world mainly by women for food and as a source of food and family cash income (Woolfe, 1992). It is tolerant of a wide range of edaphic and climatic conditions (Lebot, 2009), adapts well to areas that are marginally suitable, for the production of other crops, and are food-insecure providing a continuous supply of food or fodder throughout the year (Bourke, 1982). The plant is traditionally cultivated for food as a root crop (Ruiz et al., 1981). However, the top is also used as valuable forage for ruminants and other livestock species ((Backer et al, 1980; Gonzales et al, 2003; Giang et al, 2004). The tuberous roots and leaves of sweet potato are an excellent source of carbohydrate, protein, iron, vitamins A, C and fibre (Smart and Simmonds, 1995). Sweet potato vines have crude protein contents ranging from 16 to 29% on dry matter basis which is comparable to

*Corresponding author. E-mail: nigussiedachassa@gmail.com. Tel: +251-255530324. Fax: +251-255530325.

leguminous forages (An et al., 2003). Feeding the vines to cows as a supplement to a basal diet of other forage increased milk yield (Etela et al., 2008). The fresh tuberous root contains 80 to 90% carbohydrate of the dry matter (Dominguez, 1992), 3.6 to 5.4% crude protein, 0.72 to 1.27% fat, 2.5 to 3.25 fibre and 2.5 to 3.2% ash on a dry matter basis (Duke, 1983). Sweet potato is widely grown in Ethiopia, currently covering about 75,000 ha of land with an average national yield of about 8 Mg ha^{-1} (Assefa-Tofu et al., 2007) which is low compared to the World's average production of about 14.8 Mg ha^{-1}. The tuberous roots are used as food by humans whereas the vines are used as supplementary feed for goats (Getachew, 2000; Tesfaye et al., 2008). Product-ion is mainly for food and it is also cultivated to feed animals as well (Tesfaye et al., 2008). It ranks third after Enset [*Ensete ventricosum* (Welw.) Cheesman] and potato (*Solanum tuberosum* L.) as one of the most important root and tuber crops produced in the country (CSA, 2010).

Sweet potato varieties meant for both fodder and food (tuberous root) allow a low number of toppings which enable spreading of fodder availability over the year without significantly affecting tuberous root yields (Leon-Velarde, 2000). Increasing recognition of the great potential of the sweet potato crop as a nutritious food for humans and animals has resulted in intensified research efforts to enhance its production and consumption in recent decades (Yamakawa and Yoshimoto, 2002). Previous research showed that vine harvesting of sweet potato reduced the yield of tuberous roots (Nguyen and Bautista, 1999; Kiozya et al., 2001; An et al., 2003). Age at harvest is an important management factor that affects sweet potato fodder and tuberous root yield as well as quality (An et al., 2003). In mixed crop-livestock production systems, one limitation on productivity is the year-round requirement for feed (Leon-Velarde, 2000). Livestock feed is particularly scarce in the Afar region of Ethiopia inducing agro-pastoralists to wander with their animals in desperate search for fodder during most period of the year which is extremely dry and hot. To alleviate the problem of acute livestock feed scarcity as well as food insecurity, pastoralists along the Awash River Ethiopia have been cultivating sweet potato using irrigation (Solomon, 1999). Therefore, the demand for improved sweet potato varieties that could be used for both food and fodder production has been on the increase in the area (WARC, 2004).

Pastoralists in the Afar region of Ethiopia traditionally cut sweet potato vines at some stages of growth for use as animal feed or planting material. Besides, they top the vines to suppress production of jumbo tuberous roots which often pose the problem of prolonged cooking. Production of jumbo tuberous roots also sometimes makes necessary the task of splitting the roots into pieces to fit them into cooking pots. Pastoralists in the region have no information on the stages of growth at which vines should be harvested for fodder without com-promising yields of tuberous roots. In addition, they also use varied seedbed types to cultivate the crop. However, these planting methods have not yet been validated to establish suitability for both tuberous root and herbage production. This research was therefore under-taken with the objective of evaluating the effect of planting methods and vine harvesting dates on tuberous root and shoot yields of the crop plant.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in the Afar region of Ethiopia in the Danakil plains at Werer Agricultural Research Centre. The site is located at 9° 60' N latitude, 40° 9' E longitude and at an elevation of 740 m above sea level. The soil is a predominantly light-textured alluvial type and black in colour with a pH of 8.4 (WARC, 2007). The organic matter content of the soil ranges between 0.46 to 2.08% at 0 to 30 cm soil depth. The cation exchange capacity (CEC) varies from 25 to 50 $cmol_c$/kg soil (medium). Exchangeable Na content of the soil is higher than the contents of both magnesium and potassium (Tadesse and Bekele, 1996). The mean annual temperature is 34°C while the mean annual rainfall and evapo-transpiration are 560 and 2600 mm, respectively. The region is very hot and dry with erratic rainfall (WARC, 2007).

Experimental material

A standard sweet potato cultivar known as Koka-6 was used for the experiment. The cultivar has a spreading growth habit. It is cream-fleshed and has medium time of maturity (135 to 170 days). The cultivar was selected for the experiment because it is most adapted and widely cultivated in the area.

Preparation of seedbeds and planting material

The field was ploughed, harrowed and levelled. Seedbeds for the three planting methods were prepared with a traditional hoe. The sunken seedbed was prepared with the dimensions of 30 × 20 × 20 cm and the ridge seedbed was prepared with a height of 60 cm and a width of 60 cm (Figure 1). The flat seedbed was prepared normally by ploughing and harrowing. Vine cuttings each with 30 cm length were cut off from the tips of sweet potato stock plants in a nursery using a sharp sickle. Excess leaves were trimmed from each cutting until eight leaves were left and the cuttings were placed in bundles in an upright position in a pail half-filled with water to avoid wilting until planting in the field.

Treatments and experimental design

The treatments consisted of three vine harvesting times (harvesting the vines 45, 75, and 105 days after planting with one control treatment in which plants were left with their vines intact during the entire period of growth until the final harvest), and three planting methods or seedbed types (ridge, flat and sunken). The experiment was laid out as a randomized complete block design in a 3 × 4

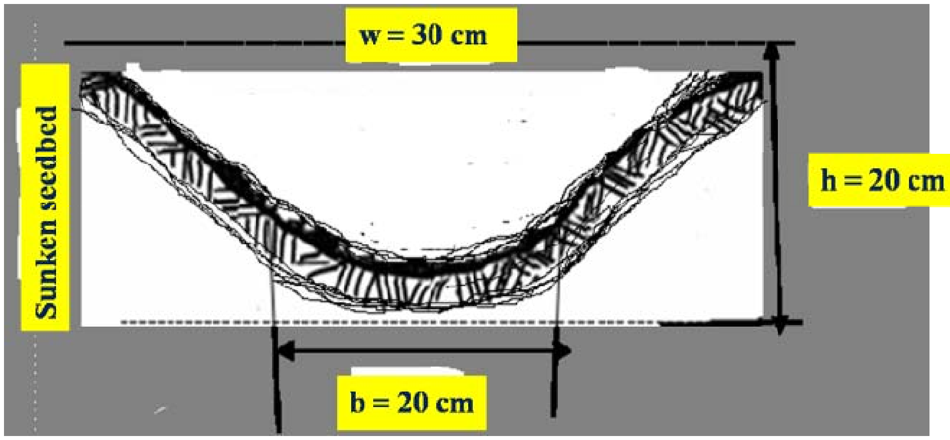

Figure 1. A schematic diagram displaying a sunken seedbed planting system for sweet potato crop: b = base of the bed; h = height of the bed and w = width of the bed.

factorial arrangement and replicated four times. The size of each plot was 4.2 × 4.2 m^2. Thus, there were 12 treatment combinations and 48 plots. The treatments were randomly assigned to each plot. Plots were separated by a distance of 1.0 m and blocks were separated by a distance of 2.0 m. There were seven rows in each plot with each row accommodating 14 plants.

