horticultura brasileira

Research

GONZALEZ, JAB; GELSLEICHTER, A; GALINA, J; SILVA, A; RIBEIRO, AJ; SILVA JÚNIOR, ADS; GUESSER, S; ZEIST, AR. Selection of superior sweet potato genotypes in the autumn-winter of Great Florianopolis. *Horticultura Brasileira* v.43, 2025, elocation e286344. DOI: http://dx.doi.org/10.1590/s0102-0536-2025- e286344

Selection of superior sweet potato genotypes in the autumn-winter of Great Florianopolis

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ABSTRACT

Sweet potato (*Ipomoea batatas* L.) productivity in Brazil averages 14 t/ha, far below its potential. This low productivity is largely due to outdated genotypes and limited research on developing new ones. This study aimed to select white, orange, and purple-fleshed sweet potato genotypes based on agronomic performance during the autumn-winter season in the Great Florianopolis region, Santa Catarina. Forty-two genotypes from the UFSC breeding program and three commercial controls were evaluated. Various parameters were evaluated, including total root production, total number of roots, number of commercial roots, commercial root production, average mass of commercial roots, percentage of dry mass of commercial roots, insect damage, root appearance, root distribution in relation to the base, soluble solids, and skin thickness. The genotype UFSC-FP-09 showed higher values of soluble solids (12.4ºBrix). Genotypes UFSC-LW-76, UFSC-LW-102, UFSC-FC-04, UFSC-LO-03, UFSC-LP-109, and UFSC-LP-43 exhibited superiority in the analyzed productivity characteristics, thus being recommended for cultivation in the region.

Keyword: *Ipomoea batatas* L, climate conditions, breeding, yield.

RESUMO

Seleção de genótipos superiores de batata-doce no outono-inverno da Grande Florianopolis

A produtividade média da batata-doce (*Ipomoea batatas* L.) no Brasil é de apenas 14 t/ha, significativamente abaixo do seu potencial. A baixa produtividade é frequentemente atribuída ao uso de genótipos obsoletos e à escassez de estudos que fomentem o desenvolvimento de novos genótipos. O objetivo deste estudo foi selecionar genótipos experimentais de batata-doce de polpa branca, laranja e roxa quanto ao desempenho agronômico no outono-inverno da Grande Florianopolis-SC. Utilizou-se 42 genótipos provenientes do programa de melhoramento genético da UFSC e três testemunhas comerciais. Foram avaliadas a produção total de raízes, número total de raízes, número de raízes comerciais, produção comercial de raízes, massa média de raízes comerciais, porcentagem de massa seca de raízes comerciais, danos causados por insetos, aparência de raízes, distribuição das raízes em relação à base, sólidos solúveis e espessura de casca. O genótipo UFSC-FP-09 apresentou maiores valores de sólidos solúveis (12,4ºBrix). Os genótipos UFSC-LW-76, UFSC-LW-102, UFSC-FC-04, UFSC-LO-03, UFSC-LP-109 e UFSC-LP-43, apresentaram superioridade para as características de produtividade analisadas, sendo indicados para cultivo na região.

Palavras-chave: *Ipomoea batatas* L; *condições climáticas, melhoramento genético, produtividade.*

Received on June 7, 2024; accepted on October 30, 2024

Sweet potato (*Ipomoea batatas* L.) is a hexaploid species (2n = 6x = 90), self-incompatible, and part of the Convolvulaceae family (Katayama *et al*., 2017). Native to Central America, it has considerable production potential globally. While propagation primarily occurs through asexual means, sexual propagation is also possible (Perrud *et al.*, 2021). The species exhibits extensive genetic variation among genotypes, resulting in a remarkable diversity of traits, including differences in color, shape, flavor, resistance, yield, and texture (Kouassi *et al.*, 2023).

The tuberous roots are the most commercially relevant part of the plant (Oliveira *et al*., 2022). Used in human and animal nutrition, these roots are also employed in the production of processed foods, textiles, cosmetics, alcohol fuel, and paper (Silva *et al.*, 2023). Sweet potato tuberous roots are classified by flesh and skin color, ranging from white to purple (Tang *et al.*, 2015). In Brazil, yellow, white, or cream-colored sweet potato flesh is most commonly consumed (Zeist *et al.*, 2022). However, tuberous roots with purple and orange-colored flesh are rich in anthocyanins and carotenoids, respectively (Toroco *et al.*, 2023). The β-carotene pigment content, a precursor of vitamin A, is most

prominent in orange-colored flesh (Zeist *et al.*, 2022).

Brazil has an average productivity of 14.6 t/ha, a relatively low rate compared to countries like Senegal (40.4 t/ha), Australia (36.42 t/ha), Egypt (33.57 t/ha), and Portugal (25.42 t/ha) (Oliveira et al., 2022; FAOSTAT, 2021). The low productivity in Brazil may be associated with several factors, including the lack of adoption of modern cultivation technologies and the use of obsolete cultivars (Leal *et al.*, 2021). When genotypes with superior traits are employed under favorable technological conditions, yields exceeding 30 t/ha can be achieved in Brazil. However, genetic materials enabling such outcomes are scarce in the country (Oliveira *et al.*, 2022; Toroco *et al.*, 2023). In the state of Santa Catarina (SC), for instance, genotypes commonly cultivated by farmers rarely exceed 20.0 t/ha (IBGE, 2023). Moreover, the cultivated area for this crop in SC is still small, with only 1,086 hectares, representing about 2% of the total cultivated area in Brazil, highlighting the need for further studies to promote its expansion.

To address these challenges, the Sweet Potato Breeding Program at the Federal University of Santa Catarina conducts controlled crosses and selects superior genotypes for the Great Florianopolis region. The selected genotypes are subjected to comprehensive agronomic evaluations, including performance tests, resistance to soil pests, and assessments of root characteristics. These efforts focus on identifying experimental genotypes with superior productive performance compared to commercial varieties.

