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Short Communication

Growing sweet potatoes [*Ipomoea batatas* (L.) Lam.)] for their greens and the impact on storage roots

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ABSTRACT

Sweet potato greens are an underused but highly nutritious vegetable that grows well in urban environments and could help alleviate food insecurity and related health problems. Therefore, trials were conducted in field rows and a green roof with seven varieties of sweet potatoes to determine whether 1) they differed in their production of greens and 2) harvesting greens influenced yield or nutrients of storage roots. There was no difference in the mass of sweet potatoes greens harvested among the varieties in either production system. Harvesting greens severely reduced the harvested mass of storage roots, although it increased the content of eight minerals in storage roots, including boron, calcium, copper, iron, phosphorous, potassium, sulfur, and zinc. Urban farmers may have to decide whether harvesting greens or storage roots are their primary objective if harvesting the former limits the latter. Future research should explore the timing of harvesting greens and the amount taken to see if different methods allow for a high yield of storage roots that are high in nutrients.

Keywords: Extensive green roof, field row, *Ipomoea batatas*, mineral, nutrient, variety trial, yield

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is native to tropical areas of the America, but has become an important staple food crop elsewhere, such as Asia and Africa (Duke, 1983; Reynolds et al., 2015). Sweet potato can be cultivated over a range of climatic conditions, exhibiting tolerance to drought and heat (Laurie et al., 2013), which makes it a resilient crop. The storage roots are good sources of multiple vitamins, minerals, carbohydrates, dietary fiber, phenolic compounds, and antioxidants (Neela and Fanta, 2019) and they can be stored for extended periods, so they can promote nutritious eating and help human populations where malnourishment is a problem (Motsa et al., 2015; Low et al., 2020). Sweet potato greens are also edible and consumed as a vegetable in parts of Asia and Africa, although they are underused worldwide. Similar to other leafy greens, such as spinach, sweet potato greens are highly nutritious and rich in vitamin B, β-carotene, iron, calcium, zinc, protein, and polyphenols (Pace et al., 1985; Yoshimoto et al., 2003; Alam, 2021). Sweet potato greens have received attention in recent years because their environmental tolerance make them an option in areas where fresh food may be scarce and their nutritional content may provide various health benefits, including protection from cancer, liver damage, inflammation, diabetes, and bacterial infection (Nguyen et al., 2021). An extract from sweet potato greens is also a folk remedy for various maladies such as asthma, bug bites, burns, diarrhea, fever, nausea, stomach distress, tumors, and anemia (Osime et al., 2008).

Sweet potato greens are not widely consumed in the United States of America (USA) and its plants are not as commonly grown in some urban areas in the USA because of the relatively low economic value of storage roots compared to high land and operating costs for urban farms. However, the USA is home to large Asian and African populations that may desire sweet potato greens. Marketing storage roots and greens to these populations, and expanding consumption of greens by other racial and ethnic groups, may increase viability of this crop in urban areas. Furthermore, many urban populations are food insecure due to food apartheid. For example, food insecurity impacts 16% of the population in Washington, DC, USA (District of Columbia Office of Planning, 2020). Food insecurity leads to a variety of negative health outcomes, which can lower overall health and limit daily activities

(Gunderson and Ziliak, 2015). Therefore, crops that are high in nutrients and suitable for cultivation in urban areas may help promote positive health outcomes by reducing food insecurity (Jeffery and Richardson, 2021; Luthria et al., 2021).

As the worldwide human population becomes more urbanized and urban agriculture becomes more commonplace, there is a need for urban crop trials that explore sustainable production methods (Cerozi et al., 2022) and diverse production systems (Richardson & Arlotta, 2021, 2022; Richardson et al., 2022). Within Washington, DC, there is space available at ground level and particularly on flat roofs in poorer areas of the city for urban agriculture to be implemented (Taylor et al., 2021). Therefore, the primary objective was to test whether production of greens differed across seven varieties of sweet potatoes in ground-level field rows and on a green roof in Washington, DC. A secondary objective was to test whether harvesting the greens influenced the production or nutrients of storage roots in field rows.

Systems and sweet potato cultivars

Two cropping systems were used at two locations: (1) the 1858 m^2 green roof at the University of the District of Columbia's (UDC) Van Ness Campus and (2) UDC's 58 ha Firebird Farm (Beltsville, MD, USA). Sweet potatoes grew in these systems from 2017 to 2018 to collect data and adjust methodology but report data solely from 2018 because the variable methods prevent comparisons across years. Slips of seven varieties of sweet potatoes *viz.*, Beauregard, Bunch Porto Rico, Georgia Jets, Ginseng, Hernandez, O'Henry, and White Hamon (Southern Exposure Seed Exchange, Mineral, VA, USA).

