ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 2
March 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2020; 20(2): 15538-15548 DOI: 10.18697/ajfand.90.18955

EARLY VINE HARVESTING OF DUAL-PURPOSE SWEET POTATO *(ipomoea batatas)* INCREASES FEEDING QUALITY AND TOTAL BIOMASS WITHOUT COMPRISING TUBER PRODUCTION

Gakige J.K[1,2], Gachuri C[2], Butterbach-bahl K[1,3] and JP Goopy[1,4]*

John Goopy

* Corresponding author email: J.Goopy@cgiar.org

[1]Mazingira Centre, International Livestock Research Institute, Nairobi, Kenya

[2]Dept. Animal Production, University of Nairobi, Nairobi, Kenya

[3]Karlsruhe Institute of Technology, Institute of Meteorology and Climate Research, Atmospheric Environmental Research, Garmisch-Partenkirchen Germany

[4]University of Melbourne, Melbourne, Australia

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 2
March 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Sweet potato is an important food crop throughout much of sub-Saharan Africa with the important attribute as a dual-purpose crop. While tuberous crops are grown for human consumption, the sweet potato can also provide substantial vine biomass suitable for feeding animals without competing for human feed resources. Sweet potato is generally low in nutrient other than carbohydrate. The newly developed orange-fleshed varieties of sweet potato, high in beta-carotene yield large quantities of vines with very little exploration of their agronomic attributes to date. Intermediate vine harvesting (ratooning) has been promoted as a strategy to further increase the value of sweet potato as a dual-purpose human/animal feed crop. The results of this practice on yields of other types of sweet potato have been equivocal or highly variable. Production effects on three new orange-fleshed dual-purpose sweet potato (Kenspot 1, SPK 013, SPK 117) developed by the International Potato Centre (CIP), of intermediate plus final (INT) versus final only (FIN) vine harvesting were assessed in a randomized block with a split plot trial. Cultivar SPK013 produced the greatest vine, tuber and total biomass yield of the three varieties tested, but also the greatest decline in tuber yields after intermediate vine harvesting. While intermediate harvesting increased vine yield in all varieties ($p<0.05$), in cultivar SPK013, it caused a 58% decline in tuber yield ($p<0.05$). The variation in performance between cultivars assessed in this study, reflects what is seen in the general literature. What is clear from the present study is that, there is a substantial interaction between environment/cultural practice and genotype. As such, it seems impossible to generalize that Intermediate vine harvesting is beneficial for vine production in the cultivars studied. It should be borne in mind that this practice may also be associated with a substantial decline in tuber yield in some cultivars. Thus, results should not be extrapolated to other varieties without investigation.

Key words: orange-fleshed, dual-purpose, forage, production, ratoon, intermediate, dairy, smallholder

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 2 March 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

INTRODUCTION

Sweet potato (*Ipomea batatas*) belongs to the family *Convlivuaceae* and is native to Central and South America [1], and a common crop in developing tropical and sub-tropical regions, principally because of its versatility and adaptability [2]. Sweet potato is ranked seventh most cultivated food crop in the world and fifth most consumed food crop in developing countries [3]. Adaptable to tropical and subtropical conditions, sweet potato is drought tolerant, grows under low soil fertility conditions, and farmers rarely experience total crop failure [3]. It is an important food crop in many rural areas [4]with higher levels of production in the East African highlands [5]. Although generally regarded as a subsistence crop, this is changing as more farmers move towards commercialization due to increased demand for food in urban areas in developing economies [6].

Sweet potato has the important, though not unique, attribute of being a dual-purpose crop, where tubers are grown principally for human consumption [7], and the crop residue (vines and leaves) provide substantial biomass suitable for feeding animals [8]. Thus, sweet potato has the potential to support livestock production without competing for human feed resources. Yield of sweet potato tubers is similar to that of cassava, while being less than yam [9], but the vine yield of sweet potato is superior to both partly because the vines can be harvested several times during the growing season [10]. Yields of sweet potato are generally in the range of 3-4 t DM/ha and 4.3-6 t DM/ha of tuber and vines, respectively, under favorable conditions [11]. However, sweet potato tubers, are high in carbohydrate (92-98% DM) [8], but low in other nutrients. New orange-fleshed varieties of sweet potato high in beta-carotene and yield of above ground biomass (sweet potato vine: SPV), suitable for animal feed have been developed [12]. Although a limited number of trials have indicated that SPV is a good source of protein (16-23% DM), low in fibre and suitable for feeding both swine and ruminants [13-15], there has been little exploration of the agronomic attributes of the new orange-fleshed, dual-purpose varieties.

