Foliage Removal Influences Sweetpotato Biomass Yields in Hydroponic Culture

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Abstract. Greenhouse studies were conducted to determine the effect of harvesting sweetpotato [*Ipomoea batatas* L. (Lam.)] foliage tips (terminal 15 cm) on storage root yield, edible biomass index (EBI), and linear growth rate. Plants were grown hydroponically from 15-cm vine cuttings planted in 0.15 × 0.15 × 1.2-m growth channels using a recirculating nutrient film technique system. Nutrients were supplied from a modified half-strength Hoagland solution with a 1 N : 2.4 K ratio. Foliage tips were removed at 14-day intervals beginning 42 days after transplanting. Final harvest was at 120 days after planting. At the end of the growing season, harvested foliage tips totaled 225 g/plant (fresh mass). Foliage removal significantly reduced storage root yield, shoot biomass, and linear growth rate expressed on a canopy cover basis. The EBI was higher for plants with foliage removed than for the control.

Sweetpotato is one of eight crops selected by the National Aeronautics and Space Administration as a potential food source for controlled ecological life support systems (CELSSs) for space missions (Hill et al., 1984). Previous work has identified environmental conditions and cultivars for hydroponic production in controlled environments (Bonsi et al., 1992; Hill et al., 1992; Mortley et al., 1991). Sweetpotatoes have a high edible biomass index (EBI) because foliage and storage roots can be consumed. The tender portions of the foliage are an excellent source of vitamins A, B₂, and C; Fe; and protein (Villareal et al., 1979). Pace et al. (1985) reported that the nutritive qualities of sweetpotato foliage are similar to those of other traditional green leafy vegetables.

If sweetpotato foliage is to be used as a vegetable in CELSS, the timing of removal must be determined carefully to optimize storage root and foliage production. In field studies conducted by Danhiya et al. (1985), storage root yields decreased by 31% to 48% when 25-cm-long shoot tips were removed and by 48% to 62% when the entire shoot was re-

moved. Similar results were reported by Nwinyi (1992), with decreases in storage root yields reaching a maximum of 63% when shoots were removed to within 2 cm from the ground during several harvesting periods. In both studies, plants were grown in the field, and the minimum shoot length removed was 25 cm from all terminal ends, thus resulting in the removal of substantial amounts of foliage. This practice may have adversely affected storage root development by reducing the amount of photoassimilates in the leaf, making less available for the root. However, the amount of foliage removed can be reduced by decreasing the harvested foliage length, which would increase the photosynthetic surface and might allow for foliage removal without adversely affecting root yields.

Preliminary work by Ogbuehi et al. (1989) suggests that foliage harvest might be feasible when plants are grown in a hydroponic system. Unlike field-grown sweetpotatoes, sweetpotato foliage growth in hydroponic culture can be prolific due to the abundant supply of plant nutrients and their ready availability. This method offers a distinct advantage over field-grown sweetpotatoes in that foliage may be removed without substantially limiting photoassimilates from leaves through foliage removal. This study was initiated to determine the effects of removing the terminal 15 cm of each vine at 14-day intervals on yield, linear growth rate, and EBI of sweetpotato grown in a nutrient film technique (NFT) system.

Materials and Methods

Sweetpotato vine cuttings, each 15 cm long, were placed in a recirculating NFT system as described by Hill et al. (1984) and

Morris et al. (1989). Four vine cuttings of the clone TU-82-155 were planted 25 cm apart in 0.15 × 0.15 × 1.2-m growth channels. Growing vines were held in place in the growth channels by a flat plate assembly (Morris et al., 1989). Foliage tips were removed from the top 15 cm of all terminal branches at 14-day intervals. However, foliage removal was initiated only at 42 days after transplanting to allow for adequate initial shoot growth and root development. The control did not have foliage removed.

Two growth channels were used for each treatment, with each channel supplied by a 30.4-liter reservoir of modified half-Hoagland nutrient solution (Hoagland and Arnon, 1950) with a 1 N : 2.4 K ratio (Table 1). The solution was pumped to the opposite end of each growth channel by a submersible pump (Teel model 1p680 A 1/2 horsepower; Dayton Electric, Chicago) and spread across each channel (1% slope) in a thin film as it flowed back into the reservoir. Nutrient solution flow rate was set at 1 liter/min using a bypass line to each reservoir with a control valve. Nutrient solution was changed at 14-day intervals, and reservoirs were refilled with deionized water if the volume of the nutrient solution was reduced to ≤8 liters before the time of solution change. When the nutrient solution was prepared and at each refilling, its pH was adjusted to between 5.8 and 6.2 by adding (1 N) HCl or NaOH. The experiment was conducted March through June in a greenhouse at ambient CO₂, 24 to 33C, 60% to 95% relative humidity, and irradiance between 200 to 1700 μmol·m⁻²·s⁻¹.

