The Journal of Agricultural Sciences - Sri Lanka
Vol. 19, No 3, September 2024. Pp 452-461
http://doi.org/10.4038/jas.v19i3.10140

Evaluation of Optimal Shoot Tip Removal Time on Tuber Yield and Nutritional Content of Sweet Potato (*Ipomoea batatas* L.) Using a Pipeline Variety

U.D.T. Perera[1*], M.B. Weerasuriya[2], and D.A.B.N. Amarasekera[1]

Received: 23rd January 2023 / Accepted: 30th May 2024

ABSTRACT

Purpose: *This study aims to evaluate the least effecting time of shoot tip removal on sweet potato tuber yield and find the best tender shoot removal time, which has the highest nutritional content in sweet potato tender shoots to use as a leafy vegetable with the lowest effect for tuber growth.*

Research Method: *The experiment was established in a Randomized Complete Block Design with three replicates and six treatments. Eighteen-inch piece of the tender shoot was removed from the apical ends of every branch of sweet potato (TJ 01 pipeline variety) vines on 6, 8, 10, 12, and 14 weeks after planting (WAP). Removed tender shoots were cut into five node cuttings from basal ends and were taken as planting materials. Tips of tender shoots with less than five nodes were taken as leafy vegetables. The weight of both planting materials and leafy vegetable parts was considered as the fresh weight of tender shoots. Number of tender shoots and fresh weight, number of planting materials, and fresh weight were recorded. Tuber yield was taken after 3½ months.*

Findings: *The number of tender shoots/ha and number of planting materials/ha were significantly higher in 10WAP while their fresh weights were not significantly different among treatments. Protein content was highest in 12WAP and 14WAP. The total weight of tubers/ha was higher in 10WAP. The best time to obtain tender shoots from sweet potato (TJ 01 pipeline variety) either as planting materials or leafy vegetables is 10WAP without adversely affecting tuber yield.*

Value: *Since nutritionally valued sweet potato foliage is wasted after harvesting, identification of alternative uses will help to introduce sweet potato as a multidisciplinary crop.*

Keywords: *Nutritional content, Shoot tip removal, Sweet potato, Tuber yield, Weeks after planting*

INTRODUCTION

Sweet potato *(Ipomoea batatas* L.) which belongs to the family Convolvulaceae globally ranked as the seventh most important food crop (Senanayake *et al.*, 2012; Low *et al.*., 2015). Other than that sweet potatoes have low calories and fat; also rich in nutrients along with anti-inflammatory in nature (Low *et al.*., 2015). Furthermore, Padmaja (2012) mentioned that sweet potatoes can be considered as '3-in-1' product because it has the qualities of cereals due to high starch, qualities of fruits due to high vitamins and pectin and qualities of vegetables due to high vitamins and mineral content. It has several nutritional attributes that make it an exceptionally healthy food. Sweet potato tubers contain 3.6 to 5.4% crude protein, 80 to 90% carbohydrates, 2.5 to 3.25% fiber, 0.72 to 1.27% fat, and 2.5 to 3.2% ash on a dry matter basis (Mvumi *et al.*, 2018). Hence, sweet potatoes can be emphasized as a reliable and affordable source of major and micronutrients.

As mentioned by Islam (2014), recent studies have shown that sweet potato leaves have nutritional and medicinal values that are important for human health.

[1]Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Matara, Sri Lanka.
[2] Farm Broadcasting Service (Ruhuna), Matara, Sri Lanka.
*pereradinusha707@gmail.com
https://orcid.org/0000-0002-2269-8986

In addition, they contain important functional components such as anthocyanin, polyphenols, and dietary fiber, which are important for human health (Islam, 2014). In addition to that, sweet potato leaves are freely available after harvest and are mostly chemical-free. Since there is a high market potential for sweet potato leaves, it is essential to identify the nutritional content of the consumable parts of sweet potato vines. Meanwhile, there is a necessity to introduce chemical-free leafy vegetables to the food plate to ensure food safety. However, according to the Department of Agriculture, Sri Lanka, the main obstacle for popularizing sweet potato cultivation is finding quality planting material. Hence production of quality planting material simultaneously with tubers and leafy vegetables will be an added advantage.

Tender shoot removal as leafy vegetables and planting material will be beneficial to expand the cultivation and increase the leafy vegetable availability. However, it is indeed a requirement to identify the effect of removal of shoots on the tuber yield and the best period for removing shoots. Similarly, it is indeed a requirement to identify the most nutritious stage of the removed shoots to consume as leafy vegetables. Therefore, the present study was conducted to identify sweet potato as a multidisciplinary crop and to find the tender shoots removal time which has the highest nutritional content in sweet potato leaves with the lowest effect for tuber growth.

