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Evaluation of colour-fleshed sweet potato genotypes for higher storage root yield and nutritional quality

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Abstract

Higher storage root yield with nutrient-rich sweet potato genotypes is essential to identify for the growers. Therefore, seven colour-fleshed sweet potato genotypes were investigated based on their growth, yield and nutritional qualities. This study explored the improved yield and nutritional quality of sweet potatoes. Sweet potato genotypes *viz.,* G_1 (BAU Sweet potato-2), G_2, G_3 (BAU Sweet potato-4), G_4 (BAU Sweet potato-3), G_5 (BARI Sweet potato-2), G_6 (BAU Sweet potato-1) and G_7 were tested following randomized complete block design with three replications. Results showed that sweet potato genotypes exhibited wide variations in growth, storage root yield and quality traits. At harvest, vine length and leaf area were most significant in G_6 and G_3, while the highest fresh weight and gross yield were obtained from G_5, which was statistically identical to G_4. Except for twigs, anthocyanin, starch and sugar, the maximum storage contents were found in the roots. G_1 contained the maximum anthocyanin and starch, while G_2 contained the highest sugar. β-carotene content was the highest in twigs, followed by leaves, leaf petioles and storage roots. The maximum β-carotene was obtained from G_3, followed by G_2 and G_1. Except for Ca, twigs retained maximum K, P, Fe and Zn, while Ca was the highest in leaves. G_2 contained the maximum Ca and K, while G_1, rich in P and G_7, retained the maximum Fe and Zn. It can be concluded that G_5, G_4, G_1 and G_6 are the yield potential genotypes, while G_2, G_3 and G_7 are anthocyanins, β-carotene, Fe and Zn rich.

Keywords

anthocyanin; color-fleshed sweet potato; minerals; starch; sugar; β-carotene

Introduction

Sweet potato (*Ipomoea batatas* L.) is a perennial crop under the family Convolvulaceae. Leaves and storage roots of sweet potatoes are very nutritious and are used as a staple food in many countries worldwide. It is grown throughout the humid tropical and subtropical regions of the world. Sweet potato is an excellent source of vitamins and antioxidants (1). Additionally, it contains significant amounts of fibre, zinc, potassium, sodium, manganese, calcium, magnesium and iron (2). Sweet potato is a highly nutritious food crop that produces better and faster under diverse agroecological conditions using minimum inputs and significantly impacts combatting malnutrition and poverty (3). It is an excellent source of vitamins A, C and E, as well as dietary fibre, calcium, potassium and iron and it contains low fat and cholesterol. It also contains moderate quantities of thiamine, riboflavin, niacin, pantothenic acid, pyridoxine and folic acid. Moderate amounts of sodium, magnesium, manganese and zinc are also present in sweet potato (3). Orange–fleshed sweet potato varieties are good sources of β-carotene, while purple-fleshed ones are rich in anthocyanin and these two antioxidants are thought to prevent chronic heart diseases and cancer (1). Increased availability of β-carotene and crude protein content is suitable for human nutrition (4).

Mature and young leaves of sweet potatoes are an excellent source of multiple water-soluble vitamins A, C, thiamin, riboflavin and vitamin B6, which are essential for human health (5). Sweet potato contains many vitamins, minerals and bioactive constituents (phenolic compounds, anthocyanins) (6). In another report (7), it was claimed that sweet potato leaves are an essential source of minerals, especially calcium, magnesium, phosphorus and potassium. It has also been noticed that the colour-fleshed sweet potato contains plenty of coloured pigments, a significant component that functions as an antioxidant in the human body. So, consuming sweet potato tuberous roots and leaves can remedy night blindness. Anthocyanins, β-carotene and minerals are the key constituents for which colour-fleshed sweet potatoes have already achieved acceptability among health-conscious people.

The farmers in Bangladesh are still using local cultivars for cultivation, which have low-yielding capacity due to the lack of vine cuttings of improved sweet potato variety. Currently, antioxidant-rich colour-fleshed sweet potato is gaining popularity among the health-conscious people of the country. As a result, farmers are looking for high-yielding colour–fleshed sweet potatoes for cultivation. Therefore, evaluating colour–flashed sweet potato genotypes is necessary to find high-yielding and nutrition-rich candidates. Department of Horticulture, Bangladesh Agricultural University has collected a dozen colour–flashed sweet potato genotypes from home and abroad. In 2020, Bangladesh Agricultural University released four sweet potato varieties based on the yield performance, namely BAU Sweet potato-1 (Orange flesh), BAU Sweet potato–2 (Purple flesh), BAU Sweet potato-3 (Cream flesh) and BAU Sweet potato-4 (Deep cream flesh). These four released varieties, along with three other potential colour-fleshed sweet potato genotypes, were included in this experiment.

Minimal research findings on the growth, storage root yield, biochemical and nutrient contents in twigs, leaves, leaf petioles and storage roots of these colour-flashed sweet potato genotypes are available. Therefore, this study has been conducted to evaluate plant growth, storage root yield, anthocyanin, β-carotene, starch, sugar and mineral contents in twigs, leaves, leaf petioles and storage roots of seven colour-fleshed sweet potato genotypes and find out high-yielding and nutrition rich genotypes for cultivation in Bangladesh.

