Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 25 September 2023
https://doi.org/10.14295/CS.v14.3996

Agronomic performance and selection of sweet-potato genotypes grown from seeds

Amarílis Beraldo Rós[1]*, Nobuyoshi Narita[1], Antonio Ismael Inácio Cardoso[2], Andréia Cristina Silva Hirata[1]

[1]São Paulo State Agency for Agribusiness Technology, Presidente Prudente, Brazil
[2]Paulista State University, Botucatu, Brazil
*Corresponding author, e-mail: amarilis.beraldo@sp.gov.br

Abstract

The low availability of varieties adapted to different crop regions, mainly regarding edaphoclimatic conditions, is one of the causes of low sweet-potato crop yields. The objective of this work was to evaluate agronomic characteristics of sweet-potato plants, from the crossing between the genotypes Londrina and Uruguaiana, grown in the region of Presidente Prudente, SP, Brazil, to select materials with high commercial yield and desirable tuberous root shape and color. The natural crossing between the genotypes Londrina and Uruguaiana grown in alternating rows resulted in 2,430 potentially viable seeds. These seeds were used for growing seedlings whose vines were grown in the field for selecting genotypes with desirable characteristics. The results showed a high diversity in skin and flesh colors; number of tuberous roots per plant, shape, fresh and dry weights, and total and commercial yields of tuberous roots. The selected genotypes were then evaluated in three experiments. Several genotypes presented higher commercial yield than their parents. Three genotypes were approved as cultivars by presenting superior agronomic characteristics than their parents.

Keywords: breeding, flesh color, *Ipomoea batatas* L., tuberous root shape, yield

Introduction

Sweet-potato (*Ipomoea batatas* L.) is the the seventh most important carbohydrate-rich food in the tropics and the sixth most produced in the world (FAO, 2021). In 2021, 105 countries produced 88.9 million Mg of sweet-potatoes; Brazil was the 14th largest producing country (FAO, 2021). Sweet potato is the crop that provides food for more people per unit area (Okada et al., 2002) and time. According to Rós et al. (2012) and Rós (2017), these crops can yield more than 40 Mg ha^{-1} of tuberous roots in 5 or 6 months.

Sweet-potato crops are important for income generation and, mainly, food safety, considering the high production of tuberous roots and other plant parts, which can be used for human and animal consumption (Kwak, 2019). Additionally, these tuberous roots can be used as raw material for ethanol production (Peressin & Feltran, 2022). These crops also stand out due to their high social importance, as they have a high demand for labor, therefore, involving large numbers of people.

Sweet potatoes are important in Brazil, since they are grown in all regions of the country. The state of Sao Paulo is the second-largest producing state in volume, but the eighth in terms of yield (IBGE, 2021), which is attributed to the growing of many cultivars that are not adapted to the region, in addition to a little use of available technological managements by most growers. However, breeding programs can enable the obtaining of new sweet-potato cultivars with high production potential and desirable tuberous root characteristics (color and shape) and better adapted to the edaphoclimatic conditions of the state of Sao Paulo (SP) (Peressin et al., 2022).

Sweet-potato species are from the Convolvulaceae family, batatas series (Austin & Huamán, 1996). Only *Ipomoea* species are hexaploid, containing 90 chromosomes (Austin, 1977). The variability within these

Received: 28 April 2022
Accepted: 11 May 2023

species is high due to allogamy and a high level of ploidy. Thus, each botanical seed is genetically different from the others, thus, each one has the potential to be a new cultivar (Jones, 1986). The plants have hermaphroditic flowers, but the species presents self-incompatibility, producing seeds through cross-pollination (Jones, 1986).

Total and commercial yields and shape of tuberous roots present high heritability (Azevedo at al., 2015). This high heritability is related to the reliability that the phenotypic expression represents the genotypic value, denoting that the environment has low effect on the evaluated characteristic (Solankey et al., 2015).

