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ARTICLE

Morphological characterization and plant density of Brazilian ornamental sweet potatoes

Caracterização morfológica e densidade de plantas de batata-doce ornamental brasileira

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Abstract
The production of flowers and ornamental plants has shown continuous growth and demanded constant innovations in the sector. The sweet potato (*Ipomoea batatas* (L.) Lam.) is a tuberous vegetable that has attracted consumers, growers and landscapers due to its ornamental characteristics of its leaves and vines. However, the introduction of sweet potatoes for ornamental purposes is recent in the Brazilian market. The objective of this study was to investigate the ornamental potential of five sweet potato genotypes (IAC104, IAC116, IAC401, IAC909 and IAC1024), through morphological characterization, in addition to evaluating the effect of plant density in pot (1, 2 and 3 plants in pot) on the development of the aerial part and storage roots. The genotypes IAC116, IAC401 and IAC909 showed characteristics of erect and compact plants, while IAC401 and IAC1024 were classified as semi-erect, with only IAC1024 showing a twining vine. Increasing the density of plants resulted in a significant increase in both the number and fresh matter of storage roots in pot, but there was no significant difference in the fresh matter of the aerial part. As a result of this study, the first five ornamental sweet potato cultivars in Brazil were registered with the Ministry of Agriculture, Livestock and Supply (MAPA), named 'IAC Claudia', 'IAC Katherine', 'IAC Mara', 'IAC Mônica' and 'IAC Yoka', with registration numbers 51087, 51090, 51091, 51092 and 51093, respectively.
Keywords: *Ipomoea batatas* (L.) Lam., ornamental plant, potted plant, floriculture, landscape

Resumo
A produção de flores e plantas ornamentais tem apresentado crescimento contínuo, e demandado constantes inovações no setor. A batata-doce (*Ipomoea batatas* (L.) Lam.) é uma hortaliça tuberosa que tem atraído produtores e paisagistas devidos as suas características ornamentais de suas folhas e ramas. No entanto, a introdução das batatas-doces com finalidade ornamental é recente no mercado brasileiro. O objetivo deste estudo foi investigar o potencial ornamental de cinco genótipos de batata-doce (IAC104, IAC116, IAC401, IAC909 e IAC1024), por meio de caracterização morfológica, além de avaliar o efeito da densidade de plantas por vaso (1, 2 e 3 plantas por vaso) no desenvolvimento da parte aérea e das raízes tuberosas. Os genótipos IAC116, IAC401 e IAC909 demonstraram características de plantas eretas e compactas, enquanto IAC401 e IAC1024 foram classificadas como semieretas, sendo que apenas a IAC1024 apresentou ápice trepador. O aumento na densidade de plantas por vaso resultou em um aumento significativo tanto no número quanto na massa fresca das raízes tuberosas por vaso, contudo, não houve diferença significativa na massa fresca da parte aérea. Como resultado deste estudo, foram registradas junto ao Ministério da Agricultura, Pecuária e Abastecimento (MAPA) as cinco primeiras cultivares de batata-doce ornamental do Brasil, denominadas 'IAC Claudia', 'IAC Katherine', 'IAC Mara', 'IAC Mônica' e 'IAC Yoka', com os números de registro 51087, 51090, 51091, 51092 e 51093, respectivamente.
Palavras-chave: *Ipomoea batatas* (L.) Lam., planta ornamental, planta envasada, floricultura, paisagismo.

Introduction

The national production of flowers and ornamental plants encompasses more than 2.5 thousand species and 17.5 thousand varieties (Ibraflor, 2022). The main production segments are ornamental plants for landscaping and gardening (24%), cut flowers (15%) and potted plants (58%) (Reis et al., 2020; Ibraflor, 2022), and in 2021 alone, the sector registered an annual growth of 15% and a turnover of 10.9 billion reais (Ibraflor, 2022).

According to Paiva et al. (2020), approximately 50% of Brazilian consumers show a preference for potted plants due to their greater durability compared to cut flowers, in addition the convenience of being easy to allocate in local garden or space available to it. Additionally, potted plants can be placed both indoor and outdoor places (Ibraflor, 2022). As a result, the demand for potted plants has increased significantly, requiring innovations in this production segment to meet consumer demands (Vargas, 2020).