Planting and crop management

Planting was done on 29 September 2008. Vines were planted by inserting the basal portions into the soil at a spacing of 30 cm between plants and 60 cm between rows. The insertion was done in such a way that the cuttings were almost horizontal, with their basal extremity located fairly shallow in the soil aimed at establishing almost two-thirds of each stem cutting length under the soil. The plots were kept free of weeds by hoeing and the plants were furrow-irrigated once per week for the whole period of growth. Vine harvesting was done in such a way that all vines of each plant were cut back to 10.0 cm above the soil level at 45, 75 and 105 days after planting (DAP) using a sharp sickle. The control plots were left uncut throughout the growing season up until the time of final harvest. Finally, both the vines and the tuberous roots were harvested on 18 March 2009.

Measurements

The sweet potato plants were allowed to grow for 172 days while monitoring growth and harvesting the vines at the specified stages of growth. The parameters studied included fresh shoot (vine) yields, dry shoot (vine) yields, number of total tuberous roots, yields of total and marketable tuberous roots and total dry matter yield of tuberous roots.

Fresh and dry weights of shoots

The fresh weight of shoots (vines with leaves) harvested per plot was determined using a weighing scale. The fresh weight of vines that were removed during each harvesting stage was recorded. The dry weight of the vines was determined after subjecting the fresh matter to a forced draft oven at 65°C until constant weight was attained.

Total fresh and dry weights of shoots

Final harvesting of the whole shoot from all plots by cutting the vines back to 2 cm at the base of the plant was done 172 days after planting, and both the fresh and dry weights of the shoots were recorded for each plot. The measured fresh and dry shoot weights at the final harvest were added to the fresh and dry shoot weights collected at the previous harvests (45 and 75 DAP) except for the control treatment for which the shoots were all collected only at the final harvest.

Number of total tuberous roots

At the final harvesting, all plants from the net plot area (5 middle rows excluding plants at both ends of each row) were harvested. The number of unmarketable tuberous roots was determined by counting the number of tuberous roots having the weight of less than 150 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 150 g. The number of total tuberous roots was determined by adding up the values of the two tuberous root categories.

Total fresh weight of tuberous roots

The total fresh yield of tuberous roots was determined by combining the weights of the marketable and the unmarketable tuberous root fresh yields.

Marketable fresh weight of tuberous roots

The marketable and unmarketable fresh yields of tuberous roots were determined by weighing the afore-mentioned tuberous root categories separately.

Table 1. Mean squares from the analysis of variance of yield and yield components of sweet potato.

	Mean squares					
Variable	**Replication**	**Clipping stage (A)**	**Seedbed type (B)**	**A × B**	**Error**	**CV (%)**
DF	3	3	2	6	33	
MTRY	3.89	97.82***	16.44*	1.77^{NS}	3.48	8.2
TTRW	3.30	154.24***	32.29**	1.34^{NS}	4.45	7.6
CSFY	32372.22	105238.88**	109352.08*	20940.97^{NS}	23341.91	24.5
CSDY	4907.13	19620.92*	6195.90^{NS}	5195.02^{NS}	5168.55	37.0
DMC	5.70	18.02**	25.001**	6.42^{NS}	3.38	6.9
MTN	2826034019	3549824848***	497959480^{NS}	590214647 ^{NS}	314400834	18.1
TTN	1502955300	18517661263***	2084149294^{NS}	2813754414^{NS}	1614790096.4	22.3

Where *, **, *** significant at P < 0.05, 0.01, 0.001 probability levels, respectively; NS = non significant; TTRW = total tuberous root weight; MTRW = marketable tuberous root weight; TTN = total tuberous root number; CTSFY = cumulative total shoot or vine fresh yield and CTSDY = cumulative total shoot or vine dry yield.

Total dry matter content of tuberous roots

The dry matter yield of tuberous roots was determined by taking a random sample of ten tuberous roots of all size categories from each plot, determining their fresh weights, slicing them into thin pieces (about 3 mm thick) and then drying the composite sample of 200 g in a forced draft oven at 65°C until constant weight was attained.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the SAS statistical analysis system (SAS Institute, Inc., Cary, NC, 2002). Differences between treatment means were separated using the Least Significant Difference (LSD) test at 5% level of significance.

RESULTS

Influence of planting methods and vine harvesting on vine (shoot) yields

Cumulative fresh as well as dry shoot (vine) yields were significantly influenced by the main effects of planting methods and vine harvesting. However, the two factors did not interact to influence both yields (Table 1).

Effect of planting methods on vine (shoot) yields

Plants grown on ridge and flat seedbeds produced significantly (P < 0.01) higher cumulative fresh shoot yields than plants grown on the sunken seedbed. The cumulative fresh shoot yields obtained from plants grown on ridge and flat seedbeds were more than those obtained from plants grown on sunken seedbed by about 22 and 17%, respectively. However, cumulative dry shoot yield was significantly higher only for ridge seedbed which exceeded the cumulative dry shoot yields obtained from flat and sunken seedbeds by about 9 and 10%, respectively (Figure 2).

Effect of vine harvesting on vine (shoot) yields

No significant differences were detected in cumulative fresh as well as dry shoot yields among plants whose vines were not harvested during growth, plants whose vines were harvested 45 days after planting and those whose vines were harvested 75 days after planting. However, plants whose vines were harvested 105 days after planting significantly (P < 0.01) out-yielded plants in all other treatments in terms of cumulative total fresh and dry vine yields. Consequently, the cumulative fresh shoot yield obtained from plants whose vines were harvested 105 days after planting was greater than those obtained from plants in the other three treatments by 36, 15 and 12%, respectively.

Similarly, the cumulative dry shoot yield of plants whose vines were harvested 105 days after planting was superior to the cumulative dry shoot yields obtained from plants in the other three treatments by 18, 11 and 10% in the same order (Figure 3).

Influence of planting methods and vine harvesting on tuberous root yields

The results revealed that planting methods and vine harvesting during growth had significant main effects on tuberous root and shoot yields. However, the two factors did not interact to affect tuberous root and shoot yields (Table 1).