The high genetic variability among sweet-potato plants grown from seeds enables the selection of genotypes that best meet specific purposes, such as high tuberous root yield (Massaroto et al., 2014; Silva et al., 2015), nutritional quality (Andrade et al., 2017), dry matter contents (Placide et al., 2015), resistance to pests (Okada et al., 2019) and diseases (Nóbrega, 2015), ethanol production yield (Vieira et al., 2016), and desirable characteristics for animal feed (Pedrosa et al., 2015).

Thus, the objective of this work was to evaluate agronomic characteristics of sweet-potato plants, from the crossing between the genotypes Londrina and Uruguaiana, grown in Presidente Prudente, SP, Brazil, to select materials with high commercial yield and desirable tuberous root shape and color.

Material And Methods

The experiment was conducted at the Apta Regional, Regional Research and Development Unit in Presidente Prudente, SP, Brazil (22°11'S, 51°23'W, and 424.29 m of altitude), from August 2017 to November 2020. The climate of the region is Aw, according to the Köppen classification, presenting two well-defined seasons: a hot, humid summer and a mild, dry winter.

The sweet-potato genotypes Londrina (also known as Canadense) and Uruguaiana were grown in alternating rows in 2017, focused on natural crosses between these materials through pollinator insects. Five thousand plants of each genotype were grown for seed production. The genotype Londrina has a purple skin and light-yellow flesh; its cycle is approximately 150-200 days. The genotype Uruguaiana has a purple skin, a second purple layer, and yellow flesh; its cycle is approximately 120-180 days. Both genotypes are commercially grown in the region of Presidente Prudente, SP, presenting good production potential and are recommended as parents for breeding programs.

A total of 6,178 seeds were collected from this crossing. The selection of potentially viable seeds consisted of immersing the seeds in water and considering those that remained suspended as unviable. Potentially viable seeds totaled 2,430 units.

Subsequently, the coat of viable seeds was removed using a box cutter to facilitate water penetration and, consequently, homogenize germination. The seeds were sown to a depth of approximately 0.5 cm in expanded 128-cell polyethylene trays in August 2017. A slow-release soil fertilizer (19-06-12 N-P-K formulation) was used at a rate of 150 g per 25 kg of a commercial substrate composed of vermiculite and *Pinus* sp. bark, as recommended by Rós et al. (2011). The seedling emergence percentage was 96.5% within a period of 3 to 5 days after sowing (DAS). The seedlings were transplanted into plastic bags containing fertilized substrate at 30 DAS.

The seedlings were transplanted to Field 1 in November 2017 to produce sufficient vegetative material for obtaining one vine per genotype. The soil of the area was previously prepared with plowing and harrowing and formation of 0.4 m-height ridges spaced 0.9 m apart; the spacing between plants was 0.5 m.

A total of 1,520 plants were selected 30 days after transplanting the seedlings to Field 1 for production of vines for planting in Field 2 to produce tuberous roots. One vine of approximately 0.35 m was collected from each selected genotype and planted in Field 2, where soil tillage, ridge formation, and spacing between plants and ridges were equal to those in the planting in Field 1.

Harvesting was carried out 150 days after planting the sweet-potato vines in Field 2 and, then, the following characteristics were evaluated: total and commercial yields of tuberous roots, number of tuberous roots, length and diameter of each tuberous root, and skin and flesh colors of tuberous roots of each genotype. Commercial tuberous root yield was determined considering tuberous roots with fresh weights between 80 and 1000 g and a smooth, uniform shape. Each of the 1,453 harvested plants produced at least one tuberous root weighing 80 grams or more. The data were grouped and described as a percentage of the evaluated population, according to the evaluated characteristic.

The sweet-potato plants with the highest yields were selected for the next phase of the study, predominantly presenting tuberous roots weighing between 300 and 600 grams, with elongated shapes (length to diameter ratio higher than or equal to 1.75), smooth and uniform appearance, and preferably with a purple skin and light-colored flesh (white, off-white, or yellow).