Sweet potato [*Ipomoea batatas* (L.) Lam.] is a tuberous herbaceous vegetable with 90 chromosomes, which makes it hexaploid (2n= 6x= 90). This characteristic results in high genotypic and phenotypic variability (Melo et al., 2020). Consequently, the species presents a great diversity of shapes and colors in leaves, vines, flesh and skin of storage roots (Jackson et al., 2020; Lebot, 2020; Melo et al., 2020).

This variability of characteristics raised the interest of the international market, resulting in the release of the first cultivars (Jackson et al., 2020). Due to the contrasting yellowish-green and dark purple leaf coloration of the varieties 'Margarita' and 'Blackie', respectively, both were released together and officially accepted by the landscaping market in 1996, being named ornamental sweet potatoes (Armitage and Garner, 2001). Following the release of these cultivars, North Caroline State University (NCSU) initiated a breeding program, by crossing the varieties 'Sulphur' and 'Blackie', with the aim of developing new varieties of ornamental sweet potatoes.

The study of sweet potato densities has an extreme importance as it can provide valuable information for the proper management of these plants in pots. Plant density can influence the quantity and size of storage roots. According to Lebot (2020), the average root size of sweet potato is determined by plant spacing.

Recently, the ornamental value of sweet potato has the interest of both producers and consumers as well as the scientific community (Osborne, 2020). Given this promising scenario, it is relevant to investigate the ornamental potential of sweet potato genotypes, considering that there are still no Brazilian ornamental cultivars. Therefore, the present research aimed to study sweet potato genotypes with ornamental characteristics, aiming at the development and registration of the first national cultivars.

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Material and Methods

Plant material

The plant material used in this study came from the sweet potato breeding program of the Agronomic Institute of Campinas (IAC). The crossing field was installed at the Horticulture Center of the Agronomic Institute (IAC), in Campinas-SP, in 2016. In this field, six cultivars were used (IAC 2-71 - Americana; IAC 66-118 - Monalisa; SRT 47 - natural variant found within the cultivar Beauregard; SRT 278 - Centenial; SRT 299 - Rio de Janeiro II and SRT 334 - Canadense), and the half-sibling progenies were obtained through free pollination. The genitors were arranged in predefined arrangements with repetitions, so that there was the same probability of crossing between them.

This crossing field produced approximately 30,000 true botanical seeds. In 2017, it was decided to plant a representative sample of this batch, resulting in a production of approximately 2000 clones in the first season of trials (2018), with the selection being reduced to the 170 best clones in the next season (2018/2019). From these 170 clones, 30 clones with ornamental potential were selected (year 2019), of which five were promising for registration as ornamental: IAC104, IAC116, IAC401, IAC909 and IAC1024.

The sweet potato genotypes provided by IAC were kept in the Horticulture sector of the Department of Crop Production of the Escola Superior de Agricultura "Luiz de Queiroz" - Universidade de São Paulo (ESALQ/USP), located in Piracicaba, São Paulo. Stock plants were formed from the storage roots and apical portions of the vines of the genotypes IAC104, IAC116, IAC401, IAC909 and IAC1024.

Trial location

The experiment was installed and conducted in a greenhouse at Sítio Tamura, located in the municipality of Itapecerica da Serra (altitude 920m, latitude 23° **43′ 1″ South, longitude 46° 50′ 56″ West, subtropical climate** Cfb), in the state of São Paulo, Brazil.

Production of seedlings for trials

The seedlings used in the experiment were obtained by taking stem cuttings from mother plants. The cuttings were taken from the apical portion of the branches, approximately 10 cm long, with 2 to 3 axillary buds (Nasser et al., 2020). Then, they were inserted into polyethylene trays filled with Vida Verde® coconut fiber substrate and kept in a greenhouse with sprinkler irrigation. After 12 days, the seedlings showed complete rooting and adequate root formation. Then, the seedlings were transplanted into polyethylene vases with 25 cm in diameter, filled with a substrate based on Base® pine bark.

