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Morphological Characteristics of Varieties of Sweet Potato, Cenoura, Margarita, Rainha and Roxa, Cultivated in Amazonas, Brazil

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Abstract

Sweet potato [*Ipomoea batatas* (L.) Lam.] is a nutritious food, from an easy-to-handle cultivation, present in all Brazilian regions, with great socioeconomic relevance. There is a wide genetic diversity of sweet potato, expressing different flesh and skin colors, and containing different nutritional values. However, only sweet potatoes with cream flesh and white or purple skin are present in the Manaus market. It is important to promote the visibility of the varieties that are being cultivated in a less expressive way, often only by the indigenous people. In this way, the valorization of the product and the conservation of agrobiodiversity will be encouraged. One obstacle to identifying varieties is that the same variety can have different names, and the same name can be given to different varieties. Therefore, it is essential that a morphological description of the varieties present locally is made. This will be a subsidy for future research and actions aimed at the development of the primary sector that has the sweet potato as its object. Given the above, this work aimed to morphologically describe the sweet potato varieties Cenoura, Margarita, Rainha and Roxa present at the Experimental Farm of the Federal University of Amazonas. The Cenoura, Rainha and Roxa varieties have different skin and/or flesh colors and a tuberous root shape, catering to different consumer tastes. The Cenoura variety (skin and orange flesh) has the potential to be cultivated by Amazonian farmers and introduced in the local market (Alves, 2021; Filgueira, 2008; Huamán, 1991).

Keywords: botany, descriptors, *Ipomoea batatas*

1. Introduction

Sweet potato [*Ipomoea batatas* L. (Lam.)] has great socioeconomic and nutritional relevance. Due to its rusticity, it is easy to grow, being an appropriate species to be cultivated in family farming. It has potential for use in tuberous roots and shoots, in human and animal food. Tuberous roots are an important source of low glycemic index carbohydrates, vitamins and minerals for the human diet, especially magnesium, potassium, phosphorus, and calcium (Aguirre et al., 2020; Nunes et al., 2020).

There is a wide genetic diversity of sweet potato, expressing different flesh and skin colors, and containing different nutritional values. According to Huamán (1991), the sweet potato can have its skin in colors: cream; Yellow; Orange; orange-brown; pink; red; reddish-purple; dark purple; and flesh in colors: white; cream; dark cream; pale yellow; dark yellow; pale orange; intermediate orange; dark orange; heavily pigmented with anthocyanins (purple).

In a study by Aguirre et al. (2020), it was found that the tuberous roots of cream-colored sweet potato had higher levels of calcium than the tuberous roots of other colors. In this same context, the purple-colored tuberous roots are rich in anthocyanins (Adebamowo et al., 2015), and with orange-colored flesh, they are rich in beta-carotene (Vizzoto et al., 2017).

Sweetpotato diversity encompasses varieties and cultivars; including biofortified cultivars, such as BRS Amélia and Beauregard, both with orange flesh, enriched in beta-carotene, provitamin A. Biofortification consists in the production of more nutritious cultivars, through selection and crossing between plants of the same species (Embrapa, 2014a, 2014b; Embrapa, 2021).

There are 32 sweet potato cultivars registered with the Ministry of Agriculture, Livestock, and Supply (MAPA, 2021). At least 33 sweet potato varieties are cited in the literature, which was managed by the Amazon Indians (Alves, 2001).

The representation of local varieties from all over Brazil, which are reasonably accepted by the producer and consumer market, are found in germplasm banks and can result in the selection of superior clones, with desirable agronomic and culinary characteristics, and also in the creation of new genotypes. One of these is the Sweet Potato Germplasm Active Bank (BAG) maintained at Embrapa Hortaliças since 1980, with more than 800 accesses. Examples of cultivars released from this bank are: Brazlândia Roxa, Brazlândia Rosada, Brazlândia Branca, Coquinho, Princesa and the orange-fleshed Beauregard. This one comes from the United States and was introduced through an exchange with the Centro Internacional de la Papa in Peru. Of the accesses present, 11.83% were introduced from other countries, 6.9% come from the North of Brazil, and 1.2% from Amazonas (10 accesses) (Lopes et al, 2012).