Intermediate, repeated harvesting of SPV has been promoted as a strategy to further increase the animal-feeding value of sweet potato crops [2, 16], but conclusions on the effects of intermediate vine harvesting are mixed. Nwinyi [17] and Larbi *et al*. [18] both reported decreased yield of both tuber and SPV at all intermediate harvesting intervals. In contrast, the work of Gomes and Carr [19] suggests no change in total biomass, with tuber yield decreasing at the expense of SPV production. However, the more recent work of Ahmed *et al*.[20] suggests there is a real production advantage to intermediate harvesting at 105d after planting, with an increased yield of SPV at no cost to tuber production. The very different results reported by investigators and differing trial conditions, suggest there are major interactions between varieties, climatic conditions and cultivation methods.

To date there has been no systematic exploration of the effect of intermediate vine harvesting on the yield and composition of the vines and tubers of the new orange-fleshed, dual- purpose sweet potato (OFDPSP) varieties grown under such regimes.

DOI: 10.18697/ajfand.90.18955

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 2
March 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

This study assessed the biomass yield and composition of vines and tubers, of three varieties of new-generation OFDPSP, grown with, or without mid-term harvesting of vines in a rain-fed system in highland Kenya. We hypothesized that, partial harvesting would enhance biomass yield of vines without affecting tuber yield.

MATERIALS AND METHODS

Study site and Experimental design

The trial was carried out at the Kakamega field station of the Kenya Agriculture and Livestock Research Organization (KALRO) (0°17'N, 34° 45'E; annual Rainfall 1971mm; Elevation 1535 m ASL)

The experiment design for the study was a completely randomized block, with a split plot and three varieties in three replications. The main plot treatments were varieties and harvest days (75 and 150 days) were the subplots treatments. The trial area was a single block measuring 26m long and 17m wide. The block was divided into three rows 3m wide with 2m space between each row and 2m space between the edge of the block and the plots. Each row featured three plots 3x6m with 2m between plots. Varieties were randomly assigned to three plots each. Subplots (3x3m) for the two harvesting treatments, Intermediate and final harvesting of vines (INT) and only harvesting at maturity (FIN) were delineated for each of the replicates.

Preparation, planting and harvesting

The plots were cleared using slashers and sprayed with a non-selective herbicide (Glyphosate 480 SL, 4L/ha). The plots were then ploughed and harrowed before the onset of long rains in March. Pre-emergence herbicide (Susplo-Emulsifiable SE) was sprayed one week before planting at a rate of 4L/ha. Three cultivars of OFSDSP (*Ipomea batatas*; cv.: Kenspot 1 (KSP1), SPK 013, SPK 117) were chosen for this study because they had been previously identified as “dual-purpose” by the International Potato Center (CIP) (unpublished data).

Cuttings were obtained from a disease-free plot within the KALRO campus and were planted in the subplots in six rows 0.5m (50cm) apart with each row having 15 plants, planted on 30cm high mounds. Weed control was carried out by hand 14d and 28d after planting.

Vines from the INT subplots were harvested at 75d post-planting by hand leaving ~200mm of vine above-ground to regrow. The final harvest was carried out for both INT and FIN treatments at 150d after planting. Vines were cut off flush with the soil then tubers were lifted. Total mass of the vines were recorded for each subplot during both harvests.

Statistical analysis

Yields of vines, tubers and total biomass were compared by a two-way ANOVA using Graphpad Prism6® software [21]. Yields were calculated per plot (area: $9m^2$) as each plot constituted the experimental unit. However, in order to provide a convenient point of comparison with the literature, the yields were extrapolated to the hectare.

DOI: 10.18697/ajfand.90.18955

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 2
March 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Differences among means were compared by least-square means method and the level of significance was determined at 0.05.

RESULTS AND DISCUSSION

There were marked differences in the yield of OFDPSP vines and tubers between cultivars and harvesting regime, but the differences caused by harvest regime were not uniform across cultivars (Figure 1). Vine and tuber yield were greatest for SPK013 (30.4t ha^{-1}; 6.8t ha^{-1}) under FIN harvest, but there were no significant differences in tuber yield between cultivars (P= 0.567), while KSP1 tended to have the lowest vine yield (9.3t ha^{-1}. $P<0.001$). The INT treatment greatly increased vine yield ($p<0.05$) in all cultivars; however, the increased vine yield observed in SPK013 occurred at the expense of tuber production, which declined by 58% (6.8t to 2.8t ha^{-1}), from the highest to the lowest yielding cultivar. By contrast, KSP1 and SPK117 were relatively resilient under the INT harvest regime, with insignificant decreases in tuber yield, while showing significant increases in yield of vines.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 2
March 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