Three experiments were conducted to compare the selected sweet-potato genotypes. Experiment 1 consisted of preferentially selecting genotypes with purple and pink skins. Experiment 2 consisted of planting genotypes that stood out in some characteristic in Experiment 1, combined with the planting of others not yet tested. Experiment 3 consisted of planting genotypes with purple skin and light-yellow flesh to evaluate their performances in the autumn-winter crop season.

The soil of the experimental area was classified as Typic Hapludult (Argissolo Vermelho Amarelo; Santos et al., 2018) of sandy texture. The chemical analysis of the 0-0.2 m soil layer showed: pH ($CaCl_2$) = 4.6; P = 2 mg dm^{-3}; K = 1.6 $mmol_c$ dm^{-3}; Al^{+3} = 1.0 $mmol_c$ dm^{-3}; Ca^{+2} = 5 $mmol_c$ dm^{-3}; Mg^{+2} = 3 $mmol_c$ dm^{-3}, organic matter = 9 g dm^{-3}, sum of bases = 10 $mmol_c$ dm^{-3}, cation exchange capacity = 29 $mmol_c$ dm^{-3}, and base saturation = 34%. Limestone was applied to the area between 70 and 90 days before implementing each experiment to raise the base saturation to 60%. Soil fertilizer application at planting consisted of 100 kg ha^{-1} of P_2O_5, 20 kg ha^{-1} of N, and 30 kg ha^{-1} of K_2O. Topdressing consisted of 30 kg ha^{-1} of N and K_2O at 30 days after planting the sweet-potato vines (Rós et al., 2015).

The three experiments were conducted using a randomized block design, with three replications. The experimental plot consisted of three ridges (rows) spaced 0.9 m apart, with 16 vines of 0.4 m each spaced 0.4 m apart, corresponding to 27,777 plants ha^{-1}. The evaluation area consisted of the 14 central plants in the middle ridge. The vines were planted horizontally, keeping their apical portion unburied.

Experiment 1 was established in December 2018 to compare 31 genotypes and their parents (Londrina and Uruguaiana). Harvesting was carried out 150 days after planting (DAP).

Experiment 2 was established in February 2020 to compare 25 genotypes and their parents. Harvesting was carried out at 150 DAP.

Experiment 3 was established in June 2020 to compare eight genotypes and their parents. Harvesting was carried out at 180 DAP due to a longer crop cycle under milder temperatures during the crop season.

Total tuberous root yield was determined considering all tuberous roots with fresh weight equal to or higher than 40 g, whereas commercial tuberous root yield was determined considering tuberous roots with fresh weights between 80 and 1000 g, a smooth and uniform appearance, and length to diameter ratio between 1.7 and 8.0.

Individual fresh weight, length, diameter, and shape (length to diameter ratio) of tuberous roots were determined using those selected as commercial tuberous roots.

The numbers of total and commercial tuberous roots and tuberous root dry weights were evaluated in genotypes from Experiment 1. Tuberous root dry weight was determined by cutting the middle portion of 10 tuberous roots into cubes, which constituted a 1000-gram sample for each plot. These materials were then dried in an oven at 60 °C until constant weight.

The data obtained were subjected to analyses of variance and the means were compared using the Scott-Knott test at 5% probability of error.

Results And Discussion

(**Table 1**) shows descriptions of the characteristics of the 1,453 sweet-potato genotypes from the crossing between the parents Londrina and Uruguaiana, evaluated in Field 2.

The number of tuberous roots of the genotypes evaluated varied from 1 to 22. This variation was lower than that found by Wera et al. (2014), who found number of tuberous roots per plant varying from 2 to 48. In the present study, the most genotypes presented 5 to 9 tuberous roots.

