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New Cultivar

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Flavor and color: 'IAC 134 AL01', the Campinas Agronomic Institute's first orange-colored pulp sweet potato cultivar

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ABSTRACT

The sweet potato cultivar 'IAC 134 AL01' has tuberous roots with high β-carotene content, with the fresh pulp having an intermediate orange colour (based on international descriptors for the crop), which turns bright orange after cooking, and a mildly sweet taste. These roots have a long-irregular shape, red skin and are of medium size, weighing, on average, 300 g and measuring 14 x 6 cm. The first biofortified sweet potato cultivar of the Campinas Agronomic Institute reaches an average yield of 43.9 t/ha and is recommended for planting in the state of São Paulo to supply the domestic market and for export.

Keywords: *Ipomoea batatas*, tuberous, plant breeding, biofortification.

RESUMO

Sabor e cor: 'IAC 134 AL01', primeira cultivar de batata-doce de polpa alaranjada do Instituto Agronômico de Campinas

A cultivar de batata-doce 'IAC 134 AL01' tem raízes tuberosas de elevado teor em β-caroteno, com a polpa fresca de coloração (com base nos descritores internacionais para a cultura) laranja intermediário, gosto levemente doce e sabor característico da espécie, e coloração laranja intenso, após cocção. Estas raízes têm formato longo-irregular, pele vermelha, e são de tamanho intermediário, pesando, em média 300 g e medindo 14 x 6 cm. A primeira cultivar de batata doce biofortificada do Instituto Agronômico de Campinas alcança o rendimento médio de 43,9 t/ha, sendo recomendada para plantio no estado de São Paulo, visando abastecer o mercado interno e a exportação.

Palavras-chave: *Ipomoea batatas*, tuberosas, melhoramento vegetal, biofortificação.

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GENERAL INFORMATION

Sweet potato is one of the most important horticultural crops as a source of carbohydrates, protein, fiber and other nutritional elements. Among the staple food crops in many countries, sweet potato is among those with the greatest potential for use as a biofortified food. This is because sweet potato is easy to grow, not demanding in terms of soil fertility, tolerant to water scarcity and relatively resistant to insect pests and pathogens. The growing characteristics of sweet potato make it relatively affordable.

The sweet taste of sweet potato is largely due to the accumulation of maltose at the expense of other sugars (Laurie *et al*., 2015), and it has a protein value per hectare similar to that of corn, provides a substantial amount of vitamin C and carotenoids (precursors of vitamin A). The concentration of carotenoids, especially β-carotene, depends on the genotype, and may differ among different cultivars of similar color (Woolfe, 2008). The ability to accumulate β-carotene in the tuber roots turned sweet potatoes a key vegetable for crop biofortification.

In recent times its production has reached 133 million tons per year, being produced in more than 100 countries (CGIAR, 2000), especially in Asia (125 million tons of annual production), where about half is destined for animal feed, with China as the largest producer (117 million tons). In Latin America, the original birthplace of sweet potatoes, production was 1.9 million tons. Since 2000, a slight decrease in harvested area has been observed, with production stabilizing (which is strongly influenced by Asia) since 2014, but with a slight increase in the Americas (Otálora *et al.*, 2023). Between 2014 and 2020 world production was in the range of 90 million tons (UNSD, 2022).

In Brazil, the highest yields for sweet potato are obtained in regions or planting seasons that present, during the vegetative cycle, a period of four months with an average temperature above 20ºC

(Peressin & Feltran, 2014). But, as it is a plant of easy adaptation to climate and soil types, it can be grown from latitude 42ºN to 35ºS, at altitudes referring to sea level up to 3,000 m, although it does not tolerate frost and its growth is severely retarded at temperatures below 10ºC (Castro *et al*., 2008).

As a reflection of increased demand due to its nutritional properties, beneficial to human health, sweet potato production in Brazil has increased in the last decade, going from 545,820 tons in 2011 to 824,680 tons in 2021 (IBGE, 2022). Faced with an increased consumption and demand for tuberous roots with high quality, an increasing number of farmers are investing in technology to obtain higher yields and products that better meet the market demands. Among that, the biofortified β-carotene enriched sweet potato cultivars arise as a marketing option, providing a health food to consumers.