MATERIALS AND METHODS

This study was conducted in the field at Agriculture Research Station, *Thelijjawila, Matara*, Sri Lanka. The agroecological zone of the area is IL1a. The average annual rainfall is about 1750 – 2500 mm and the annual temperature is about 25 – 35 °C. The soil type is red-yellow podzolic. Primary soil characters of the experimental site were analyzed and tabulated in Table 01. Soil pH was checked using a pH meter and electrical conductivity was measured using an EC meter. Soil organic matter content was checked using the Walkley and Black method (FAO, 2020). The following six treatments were used in a Randomized Complete Block design with 3 replicates.

T1: Removing tender shoots 6 weeks after planting (WAP)
T2: Removing tender shoots 8 WAP
T3: Removing tender shoots 10 WAP
T4: Removing tender shoots 12 WAP
T5: Removing tender shoots 14 WAP
T6: Shoot removal was not taken place

The land was tilled using a chisel plough to a depth of 25 cm and 3 x 1 m sized eighteen raised beds (30 cm height) were prepared. Separate raised beds were maintained for each removal time. Additionally, three replicates were used for one removal time. Twenty to twenty-five-centimeter-long healthy tip cuttings of TJ 01 pipeline sweet potato variety with five leaves were taken as planting materials. Cuttings were dipped in a fungicide solution of Mancozeb as per the instructions given on the label for 20 minutes and were planted at 20 X 20 cm spacing. Planting was done by burying one node of the cutting into the soil. The space between two raised beds was 30 cm and the number of cuttings per bed was fifty-six. Fertilizer application was done according to the recommendations of the Department of Agriculture (DOA), Sri Lanka (https://doa.gov.lk/hordi-crop-sweet-potato/,24.08.2023). Basal dressing was applied 2 WAP (Weeks After Planting) and top dressing 6 WAP. Irrigation and weeding were done manually according to the requirements. Crop management practices were conducted according to the guidelines of the DOA, Sri Lanka.

Data collection was started 6WAP. Number of tender shoots per raised bed, fresh weight of tender shoots per raised bed, number of cuttings as planting material per raised bed, fresh weight of cuttings as planting material per raised bed, fresh weight of marketable tender shoots as leafy vegetable per raised bed, protein and mineral content of tender shoots were taken as vine parameters. Harvesting was done 3 ½ months after planting (MAP). The total fresh weight of tubers per raised bed was taken as parameters of tubers. After that, per-raised bed values were converted into per-hectare values.

Once a fortnight 18 inches piece of vine was cut from the apical ends of every branch of vines in a raised bed (3m x 1m raised bed) starting from 6WAP and was maintained till the harvesting. This was practiced similarly for all three replicates. Tender shoots count was taken and weighed using a balance to obtain fresh weight. Eighteen-inch length pieces of tender shoots were separated into five node cuttings and number of cuttings as planting materials were counted. Cutting was started at the basal end of the tender shoot. Selection for planting materials and leafy vegetables was done by counting the nodes (If there were five nodes that part of the apical end was counted as planting material and less than five nodes that apical end part was considered as leafy vegetable). The weight of five node cuttings was measured to get the fresh weight of cuttings as planting materials and the fresh weight of marketable tender shoots as leafy vegetables was obtained by accumulating both weights of cuttings as planting material and the weight of cuttings considered as leafy vegetables (less than five nodes cuttings).

The protein content of tender shoots was measured by the Kjeldahl method (AOAC, 2005). The Nitrogen amounts obtained by the Kjeldahl method were multiplied by the Nitrogen-Protein Conversion Factor.

Table 1: Soil chemical properties of Thelijjawila Research Station, Matara.

Chemical property	Value
Soil pH (1:1 water)	4.6
Electrical conductivity (dS/m)	0.05
Organic matter (%)	1.35

Mineral content was calculated by obtaining ash content (Pomeranz and Meloan, 1994). Five grams of feed sample was burnt using a temperature greater than 525 °C for 4-5 hours in the muffle furnace. Then the ash content was calculated using the below equation.

$$\text{Total ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100 \qquad (1)$$

The total fresh weight of harvested tubers was measured using the weighing balance. Measured data were statistically analyzed using the SAS 9.1.3 version. Duncan's Multiple Range Test (DMRT) at a 5% probability level was used to compare treatment means which were significantly different.

RESULTS AND DISCUSSION

Number of Tender Shoots Development After Planting

The number of tender shoots per hectare at different tender shoots removal times is presented in Figure 01.
The highest number of tender shoots was obtained at 12 WAP while the lowest was recorded at 6 WAP. But 12 WAP, the number of tender shoots per hectare was not significantly different from 10 and 14 WAP (Figure 01).
Results revealed that number of tender shoots obtained can be predominantly categorized into three stages. According to Somasundaram and Mithra (2008), sweet potato growth can be divided into 3 phases, in the inceptive phase, ample growth of fibrous roots occurs and vines only grow at a moderate rate. In the middle phase, sweet potato vines grow considerably and rapidly where tuber initiation takes place. At a later stage, tuber bulking happens while very slower growth of vines and fibrous roots occurs (Somasundaram and Mithra, 2008). Peixoto et al. (2011) similarly stated that sweet potatoes showed slow primary and later growth and accelerated growth in the second stage. The present 3½ months old variety showed a similar growth pattern and the results are in line with past findings.