Final harvest occurred at 120 days after planting, at which time fresh mass of foliage and storage roots were recorded. Foliage was dried at 70C for 72 h and weighed. A 50-g random sample of storage roots was dried similarly and weighed. Foliage tips harvested at 14-day intervals were dried following the same protocol used for foliage harvested at 120 days. The EBI, which included foliage tips removed, was determined as follows: (storage root mass + foliage tips/total plant mass) × 100. Linear growth rate (LGR; grams per square meter per day) was determined on canopy cover (Mortley et al., 1991) by assum-

Table 1. Composition of modified half-strength Hoagland nutrient solution.^a

Solution composition	Concn
Stock solution (ml·liter ⁻¹)	
1 M CaCl ₂	2.0
1 M NH ₄ H ₂ PO ₄	0.5
1 M KNO ₃	3.0
1 M MgSO ₄	1.0
Solution A	0.5
Solution B	0.5
Trace-element stock solution	
Solution A (g·liter ⁻¹)	
H ₃ BO ₃	2.86
MnCl ₂ ·4H ₂ O	1.81
ZnSO ₄ ·7H ₂ O	0.22
CuSO ₄ ·H ₂ O	0.08
MoO ₃	0.09
Solution B (g·liter ⁻¹)	
EDTA ferric	5.0

^a1 N : 2.4 K ratio.

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ing that the maximum cover was limited by the available space (half the growing area within and between the growth channels). This rate was calculated as follows: LGR = storage root dry mass/canopy cover $\times$ growth period. The experiment was repeated and the data was pooled because no significant time of planting $\times$ cutting treatment interaction was found. Analysis of variance for a completely randomized design was conducted and differences between cutting treatments were tested with *t* tests.

Results and Discussion

Removing foliage tips at 14-day intervals significantly reduced final-harvest foliage fresh and dry mass (Table 2). The cumulative fresh and dry mass of foliage tips were 225 g and 23.8 g/plant, respectively. However, if the foliage removed at 14-day intervals was added to the foliage harvested at 120 days, total foliage yield (fresh mass basis) of treated plants was higher than control plants. This result indicates that, although foliage removal reduced final foliage yields, plants compensated for this loss by partitioning photosynthates into foliage growth.

Storage root yields were reduced as a result of foliage removal (Table 3). Control plants produced 37% more storage root fresh mass than plants where foliage was removed. These findings agree with those of Dahnिया et al. (1985) and Nwinyi (1992) who also found reduced storage root yields with shoot tip removal. Foliage removal likely reduced the photosynthetic surface of these plants, which is shown by the reduced linear growth rate for plants where foliage was removed at 14-day intervals compared to the control plants. This reduction likely reduced total photosynthates produced during the critical stage of root enlargement, thus resulting in reduced yields. According to Lowe and Wilson (1975), root initiation occurs 28 to 56 days after planting and root enlargement and development 28 to 98 days after planting. Removing foliage every 14 days may have had an impact on these critical physiological processes.

Treated plants had a significantly higher EBI than the control because of the harvested foliage tips. Pace et al. (1985) indicated that sweetpotato foliage tips can be a potential new green vegetable in the United States. Including sweetpotato foliage tips as part of the EBI may offer significant benefits to bioregenerative studies; eating the foliage may reduce the waste material generated from plant biomass to be recycled in a CELSS environment—a desired goal actively pursued in many bioregenerative studies.

The dry mass of harvested foliage tips increased linearly up to midseason and declined thereafter (Fig. 1). From ≈ 70 days on, the sink demand for photoassimilates was high because bulking of storage roots occurred. The presumed resulting sink demand by the roots and translocation of photoassimilates to other leaves acting as sinks may have resulted in the decrease of foliage tip dry mass from 84 days after planting. According to Kuo and

Chen (1992), during the storage root bulking period, an increased efficiency of mobilization of current assimilates to the developing storage root is essential for high storage root yield.

We have shown that foliage removal at 14-day intervals adversely affects storage root yields but increases the EBI of the sweetpotato if the foliage removed also is considered as part of the edible portion of the sweetpotato. Further research is needed to identify the ideal periods during the growth cycle when foliage removal can be practiced without adversely affecting storage root yields. According to Roper and Klueh (1994), fruit set in cranberry (*Vaccinium macrocarpon* Ait.) is more sensitive to loss of foliage tissue at the time of fruit set than early or later in the growth period. In sweetpotato, it may be possible, provided that suitable environmental conditions exist, for foliage topping to be practiced before storage root bulking because once bulking occurs, it is continuous.