Materials and Methods

Experimental site

The field experiment was conducted at the Horticulture Farm, Department of Horticulture, Bangladesh Agricultural University, Mymensingh, from November 2019 to June 2020. The experimental field site is located at 24.77 °N Latitude and 90.41 °E Longitude and approximately 14 m above sea level. The soil texture of the experimental field was silty loam. The field area is under a sub-tropical climatic zone, with high natural rainfall, relative humidity and temperature during summer and low temperature, with low moisture prevailing during winter. The average maximum-minimum temperature and sunshine hour during the experimental period were collected from the university weather yard and the data were 25.8 °C, 13.6 °C and 5.8 h, respectively.

Experimental treatments and design

Seven sweet potato genotypes were used as experimental treatment for this study. The genotypes are G_1: BAU Sweet potato-2 (Purple flesh), G_2 (Mixture of purple and white flesh), G_3: BAU Sweet potato-4 (Deep cream flesh), G_4: BAU Sweet potato–3 (Cream flesh), G_5: BARI Sweet potato-2 (Orange flesh), G_6: BAU Sweet potato-1(Orange flesh) and G_7: (Whitish flesh). The study was conducted following a randomized complete block design with three replications. The prepared land was divided into three blocks, each of which was comprised of seven plots. The treatments were randomly assigned to each block. The size of the unit plot was 1.2 m × 1.2 m. The space between blocks and plots was 50 cm and 30 cm, respectively.

Planting of vine cuttings and other cultural operations

Diseases-free vine cuttings with 18-20 cm length and 3-5 nodes of sweet potato genotypes were planted on 20th October 2019 in well-prepared experimental plots with recommended planting spacing (60 cm× 30 cm). The ridge method was adopted for cultivating healthy sweet potatoes. Recommended doses of manures and fertilizers (well-decomposed cow dung 10 t, urea 250 kg, Triple Super Phosphate 175 kg, Muriate of potash 250 kg, Gypsum 75 kg and $ZnSO_4$ 10 kg/ha) were applied during land preparation and growth stages. Intercultural operations such as weeding, vine lifting, top dressing of remaining fertilizers and earthing up were done thrice. Irrigation water was applied after each fertilizer application. No insects or disease infestations were found to damage the crop in the experimental plots, but a few mice attacked the storage roots before harvesting. The mouse was controlled by applying phostoxin aluminium phosphide tablets. Sweet potato was harvested on 10th March 2020, 140 days after vine planting.

The length of the vine, internode, leaf blade and leaf petiole were measured using a ruler from five selected plants in each replication. Leaf area was measured using a leaf area meter (Model LI-3100C, LI-COR Biosciences, USA). Data on the sweet potatoes' storage roots were recorded after the crops. The number, length, breadth and fresh weight of the storage roots per plant were recorded. The gross yield of storage roots per hectare was calculated from the yield recorded from each plot.

Anthocyanin

Anthocyanin contents in twigs, leaves, leaf petioles and storage roots were determined using the pH differential method (8). In brief, a sample solution was diluted with two different buffers (pH 1 and pH 4.5) and then measured at 520 and 700 nm, respectively. A sample of 100 g was taken and 100 mL of distilled water was added to make a homogenized solution. Then, 10 g of homogenized solution was taken and 10 mL of 70 % ethanol was added. pH 3.0 was adjusted to 3.0. Then, the solution was shaken at 30 ^{0}C for 4 hrs and centrifuged at 1440 x g for 15 min. The supernatant was collected and pH adjustment was performed at 1.0 and 4.5 using a buffer solution. Then, absorbance was read at 420 nm and 700 nm, respectively and measured as per Equation 1-2.

Total absorbance (A) =

$$(A520 - A700)\ pH\ 1.0 - (A520 - A700)\ pH\ 4.5 \quad \text{(Eqn. 1)}$$

$$\text{Total anthocyanin (g/kg)} = \frac{MW \times A \times DF}{\varepsilon \times C} \times 1000 \quad \text{(Eqn. 2)}$$

Here, MW=molecular weight of cyanidin-3- glucoside (449.2 g/mol), ε =molar extinction coefficient of cyanidin-3-glucoside (26900), DF=dilution fold (10), c=sample concentration.

β-carotene

β-carotene contents of sweet potato twigs, leaves, leaf petioles and storage roots were determined (9). In brief, dry sample of sweet potato twigs, leaves, leaf petioles and storage roots were homogenized with a pestle and mortar. Sixteen mL of acetone-hexane (2:3) solvent was added to 1.0 g of proper homogenate and mixed in a test tube. Then, the test tube was centrifuged for 5 min at 4000 rpm. Two phases were separated and the supernatant was taken in another test tube. Finally, the supernatant was taken in a cuvette and the optical density was measured at 663, 645, 505 and 453 nm wavelengths in a spectrometer using a blank hexane solvent. β-carotene was calculated according to the formula given in Equation 3.

$$\left.\begin{array}{l}\beta\text{-carotene}\\ \text{(mg/100 mL}\\ \text{of extract)}\end{array}\right\} = 0.216\times A_{663} - 1.22\times A_{645} - 0.304\times A_{505} + 0.452\times A_{453} \quad \text{(Eqn. 3)}$$

Starch

Starch contents were extracted from sweet potato twigs, leaves, leaf petioles and storage roots in hot 80 % ethanol to eliminate sugars, followed by centrifugation and retaining the residue. They were determined through anthrone reagents (10). In brief, 0.5 g of sample homogenized residue was washed repeatedly with 80 % ethanol till the washings did not produce colour with anthrone reagent. The residue was dried using a water bath and 50 mL of water and 6.5 mL of 52 % perchloric acid were added. Extraction was done at 0 $^\circ$C, followed by centrifugation and saving the supernatant. The extraction was repeated using fresh perchloric acid. Then, the supernatants and 100 ml of solution were centrifuged and pooled. A supernatant of 0.2 mL was taken and mixed with water to make a volume of 1 mL. The standards were prepared by taking 0.2, 0.4, 0.6, 0.8 and 1 mL of the working standard and the volume was 1 mL in each tube with distilled water. Four mL of anthrone reagent was added to each tube. Heating was done for 8 min in a water bath. Then, cooling was done rapidly and a reading of the intensity of green to dark green color at 630 nm was taken. Glucose content was figured out in the sample using the standard graph. The value was multiplied by a factor of 0.9 to get the starch content of the unknown sample.