There is little information about sweet potato varieties in the literature. Guedes et al. (1980) began studies with six varieties native to Amazonas: Balão, Três Quinas, Jambo, Roxinha, with a purple bark, and Rainha and Nativa, with white bark, and found yields ranging from 7 t ha^{-1} to 15 t ha^{-1} in the first cycle and 16 t ha^{-1} to 33 t ha^{-1} in the second cycle (Guedes et al., 1980). An experiment was also carried out with the varieties Arapapá, Três Quinas, Rainha and Roxinha, coming from Amazonas, and with the varieties Princesa, Brazlândia Branca, Brazlândia Rosada and Brazlândia Roxa, coming from Brasília; the most productive being the varieties Arapapá, Três Quinas and Rainha (Cardoso et al., 2000). And, Cavalcante et al. (2017) evaluated five sweet potato varieties/cultivars in the municipality of Careiro (AM): Rainha, Rubissol, Brazlândia, BDFMI#16 and Compensa, which reached yields from 3 t ha^{-1} to 14 t ha^{-1} under doses of phosphorus.

However, it is common for the same variety to have different names according to the region, and for the same name to be given to varieties with different morphological characteristics, for example, there are dozens of varieties with the name “Rainha” (Embrapa, 1995; Mateus et al., 2020). Therefore, the morphological description of sweet potato accessions is necessary to identify the variety or cultivar.

Despite the great diversity of sweet potatoes, only cream-fleshed varieties with white or pink skin are sold in Manaus (Amazonas). At fairs in municipalities in the interior of the State of Amazonas, there is greater diversity, for example, tuberous roots with orange, purple, and yellow flesh are found.

Therefore, studies aimed at valuing local varieties are of paramount importance, as they promote sustainable regional development and prevent genetic erosion of the species (Nunes et al., 2020). Therefore, this study aimed to morphologically describe the sweet potato varieties Cenoura, Margarita, Rainha, and Roxa present at the Experimental Farm of the Federal University of Amazonas.

2. Method

The study was conducted at the Experimental Farm of the Federal University of Amazonas (FAEXP/UFAM) (2º39′ S and 60º3′ W). According to Köppen’s classification, it has an Am, tropical, hot, and humid climate, with average annual temperature and rainfall of 25 to 28 °C and 2,100 mm, respectively, and relative air humidity around 84 to 90% (Dubreuil et al., 2018).

The area was prepared with a subsoiler and bricklayer, with 35 cm high windrows being made. The branches were planted with a spacing of 0.90 m between windrows and 0.30 m between plants. The area was fertilized with chicken manure at a dose of 12 t ha^{-1} (Ferreira et al., 2020; Filgueira, 2008, Rós, 2017).

The characterization of the Cenoura, Margarita, Rainha, and Roxa sweet potato varieties present at the Experimental Farm of the Federal University of Amazonas was carried out (Figure 1). At the time of harvesting a pre-existing crop, three random plants of each variety were evaluated according to 22 descriptors related to the morphological characteristics of the branches, leaves, and roots, defined by Huamán (1991), expressed in Table 1.

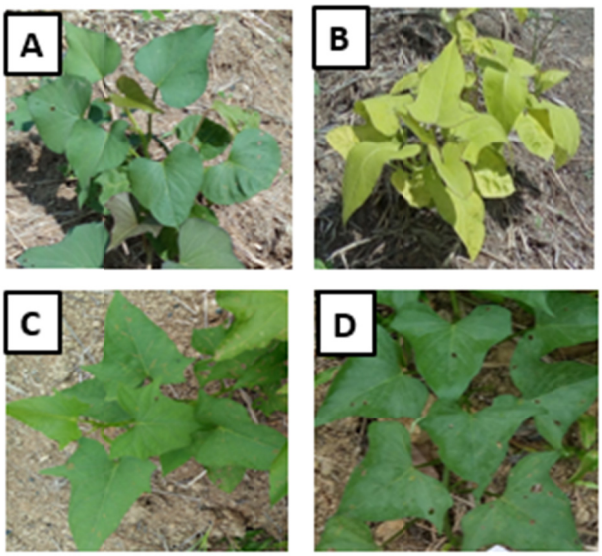

Figure 1. Varieties of sweet potato (*Ipomoea batatas*), (A) Cenoura; Margarita (B); Rainha (C); Roxa (D)