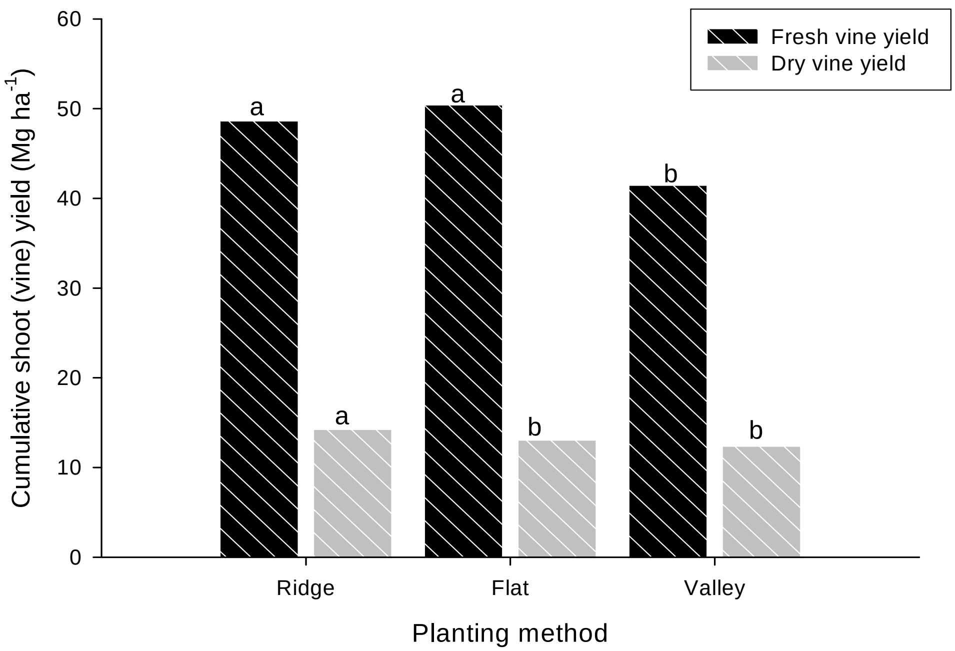

Figure 2. Vine (shoot) yield of sweet potato as influenced by planting methods. Bars represent means of four replicates (randomised blocks). Bars topped by the same letter are not significantly different at 5% level of significance within each differently shaded bar category.

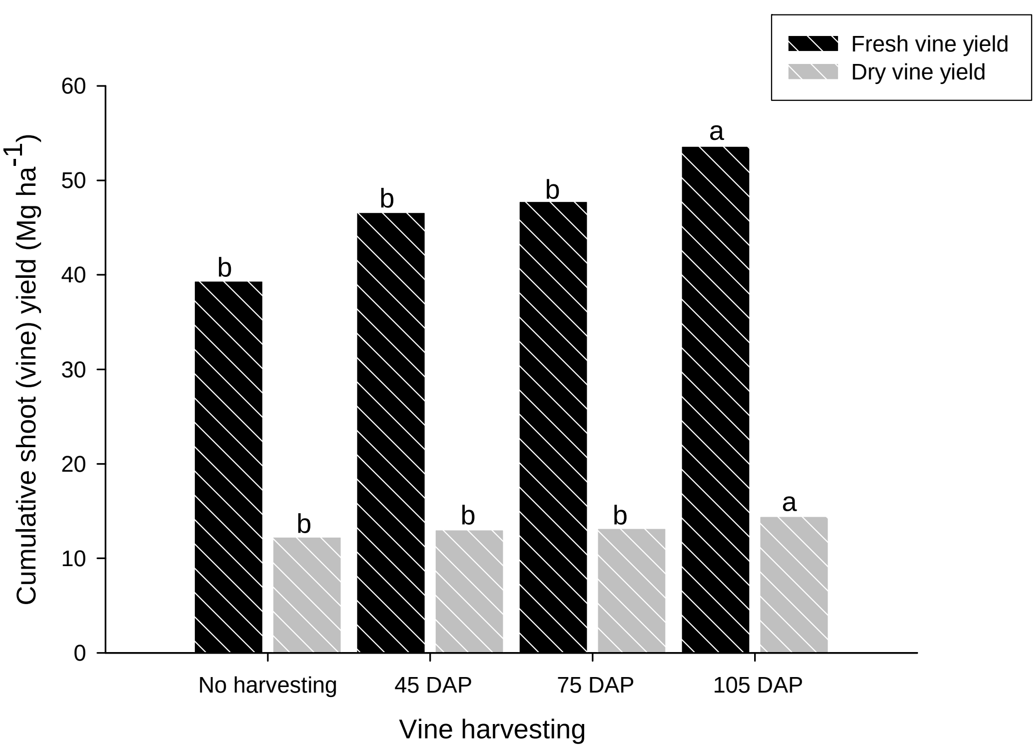

Figure 3. Vine (shoot) yields as influenced by vine harvesting. Bars represent means of four replicates (randomised blocks). Bars topped by the same letter are not significantly different at 5% level of significance within each differently shaded bar category. DAP = days after planting.

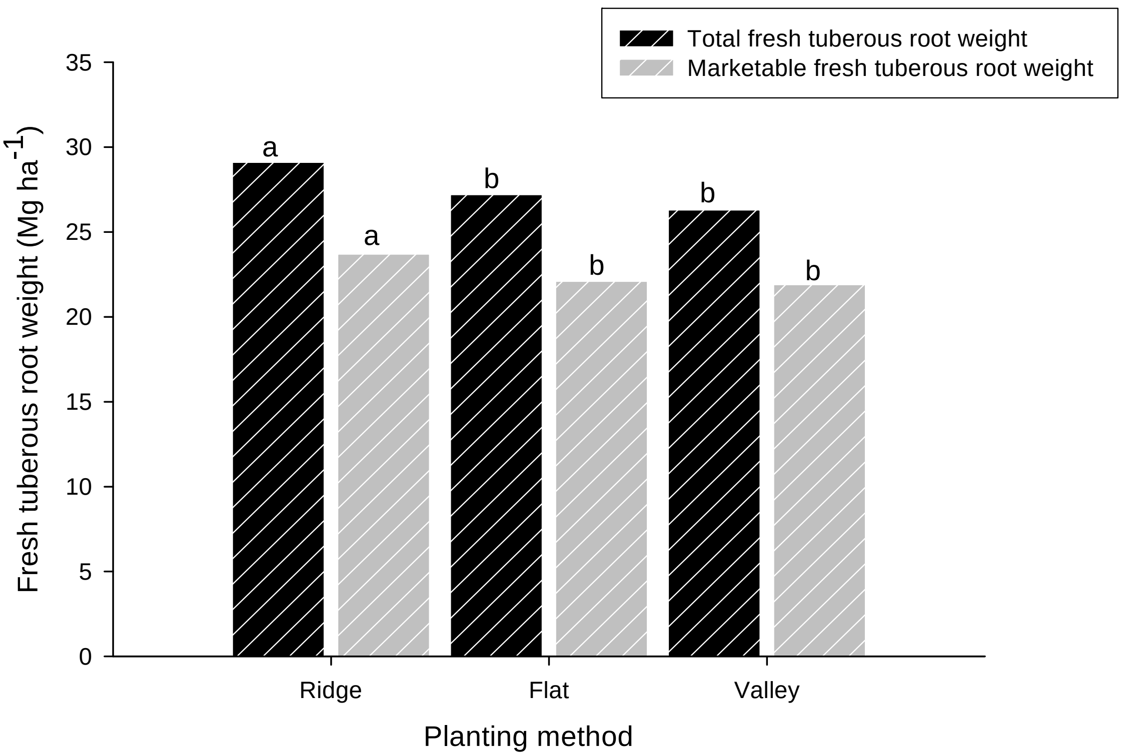

Figure 4. Weights of fresh tuberous roots of sweet potato as affected by planting methods. Bars represent means of four replicates (randomised blocks). Bars topped by the same letter are not significantly different at 5% level of significance within each differently shaded bar category.