Table 1. Description of characteristics of 1,453 sweet-potato genotypes from crosses between the genotypes Londrina and Uruguaiana. Presidente Prudente, SP, Brazil

Number of tuberous roots	Percentage of population (%)	Mean tuberous root length (cm)	Percentage of population (%)
1 - 4	31.5	8.0 – 14.9	35.9
5 - 9	58.6	15.0 – 19.9	49.3
10 - 14	9.3	20.0 – 24.9	13.2
15 - 22	0.6	25.0 – 30.5	1.6
Mean tuberous root diameter (cm)	**Percentage of population (%)**	**Production of tuberous root (g)**	**Percentage of population (%)**
2.2 – 4.9	37.1	82 – 500	10.2
5.0 – 7.9	57.0	501 – 1.000	21.2
8.0 – 14.0	5.8	1.001 – 3.000	58.3
14.1 – 19.9	0.0	3.001 – 6.000	10.1
20.0 – 29.5	0.1	6.001 – 11.000	0.2
Skin color	**Percentage of population (%)**	**Flesh color**	**Percentage of population (%)**
Purple	71.4	Light-yellow	43.9
Pink	18.4	Yellow	28.0
Off-white	7.9	Dark orange	12.6
Salmon	2.0	Intermediate orange	9.0
Brown	0.1	White	5.7
Yellow	0.1	Purple	0.4
White	0.1	Off-white	0.2
		Light orange	0.2

The mean length of tuberous roots of the genotypes evaluated varied from 8.0 to 30.5 cm; most genotypes presented 15.0 to 19.9 cm. Narasimhamurthy et al. (2018) compared 22 genotypes and found a variation in tuberous root length of 11.0 to 28.3 cm, with a heritability of 84% for this characteristic.

The mean diameter of tuberous roots of most genotypes were between 5.0 to 7.9 cm. This characteristic presents high heritability (Narasimhamurthy et al., 2018).

The production of tuberous roots varied from 82 to 11.000 g per plant, with most genotypes within the range from 1,001 to 3,000 g. According to Narasimhamurthy et al. (2018), this characteristic presented a heritability of 96%.

Despite the parents had purple skin, this characteristic presented high variation. Skins with only one color or composed of two colors (purple and pink; pink and light-pink; pink and off-white; off-white and salmon; purple and off-white; and pink and salmon) were found. The percentages were described considering the single or predominant color; most genotypes were purple.

The flesh color varied from one to three colors for the same tuberous root. Considering the single or predominant color, seven colors were described; most genotypes presented a light-yellow color. The breeding program was based on the two flesh colors of the parent genotypes (yellow and light-yellow), denoting the diversity of colors from this crossing. Visalakshi et al. (2021) studied 18 genotypes and reported nine flesh colors.

The results of the statistical analysis in Experiment 1 enabled to group the genotypes, considering total and commercial yields, numbers of total and commercial tuberous roots, and fresh and dry weights (**Table 2**).

Total yields were significantly higher in three groups (25 genotypes) when compared to the parent Londrina and in one group (2 genotypes) when compared to the parent Uruguaiana. The commercial yields were higher in three groups (23 genotypes) when compared to Londrina and in two groups (12 genotypes) when compared to Uruguaiana. The genotype 526 stood out with total and commercial yields of 73.13 and 64.27 Mg ha^{-1}, respectively (Table 2).

Total and commercial yields of tuberous roots present high heritability (Azevedo at al., 2015); thus, they are maintained in the genotypes, as the commercial multiplication of genotypes is carried out through vegetative materials.

The yields found in the present work are high and higher than the mean of the State of São Paulo (17 Mg ha^{-1}) (IBGE, 2021). Studies on the selection of sweet-potato clones have reported total yield variations from 0.78 to 475 Mg ha^{-1} (Carmona et al., 2015), 20.2 to 68.4 Mg ha^{-1} (Melo et al. (2020), and 3.53 to 22.6 Mg ha^{-1} (Wera et al., 2014).

The numbers of total and commercial tuberous roots were significantly higher in three groups (24 and 20 genotypes for numbers of total and commercial tuberous roots, respectively), compared to the parents Londrina and Uruguaiana (Table 2). Therefore, the number of tuberous roots is a production component that contributed to the expression of the high yields of these genotypes when compared to their parents.