Evaluation of plant density

To evaluate plant density, five sweet potato genotypes (IAC104, IAC116, IAC401, IAC909 and IAC1024) were used and grown in pots with a diameter of 25 cm and filled with substrate Base® pine bark. for a period of 100 days after transplanting the cuttings into the pots. The treatments consisted of three plant densities in pot: 1, 2 and 3 plants in pot. The experiment was conducted in a randomized block design with a 5x3 factorial arrangement, 5 sweet potatoes genotypes and 3 plant density treatments, with one pot per plot and 12 replications. The pots were kept in a greenhouse, with an average minimum temperature of 13 ºC and a maximum of 23 ºC, and a minimum relative humidity of 52.6% from April to July 2021.

Irrigation was carried out every two days by spaghetti microtubes, and the application of the nutrient solution was done by Fert irrigation. The nutrient solution was prepared by dissolving water-soluble salts in 1000 L of water, according to the formulation of Kampf (2005) for ornamental plants: 238g calcium nitrate, 368g potassium nitrate, 144g DAP, 170g magnesium sulfate, 27g iron sulfate (11g) + EDTA (16g), 5g borax, 2.5g manganese sulfate, 0.02g zinc sulfate, 0.02g copper sulfate and 0.05g sodium molybdate.

At 100 days after transplanting, the following evaluations were performed: fresh matter of aerial part (FMAP), number of storage roots in pot (NR) and fresh matter of storage roots in pot (FMR). For the determination of the number of storage roots in pot (NR), the storage roots of each pot were removed manually and counted in each plot.

The determination of the fresh matter of storage roots in pot (FMR) was performed by manually removing the storage roots from each pot, keeping only those that showed thickening. The adventitious roots were discarded. Then, the storage roots of each plot were weighed (in grams) using a semi-analytical balance to determine the total matter of storage roots produced by each pot.

To evaluate the fresh matter of the aerial part (FMAP), the entire aerial part of each plant was removed completely, making a cut close to the substrate. Then, the aerial part of each plot was placed in a plastic tray to accommodate all the material on the semi-analytical balance and be weighed (in grams).

The data were submitted to analysis of variance (ANOVA), and the observed means were compared using Fisher's Least Significance Difference (LSD) test at the 5% significance level, with the aid of the R statistical program.

Ornamental characterization of sweet potato genotypes

To carry out the morphological characterization of the genotypes, all the plants grown for the evaluation of densities (item 2.4) were evaluated at 100 days after transplanting into the pots, considering the parameters adapted from Huamán (1991) (Table 1). The main parameters evaluated were: twining; plant type; leaf shape; leaf lobe type; number of leaf lobes; leaf central lobe shape; leaf size (cm); immature leaf coloration; mature leaf coloration; pigmentation of veins on the abaxial side of the leaf; vine coloration; pigmentation of petiole; flowering habit; shape of flower limb; flower size (cm); bud size (cm); flower color; predominant root skin color; intensity of skin color; predominant flesh color; secondary flesh color; and distribution of secondary flesh color.

Table 1. Characteristics used for the morphological description of sweet potato genotypes (adapted from Huamán, 1991).