Effect of planting methods on fresh weight of tuberous roots

The total fresh tuberous root weight increased highly significantly ($P < 0.01$) in response to planting the vines on ridges compared to planting on flat as well as sunken seedbeds. Similarly, the marketable fresh tuberous root weight obtained from plants grown on ridges was significantly higher ($P < 0.05$) than that obtained from plants grown on flat and sunken seedbeds. Plants grown on flat and sunken seedbeds produced about 7 and 11% less total fresh tuberous root weights than plants grown on ridges. Similarly, in terms of marketable fresh tuberous root weight, ridge seedbed out-yielded flat and sunken seedbeds by about 7 and 8%, respectively (Figure 4).

Effect of vine harvesting on weight of fresh tuberous roots

Harvesting the vines during growth significantly ($P < 0.01$) reduced both marketable and total tuberous root weights. Accordingly, compared to the total fresh tuberous root weight obtained from plants whose vines were not harvested during growth, the total fresh tuberous root weights obtained from plants whose vines were harvested 45 and 75 days after planting were lower by about 36 and 22%, respectively. However, the total fresh tuberous root weight from plants whose vines were harvested 105 days after planting was reduced by a relatively lower magnitude (11%). Similarly, the reduction in marketable fresh tuberous root weight amounted to 33% for plants whose vines were harvested 45 days after planting, 25% for plants whose vines were harvested 75 days after planting and 15% for those whose vines were harvested 105 days after planting. The results further indicated that plants whose vines were harvested relatively earlier (45 days after planting) suffered the most drastic fall in both yields followed by those whose vines were harvested at the mid-stage of growth (75 days after planting) (Figure 5).

Effect of planting methods on weigh of dry tuberous roots

Growing sweet potato on flat and sunken seedbeds

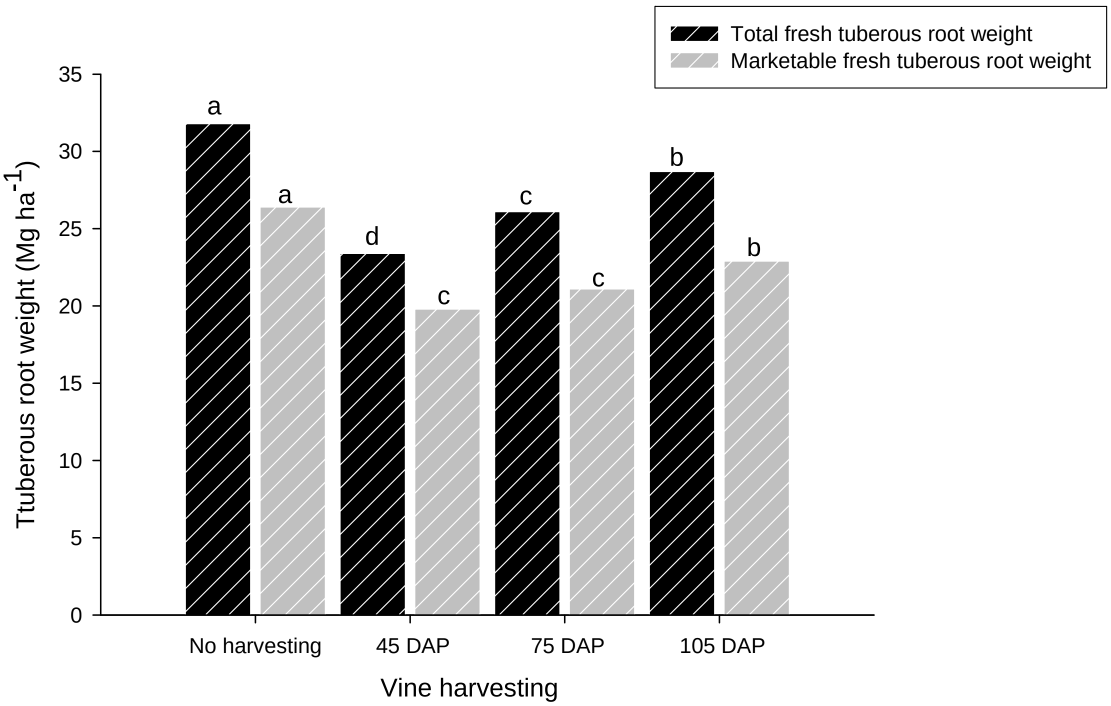

Figure 5. Weights of fresh tuberous roots sweet potato variety Koka-6 as influenced by vine harvesting. Bars represent means of four replicates (randomised blocks). Bars topped by the same letter are not significantly different at 5% level of significance within each differently shaded bar category; DAP = days after planting.

significantly ($P < 0.05$) decreased dry matter weight of tuberous roots. Thus, the dry matter weight of tuberous roots obtained from plants grown on flat and sunken seedbeds was lower than the dry matter yield produced by plants grown on ridge seedbed by about 9.0 and 5%, respectively (Figure 6).

Effect of vine harvesting on the weight of dry tuberous roots

Vine harvesting significantly ($P < 0.01$) decreased dry matter weights of tuberous roots. The tuberous root dry matter weights of plants whose vines were harvested 45 and 75 days after planting decreased by about 10 and 7.0%, respectively compared to the tuberous root dry matter weight of plants whose vines were not harvested during growth. However, plants whose vines were harvested 105 days after planting produced tuberous root dry matter weight which was in statistical parity with the tuberous root dry matter weight produced by plants whose vines were not harvested during growth. In addition, similar to the total and marketable fresh tuberous root weights, the most severe reduction in tuberous root dry matter weight occurred for plants whose vines were harvested 45 days after planting followed by those whose vines were harvested 75 days after planting (Figure 7).

Influence of planting methods on the number of tuberous roots

The three planting methods (seedbed types) produced statistically equal numbers of both total and marketable tuberous roots (Figure 8).