Experimental trials are crucial for assessing the performance and adaptability of sweet potato genotypes under challenging conditions (Toroco *et al.*, 2023), such as the autumn-winter season in southern Brazil. In this region, selecting genotypes adapted to low temperatures is critical, as the crop's development is significantly restricted under such conditions (Silva *et al.*, 2023), with growth slowing when temperatures drop below 20ºC and ceasing entirely between 12-15ºC. Selecting low-temperature-tolerant genotypes not only supports the development of more resilient varieties but also ensures a consistent year-round food supply, reducing reliance on specific harvests (Oliveira *et al.*, 2022; Toroco *et al.*, 2023).

The Great Florianopolis region in Santa Catarina, while having a low probability of frost occurrence during autumn and winter, is still subject to low temperatures. Conducting experimental trials in this region during these seasons is therefore crucial to identify sweet potato genotypes that can thrive in specific locations, even under less favorable climatic conditions. This approach directly contributes to strengthening sweet potato production in the region, addressing the demand for healthy and nutritious food year-round. In this context, the objective was to identify superior experimental sweet potato genotypes for human consumption, with white, orange, and purple flesh, in the Great Florianopolis region during the autumn-winter of 2023.

MATERIAL AND METHODS

Study location

The experiment was carried out in Antônio Carlos-SC, on a local farm (27º30'S, 48º46'W, 20 m altitude). The site falls under the Cfa classification: humid subtropical climate. The soil is classified as Red-Yellow Podzolic with an acidic profile.

Plant material and experimental design

Forty-two experimental sweet potato genotypes from the Federal University of Santa Catarina Breeding Program were evaluated. As commercial controls, the genotypes Beauregard, the most widely cultivated orange-fleshed sweet potato in the world (Zeist *et al.*, 2022), SCS370 Luiza, a purple-fleshed cultivar selected in the state of Santa Catarina (Perrud *et al.*, 2021), and Canadense, the most cultivated white-fleshed sweet potato in Brazil (Oliveira *et al.*, 2022; Perrud *et al.*, 2021) were used. Among the 42 experimental genotypes, 20 had purple flesh, 6 orange flesh, 8 white flesh, and 8 cream flesh. The experiment was conducted during the autumn-winter cycle of 2023. A 9 × 5 alpha-lattice design (9 treatments per 5 blocks) with two replications was employed. Each plot consisted of five plants.

Cultivation setup and experimental management

Deep plowing and light harrowing were performed before planting, followed by the preparation of 0.4 m-high ridges. Planting was carried out on April 1, 2023, using 12-bud vines obtained from pest- and pathogen-free nurseries. Of these 12 buds, eight were positioned below the soil and four above it during planting. The spacing adopted was 0.40 x 0.85 m (between plants within each ridge and between ridges, respectively).

Cultural practices and fertilization, including both basal and top-dressing applications, were carried out according to crop recommendations and soil chemical analysis (Echer *et al*., 2015). Weed management was performed through an application of Linuron (Afalon® SC) immediately after planting, as well as manual weeding. During the experimental period, daily data on average, maximum, and minimum air temperatures were collected using maximum

and minimum thermometers, while precipitation data were recorded using a rain gauge located 40 m from the experimental site.

Evaluated traits

Tuberous roots were harvested 157 days after planting, once most genotypes met commercial standards. Prior to root collection, the distribution of roots in the soil relative to the plant base (DRS) was assessed on a scale from 1 to 5, as follows: (1) very dispersed roots, making it impossible to identify the originating plant; (2) identifiable roots more than 50 cm from the base; (3) roots approximately 40 cm from the base; (4) roots about 30 cm from the base; and (5) roots concentrated near the plant (Toroco *et al*., 2023). Subsequently, roots were evaluated for the total number (NTR, roots/ha) and total production (RTY, t/ha) of tuberous roots; the number of commercial roots (NCR, roots/ha) and production of commercial tuberous roots (CRY, t/ha); the average mass of commercial tuberous roots (AMCR); and the percentage of dry mass of commercial tuberous roots (DM) (Toroco *et al*., 2023). Commercial roots were defined as those weighing over 80 g, with a uniform shape and free from mechanical damage, pests, or cracks (Perrud *et al*., 2021).

Resistance to insect damage (RI) was assessed using a 5-point scale (Oliveira *et al*., 2022) on five roots per CRY replication: 5= no damage; 4= rare damage; 3= few damaged roots; 2= more damaged roots; 1= unacceptable for consumption. Root appearance (AR) was evaluated on a 5-point scale (Toroco *et al*., 2023): 1= non-standard (irregular shape, large veins, deep cracks); 2= very uneven (large veins, cracks); 3= uneven (large veins, cracks); 4= slightly uneven (some veins); 5= regular fusiform (no veins, no cracks). From a sample of five CRY roots, peel thickness (PT, mm) was measured using a digital caliper, and soluble solids content (SS, °Brix) was determined using a portable refractometer. Additionally, pulp color (PC) (white, purple, cream, and orange) was evaluated (Leal *et al.*, 2021).

Data analysis

Data were analyzed using analysis of variance (ANOVA), and means were grouped using the Scott-Knott test at a 5% significance level. The mathematical model used for the analysis on the alpha lattice design can be described by:

$$Yij = \mu + ti + rj + eij$$

Where yij is the observed value of treatment i (i =1, 2 ...; v = 100) in replication j (j = 1,2 ...., r = e or 3); μ is constant inherent to all observations; ti is the effect of treatment i; rj is the effect of replication j; and eij is the random error associated with the observation yij.

Principal component analysis was employed to identify the most relevant quantitative traits among the sweet potato genotypes. The identification of the three groups was carried out through a dendrogram with a cut at an Euclidean distance of 1.25. Spearman's correlation coefficient was used to evaluate relationships among traits, identifying positive and negative correlations. All statistical analyses were conducted using the R software. The R packages used for the analyses were RIO version 1.0.1, METAN version 1.18.0, Scott Knot version 1.3-2, FACTOEXTRA version 1.0.7, and FACTOR MINER version 2.9.

RESULTS AND DISCUSSION

Meteorological conditions during the experimental trial

During the experimental period (April 1 to September 7), temperatures were higher than the historical averages for the Great Florianopolis region, SC. Historical minimum and maximum averages for the same period are 15.01ºC and 23.01ºC, respectively (INMET, 2023). However, recorded values reached 16.15ºC and 24.25ºC, respectively, with an average of 19.5ºC, representing an increase of 0.9ºC compared to the historical average. The cumulative rainfall during the experimental period totaled 510.6 mm, close to the historical average for the region, which is 537.2 mm. There were 21 days with minimum temperatures below 12ºC, which is the base temperature for sweet potato (Figure 1).