Descriptors		Grades	Descriptors		Grades	Descriptors		Grades
1.	**Twining**		**9.**	**Mature leaf size**		**17.**	**Bud size**	
	Non-twining	0		Small (<8 cm)	3		Bud lenght	cm
	Slightly twining	3		Medium (8-15 cm)	5	**18.**	**Shape of limb**	
	Moderately twining	5		Large (16-25 cm)	7		Semi-stellate	3
	Twining	7		Very large (>25 cm)	9		Pentagonal	5
	Very twining	9	**10.**	**Abaxial leaf vein pigmentation**			Rounded	7
2.	**Plant type**			Yellow	1	**19.**	**Sepal color**	
	Erect (<75cm)	3		Green	2		Green	1
	Semi-erect (75-150 cm)	5		Purple spot in the base of main rib	3		Green with purple edge	2
	Spreading (151-250 cm)	7		Purple spots in several veins	4		Green with purple spots	3
	Extremely spreading (> 250 cm)	9		Main rib partially purple	5		Green with purple areas	5
3.	**Predominant vine color**			Main ribmostly or totally purple	6		Some sepals green, others purple	6
	Green	1		All veins partially purple	7		Totally pigmented - pale purple	7
	Green with few purple spots	3		All veins mostly or totally purple	8		Totally pigmented - dark purple	9
	Green with many purple spots	4		Lower surface and veins totally purple	9	**20.**	**Predominant skin color of storage roots**	
	Green with many dark purple spots	5	**11.**	**Mature leaf color**			White	1
	Mostly purple	6		Yellow-green	1		Cream	2
	Mostly dark purple	7		Green	2		Yellow	3
	Totally purple	8		Green with purple edge	3		Orange	4
	Totally dark purple	9		Greyish-green (due to heavy pubescence)	4		Brownish orange	5
4.	**Secondary vine color**			Green with purple veins on upper surface	5		Pink	6
	Absent	0		Slightly purple	6		Red	7
	Green base	1		Mostly purple	7		Purple-red	8
	Green tip	2		Green upper, purple lower	8		Dark purple	9
	Green nodes	3		Purple both surfaces	9	**21.**	**Intensity of predominant skin color**	
	Purple base	4	**12.**	**Immature leaf color**			Pale	1
	Purple tip	5		Yellow-green	1		Intermediate	2
	Purple nodes	6		Green	2		Dark	3
	Other	7		Green with purple edge	3	**22.**	**Predominant flesh color of storage roots**	
5.	**Mature leaf shape**			Greyish-green (due to heavy pubescence)	4		White	1
	Rounded	1		Green with purple veins on upper surface	5		Cream	2
	Reniform (kidney-shaped)	2		Slightly purple	6		Dark cream	3
	Cordate (heart-shaped)	3		Mostly purple	7		Pale yellow	4
	Triangular	4		Green upper, purple lower	8		Dark yellow	5
	Hastate	5		Purple both surfaces	9		Pale orange	6
	Lobed	6	**13.**	**Petiole pigmentation**			Intermediate orange	7
	Almost divided	7		Green	1		Dark orange	8
6.	**Leaf lobes type**			Green with purple near stem	2		Strongly pigmented with anthocyanins	9
	No lateral lobes (entire)	0		Green with purple near leaf	3	**23.**	**Secondary flesh color**	
	Very slight (teeth)	1		Green with purple at both ends	4		Absent	0
	Slightly twining	3		Green with purple spots throughout petiole	5		White	1
	Moderate	5		Green with purple stripes	6		Cream	2
	Deep	7		Purple with green near leaf	7		Yellow	3
	Very deep	9		Some petioles purple, others green	8		Orange	4
7.	**Leaf lobe number**			Totally or mostly purple	9		Pink	5
	One	1	**14.**	**Flowering habit**			Red	6
	Three	3		None	0		Purple-red	7
	Five	5		Sparse	3		Purple	8
	Seven	7		Moderate	5		Dark purple	9
	Nine	9		Profuse	7	**24.**	**Distribution of secondary flesh color**	
8.	**Shape of central leaf lobe**		**15.**	**Flower color**			Absent	0
	Absent	0		White	1		Narrow ring in cortex	1
	Toothed	1		White limb with purple throat	2		Broad ring in cortex	2
	Triangular	2		White limb with pale purple ring and purple throat	3		Scattered spots in flesh	3
	Semi-circular	3		Pale purple limb with purple throat	4		Narrow ring in flesh	4
	Semi-elliptic	4		Purple	5		Broad ring in flesh	5
	Elliptic	5		Other (specify)	6		Ring and others areas in flesh	6
	Lanceolate	6	**16.**	**Flower size**			In longitudinal sections	7
	Oblanceolate	7		Flower lenght	cm		Covering most of the flesh	8
	Linear (broad)	8		Flower width	cm		Covering all flesh	9
	Linear (narrow)	9						

Results and Discussion

Density of plants in pots

There was a significant interaction between the parameters plant density and genotypes for the variable NR (number of storage roots). Sweet potato genotypes showed an increase in storage root production as plant density in pot increased. At lower densities (1 and 2 plants/pot), genotype IAC909 showed the highest average NR, while at the highest density (3 plants/pot), genotype IAC116 had the highest average. The genotype IAC1024 presented the lowest average in all densities, while the other genotypes obtained intermediate values among them.