Influence of vine harvesting on the number of tuberous roots

Harvesting the vines during growth significantly ($P < 0.01$) reduced the number of total and marketable tuberous roots. Plants whose vines were harvested 45 and 75 days after planting produced significantly lower number of total tuberous roots than plants whose vines were not harvested during growth as well as those whose vines were harvested 105 days after planting. Thus, compared to the number of total tuberous roots produced by plants whose vines were not harvested during growth, the number

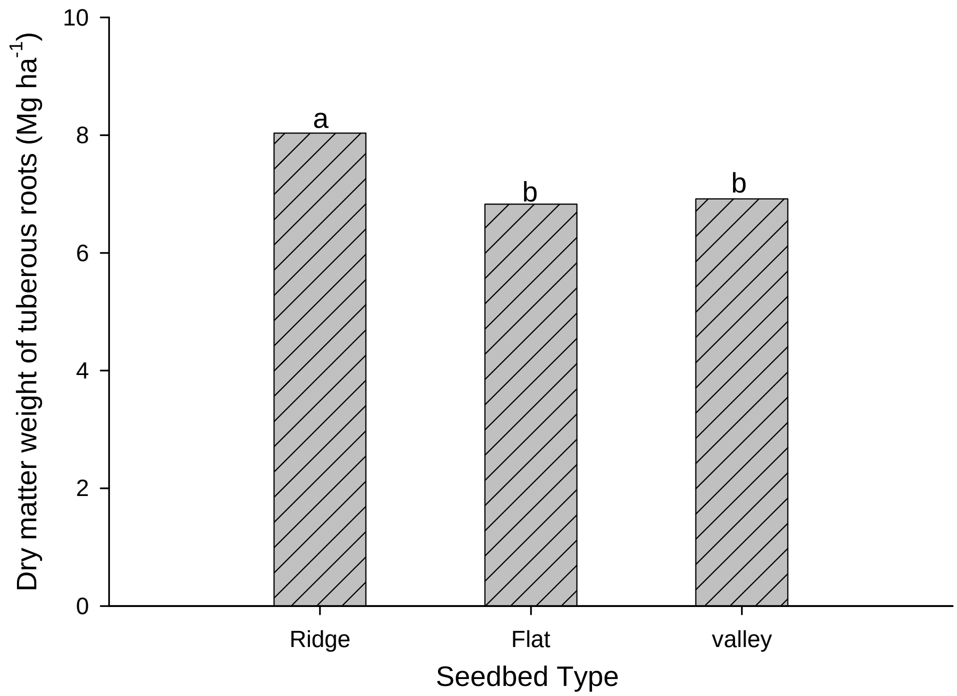

Figure 6. Dry matter weight of sweet potato tuberous roots as affected by planting method. Bars represent means of four replicates (randomised blocks). Bars topped by the same letter are not significantly different at 5% level of significance within each differently shaded bar category.

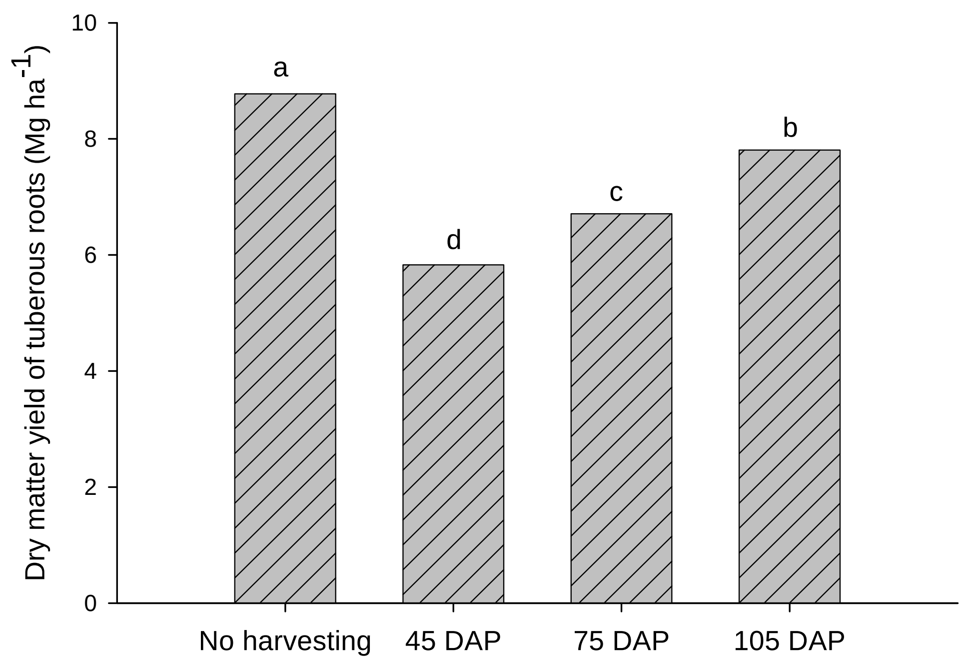

Figure 7. Dry matter weight of tuberous roots of sweet potato as influenced by vine harvesting. Bars represent means of four replicates (randomised blocks). Bars topped by the same letter are not significantly different at 5% level of significance within each differently shaded bar category; DAP = days after planting.

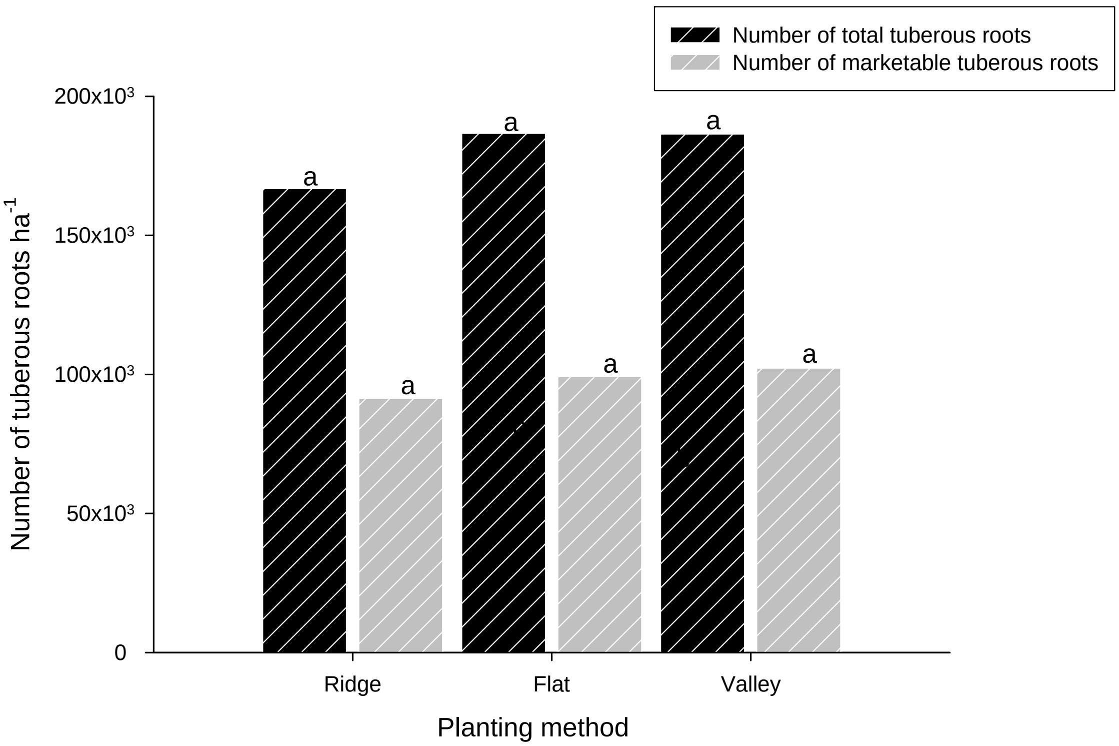

Figure 8. Number tuberous roots of sweet potato as affected by planting methods. Bars represent means of four replicates (randomised blocks). Bars topped by the same letter are not significantly different at 5% level of significance within each bar category.