Fresh Weight of Tender Shoots After Planting

The fresh weight of tender shoots at selected tender shoots removal times are tabulated in Table 02.

No significant difference (P>0.05) was observed in the fresh weight of tender shoots in specified intervals of shoot removal. At early stages of growth, a smaller number of tender shoots were obtained while at later stages a higher (Figure 01). Though the number of tender shoots per hectare was significantly lower at early stages (6WAP and 8WAP) their fresh weights were not significantly different with later stages (12WAP and 14WAP).
Somasundaram and Mithra (2008) mentioned that a portion of the photosynthates manufactured in sweet potatoes was utilized for furnishing energy for maintaining and growth process while the remaining was supplied to storage organs in proportion to their growth rate. At early stages, tubers were not initiated and thus whole photosynthates might be used for the vine growth. Similarly, at later stages, tuber initiation and bulking occur, and the photosynthates that remain after the maintenance and growth process will be stored in tubers. Sweet potatoes possess competition between stem and leaves with tubers for the photosynthates to continue for a long period. Therefore, at tuber initiation and tuber bulking stages competition for photosynthates is higher from tubers. A large number of photosynthates are translocating from source (leaves) to sink (tubers), so there may be no remaining assimilates in leaves and stems (M.B. Weerasuriya, personal communication, May 10, 2021). That might be the reason for not having a significant difference in fresh weight of tender shoots although a significantly higher number of tender shoots were obtained at later stages of growth.

Number of Cuttings as Planting Materials

The mean values of number of cuttings as planting materials obtained at different tender shoots removal times were more or less similar to the mean values of number of tender shoots obtained at different tender shoots removal times (Fig. 02). There was a significant difference (P<0.05) between early and later stages

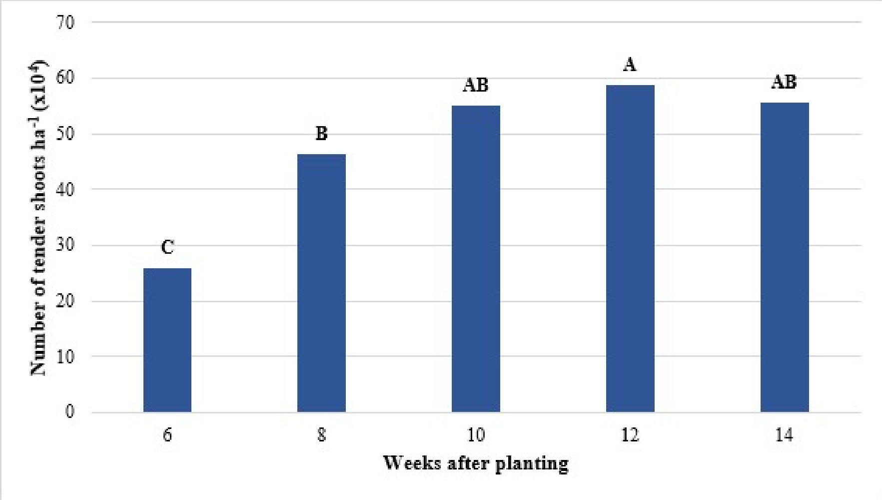

Figure 1: Number of sweet potato tender shoots per hectare at different tender shoots removal times.

Table 2: Fresh weight of sweet potato tender shoots per hectare at specified tender shoots removal times.

Treatments	Fresh weight of tender shoots (g/ha) x 10^5
6WAP	92
8WAP	79
10WAP	82
12WAP	85
14WAP	79
CV%	10.01 %

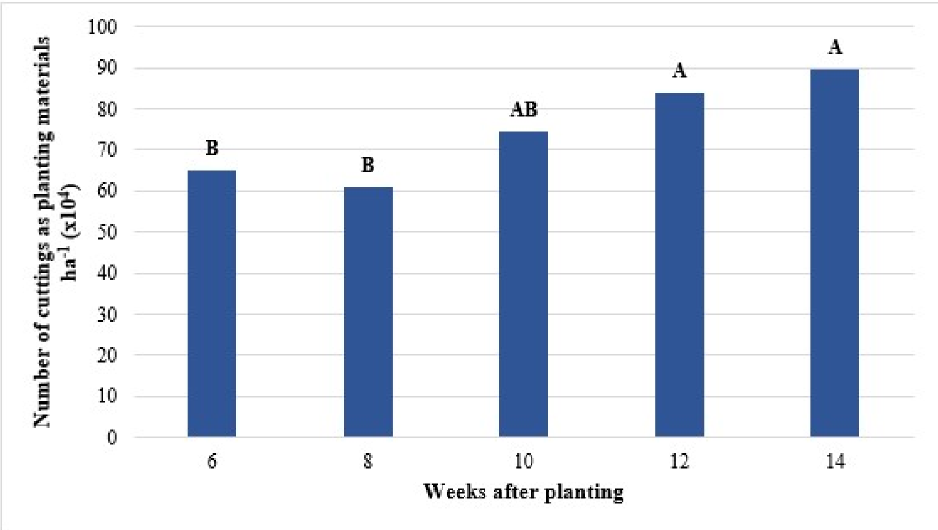

Figure 2: Number of sweet potato cuttings as planting materials per hectare at different tender shoots removal times.

for number of stem cuttings. 6WAP and 8WAP were resulted the lowest number of cuttings while 12WAP and 14WAP were the highest (Fig. 02).