Table 2 shows the results of Pearson's correlation analysis, performed to investigate possible linear relationships between the variables considered in the selection of genotypes. A high magnitude, i.e. a value close to 1, indicates a linear relationship between the observed variables. A positive correlation between the variables suggests that the selection of one trait will favor the other, while a negative correlation indicates that the choice of one trait disfavors another. A positive correlation of low but significant magnitude was found between plant density and the NR variable. This indicates that, in general, increased plant density is associated with increased number of storage roots (Table 2).

Table 2. Pearson's correlation coefficients (below diagonal) and p-values (above diagonal) between the characters DENS (plant density), NR (number of storage roots in pot), FMR (fresh matter of storage roots in pot) and FMAP (fresh matter of aerial part).

	DENS	NR	FMR	FMAP
DENS	-	<0,01	0	0,72
NR	**0,35**	-	0,01	0,86
FMR	**0,40**	**0,20**	-	<0,01
FMAP	0,03	-0,01	**-0,43**	-

Values in bold and underlined represent significant correlations at 5% probability of error by T-test. Correlations at overall mean levels for all variables

Similar results were observed in the study by Corrêa et al. (2007), where it was observed that increasing plant density in the seed potato cultivar 'Monalisa' (*Solanum tuberosum* L.) resulted in a higher number of tubers in pot, as well as increasing plant density also led to a reduction in storage fresh matter. Studies indicate that sweet potato species inherently had a negative correlation between density and root size. The roots end up competing with each other, and the plant makes an adjustment for compensation in the number and size of storage roots (Wees et al., 2016), that is, as the number of plants in a given area increases, the amount of storage roots to be formed will also increase, however their size will be smaller (Embrapa, 2021; Arancibia et al., 2014; Schultheis et al., 1999).

The results of this study corroborate with Schulteis et al. (1999), who observed that smaller plant spacing resulted in higher yield of desired size roots for marketing, while wider spacing resulted in increased yield of jumbo size roots. Smaller spacing resulted in higher total yield of sweet potatoes. Studies by Shrestha and Miles (2022) also highlighted that plant spacing affects storage root yield and size, with lower plant density favoring larger roots and higher densities resulting in smaller roots.

Regarding the total fresh matter of storage roots in pot (FMR), there was no significant interaction between density and genotypes, indicating that the fresh matter of storage roots increased similarly for all genotypes with increasing density. A moderate positive correlation (0.40) was observed between fresh matter of storage roots of the genotypes and density (Table 3). The density of plants in pot influenced linearly and significantly the storage root yield in all genotypes. Other studies also show the relationship between plant density and total yield, with higher density resulting in higher yield (Shrestha and Miles, 2022; Melo et al., 2019).

The results indicated that, on average, genotypes IAC401 and IAC104 presented the highest total FMR and were statistically different from the other genotypes. These genotypes stood out as the most productive in terms of storage root production in pot, regardless of density. Genotypes IAC116 and IAC909 showed intermediate FMR values, while IAC1024 had the lowest FMR. Previous studies show that there are differences in storage root production among potato cultivars, due to the genetic variability of the species (Melo et al., 2020). In addition, abiotic factors such as growing location, planting season, fertilization and harvest time can also influence storage root production (Andrade Júnior et al., 2012). Other studies have also shown variations in sweet potato storage root yield: 'Georgia Jet' and 'Beauregard' (Wees et al., 2016), 'Beauregard' and 'Evangeline' (Arancibia et al., 2014).

A negative correlation of low but significant magnitude (-0.43) was identified between the variables FMR (Fresh Matter of Roots) and FMAP (Fresh Matter of Aerial Part) (Table 2), which indicates an opposite relationship between source and drain. This means that if the plant directs its photoassimilate resources to the aerial part during the final phase of the cycle, when root tuberization occurs, there will be a decrease in root production, resulting in a lower FMR, and vice versa. These results were observed in genotypes IAC909 and IAC1024, while genotypes IAC116 and IAC401 showed lower growth in the aerial part (Fig. 1).

There was a significant difference only among the genotypes studied in relation to the fresh matter of the aerial part, without evidence of interaction between plant densities and genotypes. The significant difference observed between the genotypes in relation to the fresh matter of the aerial part can be attributed to the different growth of each of them. Plant density was found to have a greater impact on storage roots than on the aerial part of sweet potato. However, at the beginning of the plant growth cycle, it was observed that a higher density of plants in pot can accelerate the closing of the available space, which may be relevant for the commercial production of ornamental sweet potatoes. These speeds up the production process and allows for a quick product formation cycle for sale.