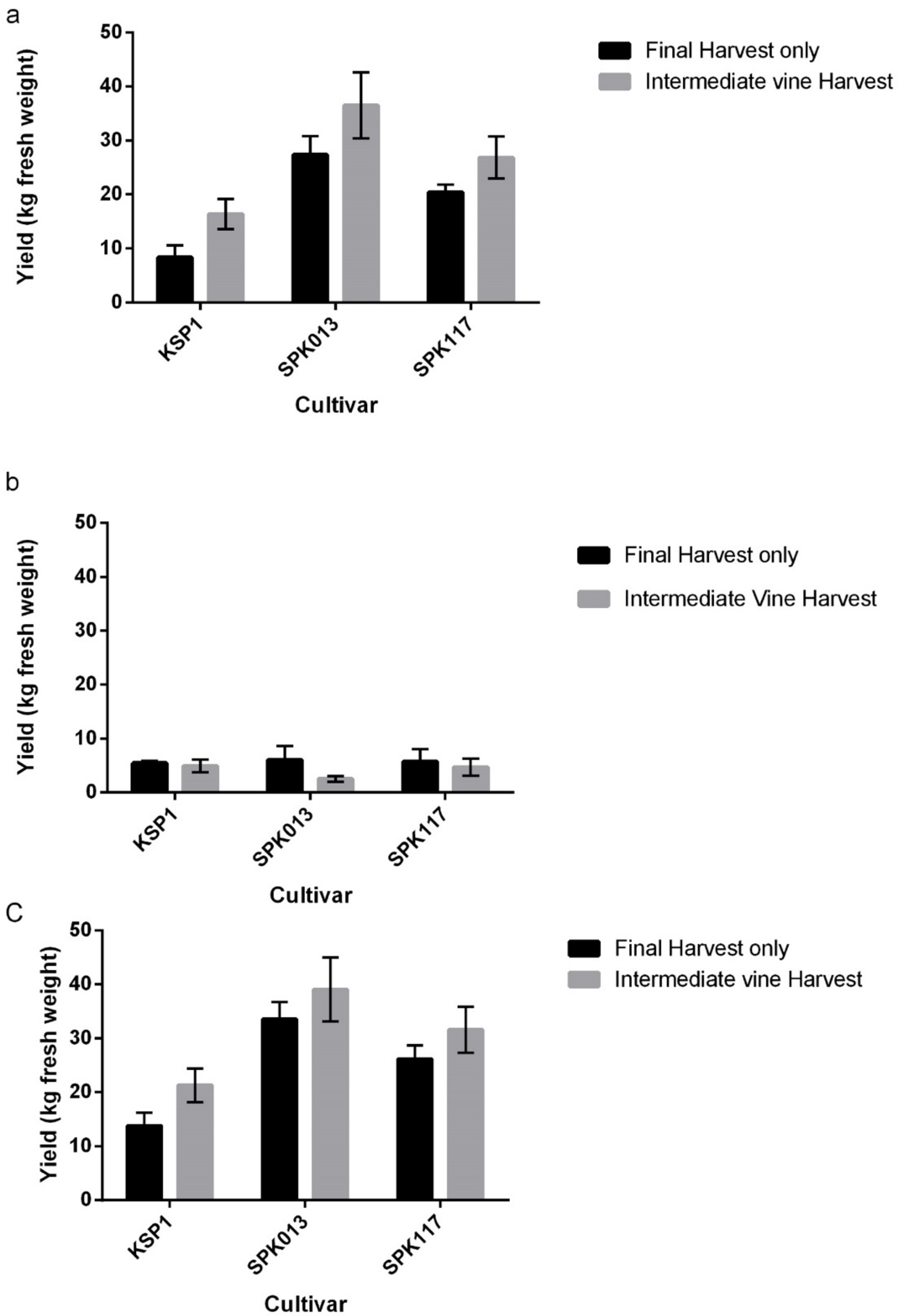

Figure 1: Yields (fresh weight (kg) per plot ($9m^2$)) of Vines (a), Tubers (b) and Total Biomass (c) of three varieties (Kenspot 1 (KSP1), SPK 013, SPK 117) of orange-fleshed, dual-purpose Sweet Potato, where vines were harvested either at maturity (150d) only (FIN) or at both 75d and 150d (INT)

DOI: 10.18697/ajfand.90.18955

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 2
March 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