Sugar

The sugar contents of sweet potato leaves, leaf petioles, twigs and storage roots were determined (11). In brief, from a sample of 100 mL, the sugar was extracted using 80 % ethanol twice (5 mL each time). The supernatant was collected and evaporated in a water bath at 80 °C. The sugar was dissolved in 10 mL of water. 0.1 mL of aliquot was taken in a separate test tube. 0.2, 0.4, 0.6, 0.8 and 1 mL of working standard solution were taken into a series of test tubes. Then, the volumes were made to 2 mL with distilled water in the sample and standard tubes. Another test tube was ready with 2 mL of distilled water alone to set a blank. One mL of alkaline copper tartrate reagent was added to each tube. The tubes were put in boiling water for ten min. Then, the tubes were cooled and 1mL of arsenomolibolic acid reagent was added. The volume was made to 10 mL by adding water to each. After 10 min the absorbance of blue color at 620 nm was recoded. Thereafter, the amount of sugar was calculated from the drawn graph.

Absorbance corresponds to 0.1ml of test = x mg of glucose

(Eqn. 4)

So, 10 mL contains = x/0.1 × 10 mg of glucose = % sugar

Nutrients

Mineral contents (P, K, Ca Zn and Fe) of different sweet potato genotypes were determined by the method of the Association of Official Agricultural Chemists guidelines (12). In brief, oven-dried (70^{0}C) samples of sweet potato twigs, leaves, leaf petioles and storage roots were grounded by a grinding machine to pass through a 20 mesh sieve. The ground plant materials (twigs, leaves, leaf petioles and sweet potato storage roots) were stored in air-tight zipper bags for further analysis.

About 0.5 g dried grind samples of twigs, leaves, leaf petioles and sweet potato storage roots were digested with 10 ml nitric acid and hydrochloric acid at 5:1 in a volumetric flask. The mixture was kept overnight for pre-digestion. After completing pre-digestion, gradually, the mixture was heated at 120^{0}C and 180^{0}C for 1 hr and 1-1.5 hrs, respectively. Then, the digestion process was completed and the digested mixture was cooled, filtered and made up to 50 mL with di–ionized distilled water. P, K, Ca Zn and Fe were determined by the atomic absorption spectrometry (Shimadzu Atomic Absorption Spectrophotometer AA-6800) using a different standard curve for each.

Statistical analysis

The data on different traits were statistically analyzed using the MSTAT Statistical Package Program. The means for all the treatments were calculated and the variance analysis (ANOVA) for all the parameters was compared using Duncans'

Multiple Range Test at 5% and 1% probability levels.

Results and Discussion

Growth

Morphological characters of selected colour-fleshed sweet potato genotypes significantly varied among each other, including vine length, length of vine internode, the diameter of vine internode, no. of vine internode, mature leaf blade length, petiole length leaf area (cm^2) (Table 1). Vine length is essential in arranging plant populations in a given space. It was observed that genotype G_6 had the longest vines (167.44 cm) and the longest internode length (7.20 cm), whereas genotype G_3 had the shortest vine length (51.67 cm) and shortest vine internode length (1.84 cm) (Table 1). Sweet potato genotypes had vine length variations ranging from 75 cm to 99 cm, which was a substantial variation (13). Significant differences in vine length were also detected across the orange-fleshed sweet potato (OFSP) types assessed (14,15). These findings are in agreement with the results of the present study. Another research (16) indicates that the vine internode length variations across sweet potato genotypes ranged from 2 to 6 cm.

Leaves are an essential organ for plants to sustain photosynthetic activity in the presence of light energy. The highest mature leaf blade length was (9.30 cm) found in G_4, followed by G_7 (9.15 cm) and the lowest (6.87 cm) in G_6 (Table 1). However, G_3 showed the highest petiole length (16.13 cm), while genotype G_6 had the lowest (6.61 cm) (Table 1). Sweet potato genotypes had petiole length variations ranging from 6 to 9.06 cm (17). The largest leaf area was (179.91 cm^2) observed in G_3, followed by G_7 (169.80 cm^2), G_5 (160.44 cm^2) and the smallest area in G_4 (73.22 cm^2) (Table 1). The leaf area variations among sweet potato genotypes ranged from 28 cm^2 to 70.99 cm^2 (18). The tested sweet potato genotypes showed significant variation in morphological characteristics. Additionally, research indicates substantial variations among the sweet potato genotypes (19, 20). The impact of environmental and genetic factors determines any plants' morphological traits. The environmental factors can be in the form of soil conditions, climate, or even the availability of water (21). It was noticed that the morphological characters include petiole, leaf venation and stem, sweet potato skin and flesh colour that are stable and are not impacted by environmental factors. On the other hand, the morphological characters such as tendril length, leaf stalk length, leaf size and tuber yield are easily changed due to environmental factors (22).