Additionally, consumption of biofortified sweet potato have a social role, once it improves vitamin A levels and may play a significant role in controlling vitamin A deficiency, with results reported in school children (Jaarsveld *et al.*, 2005). Considering the importance of biofortified sweet potato to Brazil, we presented 'IAC 134 AL01', the first sweet potato cultivar from the Agronomic Institute of Campinas with orange pulp and high β-carotene content, offering a pleasant taste. The launch of this cultivar increases the possibility of cultivating and offering this rich food to consumers, due to the possibility of access to seedlings by farmers. The new cultivar contributes to increase the small number of orange sweet potato cultivars introduced or developed in Brazil and registered (MAPA, undated -a), such as Beauregard and CIP BRS Nuti.

Origin and breeding methods

Saplings of six cultivars (IAC 2-71: 'Americana'; IAC 66-118: 'Monalisa'; SRT 47: natural variant found in cultivar 'Beauregard'; SRT 278: 'Centenial'; SRT 299: 'Rio de Janeiro II'; and SRT 334: 'Canadian') with three plots of 19 plants each were distribuited so that each member of one group (three of the random cultivars) was paired with each member of the other group (the other three cultivars) following the North Carolina II design (Acquaah, 2012), at Fazenda Santa Elisa (IAC), Campinas-SP, Brazil, in 2016. The new genotypes were obtained through open pollination, and about 30,000 true botanical seeds were produced. A representative sample of these obtained seeds was planted in 2017, resulting in a production of approximately 2,000 clones (of which no attention was paid to maternal origin) in a first stage (2018), with the selection of the 170 best clones in a later stage (2018/2019).

Aiming to finalize the clonal selection process, from 2018 to 2020, the 48 clones considered best in the previous phases were evaluated and compared with three commercial cultivars, used as checks, usually grown in the State of São Paulo: with light orange pulp, cultivar 'Uruguaiana'; with cream-colored pulp, cultivar 'Ligeirinha', and cultivar 'Canadense'. Five experiments were conducted in five different environments, as described: Mococa-SP, spring-summer, 2019; Piracicaba-SP, winter-summer, 2019; Campinas-SP, summer 2018-2019; Campinas-SP, summer-winter, 2019; and Campinas-SP, spring-summer, 2019-2020.

In the first selection phases (until 2018), analyses focused on root size, fresh pulp color and dry mass. In the following phases (from summer 2018 onwards), the experiments included three or four replicates with a minimum of five plants per plot of each access (according to availability), and then, yield (t/ha), dry matter (%), dry matter per hectare (t/ha), and β-carotene content (μg/g) in fresh pulp were obtained. Yield was estimated converting plot values (kg/plot) in tons per hectare (t/ha). Dry matter was measured by the relation of dry root (roots were dried until constant mass in the oven at 65°C), and the fresh pulp color was obtained using a Konica Minolta colorimeter through the colorimetric method of the CIELAB system (L*a*b*). According to Takahata *et al*. (1993), the a* value is highly and positively correlated with the β-carotene content in orange-fleshed sweet potatoes. The a* values were used to estimate β-carotene content in 'IAC 134 AL01' according to Laurie *et al.* (2015). For the cultivars 'Uruguaina', 'Canadense', 'Ligeirinha', β-carotene was estimated through a* according to Ameny & Wilson (1997).

Varietal description

The morphological description consisted of the international descriptors defined for the crop (Huamán, 1991), assuming class intervals based on the observed sample variation, for continuous variables, while for color and shape variables the definitions were made by more than one person. Although not all of the proposed descriptors (such as the distribution pattern of the tuberous roots) were evaluated, other characteristics that were easier to evaluate, such as peduncle and pedicel length, were considered. Five observations or measurements of each character were made, in two different situations [(one under dryland conditions (three analyses), and the other under irrigated conditions (two analyses)], in Campinas. For some clones, flowering did not occur in one of the two situations in which observations were made and, consequently, the number of observations or measurements was lower. Six analyses were made for the roots, separating them into three size intervals, within each clone and commercial cultivar, on each occasion, seeking to represent the variability observed (Governo *et al*., 2021). The most important and distinctive characteristics of the cultivar 'IAC 134 AL01' are presented, according to international descriptors and terminology (Huamán, 1991).

Plants

The plants reached total ground coverage (>90%), although the first branches issued did not grow over each other.

Stem

The branches are thin (6.1 mm) and the internodes are short (3.4 cm).

Leaves

The blades are pentalobate (Figure

1A), medium-sized in length and width (10.8 x 13.4 cm) and totally green when adult (with a purple border when young), the pilosity is sparse and the petioles are short (14.8 cm).

Inflorescence

Flowering is sparse and peduncles are long (75.3 mm); **Flowers**: medium size (40.4 x 32.8 mm), and long pedicels (12.7 mm); **Corolla**: is rounded, with white limb and purple tube (Figure 1C).