The yield of vines and of total biomass was greater for INT across all three cultivars with the total yield from the two harvests (75 and 150 days) of the INT treatment being higher than the total yields from the FIN plots. This might be because, although the determinants of biomass production increase with age, there is an optimum beyond which they decline [2]. Such a decline may be partly due to the redirection of photosynthate to produce tuber at the expense of vine production. However, the degree to which this was expressed was clearly variable. Additionally, it may be posited that when the leaves are left to grow without intermediate harvesting, there is shading of the lower leaves by the upper leaves resulting in aging and shedding of lower leaves. The INT harvesting treatment had quite a profound effect on overall plant productivity, as was observed in the large increase in total biomass production in all cultivars. This was in marked contrast to the work of some others [17, 18], while in broad agreement with Gomes and Carr [19].

The lower tuber production in the INT treatment, was not significant for two of the cultivars assessed. This might be due to a reduction in the photosynthetic rate decreasing growth. However, the observed higher biomass production is not consistent with this explanation. It can be inferred, however, that cutting vines at 75d does cause repartitioning of dry matter accumulation to favor vine production at the expense of tubers [22], although the extent to which this occurs in sweet potato is clearly variable, based on our study. Roy and Ravi [23] who found no negative effects on tuber yield from intermediate vine harvesting have argued that higher root yields are not necessarily associated with greater foliage production and that if not ratooned, sweet potato grows vigorously and produces large quantity of vines at the expense of roots.

Although the effects of intermediate harvesting of sweet potato vines on production remain somewhat equivocal, the reasons for the variability are not entirely clear. However, it is apparent from the recent work of Mwanga *et al*. [24], that there is great variability in the yield and composition of given varieties of sweet potato plant, depending on agro-climatic factors and cultivation practices. This variability, combined with the very different cultural and sampling practices reported in the extant literature, may help explain the apparent inconsistencies in results. What is clear from this study is that there is a substantial interaction between environment/cultural practice and genotype, and as such, it seems impossible to generalize the effects of intermediate harvesting across all sweet potato types or cultivars.

CONCLUSION

It is evident from this study that for the cultivars studied, partial harvesting of sweet potato vines at 75d after planting increases total biomass production but reduced tuber production for all cultivars, which was only significant in one cultivar (SPK013). Therefore, the extent to which intermediate vine harvesting is a prudent or desirable practice for farmers will be based on economics, which is principally the value placed on SPV vs tubers. If SPV is to be used as a high quality fodder, then intermediate harvesting may be an attractive option at least for the cultivars KSP1 and SPK117. However, this cannot be generalized for all sweet potato types or all OFDPSP. Therefore,

DOI: 10.18697/ajfand.90.18955

work needs to continue to characterize the agronomic attributes of sweet potato being promoted to smallholder farmers.

ACKNOWLEDGEMENT

This study was funded by the German Federal Ministry for Economic Cooperation and Development within the research projects '*In situ assessment of greenhouse gas emissions from livestock production systems in East Africa*' (Grant No. 55 21914) and '*Innovative feed system management for improving smallholder dairy production'* (Grant No. 81193730). We further acknowledged the CGIAR Fund Council, Australian Centre for International Agricultural Research (ACIAR), Irish Aid, European Union, International Fund for Agricultural Development (IFAD), Netherlands, New Zealand, UK, USAID, and Thailand for funding to the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the CGIAR Research Program on Livestock.

REFERENCES

1. **O'brien PJ** The sweet potato: its origin and dispersal. *American anthropologist*. 1972;**74(3)**:342-65.

2. **Frankow-Lindberg BE and JE Lindberg** Effect of harvesting interval and defoliation on yield and chemical composition of leaves, stems and tubers of sweet potato (Ipomoea batatas L.(Lam.)) plant parts. *Field Crops Research*. 2003;**82(1)**:49-58.

3. **Mwololo J, Mburu M and P Muturi** Performance of sweet potato varieties across environments in Kenya. *International Journal of Agronomy and Agricultural Research*. 2012;**2(10)**:1-11.

4. **Karuri HW, Olago D, Neilson R, Mararo E and J Villinger** A survey of root knot nematodes and resistance to Meloidogyne incognita in sweet potato varieties from Kenyan fields. *Crop Protection*. 2017;**92**:114-21.

5. **Bouis HE, Hotz C, McClafferty B, Meenakshi J and WH Pfeiffer** Biofortification: a new tool to reduce micronutrient malnutrition. *Food and Nutrition Bulletin*. 2011;**32(1)**:S31-S40.