Yield contributing traits

Yield contributing characters of tested genotypes of colour-fleshed sweet potatoes showed significant variation. These traits included no. of storage roots, length of storage root, breadth of storage root, fresh weight of storage roots per plant and gross yield (t/ha). The genotype G_4 had the most significant number (3.60), whereas the genotype G_2 had the lowest number (0.66) (Table 2). Another researcher indicates considerable variance in sweet potato genotypes ranging from 1.73 to 3.80 storage roots per plant (22). Storage root/ plant length varied significantly between sweet potato genotypes, ranging from 10.3 cm to 25.10 cm.

The genotype with the most significant length was G_4, while the genotype with the shortest length was G_2 (10.38 cm) (Table 2). Between 3.08 cm and 5.98 cm, the breadth of storage root/plant of different sweet potato genotypes varied significantly. The genotype G_5 had the maximum breadth (5.93 cm), whereas the genotype G_2 had the lowest breadth (3.03 cm) (Table 2). Previous research indicates the length and breadth of sweet potato storage roots (15, 23). The cultivars chosen, the storage roots length, breadth and shape all matter when sold for industrial processing (22). The tubers' form significantly impacts the speed and effectiveness of the peeling and trimming operation (23).

Across sweet potato genotypes, the storage root weight per plant varied greatly, ranging from 41.08 to 612.72 g. The genotype G_5 produced the highest fresh weight per plant (612.72 g), which was statistically equal (570.55 g) to G_4 and the lowest fresh weight (41.08 g) from the genotype G_2 (Table 2). The storage root is the primary yield of the sweet potato plant and it has a variable quantitative character. A wide range of variability was found in storage root yield (24). The weight of storage roots per plant measured the sweet potatoes' total storage root sink capacity. It was reported that the variation in storage root yield per plant in different genotypes may be due to the difference in the number of storage roots per plant, the size of individual roots or the difference in bulking rate (24, 25). The gross yield varied significantly among the genotypes. The highest gross yield was obtained from genotype G_5 (38.57 t/ha), which was statistically identical to G_4 (38.23 t/ha) and the lowest yield

Table 1. Plant growth traits of colored sweet potato genotypes

Genotype	Vine length (cm)	Vine internode length (cm)	Leaf blade length (cm)	Petiole length (cm)	Leaf area (cm^2)
G_1 (BAU Sweet potato-2)	113.28^{cd}	3.77^{c}	9.14^{ab}	9.29^{de}	122.89^{b}
G_2	89.33^{de}	2.53^{cd}	7.92^{c}	8.27^{de}	105.24^{bc}
G_3 (BAU Sweet potato-4)	51.67^{f}	1.84^{d}	8.27^{bc}	16.13^{a}	179.91^{a}
G_4 (BAU Sweet potato-3)	82.01^{e}	2.80^{cd}	9.30^{a}	12.83^{bc}	73.22^{d}
G_5 (BARI Sweet potato-2)	121.11^{bc}	2.85^{cd}	8.63^{abc}	13.58^{ab}	160.44^{a}
G_6 (BAU Sweet potato-1)	167.44^{a}	7.20^{a}	6.87^{d}	6.61^{e}	79.08^{cd}
G_7	149.22^{ab}	5.31^{b}	9.15^{a}	10.47^{cd}	169.80^{a}
$LSD_{0.05}$	29.15	1.30	0.88	3.02	28.54
$LSD_{0.01}$	40.87	1.82	1.23	4.23	40.02
Level of significance	**	**	**	**	**
CV (%)	14.82	19.42	5.82	15.37	12.61

Values with different superscripts in the same column are statistically different (α = 0.05)

Table 2. Yield-contributing traits of colored sweet potato genotypes

Genotype	No. of storage roots/ plant	Length of storage root (cm/plant)	Breadth of storage root (cm/plant)	Fresh weight of storage root (g/plant)	Gross yield (t/ha)
G_1 (BAU Sweet potato-2)	3.06^{a}	16.89^{abc}	4.78^{ab}	415.23^{b}	30.00^{b}
G_2	0.66^{c}	10.38^{c}	3.03^{c}	41.08^{d}	5.97^{d}
G_3 (BAU Sweet potato-4)	1.88^{b}	18.16^{abc}	3.61^{bc}	329.37^{bc}	16.78^{c}
G_4 (BAU Sweet potato-3)	3.62^{a}	25.10^{a}	4.65^{ab}	570.55^{a}	38.23^{a}
G_5 (BARI Sweet potato-2)	3.55^{a}	18.94^{ab}	5.93^{a}	612.72^{a}	38.57^{a}
G_6 (BAU Sweet potato-1)	2.55^{ab}	13.19^{bc}	4.45^{abc}	345.43^{bc}	22.27^{c}
G_7	3.55^{a}	18.27^{abc}	4.06^{bc}	281.44^{c}	19.66^{c}
$LSD_{0.05}$	1.14	8.26	1.59	127.76	5.70
$LSD_{0.01}$	1.60	11.58	2.23	179.13	8.00
Level of significance	**	**	**	**	**
CV (%)	23.84	26.87	20.47	19.36	13.09

Values with different superscripts in the same column are statistically different (α = 0.05)

from G_2 (5.97 t/ha) (Table 2). Variations in storage roots gross yield among the sweet potato were also noticed, which ranged from 7.95 to 35.44 t/ha (22).