Spearman's correlation analysis

The results of Spearman's correlation analysis (Figure 2) revealed positive associations among the traits RTY, NCR, and CRY. Additionally, AMCR and NTR showed positive correlations with RTY, NCR, and CRY; however, the correlation between AMCR and NTR was not statistically significant (0.26). A significant positive correlation was observed between the parameters RTY, NCR, CRY, PC, and NTR with DRS (0.57, 0.58, 0.48, 0.47, 0.47, and 0.50, respectively). DM was not correlated with productivity traits (PC, CRY, NCR, RTY, AMCR), nor was AR correlated with AMCR, RTY, NCR, CRY, NTR, DRS, or SS (Figure 2).

Trait evaluation (Tables 1 and 2)

There was a significant difference ($p<0.05$) for all evaluated traits (Tables 1 and 2), except for insect resistance. RTY and CRY results were promising, with purple-fleshed genotypes UFSC-LP-109 and UFSC-LP-43, orange-fleshed UFSC-LO-03, cream-fleshed UFSC-FC-04, and white-fleshed UFSC-LW-76 surpassing the controls Canadense, SCS370 Luiza, and Beauregard. The genotype UFSC-LP-43 achieved a CRY superior to the controls and other genotypes. Superior NCR values were observed for purple-fleshed UFSC-LP-109, UFSC-LP-43, UFSC-LP-32; orange-fleshed UFSC-LO-03; cream-fleshed UFSC-FC-04, UFSC-FC-12, UFSC-LC-34; and white-fleshed UFSC-LW-76, UFSC-LW-102, UFSC-LW-47, UFSC-LW-77, UFSC-KW-19, UFSC-KW-15, and the control Canadense. Except UFSC-LW-47, UFSC-KW-19, and UFSC-KW-15, these genotypes also stood out in the AMCR grouping, along with 14 other experimental genotypes and the commercial controls. Among the controls, Canadense exhibited the best performance in RTY, CRY, and NCR. The genotype UFSC-FP-09 and SCS370 Luiza were superior in DM.

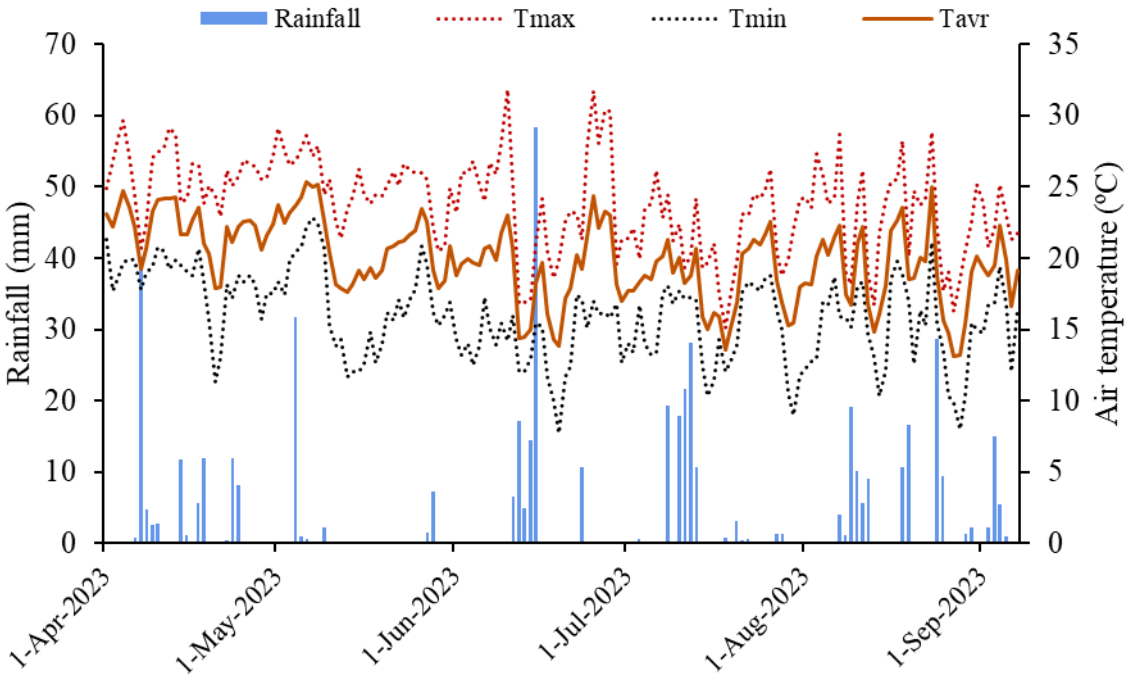

Figure 1. Rainfall, maximum temperatures (Tmax), minimum temperatures (Tmin), and average temperatures (Tavr) during the experimental period for the cultivation of sweet potato genotypes in the autumn-winter season in the Great Florianopolis region.. Great Florianopolis region, UFSC, 2023.

In the evaluation of DRS (Table 2), the experimental genotypes UFSC-LW-76, UFSC-LW-102, UFSC-FC-04, UFSC-LO-03, UFSC-LP-109, UFSC-LP-43, UFSC-LP-32, UFSC-FC-12, UFSC-LC-34, UFSC-LW-77, UFSC-LW-47, UFSC-KW-19, UFSC-LP-75, UFSC-FP-39, UFSC-KW-15, UFSC-LP-103, UFSC-LC-36, UFSC-FW-06, UFSC-KC-14, UFSC-LO-37, UFSC-KC-16, UFSC-LO-66, UFSC-FO-11, UFSC-LP-115, UFSC-FP-40, UFSC-LP-33 and UFSC-KP-17, as well as the commercial controls Canadense, SCS370 Luiza, and Beauregard, exhibited roots predominantly clustered near the plant base. For AR, superior performance was observed in Canadense, SCS370 Luiza, and Beauregard, alongside the experimental genotypes UFSC-LC-34, UFSC-LW-77, UFSC-LW-47, UFSC-KW-15, UFSC-LP-103, UFSC-LP-22, UFSC-LP-20, UFSC-LP-38, UFSC-LO-66, UFSC-LP-115, UFSC-FP-40, UFSC-LP-24, UFSC-FC-05, UFSC-KP-17, UFSC-FP-10 and UFSC-FW-42 (Table 2).