Tuberous roots

The pulp is intermediate orange (Figure 1D), being totally orange-intense after cooking, the shape is long-elliptical to long-irregular and the skin is red; they are medium-sized, weighing 200-300 g, and measuring 14 x 6 cm on average (Figure 1B).

GENERAL COMPARATIVE DATA

Commercial roots production

The analysis among five environments demonstrated that there was no significant clone x environment interactions for the traits (Table 1).

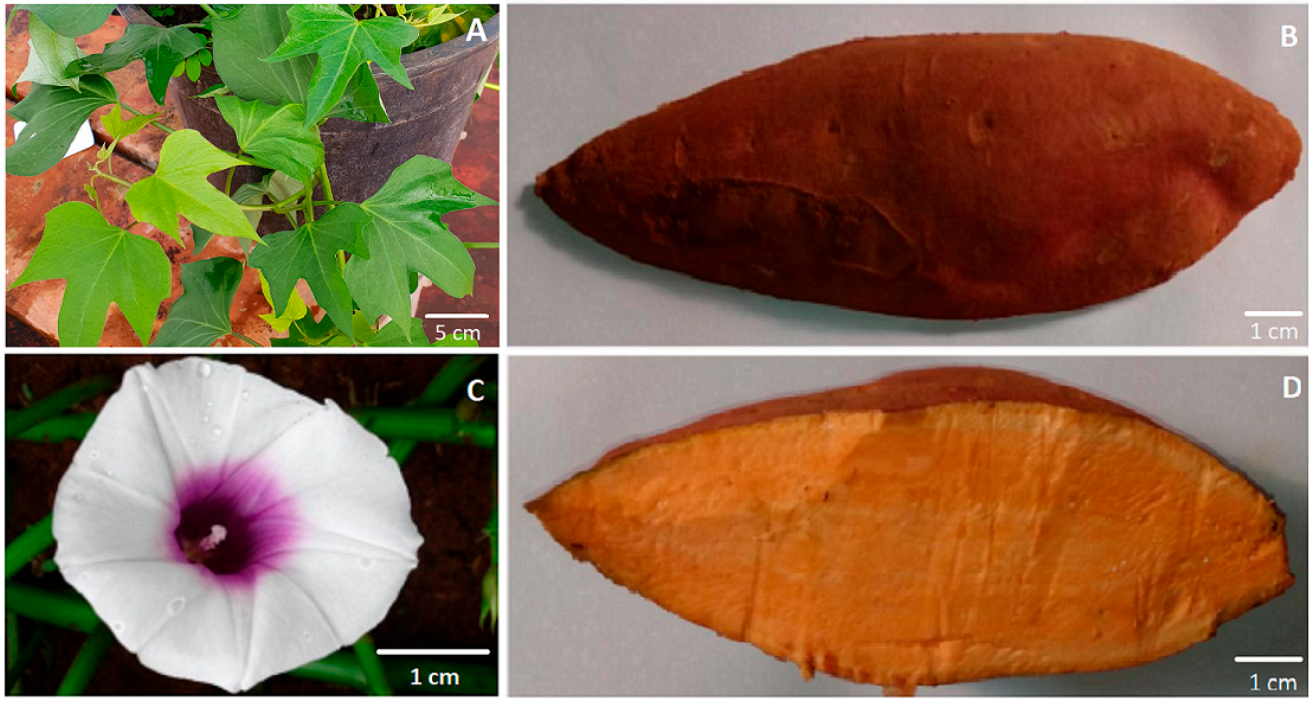

Figure 1. Sweet potato 'IAC 134 AL01': vegetative plant (A), showing the lobulation of the leaves (pentalobates); external view of the tuberous root, showing red skin (B); flower (C); and orange intermediate pulp of the fresh tuberous root, cut (D). Campinas; Instituto Agronômico, APTA Regional and ESALQ-USP; 2020.

Table 1. Analysis of variance of yield (t/ha), dry matter (%) and β-carotene content (µg/g) in tuberous roots of sweet potato 'IAC 134 AL01' and control materials (cultivars already used by farmers: 'Uruguaiana', 'Ligeirinha' and 'Canadense') in Campinas (Instituto Agronômico, summer 2018-2019, summer-winter 2019 and spring-summer 2019-2020), Mococa (APTA Regional, spring-summer 2019) and Piracicaba (Esalq/USP - winter-summer 2019). Campinas; Instituto Agronômico, APTA Regional and ESALQ-USP; 2020.