of total tuberous roots produced by plants whose vines were harvested 45 days after planting was reduced by about 28%. Furthermore, the number of total tuberous roots obtained from plants whose vines were harvested 75 days after planting was reduced by as much as 70%. On the other hand, the number of total tuberous roots produced by plants whose vines were harvested 105 days after planting was in statistical parity with the number of tuberous roots produced by plants whose vines were not harvested during growth. In terms of the number of marketable tuberous roots, however, plants whose vines were not harvested during growth out-yielded plants in all other vine-harvesting treatments (Figure 9).

DISCUSSION

Fresh and dry vine (shoot) yields

The superior cumulative fresh as well as dry shoot yields of plants whose vines were harvested 105 days after planting to the fresh and dry matter shoot yields of plants whose vines were harvested 45 and 75 days after planting may have stemmed from the relatively longer duration of leaf growth for enhanced photo-assimilation. Thus, when vine harvesting was done relatively late (105 days after planting), the accumulated carbohydrate may have been partitioned to the shoots for recuperation and enhanced regeneration of new leaves, thereby resulting in a superior cumulative shoot yield at the final harvest. This result is consistent with that of Ruiz et al. (1980) who demonstrated increments in foliage dry matter yield amounting to 26 and 17% for plants on which defoliation was practiced two and three months respectively, compared to those on which defoliation was not performed at all.

Fresh and dry tuberous root yields

The marked reduction in total and marketable fresh tuberous root weights of plants whose vines were harvested during growth may be attributed to the sub-optimal synthesis and partitioning of carbohydrates to the tubers. This may have stemmed from the disruption in growth and development of leaves caused by the vine cutting which may have reduced leaf surface area for

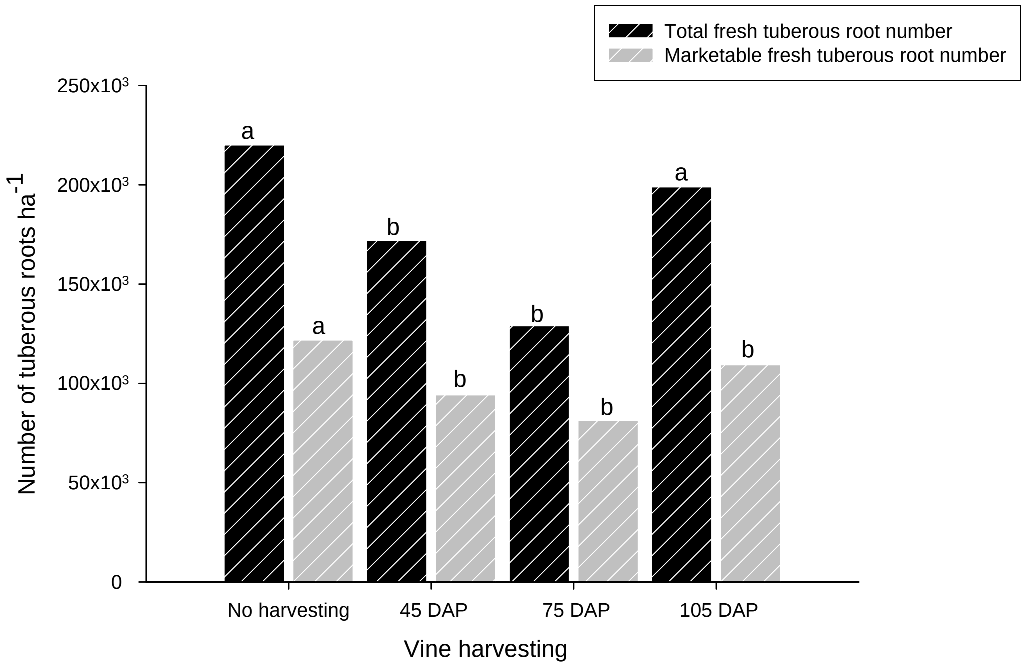

Figure 9. Number of tuberous roots of sweet potato as influenced by vine harvesting. Bars represent means of four replicates (randomised blocks). Bars topped by the same letter are not significantly different at 5% level of significance within each bar category. DAP = days after planting.

photosynthesis. This indicates that there could be a strong correlation between early optimum leaf area establishment/leaf growth and yield of tuberous roots. Consistent with this suggestion, Nwinyi (1992) also reported that removal of sweet potato vines during growth reduced the supply of photosynthate in the remaining period of growth of the plant with an eventual reduction in tuberous root yield. Corroborating the results of this study, Kiozya et al. (2001) and Nguyen and Bautista (1999) also reported that harvesting the vines of sweet potato reduced yields of tuberous roots. Similarly, Stathers et al. (2005) reported that tuberous root weight of sweet potato was significantly reduced when cuttings were taken from young plants during early growth for propagation. However, it was observed that the reduction in total and marketable fresh tuberous root weights was more severe for plants whose vines were harvested relatively early (45 and 75 days after planting) than for those whose vines were harvested relatively late (105 days after planting). This indicates that age of harvesting has impact on the magnitude of reduction with early harvesting resulting in severe decline in tuberous root yields. That age of plant at which vines are harvested during growth is an important management factor affecting sweet potato leaf fodder and tuberous root yields was previously reported by An et al. (2003).

That harvesting the vines at the last growth phase of the plant had less drastic effect on tuberous root yields was validated by the high dry matter yield and number of tuberous roots obtained from plants whose vines were harvested 105 days after planting which were statistically equal to the dry matter yield and number of tuberous roots obtained from plants whose vines were not harvested during growth. Consistent with the results of this study, Etela et al. (2008) and Larbi et al. (2007), working on sweet potato varieties with similar maturity time as the one used in this study found that tuberous root yields were not depressed when vine harvesting was done 140 days after planting and recommended that vine harvesting should be delayed up until this duration of growth to attain optimum tuberous root yields for use as human food. Consistent with the results of this study, Dahaniya et al. (1985) and Nwinyi (1992) reported that from about 112 days after planting, harvesting caused only limited reduction in tuberous root yields. Lebot (2009) also recommends that vines should be harvested late (90 to 120 days after planting) after the storage cells in the tuberous roots have developed and accumulated sufficient starch in order to avoid suppression in growth and development of tuberous roots. In agreement with the results of this study, Dann et al. (1983) earlier reported that the need for production of tuberous roots should be the main factor to be considered when deciding on when to harvest sweet potato vines for animal feed. On the other hand, Moat and Dryden (1993) reported that sweet potato forage dry matter increased whereas its protein content decreased with increase in plant age. Larbi et al. (2007) also reported that late harvesting of sweet potato shoots decreased forage quality. Therefore, optimization of vine harvesting time may be important also for maintaining nutritional quality of sweet potato vine fodder.