Regarding PT, the experimental genotypes UFSC-FC-04, UFSC-FC-12, UFSC-FO-13, UFSC-FP-40, UFSC-FW-42, UFSC-KW-15, UFSC-LC-36, UFSC-LO-37, UFSC-LP-109, UFSC-LP-115, UFSC-LP-20, UFSC-LP-33, and UFSC-LW-76, along with the controls Canadense and SCS370 Luiza, stood out by exhibiting thicknesses greater than 2.52 mm. Lastly, for SS, the experimental genotype UFSC-FP-09 achieved the highest values, followed by a secondary grouping that included the control SCS370 Luiza and the experimental genotypes UFSC-LW-102, UFSC-LP-109, UFSC-FC-12, UFSC-KC-14, and UFSC-LP-33 (Table 2).

Principal Component Analysis

PCA revealed that the first two principal components (PC1 and PC2) explained 56.40% of the variation among the 42 experimental genotypes and the three controls (Figure 3). Genotypes LW-102 (white), FC-04 (cream), LP-109 (purple),

LW-76 (white), LP-43 (purple), and LO-03 (orange) excelled in productivity-related traits and clustered in PCA Group 3. Genotypes in PCA group 2, including UFSC-FC12 and UFSC-LC-34 (cream flesh); UFSC-KW-19, UFSC-LW-77, UFSC-LW-47, and UFSC-KW-15 (white flesh); UFSC-LP-32, UFSC-LP-46, UFSC-FP-39, and UFSC-LP-103 (purple flesh); UFSC-LO-37 (orange flesh); and the control Canadense, exhibited similarities in the traits NTR, RTY, and RI.

Group 1, composed of experimental genotypes such as UFSC-FP-09, UFSC-LP-33, UFSC-LP-115, UFSC-LP-20, UFSC-FP-40, UFSC-LP-22, UFSC-LP-38, UFSC-KP-17, UFSC-LP-24, UFSC-LP-26, UFSC-FP-10, UFSC-LP-27 (purple flesh); UFSC-KC-18, UFSC-FO-05, UFSC-KC-16, UFSC-LC-36, UFSC-KC-14 (cream flesh); UFSC-LO-28, UFSC-LO-66, UFSC-FO-11, UFSC-FO-13 (orange flesh); and UFSC-FW-06, UFSC-FW-42 (white flesh), as well as the controls SCS370 Luiza and Beauregard, showed similar performance for the evaluated traits. However, this group demonstrated inferior performance in productivity-related traits compared to Group 3.

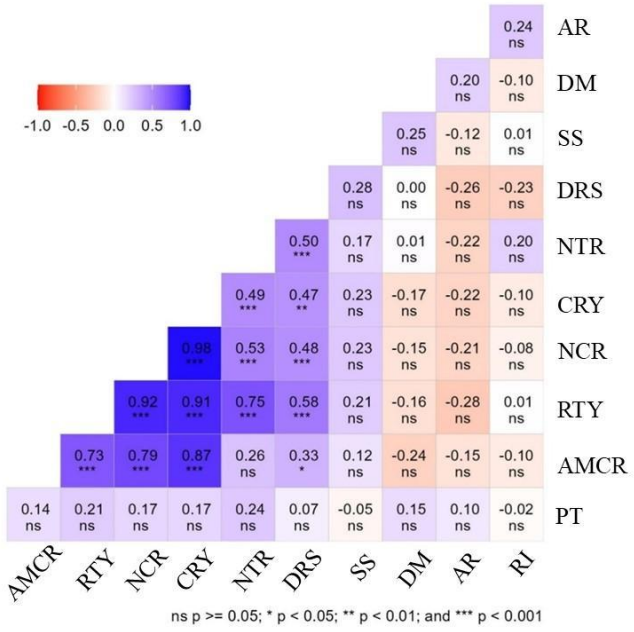

Figure 2. Spearman's rank correlation matrix among mean mass of commercial roots (AMCR), total production of tuberous roots (RTY), number of commercial tuberous roots (NCR), production of commercial tuberous roots (CRY), total number of tuberous roots (NTR), root distribution in the soil (DRS), soluble solids (SS), dry mass of tuberous roots (DM), appearance of tuberous roots (AR), soil pest damage (RI), and peel thickness (PT) of experimental sweet potato genotypes during the autumn-winter season in the Great Florianopolis region. Great Florianopolis region, UFSC, 2023.

Table 1. Total number of roots (NTR, thousands of roots/ha), total root production (RTY, t/ha), number of commercial roots (NCR, thousands of roots/ha), production of commercial roots (CRY, t/ha), mean mass of commercial roots (AMCR, g/root), and dry mass percentage of commercial roots (DM, %) for experimental sweet potato genotypes during the autumn-winter season in the Great Florianopolis region. Great Florianopolis region, UFSC, 2023.

Genotypes	NTR	RTY	NCR	CRY	AMCR	DM
UFSC-LW-76 (B[1])	276.00 a*	29.68 a*	119.00 a*	23.71 a*	199.24 a*	28.96 b*
UFSC-LW-102(B)	336.75 a	31.29 a	112.50 a	22.04 a	195.91 a	18.21 f
UFSC-FC-04 (C[2])	345.50 a	29.49 a	141.75 a	20.95 a	147.80 a	21.79 d
UFSC-LO-03 (L[3])	292.25 a	29.81 a	106.25 a	19.72 a	185.70 a	13.07 g
UFSC-LP-109 (R[4])	279.00 a	25.46 a	114.75 a	19.40 a	169.06 a	23.84 c
UFSC-LP-43 (R)	187.75 b	22.62 b	100.00 a	17.28 a	172.80 a	17.52 f
UFSC-LP-32 (R)	224.50 a	18.02 b	71.00 a	13.01 b	183.24 a	22.38 d
UFSC-FC-12 (C)	317.25 a	21.94 b	75.00 a	12.60 b	168.00 a	22.63 d
UFSC-LC-34 (C)	180.00 b	15.42 c	71.00 a	11.76 b	165.63 a	20.64 e
UFSC-LW-77 (B)	165.00 b	15.16 c	79.25 a	11.36 b	143.34 a	25.27 c
UFSC-LW-47 (B)	238.50 a	17.13 b	81.50 a	10.81 b	132.64 b	24.55 c