Tender shoots remained after obtaining all possible five-leaf node cuttings from basal ends were separated as leafy vegetables because they were less vigorous for planting. Muli and Mwakina (2016), mentioned that storage root yield in sweet potatoes was increased with the increase in size of the planted cutting. Similarly, Onwueme (1978) stated that tuber yield tends to rise with increasing the length of the vine cuttings used. However, Beyene *et al.*(2015), indicated that cuttings longer than 30cm are wasting of planting materials, as well as much shorter cuttings established slowly and offered lower yields. Furthermore, Amoah (1997) stated that 5 and 7-node cuttings gave a significantly higher tuber yield over 3-node cuttings. But there was no advantage of 7 node cuttings over the 5 node cuttings. Therefore, in the present study, five-leaf node cuttings were separated as planting material.

Fresh Weight of Cuttings as Planting Materials

A significant difference was not observed (P>0.05) between treatments in fresh weight of cuttings as planting materials (Table 03). Stems and leaves have more photosynthetic assimilates in the early stages. At tuber initiation and bulking stages, a large amount of photosynthates are translocated to tubers resulting in low assimilates in stems and leaves (Somasundaram and Mithra, 2008). Hence, no significant increment in fresh weight was observed in fresh weight of as planting materials at later stages although the number of cuttings as planting materials was significantly higher at later stages.

Fresh Weight of Marketable Tender Shoots as Leafy Vegetable

Cumulative values of fresh weight less than five-leaf node cuttings and cuttings as planting materials were taken. Measured weights were statistically analyzed and the results are tabulated in Table 04.

There is no significant difference (P>0.05) between treatments in fresh weight of marketable tender shoots as leafy vegetables. When taking the fresh weights of marketable tender shoots as leafy vegetables, the leaves that were not suitable for human consumption due to pest and disease attacks were not considered.

The Impact of Tender Shoots Removal Time on the Protein Content of Tender Shoots

A significant difference was observed (P<0.05) in protein content between treatments (Fig. 03). The highest amount of protein content was observed in 14WAP and the lowest was 6WAP and 8WAP. However, no significant difference was observed between 14WAP and 12WAP.

Frankow-Lindberg *et al*. (2003) and Farrell *et al*. (2000) stated that sweet potato vines have a great crude protein content (18-30% in DM), which is equivalent to leguminous forages. The yields and qualities of forage species differ according to the age of the forage plant. Suárez *et al*. (2020), mentioned that sweet potato leaves during a particular harvesting period have more nutritional value and are more beneficial for human health. Sweet potato leaves could be harvested in the latter period without loss in the nutritional value present in the leaves (Suárez *et al*., 2020). The present study indicated that sweet potato tender shoots are intended to be used as leafy vegetables and preferable stages are 12WAP and 14WAP.

The Impact of Tender Shoots Removal Time on the Mineral Content of Tender Shoots

The ash content values which stand for the mineral content are tabulated in Table 05. A significant difference (P>0.05) in mineral content between treatments was not observed. Determination of ash content is vital since ash or mineral content is the residual part of the food or any other organic material after it is burnt to very high temperatures of about 550 °C (Pomeranz and Meloan, 1994). In the ash component potassium, magnesium, sodium, and calcium exist in greater quantities while copper, iron, aluminum, zinc, manganese, fluorine, iodine, or arsenic exist in smaller amounts and other elements exist in trace amounts. The total mineral content in foods is represented by the ash content. Although minerals represent a little part of dry matter, most often less than 7% of the total, they play a considerable role from a physio-chemical and nutritional point of view (www.foodscience-avenue.com,24.08.2023). Since there is no significant difference between treatments in mineral content, consuming leaves at any stage will be beneficial for human health.