The reduction in the number of tuberous roots in response to harvesting the vines 45 and 75 days after planting may be attributed to the negative impact of vine harvesting on source-sink activity of the plant when done relatively early. The early vine-harvesting may have led to minimal partitioning of carbohydrate to the tuberous roots thereby reducing their numbers. These results are consistent with those of Lugojja et al. (2001) who reported that the mean number of sweet potato tuberous roots per hectare decreased significantly following vine harvesting. The significantly higher tuberous root yields from ridge seedbed rather than from either flat or sunken seedbed could be ascribed to the loose top soil in which the storage roots were able to grow and develop bulking profusely due to enhanced nutrient and moisture supply as well as good drainage and aeration. This result is in agreement with that of Busha-Ababu (2006) who found that sweet potato plants grown on ridges produced significantly higher tuberous root yields than those grown on flat seedbeds. Consistent with these results, Anikwe et al. (2007) also reported that planting on ridge seedbed resulted in a markedly superior cocoyam yield compared to planting on flat seedbed which was attributed to reduced soil compaction and enhanced aeration at the early stages of crop development. The decrease in the total and marketable tuberous root yields of sweet potato plants in response to planting on flat or sunken seedbed compared to ridge seedbed might be attributed to the relatively compact soil in the former which may limit tuber root bulking.

In agreement with this result, Busha-Ababu (2006) found that sweet potato plants grown on flat seedbeds grew excess foliage at the expense of storage roots resulting in low yields. This result also confirms that of Agbede and Adekiya (2009) who reported that ridge planting of sweet potato increased the yield of tuberous roots by about 64% compared to flat planting with just manual clearing of the land. This may signify that flat and sunken seedbeds relatively depress bulking of tuberous roots due to less optimal tilth for growth and bulking of tuberous roots than ridge seedbed. Furthermore, the predisposition of sweet potato roots to water-logging and poor aeration due to the stagnating irrigation water at least temporarily on flat and sunken seedbeds could be responsible for the restriction in growth and bulking of root tubers (Terefe-Belihu, 1995). In general, vine harvesting during growth generally affected tuber production more than it affected shoot production. This can be explained by the strong correlation that exists between leaf area/leaf growth and tuber yield (Mannan et al., 1992; Kakaty et al., 1992). According to An et al. (2003), removal of up to 50% of the vines at an interval of 30 days was found to result in a reduction of tuber yield by about 20%, while removing a greater proportion of vines reduced tuber yield by almost 50%. Similar results were reported by others (Nguyen and Bautista, 1999). Leaf yield, on the other hand, was little affected by either harvesting interval or by the proportion of vines harvested. Thus, the need for tuber production will be the main factor to be considered when deciding on how to harvest sweet potato vines for animal feed (Dann et al., 1983).

This study has revealed that harvesting sweet potato vines at early and active stages of vegetative growth drastically reduced fresh tuberous root yield, dry tuberous root yield, and the number of tuberous roots, shoot fresh yield, and shoot dry matter yield. However, harvesting the vines 105 days after planting led to insignificant reduction in the production of dry matter yield and number of tuberous roots. What is more, harvesting the vines 105 days after planting resulted in shoot fresh and dry matter yields that were superior to those produced by plants whose vines were not harvested as well as those whose vines were harvested 45 and 75 days after planting.

Conclusion

In this study, planting sweet potato on ridges and harvesting the vines when about 60% of the growth phase of the plant was complete enhanced the production of herbage for animal feed without compromising yield of tuberous roots to be used for human food. Therefore, pastoralists as well as sedentary smallholder farmers in Ethiopia who produce sweet potato using furrow irrigation should plant the crop on ridges and harvest the vines for animal feed at a later stage of growth by which time tuberous roots may have grown and bulked sufficiently. The farmers should also plant several adaptable cultivars having similar or different maturity times to spread vine harvests throughout the season for ensuring sustained availability of food for humans and fodder for animals. However, the right time to harvest vines for optimizing yields of tuberous roots and herbage may vary depending on maturity time and other characteristics of sweet potato cultivars. Therefore, research should be done further on different sweet potato cultivars to determine appropriate vine harvesting stages of growth of cultivars for optimum production of both tuberous roots for food and herbage for fodder.

ACKNOWLEDGEMENTS

Thanks are due to IPAS (Institute of Pastoral and Agro-pastoral Studies) for providing a full financial support for the first author for doing a study leading to the Degree of Master of Sciences in Agriculture at Haramaya University which led to the writing of this article. We also thank the Afar Pastoral and Agro Pastoral Research Institute (APARI) and Haramaya University for facilitating provision of technical and financial supports for the study.

REFERENCES

Agbede TM, Adekiya AO (2009). Tillage effects on soil properties and performance on an alfisol in south-western Nigeria. American – Eurasian J. Sustain. Agric., 3(3): 561-568.

An LV, Frankow-Lindeberg BE, Lindeberg JE (2003). Effect of harvesting interval and defoliation on yield and chemical composition of leaves, stems, and tubers of sweet potato (*Ipomoea batatas* (L) Lam) cultivars. Field crops Research 82(1): 49-85.

Anikwe MAN, Mbah CN, Ezeaku PI, Onyia VN (2007). Tillage and plastic mulch effects on soil properties and growth and yield of cocoyam (*Colocasia esculenta*) on an ultisol in south-eastern Nigeria. Soil & Tillage Research, 93: 264–272.

Assefa T, Teshome A, Engida T, Tesfaye T (2007). Summary of progress on orange-fleshed sweet potato research and development in Ethiopia. Proceedings of the 13th ISTRC Symposium, pp. 728 – 731, Arusha, Tanzania.

Backer J, Ruiz ME, Munoz H, Pichnat AM (1980). The use of sweet potato (*Ipomoea batatas* (L) Lam) in animal feeding II. Beef production. Trop. Animal Prod, 5(2): 152-160. (Ref. not cited in the main text of your manuscript.)

Bourke RM (1982). Sweet potato in Papua New Guinea. pp. 45-57. In: R.L. Villarreal and T.D. Griggs, (eds), Sweet potato. Proceedings of the first Tnt. Symp Taiwan, China.

Busha A (2006). Effect of N and P Application and Seedbed Types on Growth, Yield and Nutrient Content of Sweet Potato [*Ipomoea batatas* L. (Lam)], Grown in West Wollega. M.Sc. Thesis presented to the School of Graduate Studies of Haramaya University. p. 87

CSA (Central Statistical Authority) (2010). Statistical report on Area of Production of Crops. Central Statistical Agency, Addis Ababa, Ethiopia.