UFSC-LP-46 (R)	187.00 b	16.20 b	52.25 b	10.17 b	194.64 a	23.41 c
UFSC-KW-19 (B)	271.25 a	18.47 b	73.00 a	10.10 b	138.36 b	25.93 c
UFSC-LP-75 (R)	134.75 b	12.26 c	48.00 b	8.52 c	177.50 a	21.53 d
UFSC-FP-39 (R)	117.50 b	12.46 c	46.00 b	8.47 c	184.13 a	22.97 d
UFSC-KW-15 (B)	392.25 a	20.10 b	68.75 a	8.20 c	119.27 b	24.97 c
UFSC-LP-103 (R)	201.75 b	14.88 c	48.00 b	8.00 c	166.67 a	18.05 f
UFSC-LC-36 (C)	139.25 b	11.12 c	29.25 b	6.74 c	230.43 a	21.04 e
UFSC-LP-22 (R)	81.50 b	8.58 c	37.50 b	6.51 c	166.67 a	22.71 d
UFSC-FW-06 (B)	249.25 a	14.01 c	50.00 b	6.26 c	125.22 b	19.01 f
UFSC-KC-14 (C)	186.25 b	11.11 c	39.75 b	6.17 c	155.22 a	26.74 c
UFSC-LP-20 (R)	67.50 b	7.45 c	33.50 b	6.14 c	183.28 a	28.93 b
UFSC-LO-37 (L)	309.75 a	16.47 b	41.75 b	5.12 c	122.66 b	19.93 e
UFSC-LO-28 (L)	274.25 a	11.32 c	31.25 b	5.03 c	160.96 a	20.62 e
UFSC-KC-16 (C)	167.25 b	10.23 c	37.50 b	4.95 c	132.35 b	20.99 e
UFSC-LP-38 (R)	126.00 b	7.95 c	25.25 b	4.08 c	161.58 a	24.92 c
UFSC-LO-66 (L)	112.75 b	6.82 c	31.25 b	4.08 c	130.56 b	17.74 f
UFSC-FO-11 (L)	173.75 b	9.74 c	27.25 b	4.06 c	148.99 a	26.46 c
UFSC-LP-26 (R)	130.50 b	7.47 c	31.25 b	3.64 c	116.48 b	24.79 c
UFSC-LP-115 (R)	181.50 b	9.65 c	31.25 b	3.60 c	115.20 b	24.08 c
UFSC-KC-18 (C)	117.50 b	6.03 c	14.75 b	2.73 c	185.08 a	18.47 f
UFSC-FP-09 (R)	197.25 b	9.90 c	23.00 b	2.61 c	113.48 b	31.57 a
UFSC-FO-13 (L)	120.50 b	8.01 c	23.00 b	2.59 c	112.61 b	18.04 f
UFSC-FP-40 (R)	122.75 b	6.60 c	14.75 b	2.58 c	174.92 a	22.28 d
UFSC-LP-33 (R)	199.50 b	7.76 c	14.75 b	2.29 c	155.25 a	25.35 c
UFSC-LP-24 (R)	159.50 b	5.33 c	14.50 b	1.63 c	112.41 b	22.56 d
UFSC-LP-27 (R)	112.75 b	4.19 c	+	+	+	+
UFSC-LP-95 (R)	79.25 b	2.65 c	+	+	+	+
UFSC-FC-05 (C)	291.00 a	8.50 c	+	+	+	+
UFSC-KP-17 (R)	230.75 a	10.40 c	+	+	+	+
UFSC-FP-10 (R)	111.25 b	15.58 c	+	+	+	+
UFSC-FW-42 (B)	138.25 b	0.71 c	+	+	+	+
Canadense	244.50 a	23.24 b	79.25 a	13.80 b	174.13 a	20.14 e
SCS370 Luiza	92.50 b	6.61 c	27.25 b	4.22 c	154.86 a	31.65 a
Beauregard	255.50 a	6.71 c	47.75 b	8.00 c	167.54 a	26.08 c
CV (%)	33.06	36.65	66.42	61.46	45.56	5.14

*Means followed by same letters in the column belong to the same group according to the Scott-Knott test ($p<0.05$). +Genotypes did not produce commercial roots. B[1]= white-fleshed genotypes. C[2]= cream-fleshed genotypes. L[3]= orange-fleshed genotypes. R[4]= purple-fleshed genotypes.

Table 2. Root distribution relative to the plant base (DRS, scored on a scale from 1 to 5 where 1= very dispersed roots; 5= roots concentrated near the plant), resistance to insect damage (RI, scored on a scale from 1 to 5 where 1= unacceptable for consumption; 5= no damage), appearance of tuberous roots [AR, scored on a scale from 1 to 5 where 1= no standard; 5= regular fusiform (no veins, no crack)], peel thickness (PT, in mm), and soluble solids (SS, ºBrix) for experimental sweet potato genotypes during the autumn-winter season in the Great Florianopolis region. Great Florianopolis region, UFSC, 2023.