The Impact of Tender Shoots Removal Time on Total Fresh Weight of Tubers

Sweet potato tubers in experimental plots were harvested at 14WAP and the total tuber weight from each raised bed was measured. Data were statistically analyzed and results are tabulated in Table 06 and graphically represented in Figure 04 with the mean values. Data revealed that there was a significant difference (P<0.05) between treatments in the total fresh weight of tubers per hectare. The highest total fresh weight was observed in the control experimental sites where the removal of tender shoots did not take place (Table 06). But it is not significantly different from the total fresh weight of 10WAP, 12WAP and 14WAP. The lowest yield was recorded in the plots where shoot removal was practiced at 6WAP and followed by 8WAP. Since statistical analysis revealed that there is no significant yield difference between 10WAP, 12WAP, and 14WAP with the controlled experimental plots (Table 06) shoot removal could be

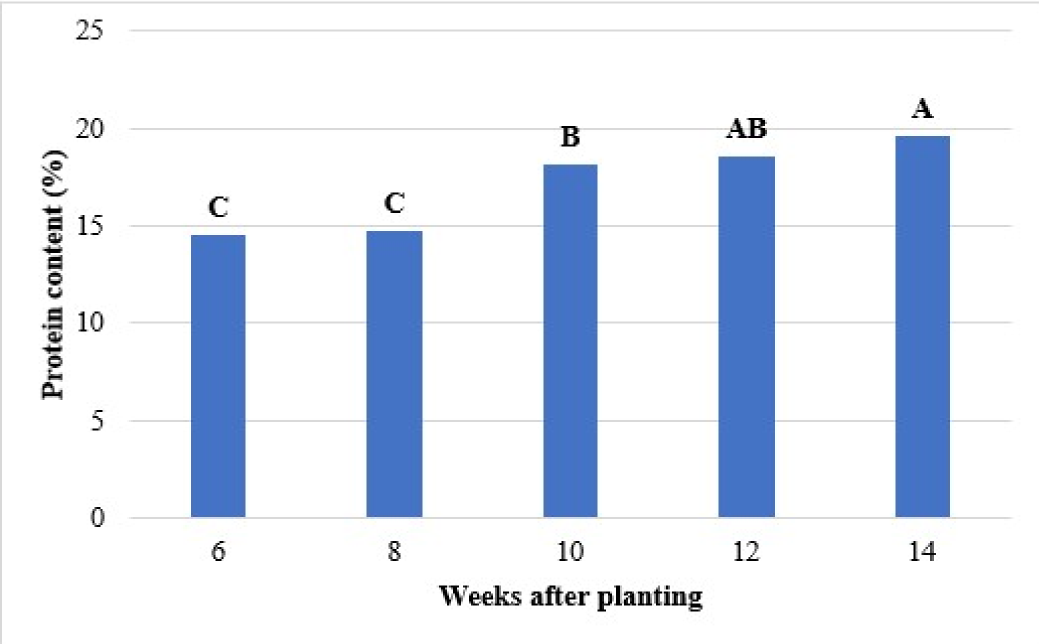

Figure 3: Protein content of sweet potato tender shoots at different tender shoots removal times.

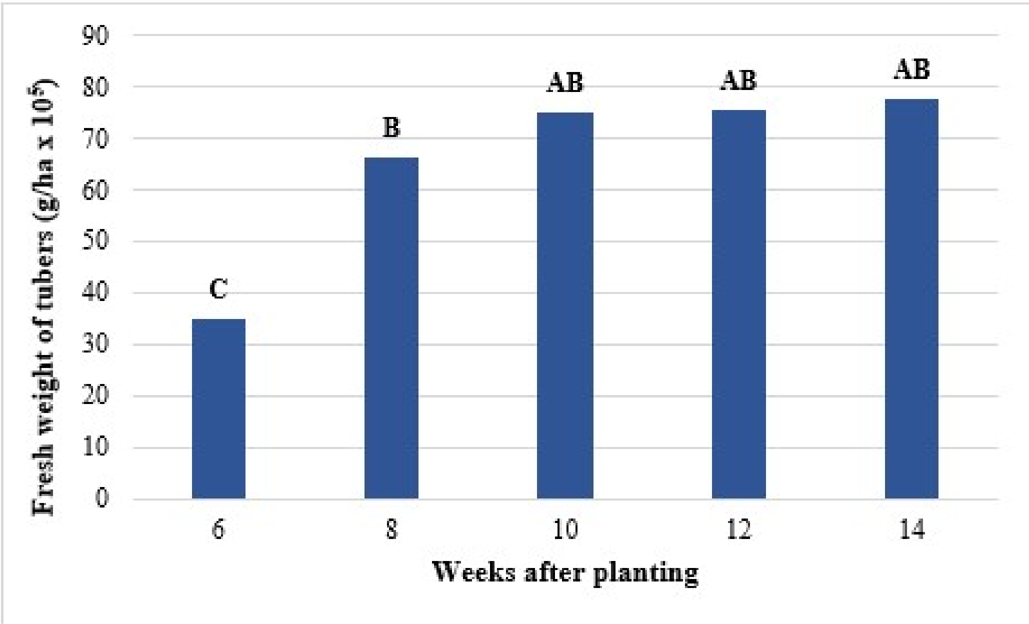

Figure 4: Fresh weight of sweet potato tubers per hectare at different tender shoots removal times.

Table 3: Fresh weight of sweet potato cuttings as planting materials per hectare at different tender shoots removal times.