Anthocyanin

Most sweet potato varieties have white or yellow flesh, but others have orange or purple flesh that contains anthocyanins or carotenoids. The most common subclass of coloured flavonoids, anthocyanins, are found in many plants as red, purple, or blue pigmentations (26). Different kinds of sweet potatoes exhibited various colour values. There are several kinds of pigments present in sweet potato, such as anthocyanidins, which present red or purple colour, β-carotene which appears dark green, yellow or orange colour and flavonoids, which produce yellow colour. In other words, purple sweet potato species mainly contain anthocyanins; however, primarily yellow and orange sweet potato species possess carotenoids (β-carotene) (27).

In the current study, genotype substantially impacted the anthocyanin concentration of the sweet potatoes' twigs, leaves, leaf petioles and storage roots. The G_7 showed the highest anthocyanin concentration across the board (72.12 mg/100g DW in leaves, 77.94 mg/100g DW in leaf petioles and 78.12 mg/100g DW in twigs). Petiole anthocyanin levels in G_2 were similarly more significant (78.39 mg/100g DW). Whereas the sweet potato leaves from G_1 displayed the lowest anthocyanin level (62.30 mg/100g DW), the twig from G_2 displayed the lowest anthocyanin content (71.32 mg/100g DW) and the leaf petiole from G_5 displayed the lowest anthocyanin content (71.21 mg/100g DW). G_1 had the highest anthocyanin concentration in the sweet potato storage roots (190.12 mg/100g DW), whereas G_7 had the lowest (113.20 mg/100g DW) (Table 3). Several genotypes of sweet potatoes have varying anthocyanin contents in their leaves, stems and storage roots (28).

β-carotene

The levels of β-carotene in the sweet potatoes' twigs, leaves, leaf petioles and storage roots were significantly influenced by the genotype of the sweet potato. The amounts β-carotene found in twigs, leaves, leaf petioles and storage roots were 84.56-172.86 mg/100 g DW, 69.50-88.43 mg/100 g DW, 120-187.59 mg/100 g DW and 17.03-35.03 mg/100 g DW, respectively (Table 4). The carotenoid concentration of all plant parts is higher in leaves (16.43-34.47 mg/100 g DW) than in storage root (not detected -11.1 mg/100 g DW) (29). The amount of β-carotene found in the storage roots is comparable to the 5.9 mg/100 g and 0.38 mg/100 g (30, 31). However, the amount of β-carotene in the leaves was averaged at 53.32 mg/100 g for Tanzanian sweet potatoes (32). While the β-carotene contents in white flesh sweet potato ranged from 91.95± 2.05 μg/g DW (33). This variation in β-carotene contents may be due to the differences in cultivars, weather and soil properties.

Starch

Percent starch in the sweet potatoes' twigs, leaves, leaf petioles and storage roots were significantly influenced by genotype. Starch content found in twigs, leaves, leaf petiole and storage roots was 13.87-18.76 %, 18.43-21.36 %, 16.14-21.20 %, 35.70-42.43 % in DW, respectively (Table 5). Similar findings reported that the starch content of leaves and storage roots of sweet potatoes varied from 13.40-18.64 % to 50.45–54.53 %, respectively (18). They reported that the starch content of the storage roots of sweet potatoes varied

Table 3. Anthocyanin contents in twig, leaves, leaf petiole and storage root of sweet potato

Genotype	Anthocyanin content (mg/100g DW)			
	Twigs	Leaves	Leaf petioles	Storage roots
G_1 (BAU Sweet potato-2)	71.74^{ef}	62.30^{d}	74.89^{c}	190.12^{a}
G_2	71.32^{f}	64.30^{c}	78.39^{a}	170.31^{b}
G_3 (BAU Sweet potato-4)	71.90^{e}	64.12^{c}	76.34^{b}	114.70^{de}
G_4 (BAU Sweet potato-3)	74.21^{b}	66.76^{b}	76.12^{b}	117.29^{cd}
G_5 (BARI Sweet potato-2)	72.54^{d}	64.23^{c}	71.21^{e}	118.23^{c}
G_6 (BAU Sweet potato-1)	73.21^{c}	63.77^{c}	73.31^{d}	119.21^{c}
G_7	78.12^{a}	72.12^{a}	77.94^{a}	113.20^{e}
$LSD_{0.05}$	0.48	1.25	0.73	3.07
$LSD_{0.01}$	0.68	1.75	1.02	4.30
Level of significance	**	**	**	**
CV (%)	0.37	1.07	0.54	1.28

Values with different superscripts in the same column are statistically different (α = 0.05)

Table 4. β-carotene contents in twigs, leaves, leaf petioles and storage roots of sweet potato

Genotype	β-carotene contents (mg/100g DW) in			
	Twigs	Leaves	Leaf petioles	Storage roots
G_1 (BAU Sweet potato-2)	163.41^{bc}	138.15^{c}	78.20^{b}	30.99^{b}
G_2	168.37^{b}	108.34^{e}	74.33^{c}	32.27^{b}
G_3 (BAU Sweet potato-4)	187.59^{a}	150.38^{b}	88.43^{a}	21.51^{d}
G_4 (BAU Sweet potato-3)	138.23^{e}	164.83^{a}	69.50^{d}	17.03^{e}
G_5 (BARI Sweet potato-2)	120.09^{f}	172.86^{a}	71.21^{cd}	35.03^{a}
G_6 (BAU Sweet potato-1)	153.76^{cd}	121.04^{d}	74.34^{c}	34.91^{a}
G_7	149.23^{d}	84.56^{f}	73.76^{c}	24.61^{c}
$LSD_{0.05}$	10.98	10.99	3.41	2.31
$LSD_{0.01}$	15.39	15.40	4.78	3.24
Level of significance	**	**	**	**
CV (%)	4.00	4.60	2.53	4.64