Genotypes	**DRS**	**RI**	**AR**	**PT**	**SS**
UFSC-LW-76 (B[1])	5.00 a*	4.00 a*	2.00 b*	3.16 a*	10.82, b*
UFSC-LW-102 (B)	5.00 a	4.00 a	2.50 b	2.14 b	10.93, b
UFSC-FC-04 (C[2])	5.00 a	4.00 a	3.00 b	2.64 a	8.18, d

UFSC-LO-03 (L[3])	5.00 a	4.00 a	1.00 b	1.73 b	6.72, e
UFSC-LP-109 (R[4])	5.00 a	5.00 a	3.00 b	2.85 a	9.75, b
UFSC-LP-43 (R)	5.00 a	4.00 a	1.00 b	1.55 b	8.12, d
UFSC-LP-32 (R)	5.00 a	5.00 a	2.50 b	1.42 b	8.65, c
UFSC-FC-12 (C)	5.00 a	4.00 a	2.50 b	3.33 a	10.16, b
UFSC-LC-34 (C)	5.00 a	4.00 a	4.50 a	2.21 b	7.2, e
UFSC-LW-77 (B)	5.00 a	4.00 a	4.00 a	2.10 b	8.81, c
UFSC-LW-47 (B)	5.00 a	5.00 a	4.50 a	1.66 b	9.07, c
UFSC-LP-46 (R)	4.50 b	4.00 a	3.00 b	2.17 b	8.15, d
UFSC-KW-19 (B)	5.00 a	4.00 a	3.00 b	1.80 b	8.0, d
UFSC-LP-75 (R)	5.00 a	4.00 a	3.00 b	2.02 b	9.09, c
UFSC-FP-39 (R)	5.00 a	5.00 a	3.00 b	1.71 b	8.95, c
UFSC-KW-15 (B)	5.00 a	4.00 a	4.50 a	2.58 a	7.35, e
UFSC-LP-103 (R)	5.00 a	4.00 a	3.50 a	1.89 b	7.99, d
UFSC-LC-36 (C)	5.00 a	3.50 a	2.50 b	2.54 a	7.67, e
UFSC-LP-22 (R)	4.50 b	4.50 a	4.50 a	1.72 b	9.25, c
UFSC-FW-06 (B)	5.00 a	4.00 a	2.00 b	1.84 b	8.43, d
UFSC-KC-14 (C)	5.00 a	4.00 a	2.50 b	1.66 b	10.2, b
UFSC-LP-20 (R)	4.00 c	5.00 a	4.50 a	2.86 a	7.39, e
UFSC-LO-37 (L)	5.00 a	4.50 a	3.00 b	2.92 a	7.09, e
UFSC-LO-28 (L)	4.50 b	5.00 a	4.50 a	1.74 b	8.11, d
UFSC-KC-16 (C)	5.00 a	4.00 a	3.00 b	2.03 b	7.54, e
UFSC-LP-38 (R)	4.00 c	4.00 a	4.50 a	1.96 b	8.01, d
UFSC-LO-66 (L)	5.00 a	4.00 a	4.00 a	1.70 b	8.75, c
UFSC-FO-11 (L)	5.00 a	3.50 a	3.00 b	1.38 b	8.2, d
UFSC-LP-26 (R)	4.00 c	5.00 a	3.50 a	2.09 b	7.49, e
UFSC-LP-115 (R)	5.00 a	3.50 a	4.00 a	2.80 a	8.19, d
UFSC-KC-18 (C)	4.00 c	4.00 a	3.00 b	2.11 b	8.32, d
UFSC-FP-09 (R)	4.50 b	4.00 a	3.00 b	1.97 b	12.4, a
UFSC-FO-13 (L)	4.00 c	5.00 a	2.50 b	2.34 a	6.42, e
UFSC-FP-40 (R)	5.00 a	3.50 a	3.50 a	2.30 a	8.44, d
UFSC-LP-33 (R)	5.00 a	4.50 a	3.00 b	2.52 a	10.21, b
UFSC-LP-24 (R)	4.00 c	4.50 a	4.00 a	1.63 b	8.47, d
UFSC-LP-27 (R)	4.00 c	4.00 a	3.00 b	1.80 b	7.25, e
UFSC-LP-95 (R)	4.00 c	4.50 a	3.00 b	1.53 b	6.86, e
UFSC-FC-05 (C)	5.00 a	5.00 a	4.00 a	2.22 b	8.03, d
UFSC-KP-17 (R)	5.00 a	5.00 a	4.50 a	2.10 b	8.94, c
UFSC-FP-10 (R)	5.00 a	5.00 a	4.00 a	1.51 b	8.32, d
UFSC-FW-42 (B)	4.00 c	5.00 a	4.00 a	2.57 a	7.52, e
Canadense	5.00 a	4.00 a	4.50 a	2.48 a	7.85, d
SCS370 Luiza	5.00 a	4.00 a	4.00 a	2.76 a	10.2, b
Beauregard	5.00 a	4.50 a	4.00 a	1.69 b	8.3, d
CV (%)	5.07	17.74	26.1	14.53	5.62

* Means followed by the same letter in the column belong to the same group according to the Scott-Knott test ($p<0.05$). B[1]= white-fleshed genotypes; C[2]= cream-fleshed genotypes; L[3]= orange-fleshed genotypes; and R[4]= purple-fleshed genotypes.

Implications and perspectives of sweet potato genotype selection for the autumn-winter season in a subtropical environment

This study aimed to identify superior sweet potato (*Ipomoea batatas* L.) genotypes with enhanced agronomic performance during the autumn-winter season in the Greater Florianopolis region, SC. This research addressed the knowledge gap in sweet potato adaptability and productivity under the region's specific climatic conditions, a critical step for advancing subtropical crop cultivation.