UDC's green roof planter boxes (hereafter 'Green Roof Planters')

Twenty-eight planter boxes that each had a surface area of 0.9 m^2 and depth of 46 cm were used. Green roof planters were positioned around the roof's periphery and filled to a depth of approximately 30 cm with rooflite® semi-intensive green roof media (Skyland USA, Landenberg, PA, USA), which had an average pH of 7.4, soil organic matter (loss on ignition %) of 33%, calcium of 581 mg/kg, magnesium of 48 mg/kg, and potassium of 41 mg/kg. The boxes were only partially filled to prevent exceeding the weight-bearing limit of the roof. A total of four sets of seven boxes were along three edges of the roof: two on the south, one on the west, and one on the north side. The seven varieties of potatoes were randomly assigned to the seven boxes in each set, with each box containing three slips of the same variety planted 61 cm apart. This created a randomized complete block design with each block being a set of seven boxes and each box being a replicate (n = 4). Drip irrigation was used as needed to supplement rainwater. Plants were fertilized once due to a suspected iron deficiency with 1 teaspoon of DTPA iron chelate (CropKing, Inc, Lodi, OH, USA) mixed into 3.8 L water. Backpack sprayer was used to apply the fertilizer evenly across leaves and soil within all planter boxes. No other fertilizers or amendments were added.

Firebird farm field rows (hereafter 'field rows')

Five slips of each sweet potato variety was planted in each of two tilled field rows using a completely randomized design, with each slip being a replicate (n = 5). The slips were spaced 30.5 cm apart and watered with a manually operated drip tape system as needed. One of these rows was designated as the "clipped" row because vines and leaves were harvested, whereas the other was the "control" row because no vines and leaves were harvested. The loam soil had an average pH of 6.9, soil organic matter (loss on ignition %) of 12%, calcium of 2,766 mg/kg, magnesium of 152 mg/kg, and potassium of 174 mg/kg. No fertilizers or amendments were added.

Plant productivity and minerals

Sweet potato greens were harvested three times from all plants in green roof planters (17-18 August, 21-22 September, 23 October) and the clipped field row (10-12 August, 15-22 September, 16-22 October). Greens were not harvested from the control field row in order to ascertain differences in production and mineral content of storage roots when greens were clipped versus unclipped. Leaves were harvested by cutting all vines from a plant at 61 cm from the base and removing all leaves (including petioles) from detached vines. Marketable leaves were weighed separately from non-marketable leaves. Marketable leaves had feeding damage, discoloration, and disease on one quarter of the leaf or less. The green roof had multiple plants per replicate, some of which died, so we divided the total mass from all harvested leaves by the number of plants and harvests to calculate mass on a per-plant, per-harvest basis.

Storage roots were harvested in field rows the week of 22 October by hand with shovels and weighed marketable storage roots (*i.e.* free from rot) separately from non-marketable storage roots. From this harvest, samples of 'Ginseng' and 'Hernandez' were collected in the control and clipped field rows for analysis of mineral nutrients. These two varieties were selected because they produced enough storage roots of different sizes in both field rows to allow for adequate replication. For each variety and field row, one medium and one large storage root were analyzed from each of three replicates for a total of six samples per variety and field row. Storage roots were rinsed to remove debris and then sliced, freeze-dried, ground, and stored them at -80°C in sealed cryotubes. Samples were shipped on ice to New Age Laboratories (South Haven, MI, USA) where content of 11 mineral nutrients, including boron, calcium, copper, iron, potassium, magnesium, manganese, sodium, phosphorus, sulfur, and zinc, was determined by inductively coupled plasma optimal emission spectrometry (AOAC International 2012). Results are presented on a dry matter basis.

Statistical analyses

The differences were analysed in mass of greens across varieties within a cropping system with separate general linear models (PROC GLM; SAS Institute 2020). Differences in the mass of storage roots across treatments (*i.e.* control versus clipped) in field rows were analyzed with a general linear model. Square-root transformation was used on the data to meet assumptions of normality prior to analysis. Means for non-transformed data are presented in the results. Differences in minerals in storage roots across treatments were also analyzed with separate general linear models. Since it was unable to collect a third sample of large storage roots for 'Hernandez' in the control row, we included storage root size as a variable in the general linear models. However, the content of minerals in storage roots was not influenced by their size (all p values > 0.12), so lacking one replicate of large storage roots would not alter the overall results. The Tukey–Kramer means separation test was used for all analyses to determine which means differed ($p < 0.05$).

There was no difference in the mass of sweet potatoes greens among varieties in the green roof planters (F = 0.68, DF = 6, p = 0.67) or the field rows (F = 1.41, DF = 6, p = 0.25). The mean yield harvested from each plant during each harvest was 70.7 ± 3.7 g and 299 ± 17.6 g in green roof planters and field rows, respectively. If the primary purpose is to grow sweet potato plants to harvest greens, then other characteristics of the plant, such as habit, taste, and nutrient content, may dictate which variety to select rather than yield. However, there is some evidence that other varieties that we largely did not use in our trial could differ in their yield of leaves (Anabire, 2021), so future research investigating more varieties in common urban and rural production systems is needed.