Values with different superscripts in the same column are statistically different (α = 0.05)

Table 5. Starch contents in twigs, leaves, leaf petioles and storage roots of sweet potato

Genotype	Starch contents (% of DW) in			
	Twigs	Leaves	Leaf petioles	Storage roots
G_1 (BAU Sweet potato-2)	17.80^{bcd}	18.76^{a}	20.28^{ab}	42.43^{a}
G_2	16.14^{d}	13.87^{d}	19.70^{bc}	38.70^{b}
G_3 (BAU Sweet potato-4)	21.20^{a}	14.11^{d}	21.33^{a}	37.35^{c}
G_4 (BAU Sweet potato-3)	17.34^{cd}	17.27^{bc}	21.36^{a}	36.20^{e}
G_5 (BARI Sweet potato-2)	19.21^{b}	16.31^{c}	19.70^{bc}	35.70^{f}
G_6 (BAU Sweet potato-1)	18.36^{bc}	17.20^{bc}	18.43^{c}	36.81^{d}
G_7	17.21^{cd}	18.16^{ab}	19.70^{bc}	37.50^{c}
$LSD_{0.05}$	1.70	1.02	1.32	0.50
$LSD_{0.01}$	2.39	1.42	1.85	0.70
Level of significance	**	**	**	**
CV (%)	5.26	3.45	3.69	0.74

Values with different superscripts in the same column are statistically different (α = 0.05)

from 19.9 % to 28.5 %. However, in an earlier study, (34) reported that purple-fleshed sweet potato contained 59.42 % starch. In the current study, genotype G_1 is a purple-fleshed genotype with 42.43 % starch.

Sugar

The genotype of the sweet potato was discovered to have a substantial impact on the % sugar content in the sweet potatoes' twigs, leaves, leaf petioles and storage roots. Percent sugar present in twigs, leaves, leaf petioles and storage roots in dry weight was 3.22-4.87 %, 7.01-9.31 %, 5.02-7.35 % and 14.28-17.22 %, respectively (Table 6). Research indicates that the total sugar content of the sweet potato genotypes' storage root ranged from 4.74 to 6.85 % (35).

Nutrients

There was a significant difference among the tested sweet potato genotypes in Ca, K, P contents (% of DW) and Fe, Zn (in mg/kg) of twigs, leaves, leaf petioles and storage roots. Considering all genotypes, G_5 contained the highest Ca (1.72 %), but G_1 had the lowest Ca (1.10 %), which was statistically equivalent to G_7 (1.15 %) in sweet potato twigs (Table 7). In leaves, G_2 had the highest Ca (3.48 %), whilst G_7 had the lowest (2.36 %) Ca (Table 7). In addition, a study found (18) that the Ca content of leaves was 0.80 % ± 0.01 % -1.29 % ± 0.03 %. According to the nutritional quality index, sweet potato leaves are good protein, fibre and mineral sources, especially K, P, Ca, Mg, Fe, Mn and Cu (7).

In the sweet potato storage roots, G_5, which was statistically equal to G_3 (1.29 %), had the lowest Ca content (1.18 %), whereas G_2 had the highest (1.72 %) Ca level of all the

Table 6. Sugar contents in twigs, leaves, leaf petioles and storage roots

Genotypes	Sugar contents (% of DW) in			
	Twigs	Leaves	Leaf petioles	Storage roots
G_1 (BAU Sweet potato-2)	7.01^{e}	4.87^{a}	6.80^{b}	16.39^{b}
G_2	6.74^{f}	3.41^{c}	5.35^{ef}	17.22^{a}
G_3 (BAU Sweet potato-4)	6.81^{f}	3.47^{c}	5.02^{f}	15.31^{c}
G_4 (BAU Sweet potato-3)	8.20^{c}	3.48^{c}	5.88^{d}	14.28^{d}
G_5 (BARI Sweet potato-2)	7.55^{d}	3.22^{d}	7.35^{a}	15.26^{c}
G_6 (BAU Sweet potato-1)	8.88^{b}	3.27^{d}	6.28^{c}	16.28^{b}
G_7	9.31^{a}	3.99^{b}	5.38^{e}	15.33^{c}
$LSD_{0.05}$	0.20	0.09	0.35	0.47
$LSD_{0.01}$	0.28	0.13	0.49	0.66
Level of significance	**	**	**	**
CV (%)	1.43	1.44	3.25	1.68

Values with different superscripts in the same column are statistically different (α = 0.05).

Table 7. Calcium contents in twigs, leaves, leaf petioles and storage roots of sweet potato.

Genotype	Calcium contents (% of DW) in			
	Twigs	Leaves	Leaf petioles	Storage roots
G_1 (BAU Sweet potato-2)	1.10^{c}	3.18^{ab}	0.75^{c}	1.50^{bc}
G_2	1.33^{b}	3.48^{a}	0.80^{ab}	1.72^{a}
G_3 (BAU Sweet potato-4)	1.35^{b}	3.39^{ab}	0.80^{ab}	1.29^{d}
G_4 (BAU Sweet potato-3)	1.30^{b}	3.19^{ab}	0.80^{ab}	1.30^{cd}
G_5 (BARI Sweet potato-2)	1.72^{a}	3.03^{bc}	0.76^{bc}	1.18^{d}
G_6 (BAU Sweet potato-1)	1.41^{b}	2.70^{cd}	0.82^{a}	1.37^{cd}
G_7	1.15^{c}	2.36^{d}	0.54^{d}	1.66^{ab}
$LSD_{0.05}$	0.12	0.41	0.05	0.20
$LSD_{0.01}$	0.17	0.58	0.06	0.28
Level of significance	**	**	**	**
CV (%)	5.00	7.66	3.43	7.88

Values with different superscripts in the same column are statistically different (α = 0.05).

genotypes (Table 7). In contrast, in a range of Ca 20-41 mg/100 g, Ca contents of the storage roots of the studied sweet potato genotypes ranged from 0.23 % ± 0.01 %-0.32 % ± 0.01 % (19, 36). Also, the Ca contents of storage roots of 10 sweet potato genotypes ranged from 23.04 to 29.97 mg/100 g (37).