Table 1. Morphological descriptors for sweet potato (*Ipomoea batatas*) (Huamán, 1991)

Descriptor	Characteristic
1. Length of the main vines	Erect (< 75 cm); Semi-erect (75-150 cm); Spreading (151-250 cm); Extremely spreading (> 250 cm)
2. Vine internode length	Very short (< 3 cm); Short (3-5 cm); Intermediate (6-9 cm); Long (10-12 cm); Very long (> 12 cm)
3. Vine internode diameter	Very thin (< 4 mm); Thin (4-6 mm); Intermediate (7-9 mm); Thick (10-12 mm); Very thick (> 12 mm)
4. Predominant vine colour	Green; Green with few purple spots; Green with many purple spots; Green with many dark purple spots; Mostly purple; Mostly dark purple; Totally purple; Totally dark purple
5. Secondary vine colour	Absent; Green base; Green tip; Green nodes; Purple base; Purple tip; Purple nodes; Other
6. General outline of the leaf	Rounded; Reniform (Kidney-shaped); Cordate (heart-shaped); Triangular; Hastate (trilobular and spear-shaped with the basal lobes more or less divergent); Lobed; Almost divided
7. Leaf lobes type	No lateral lobes (entire); Very slight (teeth); Slight; Moderate; Deep; Very deep
8. Leaf lobe number	One; Three; Five; Seven; Many
9. Shape of central leaf lobe	Absent; Toothed; Triangular; Semi-circular; Semi-elliptic; Elliptic; Lanceolate; Oblanceolate; Linear (broad); Linear (narrow)
10. Mature leaf size	Small (< 8 cm); Medium (8-15 cm); Large (16-25 cm); Very large (> 25 cm)
11. Abaxial leaf vein pigmentation	Yellow; Green; Purple spot in the base of main rib; Purple spots in several veins; Main rib partially purple; Main rib mostly or totally purple; All veins partially purple; All veins mostly or totally purple; Lower surface and veins totally purple
12. Mature leaf colour	Yellow-green; Green; Green with purple edge; Greyish-green (due to heavy pubescence); Green with purple veins on upper surface; Slightly purple; Mostly purple; Green Upper, purple lower; Purple both surfaces
13. Immature leaf colour	Yellow-green; Green; Green with purple edge; Greyish-green (due to heavy pubescence); Green with purple veins on upper surface; Slightly purple; Mostly purple; Green Upper, purple lower; Purple both surfaces
14. Petiole length	Very short (< 10cm); Short (12-20 cm); Intermediate (21-30 cm); Long (31-40 cm); Very long (> 40 cm)
15. Petiole pigmentation	Green; Green with purple near stem; Green with purple near leaf; Green with purple at both ends; Green with purple spots throughout petiole; Green with purple stripes; Purple with green near leaf; Some petioles purple, others green; Totally or mostly purple
16. Storage root shape	Round; Round elliptic; Elliptic; Ovate; Obovate; Oblong; Long oblong; Long elliptic; Long irregular or curved
17. Storage root skin colour	White; Cream; Yellow; Orange; Brownish orange; Pink; Red; Purple-red; Dark purple
18. Intensity of predeminant skin colour	Pale; Intermediate; Dark
19. Secondary skin colour	Absent; White; Cream; Yellow; Orange; Brownish orange; Pink; Red; Purple-red; Dark purple
20. Predominat flesh colour	White; Cream; Dark cream; Pale yellow; Dark Yellow; Pale orange; Intermediate orange; Dark orange; Strongly pigmented with anthocyanins
21. Secondary flesh colour	Absent; White; Cream; Yellow; Orange; Pink; Red; Purple-red; Purple; Dark purple
22. Distribution of secondary flesh colour	Absente; Narrow ring in cortex; Broad ring in cortex; Scattered spots in flesh; Narrow ring in flesh; Broad ring in flesh; Ring and other areas in flesh; In longitudinal sections; Covering most of the flesh; Covering all flesh