Varieties differed in the mass of storage roots they produced (Table 1). The variety Bunch Porto Rico recorded highest production of storage roots followed by Georgia Jets, Hernandez, and O'Henry in the control field row, yielded approximately 3 to 5.6 times more mass of storage roots than 'White Hamon,' which was the lowest producer. The average mass of storage roots across all varieties in the control row was nearly 4.8 times more than when greens were clipped (Table 1), indicating that harvesting greens severely reduced the production of storage roots. Previous research found that harvesting sweet potato leaves mostly did not reduce production of storage roots (Anabire, 2021). The incongruence between present results is likely due to the harvesting method. Vines were harvested in addition to leaves and removed most of the aboveground biomass each time harvested, whereas, Anabire (2021) removed only a small portion of the young, aerial leaves. The immature leaves are the most frequently consumed, but all leaves and stems are edible and can be prepared in multiple ways. Harvesting leaves repeatedly from sweet potato plants has been shown to decrease the nutrient content of leaves in the second and third harvests (Pace et al., 1988). The present results taken together with these other studies suggest that a grower needs to consider their priorities before developing a harvesting strategy for sweet potato greens and storage roots. Maximizing yield of storage roots may require that only a small portion of leaves be removed once, or a larger quantity removed late in the development of storage roots. This harvesting strategy may also maximize nutrient content of leaves (Pace et al., 1988; Suárez et al., 2020), although leaf quality declines very late in the season, so nutrient content might, too. Alternatively, maximizing yield of leaves and harvesting efficiency may require repeated harvests of most of the aboveground biomass.

Table 1 : Mean mass (g) of sweet potato storage roots across seven varieties and two treatments

Variety	Treatment	
	Clipped	Control
Beauregard	137.3^{a}	868.5^{bc}
Bunch Porto Rico	352.0^{a}	1130.2^{ab}
Georgia Jets	332.5_{a}	2004.4^{a}
Ginseng	294.5^{a}	748.5^{bc}
Hernandez	220.9^{a}	1254.6^{ab}
O'Henry	287.2^{a}	1377.3^{ab}
White Hamon	1.7 b	356.9^{c}
Treatment mean	232.3	1105.8

clipped = vines and leaves were harvested; control = vines and leaves were not harvested.

Means with different letters within a column are different (Tukey–Kramer means separation test, $p < 0.05$). Treatment means are also different ($F = 160.6$, df = 1, $p < 0.01$).

The amount of eight minerals in storage roots differed across treatments, with higher levels of boron, calcium, copper, iron, phosphorous, potassium, sulfur, and zinc in plants where greens had been clipped (Table 2). The difference in calcium was especially large, with the amount of calcium in storage roots almost double when greens were clipped than in storage roots from the control field row. The mechanism that resulted in higher amounts of some minerals in storage roots when greens were clipped is unknown. Perhaps since storage roots are reserves of carbohydrates, minerals, and vitamins that enable plant growth, the higher minerals in storage roots when greens were harvested could be due to the fact that there were times the plants had very little aboveground biomass to which to direct these reserves of energy. Increases in nutrients in storage roots are a positive development of removing greens, but a much lower yield of storage roots is a negative tradeoff.

Table 2 : Mean of minerals mg/kg that differed in storage roots of sweet potatoes across two treatments

Mineral	Treatment		*p*
	Clipped	Control	
Boron	9.7^{a}	7.4^{b}	<0.01
Calcium	3886^{a}	1862^{b}	<0.01
Copper	9.6^{a}	5.9^{ab}	<0.01
Iron	82.0^{a}	42.0^{b}	<0.01
Magnesium	1052	954	0.28
Manganese	44.7	30.2	0.05
Phosphorous	2529^{a}	1984^{b}	<0.01
Potassium	$18{,}298^{a}$	$16{,}417^{b}$	0.02
Sodium	488	518	0.85
Sulfur	1122^{a}	857^{b}	<0.01
Zinc	10.4^{a}	6.5^{b}	<0.01

clipped = vines and leaves were harvested; control = vines and leaves were not harvested.

Means with different letters within a row are different (Tukey–Kramer means separation test, $p < 0.05$).

The sweet potato varieties did not influence the yield of greens. Also, harvesting greens severely reduced the harvested mass of storage roots, but increased the content of eight minerals in storage roots. Urban farmers may have to decide whether harvesting greens or storage roots is their primary objective if harvesting the former limits the latter. Future research should explore the timing of harvesting greens and the amount taken to see if different methods allow for a good harvest of storage roots that are high in nutrients and also elucidate the mechanism that results in increased mineral concentration in storage roots when greens are harvested. Overall, sweet potato greens are an underused vegetable that grows well in urban areas and are highly nutritious, so there is a need for more trials in urban environments that maximizes its production, economic value, and nutritional content.

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