Dahniya MT, Hahn SK, Oputa CO (1985). Effect of shoot removal on shoot and root yields of sweet potato. Experi Agric., 21: 183-186.

Dann PR, Axelsen A, Dear S, Williams ER, Edwards CBH (1983). Herbage, grain, and animal production from whiter-grazed cereal crops. Austral. J. Experi. Agric. Animal Husband, 23:154-161

Dominguez PL (1992). Feeding of sweet potato in monogastrics. In: (Machin D. And Nyvold S. (eds). Roots, tubers, plantains and bananas in animal feeding (Animal production and health paper No. 95). Food and Agriculture Organization: Rome, Italy. pp. 217-233.

Duke JA (1983). *Ipomoea batatas*. Handbook of Energy Crops. Unpublished. [http://www.hort.purdue.edu/newcrop/default.html].

Etela I, Oji UI, Kalio GA, Tona GO (2008). Studies on sweet potato forage and dried brewers' grains as supplements to green panic for Bunaji cows. Tropical Grasslands, 42: 245-251.

Getachew A, Roger CM, Tilahun S (2000). Increasing food security through improved goat production: a progress report of a UNICEF-funded international development partnership between Langston University and Alemaya University. In: R.C. Merkel, G. Abebeand A.L. Goetsh (eds). The opportunities and challenges of enhancing goat production in east Africa. Proceedings of a conference held at Debub University, Awassa, Ethiopia from November 10-12 2000. E (Kika) de la Garza institute for goat research, Langston University, Langston, Ok. pp. 118-126.

Giang HH, Ly LV, Ogle B (2004). Digestibility of dried and ensiled sweet potato roots and vines and their effect on the performance and economic efficiency of FI cross bred fattening pigs. Livestock Research for Rural Development. pp. 6-7.

Gonzalez C, Diaz I, Vecchionacce H, Ly J (2003). Performance traits of pigs fed sweet potato (*Ipomoea batatas* L.) foliage *ad libitum* and graded levels of protein. Livestock research for rural development. pp. 9-15

Kakaty BM, Thamburaj S, Stalin P (1992). Study on the growth and yield of sweet potato at different stages of harvest. J. R. Crops (India), 18: 73-76.

Kiozya HC, Mtunda K, Kapinga R, Chirimi B, Rwiza E (2001). Effect of leaf harvesting frequency on growth and yield of sweet potato in the Lake Zone of Tanzania. Afri. Crop Sci. J., 9(1): 97-103.

Larbi A, Etela L, Nwokocha HN, Oji UI, Anyanwu NJ, Gbaraneh LD, Anioke SC, Balogun RO, Muhammad IR (2007). Fodder and Tuber yields and Fodder quality of sweet potato cultivars at different maturity stages in the west African humid forest and savanna zones. Animal. Feed. Sci.Technol., 135: 126-138.

Lebot V (2009). Tropical root and tuber crops: cassava, sweet potato, yams and aroids CAB International publishers. 413p.

Leon-Verlarde CU (2000). Using competing traits to select dual-purpose sweet potato in native germplasm. International Potato C (CIP), Lima, Peru. pp. 289-294

Lugojja F, Ogenga-Latigo MW, Smith NEJM (2001). Impact of defoliation on the agronomic performance of sweetpotato in Uganda. Afri. Crop Sci. J., 9: 103-108.

Mannan MA, Bhuiyan MKR, Quasem A, Rashid MM, Siddique MA (1992). Study on the growth and partitioning of dry matter in sweet potato. J. Root Crops, 18: 1–5.

Moat M, Dryden GM (1993). Nutritive value of sweet potato forage *Ipomoea batatas* (L) Lam) as a ruminant animal feed. Papua-New Guinea J. Agric. Fore. Fishery, 36(1): 79-85.

Nguyen BL, Bautista OK (1999). Extent and mechanism of yield reduction in sweet potato grown for tops and roots. Philos. Agric., 82: 137–150.

Nwinyi SCO (1992). Effect of age of shoot removal on tuber and shoot yields at harvest of five sweet potato (*Ipomoea batatas* (L) Lam.) cultivars. Field crops Research 29(1): 47-54.

Ruiz ME, Lozano E, Ruiz A (1981). Utilization of sweet potatoes (*Ipomoea batatas* (L) Lam) in animal feeding. III. Addition of various levels of roots and urea to sweet potato forage silage. Trop. Animal Prod., 6(3): 234 -244.

Ruiz ME, Pezo D, Martinez L (1980). The use of sweet potato *[Ipomoea batatas* (L) Lam] in animal feeding. I. Agronomic aspects. Trop. Animal Prod., 5(2): 144-151.

SAS Institute Inc (2002). SAS Release 9.1 [Computer Programme]. SAS Institute Inc., Cary, N.C.

Smart J, Simmonds NW (1995). Evolution of Crop Plants. 2nd Edn., John Wiley and Sons, Inc., New York, pp: 57-61.

Solomon E (1999). Yield performance of sweet potato cultivars at Werer under irrigation, AgriTopia quarterly news letter of Ethiopian Agricultural Research Organization (EARO), Addis Ababa. pp. 2-14

Stathers T, Namanda S, Mwanga ROM, Khisa G, Kapinga R (2005). Manual for Sweet Potato Integrated Production and Pest Management for Farmer Field Schools in Sub-Saharan Africa. International Potato Centre, CIP, Kampala. V. p.31. ISBN 9970-895-01-x.

Tadesse G, Bekele E (1996). Saline and Saline Sodic soils of the Middle Awash Valley of Ethiopia. In: Teshome Yizengaw, Eyasu Mokonnen , and Mintesinot Behailu (eds.). Proceedings of the third conference of the Ethiopian Society of soil Science, February 28 -29, 1996. Addis Ababa, Ethiopia. p 194.

Terefe B (1995). Research achievements (1986-1995) and future research strategies of sweet potato improvement program in Ethiopia. p38. In: proceeding of the 25th anniversary of Nazareth Agricultural Research Centre, 20-23 Sept. 1995, Nazareth, Ethiopia.

Tesfaye K, Tesfaye L, Estifanos T, Mieso G (2008). Effect of level of substitution of sweet potato (*Ipomoea batatas* L.) vines for concentrate on body weight gain and carcass characteristics of browsing Arsi-Bale goats. J. Cell Anim. Biol., 2(2): 036-042.

WARC (Werer Agricultural Research Centre) (2004). Werer Agricultural Research Centre progress report, Werer, Ethiopia. p.20.

WARC (Werer Agricultural Research Centre) (2007). Werer Agricultural Research Centre progress report, Werer, Ethiopia. p. 27.

Woolfe JA (1992). Sweet potato: An untapped food resource. Cambridge University Press, Cambridge, 643p.

Yamakawa O, Yoshimoto M (2002). Sweet potato as food material with physiological functions. Acta Hort., 583: 179-185.