Treatments	Fresh weight of cuttings as planting materials (g/ha) x10^5
6WAP	74
8WAP	69
10WAP	70
12WAP	72
14WAP	70
CV%	11.93 %

Table 4: Fresh weight of marketable tender shoots of sweet potato as leafy vegetable per hectare at different tender shoot removal times.

Treatments	Fresh weight of marketable tender shoots as leafy vegetable (g/ha)10^{5}
6WAP	79
8WAP	76
10WAP	78
12WAP	78
14WAP	75
CV%	10.14 %

Table 5: Mineral content of sweet potato tender shoots at different tender shoots removal times.

Treatments	Mineral content (%)
6WAP	1.3
8WAP	1.5
10WAP	1.3
12WAP	1.6
14WAP	1.6
CV%	22.68 %

Table 6: Fresh weight of sweet potato tubers per hectare at different tender shoots removal times.

Treatments	Fresh weight of tubers (g/ha) x10^5
6WAP	35 C
8WAP	67 B
10WAP	75 AB
12WAP	75AB
14WAP	78 AB
Control	103 A
CV%	21.27 %

started 10 weeks after planting without a significant yield reduction.

The relation between the assimilate source (photosynthetic tissue) and the main assimilate sink (storage roots) and their comparative significance to crop yields has been studied for sweet potatoes (Lewthwaite *et al*., 2000). According to Ravi and Saravanan (2012), the rate of photosynthesis is excessive during the early growth phase and reduces at the end of the growth. The photosynthetic capacity of the leaf blade is associated with the thickening property of tubers. Therefore, removing tender shoots at early stages of vegetative growth is detrimental to tuber yield due to the reduction of photosynthetic area (Ravi and Saravanan, 2012). Reducing of photosynthetic area affects for reducing the food production in sweet potato vines. Then it affects for reducing the formation and bulking of tubers. Mvumi *et al*. (2018) stated that vine-cutting harvesting time greatly affects the root tuber yield of sweet potatoes. As recorded by them higher root tuber yield was obtained when the vine harvesting frequency was lowered. A significantly higher total root tuber yield was obtained from vines harvested once at 8 weeks compared to vines harvested twice at 8 and 10

WAP; thrice at 8, 10, and 12 WAP; and 4 times at 8, 10, 12, and 14 WAP. The results of the present experiment too in line with past findings.

The same results were obtained by Frankow-Lindberg *et al*. (2003), who mentioned that vine harvesting interval affected tuber production of sweet potatoes. They recorded the lowest tuber dry matter yield for 15 days vine harvesting interval while the highest tuber dry matter yield was obtained from vine harvesting 120 days after planting. Mohammed *et al*. (2012) also mentioned that the total fresh root tuber weight from vines that were harvested 105 DAP (Days After Planting) declined by a comparatively lower percentage (11%) while the total fresh root tuber weight from vines that were harvested 45 and 75 DAP were declined by about 36 and 22%, respectively. Thus, they concluded that vines that were harvested comparatively earlier (45 DAP) experienced an extreme reduction in total fresh root tuber yields followed by vines that were harvested at the mid-growth stage (75 DAP). Furthermore, they stated that the distinct decrement in fresh root tuber weights of vines that were harvested during the growth period may be due to the disruption of the photosynthetic tissue caused by vine cutting, resulting in a reduction in the carbohydrate partitioning to tubers. Therefore, they stated that there could be a strong relationship between the establishment of early optimum leaf area and sweet potato tuber yield.

Therefore, in 3½ month sweet potato varieties, tender shoots can be removed from 10WAP without a significant effect on tuber yield reduction. Similarly, previous studies conducted for Wariyapola Red and Ama sweet potato varieties at the Agriculture Research Station, *Thelijjawila* showed that there was no significant difference in tuber yield due to the tender shoots removal after 10WAP (unpublished data).

Until now, research regarding sweet potatoes has mainly focused on the production of tubers. There are very few studies on the production of sweet potato leaves and their chemical composition as well as the effects of leaf harvesting on tuber yield. Frankow-Lindberg *et al*. (2003), stated that sweet potatoes are planted either for tubers or forage production, depending on the purpose and the season. As cited by them Dung (2001) reported that experiments on potential crops for forage production in Vietnam have revealed that sweet potato leaves are a prospective source of crude protein for livestock since the crude protein content is relatively high while fibrous constituents are limited. In addition, Farrell *et al*. (2000) recorded that sweet potato leaves are abundantly used as a food source for different animal species in many countries. Moreover, as mentioned by them sweet potato leaves are greatly appetizing for pigs and thus they could be used to replace a part of the traditional protein sources.

Crowder and Chedda (1982) reported that cutting sweet potato vines at 4-week intervals did not considerably increase the fodder yield whereas tuber production and total biomass yield were drastically decreased. As well, vine harvesting at 6 and 8-week intervals significantly increased fodder yield at the expense of root yield. As cited by them Nwinyi (1992), reported that removing sweet potato vines during the crop cycle declines the provision of photosynthates during the remainder of vines' growth with an ultimate decrement in root tuber yield. With these studies, Kiozya *et al*. (2001), Nguyen and Bautista(1999) and Stathers *et al*. (2005) recorded that the tuber weight of sweet potatoes considerably declined when cuttings were taken from immature vines during the early growth phase of vines. This stipulates that age at vine harvesting has an impact on the amount of the reduction of tuber yield which early harvesting results in a substantial decline in tuber yield.