Genotype G_2 showed the highest K content (3.09 %), whereas G_5 had the lowest K (1.84 %) in twigs of sweet potato. G_6 exhibited the highest K content (1.67 %), whereas G_7 had the lowest K (1.49 %) in sweet potato leaves (Table 8). In addition, a group of researchers reported that the K content in leaves was 1.22 % ± 0.01 % -1.41 % ± 0.01 % (18). In leaf petioles, G_3 had the greatest K level (1.56 %) among all the genotypes. G_7 had the lowest K level (0.73 %) in storage roots (Table 8). These findings are in agreement with the results of (18). They noticed that K contents in storage roots ranged from 0.88 % ± 0.01 % -1.24 % ± 0.04 %. In addition, another research (38) indicates that the K content of sweet potatoes was 300.02 mg/100 g, although it claimed that it ranged from 245 to 403 mg/100 g (36). Research indicates that the range of K content in sweet potato genotypes varied from 308.67 to 328.67 mg/100 g.

G_1 contained the highest P (0.49 %), whereas G_5 contained the lowest P (0.34 %) content in sweet potato twigs. In leaves, G_7 had the highest P (0.38 %) and G_1 had the lowest P contents (0.10 %), which was statistically equal to G_5 (0.11 %) and G_6 (0.11 %) (Table 9). A study reported that the P contents of leaves were 5.25 % ± 0.02 % -6.96 % ± 0.04 % (18). G_5 contained the highest P (0.53 %) in leaf petiole, whereas G_2 had the lowest P (0.08 %) content. On the other hand, the lowest levels of P (0.21 %) were found in storage roots from G_6 and G_7 (Table 9). In storage roots, the P content ranged from 2.73 % ± 0.04 % to 3.22 % ± 0.10 % (18). Another research indicates that the P content of sweet potato storage roots ranged from 38 to 64 mg/100 g (36). Similarly, the P content in sweet potato was 42.33-46.33 mg/100 g (36).

The maximum amount of Fe (784.14 mg/kg) was obtained from twigs of G_7, while G_3 contained the minimum Fe (527.26 mg/kg). G_1 exhibited the highest level of Fe (113.48 mg/kg) in leaves and the lowest Fe (94.20 mg/kg) obtained in sweet potato leaves of G_5, which was statistically identical to G_2 (97.37 mg/kg) and G_7 (98.49 mg/kg). The genotype G_2 contained the most Fe (177.19 mg/kg) and G_7 had the lowest Fe (142.18 mg/kg) in sweet potato leaf petioles (Table 10). The genotype G_7 contained the most iron of all the others (175.63 mg/kg), which was statistically equal to G_5 (175.63 mg/kg), G_3 (173.43 mg/kg) and G_4 (172.37 mg/kg). Another investigation (39) found that new storage roots for North American breeding material contain up to 10 ppm Fe. The Fe contents of storage roots of sweet potato ranged from 18 to 28.4 mg/kg (40).

Regarding Zn content, G7 exhibited the highest level of zinc (35.50 mg/kg) in sweet potato twigs compared to all the genotypes (Table 11). G_7 had the highest Zn (33.90 mg/kg) in leaves. On the other hand, G_5 had the lowest Zn (27.50 mg/kg) in leaves, which was statistically similar to G_4 (27.80 mg/kg) and G_6 (28.40 mg/kg) (Table 11). In leaf petioles, G_7 contained the highest total Zn (33.40 mg/kg) (Table 11). In storage roots, the genotype with the highest (13.10 mg/kg) quantity of total Zn was G_3. Another study found that new storage roots for North American breeding material contain up to 6.4 mg/kg Zn (39).

Table 8. Potassium contents in twigs, leaves, leaf petioles and storage roots of sweet potato

Genotype	Potassium contents (% of DW) in			
	Twigs	Leaves	Leaf petioles	Storage roots
G_1 (BAU Sweet potato-2)	2.05^{d}	1.64^{ab}	1.08^{d}	0.78^{de}
G_2	3.09^{a}	1.56^{c}	1.33^{b}	0.88^{b}
G_3 (BAU Sweet potato-4)	2.29^{c}	1.59^{bc}	1.56^{a}	0.80^{cd}
G_4 (BAU Sweet potato-3)	2.03^{d}	1.55^{c}	1.52^{a}	0.85^{bc}
G_5 (BARI Sweet potato-2)	1.84^{e}	1.63^{ab}	1.53^{a}	0.98^{a}
G_6 (BAU Sweet potato-1)	2.11^{d}	1.67^{a}	1.09^{d}	0.84^{bcd}
G_7	2.58^{b}	1.49^{d}	1.20^{c}	0.73^{e}
$LSD_{0.05}$	0.18	0.06	0.08	0.06
$LSD_{0.01}$	0.25	0.08	0.12	0.09
Level of significance	**	**	**	**
CV (%)	4.38	2.12	3.57	4.31