3. Results and Discussion

The data revealed that all varieties are extremely spreading, with intermediary internode diameter and green vines, without secondary coloration. The Margarita variety has a shorter internode length, compared to the other varieties, followed by the Cenoura (Table 2).

Regarding the characteristics of the leaves, all the varieties have medium size of the mature leaf. The Cenoura and Roxa varieties have a triangular-shaped leaf; Margarita, cordate, and Rainha, lobed. Rainha has three to five deep lobes; Margarita and Roxa have only one lobe, no latereal lobes; Cenoura have from one to three lobes, that is, both leaves without lateral lobes and leaves with moderate lateral lobes in the same vine. Cenoura has absent central lobe shape or triangular or semi-elliptical; Margarita and Roxa, absent; and Rainha, semi-elliptical. Rainha has purple spots at the base of the main rib, while the veins of the other varieties are green. The color of the mature leaves of all varieties is green, however, Margarita has a "neon" tone. The immature leaves of Margarita and Rainha are green, but those of Cenoura and Roxa are green with purple edge. The petiole length of the Margarita variety is shorter than that of the other varieties. The petiole of Cenoura and Roxa is green, Margarita's petiole is green (light) with purple near stem, and Rainha`s petiole is green with purple near leaf (Table 2).

Regarding tuberous roots, the Cenoura, Rainha, and Roxa varieties have distinct characteristics (Figure 2). The tuberous root shapes of the Cenoura variety were round, elliptical, and ovate; of the Rainha were round and obovate; and Roxa was obovate, long elliptical and long irregular or curved. Rainha has white skin and cream flesh, Roxa has purple-red skin and cream flesh, and Cenoura has intermediate orange skin and flesh. The variety Margarita did not produce tuberous roots 180 days after planting (Table 2).

Table 2. Morphological characterization of the varieties of sweet potato (*Ipomoea batatas*), Cenoura, Margarita, Rainha, and Roxa

Morphological descriptors	Cenoura	Margarita	Rainha	Roxa
1. Length of the main vines	Extremely spreading	Extremely spreading	Extremely spreading	Extremely spreading
2. Vine internode length	Short	Very Short	Intermediate	Intermediate
3. Vine internode diameter	Intermediário	Intermediário	Intermediário	Intermediário
4. Predominant vine colour	Green	Green	Green	Green
5. Secondary vine colour	Absent	Absent	Absent	Absent
6. General outline of the leaf	Triangular	Cordate	Lobed	Triangular
7. Leaf lobes type	No lateral lobes or Moderate	No lateral lobes	Deep	No lateral lobes
8. Leaf lobe number	One or Three	One	Three or Five	One
9. Shape of central leaf lobe	Absent or Triangular or Semi-elliptic	Absent	Semi-elliptic	Absent
10. Mature leaf size	Medium	Medium	Medium	Medium
11. Abaxial leaf vein pigmentation	Green	Green	Purple spot in the base of main rib	Green
12. Mature leaf colour	Green	Green ("neon")	Green	Green
13. Immature leaf colour	Green with purple edge	Green	Green	Green with purple edge
14. Petiole length	Intermediate	Short	Intermediate	Intermediate
15. Petiole pigmentation	Green	Green (light) with purple near stem	Green with purple near leaf	Green
16. Storage root shape	Round elliptic; Ovate	-	Round; Obovate	Obovate; Long elliptic; Long irregular or curved
17. Storage root skin colour	Orange	-	White	Purple-red
18. Intensity of predeminant skin colour	Intermediate	-	Pale	Intermediate
19. Secondary skin colour	Absent	-	Absent	Absent
20. Predominat flesh colour	Intermediate Orange	-	Cream	Cream
21. Secondary flesh colour	Absent	-	Absent	Absent
22. Distribution of secondary flesh colour	Absent	-	Absent	Absent

The unanimity of the studied varieties in presenting extremely spreading vines is advantageous, as it implies covering the ground more efficiently in terms of competition with weeds. It is noteworthy that a 99.7% reduction in sweet potato yield has already been found due to weed interference (Santos et al., 2018).