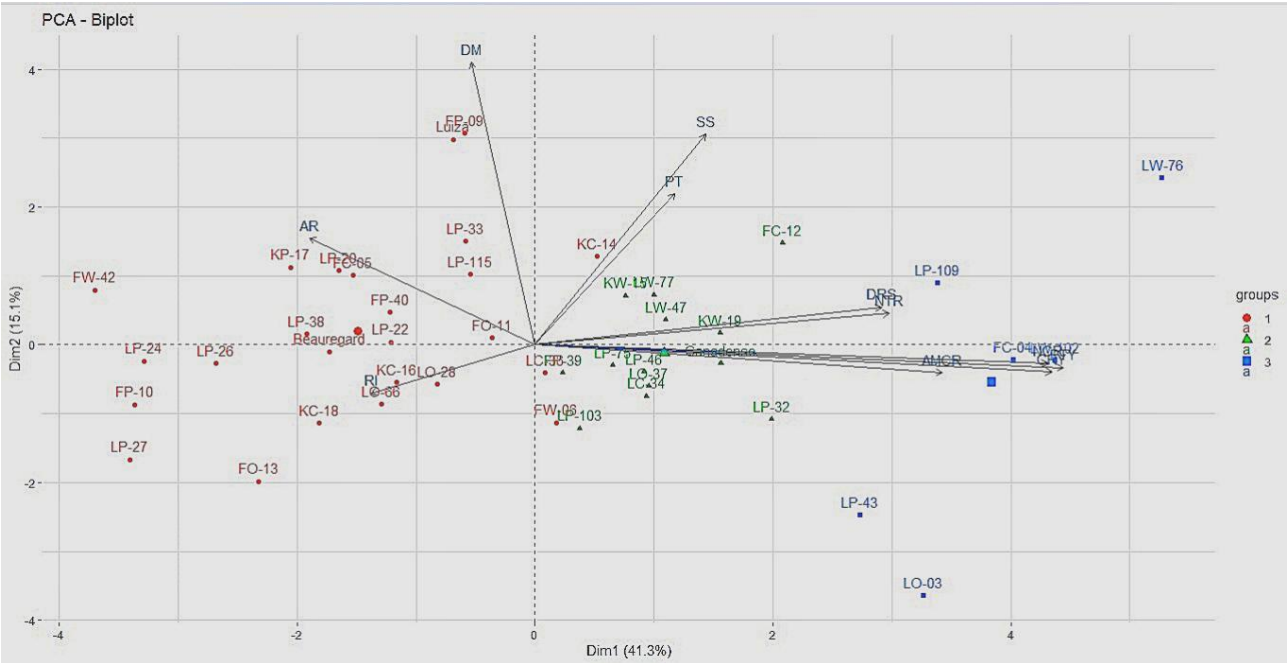

Figure 3. Principal component analysis (PCA) of quantitative and qualitative traits of the 42 experimental sweet potato genotypes and the commercial controls Canadense, SCS370 Luiza, and Beauregard, cultivated during the autumn-winter season in the Great Florianopolis region. Great Florianopolis region, UFSC, 2023.

The experiment, conducted under non-irrigated conditions, recorded 510.6 mm of rainfall between April 1 and September 7, including a prolonged dry spell from May 7 to May 27 (Figure 1). Notably, sweet potato requires approximately 500 mm of water throughout growth and development cycle to ensure optimal tuberous root production (Olah, 2019). Water scarcity during critical development stages can lead to physiological deficiencies, adversely affecting the biosynthesis of key compounds such as starch, beta-carotene, and anthocyanins. In the Florianopolis region, SC, during the autumn-winter season, climatic conditions present additional challenges, with temperature fluctuations ranging from below 12ºC to above 33ºC, which can adversely impact plant growth (Olah, 2019). The ideal temperature range for sweet potato cultivation is 12ºC, 30ºC, and 40ºC for minimum, optimal, and maximum, respectively (Erpen *et al*., 2013). During the experimental period, temperatures dropped below 12ºC on 21 occasions, likely posing critical limitations for root development. Furthermore, the average recorded temperature was 19.5ºC, significantly lower than the optimal value of 30ºC (Erpen *et al*., 2013). In this context, the experiment allowed for the identification of genotypes with potential adaptability for cultivation during the autumn-winter cycle in the region.

Genotypes UFSC-LW-76, UFSC-LW-102, UFSC-FC-04, UFSC-LO-03, UFSC-LP-109, and UFSC-LP-43 achieved NCR and CRY values ranging from 17.28 to 23.71 t/ha (Table 1.) These results highlight their potential as promising options for sweet potato cultivation outside the optimal planting season. Total root production remains a critical criterion for evaluating new experimental sweet potato genotypes (Zeist *et al*., 2022). In this context, productive performance becomes highly relevant when associated with total cultivation factors, such as NTR and RTY. Genotypes UFSC-LW-76, UFSC-LW-102, UFSC-FC-04, UFSC-LO-03, and UFSC-LP-109 demonstrated superiority in these parameters during the autumn-winter cycle. Commercial root production is the primary indicator of economic viability and direct applicability for both consumers and producers (Perrud *et al*., 2021). However, RTY is particularly significant when referring to the use of roots for industrial purposes or animal feed (Samborski *et al.*, 2020). The analysis of figure 3 reveals that the parameters NTR, RTY, NCR, and CRY exhibit similarities, indicating potential for both human consumption (NCR and CRY) and industrial applications (NTR and RTY).

The experimental sweet potato genotypes UFSC-LW-76 and UFSC-LW-102 (white flesh), UFSC-FC-04 (cream flesh), UFSC-LO-03 (orange flesh), and UFSC-LP-109 (purple flesh) were grouped with high similarity in the evaluated parameters and excelled in NTR, RTY, NCR, CRY, and DRS. The superior performance of colored-flesh experimental genotypes, such as UFSC-LO-03 and UFSC-LP-109, supports biofortification. This is because genotypes with orange or purple flesh often exhibit higher nutritional values (Leal *et al.*, 2021). Producing biofortified roots during atypical sweet potato growing seasons can enhance food security and boost profitability (Toroco *et al*., 2023). Additionally, the consumption of sweet potatoes with colored flesh not only enhances the nutritional quality of food but also opens doors to more profitable markets through the export of production in Brazil (Zeist *et al*., 2022).

Genotypes UFSC-LW-76 and UFSC-LW-102 (white flesh), UFSC-FC-04 (cream flesh), UFSC-LO-03 (orange flesh), and UFSC-LP-109 (purple flesh) showed a good distribution of roots about the base of the plant (DRS), clustering together with the control varieties Canadense, SCS370 Luiza, and Beauregard. This characteristic is very important as it prevents roots from being left in the field due to their distance from the main plant, and in some cases, also facilitates the mechanical harvesting of the roots.

Regarding DM, the experimental genotype UFSC-FP-09, along with the experimental control SCS370 Luiza, showed higher values for this trait compared to the others (Table 1). A higher percentage of dry matter is of great interest to the industry, as it contributes to increased processing yield and a reduction in the amount of residual water (Routray *et al*., 2023). Conversely, genotypes such as UFSC-LP-32, UFSC-FC-12, UFSC-LC-34, UFSC-LW-77, UFSC-LW-47, UFSC-LP-46, UFSC-KW-19, UFSC-LP-75, UFSC-FP-39, UFSC-KW-15, and UFSC-LP-103, with DM ranging between 18.05% and 25.95%, may offer better palatability for consumption of boiled or roasted roots. These genotypes were grouped with high similarity to each other and to the control variety Canadense (Figure 3), which is the most cultivated and consumed sweet potato in Brazil. However, a higher dry matter content in the roots, such as values above 25%, can provide a longer shelf life, extending the conservation of the product on shelves. Therefore, the diversity in DM observed among the genotypes is crucial to meet the various demands of sweet potato cultivation, whether in terms of processing yield for the industry or desirable characteristics for direct root consumption, highlighting the importance of careful genotype selection according to specific needs (Choi *et al*., 2022).