6. **Widodo Y, Wahyuningsih S and A Ueda** Sweet Potato Production for Bio-ethanol and Food Related Industry in Indonesia: Challenges for Sustainability. *Procedia Chemistry*. 2015;**14(2015)**:493-500.

7. **Kapinga R, Ortiz O and J Ndunguru** Handbook of Sweet potato Integrated Crop Management. **In**: Omiat E, Tumwegamire S, editors. Research Outputs and Programs for East Africa (1995-2006). Kampala, Uganda: International Potato Center (CIP); 2007. p. 71-91.

8. **Wanapat M** Potential uses of local feed resources for ruminants. *Tropical Animal Health and Production*. 2009;**41(7)**:1035-49.

9. **Terry ER, Akoroda M and O Arene** editors. Tropical root crops: root crops and the African food crisis. Third Triennial Symposium of the International Society for Tropical Root Crops; 17-23 Aug1986; Owerri, Nigeria: IDRC, Ottawa, ON, CA.

10. **Hong N, Wanapat M, Wachirapakorn C, Pakdee P and P Rowlinson** Effects of timing of initial cutting and subsequent cutting on yields and chemical compositions of cassava hay and its supplementation on lactating dairy cows. *Asian Australas J Anim Sci*. 2003;**16(12)**:1763-9.

11. **Khalid AFE, Elamin KM, Amin AE, Eldar AAT, Mohamed ME, Mohammed MADA and HE Hassan** Effects of Using Fresh Sweet Potato (Ipomoea Batatas) Vines on Performance and Milk Yield of Lactating Nubian Goats. *Journal of Animal Science Advances*. 2013;**3(5)**:226-32.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 20 No. 2 March 2020 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

12. **Hotz C, Loechl C, Lubowa A, Tumwine JK, Ndeezi G, Nandutu Masawi A, Baingana R, Carriquiry A, de Brauw A and JV Meenakshi** Introduction of β-carotene–rich orange sweet potato in rural Uganda resulted in increased vitamin A intakes among children and women and improved vitamin A status among children. *The Journal of nutrition*. 2012;**142(10)**:1871-80.

13. **Phuc BHN** Tropical Forages for Growing Pigs: Digestion and Nutritive Value: Swedish University of Agricultural Sciences; 2000.

14. **Dung NNX, Manh LH and P Udén** Tropical fibre sources for pigs—digestibility, digesta retention and estimation of fibre digestibility in vitro. *Animal Feed Science and Technology*. 2002;**102(1-4)**:109-24.

15. **Megersa T, Urge M and A Nurfeta** Effects of feeding sweet potato (Ipomoea batatas) vines as a supplement on feed intake, growth performance, digestibility and carcass characteristics of Sidama goats fed a basal diet of natural grass hay. *Tropical Animal Health and Production*. 2013;**45(2)**:593-601.

16. **Lukuyu BA, Kinyua J, Agili S, Gachuiri C and J Low** Evaluation of sweetpotato varieties for the potential of dual-purpose in different agroecological zones of Kenya. **In**: Vanlauwe B. vAP, Blomme G. (eds), editor. Challenges and Opportunities for Agricultural Intensification of the Humid Highland Systems of Sub-Saharan Africa. Switzerland: Springer; 2014. p. 217-31.

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

18. **Larbi A, Etela I, Nwokocha H, Oji U, Anyanwu N, Gbaraneh L, Anioke S, Balogun R and I Muhammad** 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 Science and Technology*. 2007;**135(1)**:126-38.

19. **Gomes F and M Carr** Effects of water availability and vine harvesting frequency on the productivity of sweet potato in Southern Mozambique. I. Storage root and vine yields. *Experimental Agriculture*. 2001;**37(4)**:523-37.

20. **Ahmed M, Nigussie-Dechassa R and B Abebie** 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. *African Journal of Agricultural Research*. 2012;**7(7)**:1129-41.

21. **GraphPad**. GraphPad Prism La Jolla California USA2012.

22. **Mannan M, Bhuiyan M, Quasem A, Rashid M and M Siddique** Study on the growth and partitioning of dry matter in sweet potato. *J Root Crops*. 1992;**18**:1-5.

23. **Chowdhury S and V Ravi** Effect of clipping of vines on the biomass yield in sweet potato. *Journal of Root Crops*. 1990;**16(1)**:4-7.

24. **Mwanga RO, Kyalo G, Ssemakula GN, Niringiye C, Yada B, Otema MA, Namakula J, Alajo A, Kigozi B and RN Makumbi** 'NASPOT 12 O'and 'NASPOT 13 O'Sweetpotato. *HortScience*. 2016;**51(3)**:291-5.