The sweet potato plant has compensation capacity, adjusting its aerial part according to the space available to grow. At the end of the cycle, it was observed that the pots with only one plant showed almost no difference in the aerial part compared to the pots containing two or three plants (Fig. 1). This result is significant from an ornamental point of view, as the spatial compensation capacity of the sweet potato plant offers greater flexibility in the composition of landscape arrangements. Therefore, sweet potato can be used as a ground cover plant, and it is possible to achieve this effect both with spaced plants and by increasing the plant density to achieve area closure in a shorter period. This provides versatile options for landscape design and allows the creation of aesthetically pleasing arrangements.

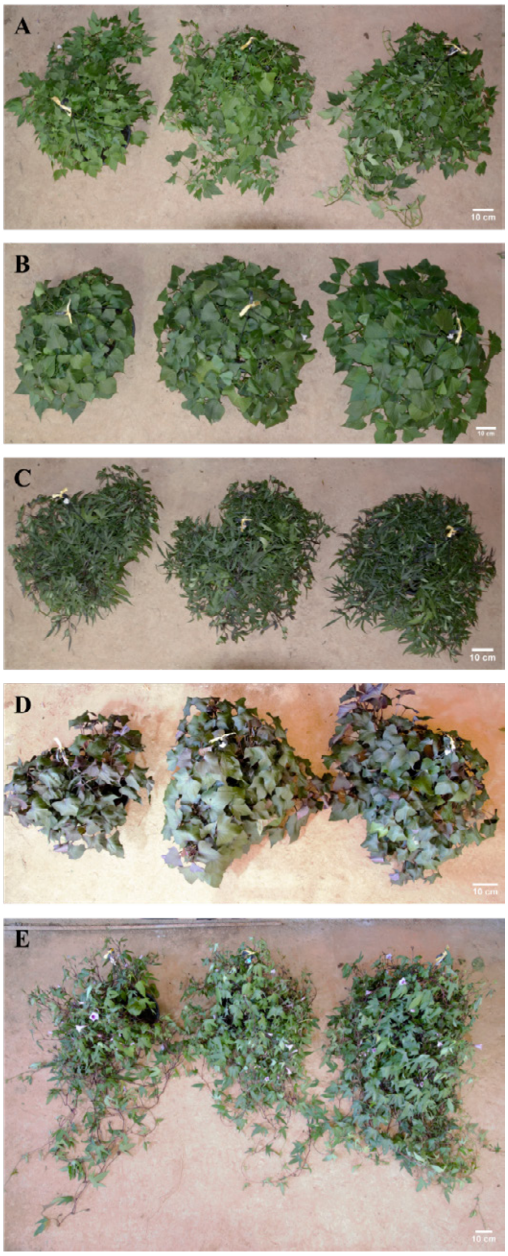

Fig. 1: Effect of plant density on aerial part growth of the genotypes: A) IAC Claudia; B) IAC Katherine; C) IAC Mara; D) IAC Mônica; E) IAC Yoka. From left to right: density of 1 plant/pot; 2 plants/pot and 3 plants/pot. Images: Mônica Mieko Nakanishi Tamura.

Ornamental characterization of genotypes

The results of the ornamental characterization of the sweet potato genotypes were forwarded by the IAC for registration with the MAPA, thus IAC104, IAC116, IAC401, IAC909 and IAC1024 receveid the names IAC Claudia, IAC Katherine, IAC Mara, IAC Mônica and IAC Yoka, with the respective registration numbers 51087, 51090, 51091, 51092 and 51093. They are the firsts five ornamental sweet potato cultivars registered in Brazil. The ornamental characteristics of the genotypes evaluated are described below (Table 3 and Fig. 2).