Source of variation	Degrees of freedom	Mean Square		
		Yield	Dry matter	β-carotene
Block/Environment	10	101.3 ^{ns}	2.5 ^{ns}	32.0 ^{ns}
Cultivar (Clone)	3	683.3 *	128.4 **	28436.8 **
Environment	4	1679.9 **	45.1 **	48.9 ^{ns}
Cultivar (Clone) x Environment	12	148.3 ^{ns}	4.2 ^{ns}	5.9 ^{ns}
Residuals	30	158.9	2.1	21.3
CV (%)	-	31.9	5.4	17.2

**Significant by F test at p<0.01; *Significant by F test at p<0.05; ^{ns} Non-significant.

Then, the evaluation based on the overall means was a representative and a robust result. With high commercial yield of 43.9 t/ha, the cultivar 'IAC 134 AL01' stood out in relation to the control cultivar 'Uruguaiana', presenting similar yield to cultivars 'Canadense' and 'Ligeirinha' (Table 2). Once the 'IAC 134 AL01' was evaluated in Campinas-SP, Piracicaba-SP and Mococa-SP, this new orange pulp root cultivar can be recommended for cultivation in the State of São Paulo.

Table 2. Averages of yield (t/ha), dry matter (%) and β-carotene content (µg/g) in tuberous roots of sweet potato 'IAC 134 AL01' and control materials (cultivars already used by farmers: 'Uruguaiana', 'Ligeirinha' and 'Canadense') in Campinas (Instituto Agronômico), Mococa (APTA Regional) and Piracicaba (Esalq/USP). 2018-2020. Campinas; Instituto Agronômico, APTA Regional and ESALQ-USP; 2020.

Clone	Yield	Dry matter	β-carotene
'IAC 134 AL01'	43.9 a	25.5 B	98.8 a
'Uruguaiana'	30.4 b	30.4 A	0.9 b
'Ligeirinha'	38.4 ab	26.9 B	< 0.1 b
'Canadense'	45.2 a	23.4 C	< 0.1 b
Mean	39.5	26.6	24.9
Controls mean	38.0	26.9	0.3

Different letters in the same column indicate that means are different by LSD test ($p<0.05$).

Dry matter content

In relation to the control cultivars, individually, the cultivar 'IAC 134 AL01' showed higher dry matter percentage (25.5%) in relation to the cultivar 'Canadense', lower in relation to the cultivar 'Uruguaiana' and similar to the cultivar 'Ligeirinha' (Table 2). Silva (2021) reported a negative correlation between dry matter and β-carotene content. Although there are difficulties in obtaining sweet potato clones with intense orange pulp and high dry matter content, simultaneous selection gains for these traits proved to be possible.

Culinary quality

The intense orange coloration when cooked and its very sweet taste make the 'IAC 134 AL01' cultivar an opportunity in the market, both to fill a national gap and for export.

Disease reaction

Sweet potato is considered a rustic crop, although pests and diseases are being recognized in Brazil and in other countries (Peressin *et al*., 2022). The experimental area was relatively small and good agricultural practices (Peressin *et al.*, 2022) were adopted, and during the experimentation, the occurrence of pests and diseases was negligible, and it was not possible to measure any interference in the selection process. A small number of pesticides are registered for use on sweet potatoes (MAPA, undated -b), but the authorization process is dynamic and more products may become available.

Crop management

The management practices of 'IAC 134 AL01' are common to those used for other cultivars of sweet potatoes. The 'IAC 134 AL01' cultivar stood out for presenting very high stability, in relation to the different growing conditions, maintaining high yield (Silva, 2021).

Chemical characteristics

The cultivar 'IAC 134 AL01' presented, in average 98.8 µg/g of β-carotene in the fresh pulp (Table 2), standing out for its high β-carotene content.

Sapling maintenance and distribution

The sweet potato cultivar 'IAC 134 AL01' was registered by the Ministry of Agriculture, Livestock and Supply under number 49339 (MAPA, undated –a). The stock plants are maintained in protected cultivation with anti-aphyd screens and *in vitro* cultivation in the laboratory, under the responsibility of the Campinas Agronomic Institute. Information about saplings can be obtained at "IAC - Instituto Agronômico, Fazenda Santa Elisa, Centro de Horticultura. Av. Theodureto de Almeida Camargo, 1500. Jardim Nossa Senhora Auxiliadora, Campinas-SP, Brasil. CEP 13075-630; e-mail: valdemir.peressin@sp.gov.br.

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