The three varieties have different skin and/or flesh colors and tuberous root shapes (Figure 2), catering to different consumer tastes, having different applicability in food production and the preparation of dishes. The color of the tuberous roots plays an important role in the differentiation of genotypes and the quality characteristics of the tuberous root (Vizzoto et al., 2017).

Figure 2. Characteristics of the shape and color of the skin and flesh of the tuberous roots of the varieties of sweet potato (*Ipomoea batatas*), Cenoura (A), Rainha (B) and Roxa (C)

According to Silva et al. (2021), due to the distinct characteristics of the starches present in the different colors of sweet potato flesh, the white and orange flesh-colored varieties, such as the Cenoura variety, are suitable for use in foods processed at high temperatures, such as sauces and chips; and tuberous roots with cream flesh, such as Rainha and Roxa, and tuberous roots with purple flesh are indicated for foods that require less heating, such as dairy desserts, kinds of pasta and loaves of bread. Furthermore, they observed that there was no difference in the amount of ash, proteins, fibers, carbohydrates, and lipids between the different flesh colors. However, Oliveira et al. (2019) found different levels of ash, proteins, carbohydrates, lipids, ascorbic acid, and carotenoids among genotypes with skin and flesh varying in cream and purple colors.

In a study carried out with tuberous roots of sweet potato with white, cream, orange, and purple flesh, carotenoids were present in all flesh colors, but the highest contents were found in the orange flesh genotypes. β-carotene is the main carotenoid mentioned in orange-fleshed sweet potato, being responsible for this color, it is the precursor of vitamin A, playing a role in health promotion (Hayase & Kato, 1984; Vizzoto et al., 2017).

It is common to find sweet potatoes in supermarkets and fairs in Manaus, however, only with the characteristics of a creamy flesh and purple or white skin. The Cenoura variety (orange flesh and skin) has the potential to be cultivated by Amazonian farmers and introduced in the local market. However, interventions are needed to promote this, such as research that purchased the variety's productivity and sensory acceptance, as well as extension actions so that this propagation material reaches producers along with management techniques.

An example of a successful introduction of a sweet potato cultivar with characteristics similar to the variety in question occurred in the State of Bahia. Cultivar Beauregard (orange-colored skin and flesh) was introduced in fairs in the city of Cruz das Almas (BA), aiming to improve the food quality of the local population. The cultivar was called "Cenoura potato" by farmers in the region, due to the similarity in color between the two vegetables. There was wide acceptance by local consumers and farmers. These confirmed the desirable characteristics of this potato, such as good productivity, pleasant flavor, soft texture, and attractive color, said to be the best seller compared to the white flesh (Silveira et al., 2020).

And yet, as a reflection of the success of this experience, the producers have increased the planting area and also distributed propagation material for the Cenoura potato to other producers in their contact network. Consumers, on the other hand, confirmed the pleasant taste and showed interest in the nutritional properties, in addition, two interviewees stated that the orange potato has the differential of not causing stomach irritation as other sweet potato varieties do to them (Silveira et al., 2020).

4. Conclusion

The Cenoura, Margarita, Rainha, and Roxa varieties have extremely spreading vines, covering the soil well, having a competitive advantage with weeds.

The varieties Cenoura (orange skin and flesh), Rainha (white skin and cream flesh), and Roxa (purple skin and cream flesh), as they have different skin and/or flesh colors and tuberous root shapes, meet different consumer tastes, having market potential.

The Cenoura variety (skin and orange flesh), rich in beta-carotene, has the potential to be introduced in the local market, requiring extension actions to distribute propagation material.

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