Table 3. Morphological characterization of sweet potato genotypes IAC104, IAC116, IAC401, IAC909 and IAC1024

	Descriptors	Genotypes				
		IAC104	IAC116	IAC401	IAC909	IAC1024
1.	Twining	Non-twining	Non-twining	Non-twining	Non-twining	Twining
2.	Plant type	Semierects (75-150 cm)	Erects (<75 cm)	Erects (<75 cm)	Erects (<75 cm)	Semierects (75-150 cm)
3.	Vine pigmentation	Green with many purple spots on upper surface	Green with few purple spots on upper surface	Mostly purple	Totally dark purple	Totally purple
4.	Secondary vine color	Absent	Absent	Absent	Absent	Green tip
5.	Mature leaf shape	Hastate	Cordate (heart-shaped)	Almost divided	Triangular	Lobed
6.	Leaf lobes type	Moderate	Very slight (teeth)	Very deep	Slight	Deep
7.	Leaf lobe number	3	1	5	3	5
8.	Shape of central leaf lobe	Semi-elliptic	Toothed	Lanceolate	Triangular	Elliptic
9.	Mature leaf size (cm)	10,17	10,68	12,66	12,43	10,04
10.	Immature leaf color	Green with purple edge	Green with purple edge	Mostly purple	Purple both surfaces	Green with purple edge
11.	Mature leaf color	Green	Green	Green	Green with purple veins on upper surface and totally purple on lower surface	Green with purple edge
12.	Abaxial leaf vein pig-mentation	Green	Green	Green	Lower surface and veins totally purple	Purple spot in the base of main rib
13.	Petiole pigmentation	Green with purple near leaf	Green with purple near leaf	Green with purple near leaf	Totally or mostly purple	Totally or mostly purple
14.	Flowering habit	Sparse	Sparse	None	Sparse	Profuse
15.	Shape of limb of flower	Pentagonal	Semi-stellate	-	Rounded	Pentagonal
16.	Flower size	3,37	3,53	-	3,87	3,21
		3,25	3,43	-	3,67	3,45
17.	Bud size - lenght (cm)	2,63	2,68	-	3,13	2,48
18.	Flower color	White limb with purple throat	White limb with purple throat	-	Pale purple limb with purple throat	White limb with purple throat
19.	Sepal color	Green	Green	-	Totally pigmented - dark purple	Totally pigmented - dark purple
20.	Predominant skin color of storage roots	Cream	Pink	Red	Dark purple	Purple-red
21.	Intensity of predominant skin color	Intermediate	Pale	Intermediate	Dark	Dark
22.	Predominant flesh color of storage roots	Dark yellow	Pale yellow	Dark orange	Strongly pigmented with anthocyanins	Strongly pigmented with anthocyanins
23.	Secondary flesh color of storage roots	Absent	Absent	Absent	White	White
24.	Distribution of second-ary flesh color	Absent	Absent	Absent	Narrow ring in cortex	Narrow ring in cortex

Fig. 2. Sweet potato genotypes: A) IAC Claudia; B) IAC Katherine; C) IAC Mara; D) IAC Mônica; and E) IAC Yoka. Images: Mônica Mieko Nakanishi Tamura.

The genotype IAC104 (Table 3 and Fig. 2A) has distinct characteristics, including hastate leaves and green coloration with purple edge when immature, and becoming totally green when mature, resembling the American variety Sweet CarolineTM ‘Light Green’ (Pecota et al., 2004). However, unlike the compact form of the commercial variety, IAC104 has longer vines due to its vigorous growth. This particularity makes the IAC104 genotype suitable for filling garden areas as well as for composing pots, where it can create a beautiful pendant effect.

The genotypes IAC116, IAC401 and IAC909 (Table 3 and Fig. 2 B, C and D) stand out due to the shape and coloration of their leaves. Leaf shape plays an important role in the composition of arrangements as it conveys a sense of movement. The rounded shape can communicate softness, while the pointed shape can express liveliness (Sousa et al., 2018). The shape of the leaves has an influence on the coverage of the aerial part (Jackson et al., 2020), since the leaf area is what provides the closure of the pot. This highlights the relevance of plant architecture and diameter in the selection of varieties for ornamental use (Silva et al., 2020). Leaf coloration also plays a relevant role in the selection of ornamental cultivars, since it contributes to the visual attractiveness of the arrangement (Sousa et al., 2018; Jackson et al., 2020).