Literature Cited

- Bonsi C.K., P.A. Loretan, W.A. Hill, and D.G. Mortley. 1992. Response of sweetpotatoes to continuous light. *HortScience* 27:471.
- Dahnिया, M.T., S.K. Hahn, and C.O. Oputa. 1985. Effect of shoot removal on shoot and root yields of sweetpotato. *Expt. Agr.* 21:183–186.
- Gifford, R.M., J.H. Thorne, W.D. Hitz, and R.T. Giaquinta. 1984. Crop productivity and photoassimilate partitioning. *Science* 225(4464):801–808.
- Hill, W.A., P.A. Loretan, and C.K. Bonsi (eds.). 1984. The sweetpotato for space missions, p. 1–12. Carver Research Foundation, Tuskegee Univ. and George Washington Carver Agr. Expt. Sta., Tuskegee, Ala.
- Hill, W.A., D.G. Mortley, C.L. Macowiak, P.A. Loretan, T.W. Tibbitts, R.M. Wheeler, C.K. Bonsi, and C.E. Morris. 1992. Growing root, tuber and nut crops hydroponically for CELSS. *Adv. Space Res.* 12(5):125–131.
- Hoagland, D.R. and D.I. Arnon. 1950. The water-culture method for growing plants without soil. Univ. of California Agr. Expt. Sta. Circ. 347 (revised ed.).

Table 2. Effect of biweekly foliage removal on foliage yield of TU-82-155 sweetpotatoes grown in nutrient film technique system.

Foliage removed	Foliage mass (g/plant)		
	Fresh		Dry (at final harvest)
	At final harvest	Total	
Yes	180	404	21.1
No	306	306	35.8
Significance	***	*	***

*, ***, Significant at $P \leq 0.05$ or 0.001, respectively, using the Students *t* test.

Table 3. Effect of biweekly foliage removal on yield, growth rate, and edible biomass index of TU-82-155 sweetpotatoes grown in nutrient film technique system.

Foliage removed	Storage root (no./plant)	Plant mass (g/plant)		Linear growth rate of canopy cover (g·m ⁻² ·day ⁻¹)	EBI (%)	
		Fresh	Dry		Root	Root + foliage
Yes	2.3	357	49.8	3.8	67.6	74.9
No	2.5	570	84.7	6.6	69.1	69.1
Significance	NS	**	**	***	NS	*

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively, according to Students *t* test.

Fig. 1. Dry mass of sweetpotato foliage tips at six harvest dates.

- Kuo, G. and H. Chen. 1992. Source-sink relationships of sweetpotato, p. 282-295. In: W.A. Hill, C.K. Bonsi, and P.A. Loretan (eds.). Sweetpotato for the 21st century. Tuskegee Univ., Tuskegee, Ala.
- Lowe, S.B. and L.B. Wilson. 1975. Yield and yield components of six sweet potato (*Ipomoea batatas* L.) cultivars I. Contribution of yield component to tuber yield. Expt. Agr. 11:39-48.
- Morris, C.E., P.A. Loretan, C.K. Bonsi, and W.A. Hill. 1989. Movable root contact pressure plate assembly for hydroponic system. U.S. patent no. 860,490.
- Mortley, D.G., C.K. Bonsi, P.A. Loretan, C.E. Morris, W.A. Hill, and C.R. Ogbuehi. 1991. Evaluation of sweetpotato genotypes for adaptability to hydroponic systems. Crop Sci. 31:845-847.
- Mortley, D.G., P.A. Loretan, C.K. Bonsi, W.A. Hill, and C.E. Morris. 1991. Plant spacing influences yield and linear growth rate of sweetpotatoes grown hydroponically. HortScience 26:1274-1275.
- Nwinyi, S.C.O. 1992. Effect of age at shoot removal on tuber and shoot yields at harvest of five sweetpotato (*Ipomoea batatas* (L) Lam) cultivars. Field Crops Res. 29:47-54.
- Ogbuehi, C.R., P.A. Loretan, C.K. Bonsi, W.A. Hill, C.E. Morris, P.K. Biswas, and D.G. Mortley. 1989. Effect of biweekly shoot tip harvests on the growth and yield of "Georgia Jet" sweetpotato grown hydroponically, p. 9-14. In: Y.D. Sanders, Y.B. Freeman, and M.C. George (eds.). Natl. Aeronautics and Space Admin.-Historically Black Colleges and Universities Space Sci. and Eng. Res. Forum Proc., Huntsville, Ala., 22-26 Mar. 1989.
- Pace, R.D., G.G. Dull, and B.R. Phills. 1985. Proximate composition of sweetpotato greens in relation to cultivar, harvest date, crop year and processing. J Food Sci. 50:537.
- Pace, R.D., T.E. Sibiya, B.R. Phills, and G.G. Dull. 1985. Ca, Fe and Zn content of 'Jewel' sweetpotato greens as affected by harvesting practices. J Food Sci. 50:940-941.
- Roper, T.R. and J.S. Klueh. 1994. Removing new growth reduces fruiting in cranberry. HortScience 29:199-201.
- Villareal, R.L., S.C.S. Tsou, S.K. Lin, and S.C. Chou. 1979. Use of sweetpotato leaf tips as vegetable. II. Evaluation of yield and nutritive quality. Expt. Agr. 15:117-122.