Concerning RI and AR, Group 1 genotypes (Figure 3) showed superior performance in both parameters. Although RI did not present significant differences between the experimental genotypes and the control varieties, a visual analysis of Figure 3 highlighted a notable proximity between Group 1 genotypes and these parameters. This observation was mirrored in the evaluation of AR, with genotypes such as UFSC-LW-77, UFSC-LW-47 (both with white flesh), UFSC-LP-38, UFSC-LP-24, UFSC-LP-22, UFSC-LP-20, UFSC-LP-115, UFSC-LP-103 (all with purple flesh), UFSC-LO-66, UFSC-LO-28 (with orange flesh), UFSC-LC-34 (with cream flesh), UFSC-KW-15 (with white flesh), UFSC-KP-17, UFSC-FW-42, UFSC-FP-40, UFSC-FP-10 (all with purple flesh), and UFSC-FC-05 (with cream flesh), as well as the control varieties SCS370 Luiza and Canadense, demonstrating superior results. Beyond insect resistance, root shape is critical for AR, a key factor in market acceptance. Consumer decisions increasingly consider product aesthetics, emphasizing the importance of selecting genotypes with visually appealing traits (Toroco *et al*., 2023). Genotypes grouped in Group 1 were notably superior in these characteristics, highlighting their potential for market introduction, not only agronomically to meet farmers' needs but also commercially for consumers.

Groups 2 and 3 (Figure 3) revealed a significant correlation of genotypes with PT, demonstrating that genotypes such as UFSC-LW-76, UFSC-FC-04, UFSC-FC-12 (all with cream flesh), UFSC-FO-13 (with orange flesh), UFSC-FP-40, UFSC-FW-42 (both with purple flesh), UFSC-KW-15 (with white flesh), UFSC-LC-36 (with cream flesh), UFSC-LO-37 (with orange flesh), and UFSC-LP-109, UFSC-LP-115, UFSC-LP-20, UFSC-LP-33 (all with purple flesh), along with the controls Canadense and SCS370 Luiza, exhibited superior performance. This characteristic is intrinsically linked to protection against physical damage, insect attacks, and diseases, which is crucial during storage and transport (Choi *et al*., 2022). Furthermore, skin thickness contributes to extending the product's shelf life after harvest, providing an important competitive advantage in the market.

In the clusters (Figure 3), the similarities regarding SS were not significant, except for results in specific genotypes between groups. The genotype UFSC-FP-09 (with purple flesh) stood out, with a value of 12.4ºBrix (Table 2), a significant value suggesting a sweeter flavor, a characteristic highly valued in trade (Gemenet *et al*., 2020). Although the SS parameter showed low correlation between the groups, the detailed analysis revealed that genotypes with white and cream flesh, including UFSC-LW-76, UFSC-LW-102, UFSC-LW-77, UFSC-LW-47, UFSC-KW-19, UFSC-FW-06, UFSC-FC-04, UFSC-FC-12, UFSC-KC-14, UFSC-KC-18, and UFSC-FC-05, exhibited SS values ranging from 8.0 to 10.93ºBrix, surpassing the control Canadense with the same flesh color. Additionally, among the genotypes with purple flesh, UFSC-LP-33 and UFSC-FP-09 reached SS values of 10.21 and 12.4ºBrix, respectively, showing performance equal to or superior to the control SCS370 Luiza with the same flesh color.

Plants sensitive to low-temperature stress can be affected at all stages of development (Aslam *et al*., 2022). This type of stress can be categorized into two types: cooling stress, where temperatures are low but positive (0 to 15°C), and freezing stress (below 0°C), where most plants cannot survive. Tropical and subtropical crops such as maize, soybean, potato, sweet potato, cotton, and tomato are sensitive and unable to acclimate under freezing conditions (Hwarari *et al*., 2022). However, these plants, even if limited, may possess biochemical and physiological mechanisms that allow them to tolerate low-temperature stress above the freezing point. The first stress response is the modification of the plasma membrane, altering its physical and chemical properties, and shifting from a liquid state to a gel-like state, resulting from an imbalanced ion exchange (with dehydration, wilting, and yellowing being visible symptoms). Other stress tolerance mechanisms include the accumulation of reactive oxygen species (Singh *et al*., 2020), and the reduction of stomatal conductance (Ehonen *et al*., 2019). Other gene regulation mechanisms can be classified as either abscisic acid (ABA)-dependent or independent, involving H_2O_2 and Ca^{+2} (Javed *et al*., 2020). The activation of gene expression in response to low temperatures occurs through the MAPK cascade, linking external stimuli to intracellular responses (Saucedo-García *et al*., 2021).

The superior genotypes identified in this study hold potential for advancing sweet potato cultivation in subtropical regions, addressing the challenges of low temperatures even in frost-free conditions. The results highlighted genotypes UFSC-LW-76, UFSC-LW-102, UFSC-FC-04, UFSC-LO-03, UFSC-LP-109, and UFSC-LP-43 as promising for extending the sweet potato growing period in the Great Florianopolis region, an important aspect for food security and agricultural production diversification. Of particular significance is the superior performance of the genotypes with colored flesh roots, UFSC-LO-03 (orange flesh), UFSC-LP-109, and UFSC-LP-43 (both purple), indicating their potential for biofortification. These genotypes offer a foundation for future breeding initiatives, optimizing sweet potato cultivation in subtropical regions while bolstering food security.

ACKNOWLEDGMENTS

The authors thank the Federal University of Santa Catarina and CNPq for the scholarships, as well as, especially, the family of Mr. Tarcísio Guesser, a farmer from the municipality of Antônio Carlos, where the experiment was conducted.

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