The variety IAC116 (Table 3 and Fig. 2B) has green leaves with a cordate shape, resembling the commercial varieties of the Sweet HeartTM series, in particular Sweet Caroline Sweetheart Light Green (Yencho et al., 2008). On the other hand, IAC401 (Table 3 and Fig. 2C) has a special relevance due to the shape of its leaves, which are almost divided into five rather deep lobes. The central lobe of the leaves has a lanceolate shape. Immature leaves exhibit a dark purple coloration on the adaxial side and green on the abaxial side but turn green when mature. These characteristics are similar to the Illusion® Emerald Lace variety ‘NCORNSP-012EMLC’ (Yencho and Pecota, 2011; Proven Winners, 2022). Sousa et al. (2018) also observed a variability of leaf shapes and colors in five sweet potato accessions, with ornamental potential.

The genotype IAC909 (Table 3 and Fig. 2D) exhibits remarkable characteristics, including triangular leaves and a purplish-green coloration. In addition, its branches are completely purple due to the presence of the pigment anthocyanin. This dark coloration is highly valued for ornamental sweet potatoes, as it creates a striking contrast with the vibrant colors of herbaceous flowering plants, allowing interesting combinations both in pots and in the composition of garden beds.

Compact-growing sweet potato cultivars have a denser canopy and plant closure occurs in the early stages of growth, in contrast to long-branched varieties (Jackson et al., 2020). This selection criterion is also applied to other ornamental horticultural species grown in pots, such as peppers, where small-sized plants with colorful fruits that contrast with the green leaves are preferred (Finger et al., 2012; Neitzke et al., 2016). Therefore, the genotypes IAC116, IAC401 and IAC909, which have more compact growth, have potential for use in small area gardens, hanging pots or in ground arrangements. This form of pot cultivation can be particularly interesting to decorate limited spaces, such as apartment balconies.

Genotype IAC 1024 (Table 3 and Fig. 2E) is characterized by abundant flowering and its curling habit, which makes it suitable for use in upright structures. This genotype resembles the sweet potato cultivars ‘SolarTowerTM Black’ and ‘SolarTowerTM Lime’ (Anonymous, 2022a, 2022b; Jackson et al., 2020) which have dark purple and lime green foliage hues, respectively. Due to its upward growth habit, IAC1024 has potential for use in living fences, fencing, green walls, and pergolas. The voluble vines stand out for their rusticity, and constitute an important resource in landscaping, due to the versatility of uses in arbors, walls, and pergolas.

The presence of flowers in the genotypes selected for this research is a very relevant characteristic, giving them a competitive advantage compared to the cultivars already launched in the American and European market, which have little or no flowers. Flowering allows new uses for these plants, not limiting them to use as foliage and area lining.

Conclusions

The morphological characterization showed the ornamental potential of the sweet potato genotypes IAC104, IAC116, IAC401, IAC909 and IAC1024, with emphasis on the diversity of leaf shapes and colors, growth habit and the presence of flowers. The genotypes IAC 116, IAC401 and IAC909 are erect and compact plants, being recommended for pots and gardens in small areas and apartment balconies. On the other hand, IAC 104 and IAC 1024 are semi-erect, and only IAC1024 has a climbing habit, which allows its use in vertical structures, such as arbors, pergolas, living fences and green walls. The branches of the genotype IAC104 are pendulous, ideal for hanging pots and use as bedding. The higher plant density, 3 plants in pot, increased the production of storage roots and favored the closing of the aerial part, and enabled a commercial standard of the pot for sale. The genotypes studied, under the acronyms IAC104, IAC116, IAC401, IAC909 and IAC1024 resulted in the first five Brazilian ornamental sweet potato cultivars registered with MAPA, by the Instituto Agronômico de Campinas - IAC, being named IAC Claudia, IAC Katherine, IAC Mara, IAC Mônica and IAC Yoka, with the respective registration numbers 51087, 51090, 51091, 51092 and 51093.

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Authors Contribution

MMNT, CFMM, FAP: Conceptualization; **MMNT**: Data collection; **MMNT, FAP**: Data analysis; **MMNT, CFMM**: Drafting the article; **MMNT, CFMM, FAP, VAP, CG, EGF**, **JCF, LCB, LCA**: Review of the article.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

Data will be made available on request.

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