Furthermore, Lebot (2009) recommended that sweet potato vines could be harvested late (90 to 120 DAP) after the storage tissue in sweet potato tubers has grown and stored a substantial amount of starch to prevent the suppression of sweet potato tuber growth. According to Afzal *et al*. (2021), sweet potatoes can improve resilience and decrease the susceptibility of smallholder agricultural production systems to the effects of climate change and other destruction. As cited by Afzal *et al*. (2021), Sakai *et al*. (2020) have mentioned that sweet potato, has begun to attract the attention of policymakers and researchers, as it offers a lot of potential opportunities to smallholder farmers in terms of increasing agricultural productivity. It is mostly grown in developing countries with low per capita income. Improving the production of sweet potatoes is regarded as a way to enhance food security and to decline poverty among the poorer divisions of urban and rural populations (Scott and Maldonado, 1999). Sweet potato ensures poverty reduction by generating sustainable income opportunities for small farmers. This is due to its profitable nature, high carbohydrate content emphasizes the capability of biofuel production, high multiplication rates cause the selling of vines, low agricultural input requirement results in low production costs, and high yielding ability (Afzal *et al*., 2021). Thus, a sustainable sweet potato production system is an indeed requirement to facilitate higher demands for food security.

In the present study, the removal of tender shoots in sweet potato vines adversely affected tuber yield during the primary stages of growth and it gets reduced with time. The age of the sweet potato plant at vine harvesting is a foremost factor that affects tuber and fodder yields both quantitatively and qualitatively. Mohammed *et al*. (2012) stated that optimum production of herbage without compromising yield loss could be obtained by harvesting shoot cuttings when 60% of the plant growth phase is completed. They further mentioned that the shortage of food and fodder due to frequent droughts has caused huge problems in human and livestock survival. Therefore, sweet potato being a drought-tolerant crop, sweet potato production as a dual-purpose plant has been gradually increasing to ensure food security in the region.

CONCLUSION

To fulfill the planting material requirement of a 3½ month old variety shoot removal could be started 10 weeks after planting without a significant yield reduction. It is advisable and important to promote sweet potato tender shoots as a leafy vegetable. The protein content of leaves of the selected variety recorded higher values in 10 WAP. Moreover, mineral content is not significantly changed with time. Since nutritionally the optimum condition for taking shoot tips as leafy vegetables is 10 WAP with no significant reduction in yield.

Hence present study revealed that the best time for obtaining tender shoots either for planting material or culinary purposes is ten weeks after planting for three and half months old sweet potato varieties without significant reduction in tuber yield.

Disclaimer

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Department of Food Science and Technology, Faculty of Agriculture, University of Ruhuna, Sri Lanka for providing laboratory analytical facilities.

REFERENCES

Afzal, N., Afionis, S., Stringer, L.C., Favretto, N., Sakai, M.and Sakai, P. (2021). Benefits and trade-offs of smallholder sweet potato cultivation as a pathway toward achieving sustainable development goals. *Sustainability*, 13(2), 552. https://doi.org/10.3390/su13020552

Amoah, F.M. (1997). The effect of several nodes per cutting and potassium fertilizer on the growth, yield, and yield components of sweet potatoes (*Ipomoea batatas Poir*). *Ghana Journal of Agricultural Science*, 30(1), 53-62. https://doi.org/10.4314/gjas.v30i1.1978

AOAC Official Method 2003.06 (2005). *Official Methods of Analysis of AOAC International*, 18th Ed., AOAC International, Gaithersburg, MD. http://hdl.handle.net/10637/3158. Accessed: 24.08.2023.

Crowder, L.V. and Chheda, H.R. (1982). *Tropical grassland husbandry*. Longman Group Ltd., London, England.

Dung, N.N.X. (2001). Evaluation of green plants and by-products from the Mekong Delta with emphasis on fiber utilization by pigs. Swedish University of Agricultural Sciences, Uppsala, Sweden.

FAO, G. (2020). *Standard operating procedures for soil organic carbon: Walkley and Black method*. GLOSOLAN's Best Practice Manual. GLOSOLAN-SOP-02. FAO, Rome.

Islam, S. (2014). Nutritional and medicinal qualities of sweet potato tops and leaves. Cooperative Extension Service, University of Arkansas at Pine Bluff, United States.

Kiozya, H.C., 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. *African Crop Science Journal*, *9*(1), 97-103. https://tspace.library.utoronto.ca/html/1807/21204/cs01039.html. Accessed: 24.08.2023.