Values with different superscripts in the same column are statistically different (α = 0.05)

Table 9. Phosphorus contents in twigs, leaves, leaf petioles and storage roots of sweet potato

Genotype	Phosphorus contents (% of DW) in			
	Twigs	Leaves	Leaf petioles	Storage roots
G_1 (BAU Sweet potato-2)	0.49[a]	0.10[d]	0.34[b]	0.25[b]
G_2	0.42[b]	0.22[c]	0.08[e]	0.28[ab]
G_3 (BAU Sweet potato-4)	0.39[bc]	0.25[c]	0.28[c]	0.29[a]
G_4 (BAU Sweet potato-3)	0.36[cd]	0.33[b]	0.13[d]	0.26[ab]
G_5 (BARI Sweet potato-2)	0.34[d]	0.11[d]	0.53[a]	0.29[a]
G_6 (BAU Sweet potato-1)	0.36[cd]	0.11[d]	0.30[c]	0.21[c]
G_7	0.40[b]	0.38[a]	0.12[d]	0.21[c]
$LSD_{0.05}$	0.04	0.05	0.04	0.04
$LSD_{0.01}$	0.05	0.07	0.05	0.05
Level of significance	**	**	**	**
CV (%)	5.52	12.76	8.51	7.90

Values with different superscripts in the same column are statistically different ($\alpha = 0.05$)

Table 10. Iron contents in twigs, leaves, leaf petioles and storage roots of sweet potato

Genotype	Iron contents (mg/kg of DW) in			
	Twigs	Leaves	Leaf petioles	Storage roots
G_1 (BAU Sweet potato-2)	533.38[de]	113.48[a]	172.15[ab]	128.33[c]
G_2	661.74[b]	97.37[c]	177.19[a]	132.60[c]
G_3 (BAU Sweet potato-4)	527.26[e]	106.27[b]	166.12[b]	173.43[a]
G_4 (BAU Sweet potato-3)	538.12[de]	106.12[b]	147.10[de]	172.37[a]
G_5 (BARI Sweet potato-2)	584.17[c]	94.20[c]	150.22[cd]	175.46[a]
G_6 (BAU Sweet potato-1)	567.31[cd]	100.18[bc]	157.06[c]	161.47[b]
G_7	784.14[a]	98.49[c]	142.18[e]	175.63[a]
$LSD_{0.05}$	34.54	6.36	7.29	7.17
$LSD_{0.01}$	48.43	8.92	10.22	10.05
Level of significance	**	**	**	**
CV (%)	3.24	3.50	2.58	2.52

Values with different superscripts in the same column are statistically different ($\alpha = 0.05$).

Table 11. Zinc contents in twigs, leaves, leaf petioles and storage roots of sweet potato

Genotype	Zinc contents (mg/kg of DW) in			
	Twigs	Leaves	Leaf petioles	Storage roots
G_1 (BAU Sweet potato-2)	31.30[b]	28.50[bc]	27.70[c]	9.50[bc]
G_2	31.60[b]	31.40[ab]	28.40[c]	9.70[b]
G_3 (BAU Sweet potato-4)	32.50[b]	29.10[bc]	31.40[b]	13.10[a]
G_4 (BAU Sweet potato-3)	32.50[b]	27.80[c]	32.50[ab]	8.70[d]
G_5 (BARI Sweet potato-2)	31.30[b]	27.50[c]	32.00[ab]	8.90[cd]
G_6 (BAU Sweet potato-1)	32.20[b]	28.40[c]	33.10[ab]	9.50[bc]
G_7	35.50[a]	33.90[a]	33.40[a]	7.30[e]
$LSD_{0.05}$	1.89	2.93	1.97	0.74
$LSD_{0.01}$	2.64	4.11	2.76	1.03
Level of significance	**	**	**	**
CV (%)	3.27	5.58	3.55	4.34

Values with different superscripts in the same column are statistically different ($\alpha = 0.05$)

Research indicates the zinc contents of storage roots ranged from 8.6 to 14.4 mg/kg (40). Except nitrogen-free extract and starch, sweet potato leaves' proximate composition and mineral contents were higher than those of storage roots (18).

Conclusion

This study evaluated the growth, yield and nutritional qualities of seven colour-fleshed sweet potato genotypes. It was observed that different genotypes performed differently on growth, yield, biochemical and mineral contents in twigs, leaves, leaf petiole and storage roots of sweet potato genotypes. The highest vine length and leaf area were found in G_6 and G_3, respectively. The storage root fresh weight and gross yield per hectare were maximum from G5 (BARI Sweet potato-2), statistically identical to G_4 (BAU Sweet potato-3). These two genotypes showed the highest yield potentiality compared to other tested genotypes. In connection to the biochemical and mineral contents, G_1 (BAU Sweet potato-2) represents higher anthocyanins, starch and P, while G_2 contained improved sugar, Ca and K. G_3 (BAU Sweet potato-4) rich in β-carotene contents in the twigs and G_7 found to be the rich sources of Fe and Zn. Genotype G_4 can be recommended for commercial cultivation, while G_7 can be used as a breeding material to develop micronutrient-rich sweet potato varieties.

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Authors' contributions

MMH and MAR design the concept of the study. ET experimented and collected data from fields & laboratories. MMH, ET performed data compilation analysis and drafted the manuscript. MHR helped correct the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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