Lebot, V. (2009). *Tropical Root and Tuber Crops. Cassava, Sweet Potato, Yams and Aroids*. *Experimental Agriculture*, 45(3), 382-382. https://doi.org/10.1017/S0014479709007832

Lewthwaite, S.L., Triggs, C.M. (2000). Preliminary study on sweet potato growth: I. Dry matter partitioning. *Agronomy Journal New Zealand*, 30, 143-149.

Low, J., Nyongesa, M., Quinn, S., & Parker, M. (2015). *Potato and sweet potato in Africa. Transforming the value chains for food and nutrition security*. Boston (USA): CABI International. ISBN 978-1-78064-420-2. 632 pages. https://doi.org/10.1079/9781780644202.0000

Mohammed, A., Nigussie-Dechassa, R., Bekele, A. (2012). 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*, 7(7), 1129-1141. https://doi.org/10.5897/AJAR11.894

Muli, M.B., Mwakina, D. (2016). Effect of variety and size of stem cutting on flesh root yield and yield components of sweet potato. *Journal of Agricultural Science and Technology*, 6, 175-179. https://doi.org/10.17265/2161-6264/2016.03.004

Mvumi, C., Zendera, B., Mashayamombe, B. (2018). Vine harvesting frequency impact on tuber yield attributes of commonest sweet potato cultivar in Sub-Saharan Africa. *International Journal of Agronomy and Agricultural Research*, 12(6), 30-38.

Nguyen, B.L., Bautista, O.K. (1999). Extent and mechanism of yield reduction in sweet potato grown for tops and roots. *Philippine Agricultural Scientist*, 82, 137-150.

Nwinyi, S.C.O. (1992). Effect of age at shoot removal on tuber and shoot yields at harvest of five sweet potatoes (*Ipomoea batatas* (L.) Lam) cultivars. *Field Crops Research*, 29(1), 47-54. https://doi.org/10.1016/0378-4290(92)90075-K

Onwueme, I.C. (1978). *The tropical tuber crops: yams, cassava, sweet potato, and cocoyams*. John Wiley and Sons, United Kingdom. 248 pp. ISBN: 0471996076. https://www.cabdirect.org/cabdirect/abstract/19786725011. Accessed: 24.08.2023.

Padmaja, G., Sheriff, J.T., Sajeev, M.S. (2012). Food uses and nutritional benefits of sweet potato. *Fruit, Vegetable and Cereal Science and Biotechnology*, 6(1), 115-123.

Peixoto, C.P., Cruz, T.V., Peixoto, M.F.S.P. (2011). Análise quantitativa do crescimento de plantas: conceitos e prática. *Enciclopédia Biosfera*, 7(13). https://www.conhecer.org.br/enciclop/2011b/ciencias%20agrarias/analise%20quantitativa.pdf. Accessed: 24.08.2023.

Pomeranz, Y., Meloan, C.E. (1994). Determination of moisture. In *Food analysis: Theory and practice* (3rd Edition). CHAPMAN & HALL, London. pp. 575-601.

Ravi, V., Saravanan, R. (2012). Crop physiology of sweet potato. *Fruit, Vegetable and Cereal Science and Biotechnology*, 6(1), 17-29.

Sakai, P., Afionis, S., Favretto, N., Stringer, L.C., Ward, C., Sakai, M., Weirich Neto, P.H., Rocha, C.H., Alberti Gomes, J., de Souza, N.M., Afzal, N. (2020). Understanding the implications of alternative bioenergy crops to support smallholder farmers in Brazil. *Sustainability*, 12(5), 2146. https://doi.org/10.3390/su12052146

Scott, G.J., & Maldonado, L. (1999). Sweet potato for the new millennium: Trends in production and utilization in developing countries. *International Sweet Potato Center, Impact on a Changing World: Progress Report*, Lima, Peru, 434-458. http://www.sweetpotatoknowledge.org/wp-content/uploads/2016/04/Sweetpotato-for-the-New-Millennium-Trends-in-Production-and-Utilization-in-Developing-Countries.pdf. Accessed: 24.08.2023.

Senanayake, S.A., Ranaweera, K.K.D.S., Gunaratne, A., Bamunuarachchi, A. (2012). Preliminary study of mineral constituents in selected cultivars of root and tuber crops in Sri Lanka. *Vidyodaya Journal of Science*, 17(1), 24-30.

Somasundaram, K., Mithra, V.S. (2008). MADHURAM: A simulation model for sweet potato growth. *World Journal of Agricultural Sciences*, India, 4(2), 241-254.

Stathers, T., Namanda, S., Mwanga, R.O.M., Khisa, G., Kapinga, R. (2005). *Manual for sweet potato integrated production and pest management farmer field schools in sub-Saharan Africa*. CIP, Uganda. 168 pages.

Suárez, S., Mu, T., Sun, H., Añón, M.C. (2020). Antioxidant activity, nutritional, and phenolic composition of sweet potato leaves as affected by harvesting period. *International Journal of Food Properties*, 23(1), 178-188. https://doi.org/10.1080/10942912.2020.1716796