The parent Londrina was in the group with the highest individual fresh weights, which included other 12 genotypes; 19 genotypes were grouped with Uruguaiana, presenting the lowest fresh weights. The parents Uruguaiana and Londrina presented higher dry weights, together with other 11 genotypes; the genotype with the highest commercial yield (526) was grouped in the group with the lowest dry weights. The dry weight varied from 18.88% to 30.18% (Table 2). High variation in dry weight among genotypes was also found by Wera et al. (2014), who reported values between 13.60% and 27.80%, and by Narasimhamurthy et al. (2018), who reported values between 17.30% and 35.98%. This characteristic presents high heritability (Narasimhamurthy et al., 2018). According to Nóbrega et al. (2019), dry weight is an important parameter from the industrial point of view, as a high dry matter content has a higher starch content and generate less residual water. It is also important for sweet-potato production for fresh consumption, as consumers prefer drier fleshes for food preparation.

The materials were divided into two groups based on tuberous root shape (length to diameter ratio) (**Table 3**). The group with the most elongated shape (higher length to diameter ratio) included the parent Uruguaiana and 13 genotypes; the group with the less elongated shape included the parent Londrina and 18 genotypes.

The materials were divided into two groups based on their tuberous root lengths. Londrina, Uruguaiana, and 16 genotypes were in the group with the longest lengths (Table 3). The materials were divided in two groups regarding tuberous root diameter; Londrina and Uruguaiana were in different groups; Londrina and 13 genotypes were in the group with the largest diameters (Table 3). Senff et al. (2021) evaluated sweet-potato varieties and found differences regarding tuberous root length and diameter. Neiva et al. (2011) evaluated sweet-potato accessions from a germplasm bank and reported high morphological variability between sweet-potato

Table 2. Total and commercial yields, numbers of total and commercial tuberous roots, individual fresh weight, and dry weight of tuberous roots of sweet-potato genotypes and their parents (genotypes Londrina and Uruguaiana)

Genotype	Total yield (Mg ha^{-1})	Commercial yield (Mg ha^{-1})	Total number of tuberous roots ha^{-1}(×1000)	Number of commercial tuberous roots ha^{-1} (×1000)	Fresh weight (g)	Dry weight (%)
526	73.13 a	64.27 a	306.85 a	254.94 a	256.89 a	18.92 d
1358	65.77 a	22.38 d	235.85 b	93.89 d	241.02 b	21.23 c
968	55.27 b	45.64 b	206.30 b	161.74 c	277.28 a	22.22 c
1346	53.53 b	37.97 b	311.73 a	222.24 b	171.07 b	26.92 b
198	51.47 b	40.51 b	199.86 b	139.50 c	294.88 a	25.87 b
323	49.38 b	42.38 b	226.29 b	164.14 c	265.73 a	27.83 a
1315	49.04 b	44.17 b	191.98 b	156.34 c	284.18 a	23.50 c
862	47.92 b	28.68 c	193.21 b	130.97 c	216.19 b	28.35 a
308	47.22 b	41.19 b	164.68 c	133.42 c	309.26 a	24.71 b
1238	46.14 b	28.60 c	146.91 c	142.92 c	221.43 b	18.88 d
Uruguaiana	44.42 b	25.60 c	121.83 d	104.82 d	247.82 b	30.18 a
1005	42.15 c	37.56 b	210.49 b	160.15 c	234.83 b	28.27 a
620	42.03 c	33.00 c	297.65 a	190.12 b	173.59 b	26.79 b
1424	41.66 c	39.94 b	177.16 c	158.02 c	251.42 b	25.80 b
1308	41.51 c	20.39 d	155.55 c	87.78 d	229.38 b	23.07 c
1409	41.28 c	27.82 c	118.75 d	78.75 d	359.80 a	25.48 b
272	40.73 c	33.08 c	233.95 b	174.07 c	192.70 b	28.20 a
782	39.63 c	38.49 b	178.19 c	150.62 c	257.83 a	25.36 b
939	38.38 c	28.88 c	119.14 d	099.10 d	307.51 a	25.66 b
1232	37.96 c	35.27 b	172.84 c	144.35 c	245.02 b	29.12 a
1262	36.30 c	32.04 c	196.29 b	141.35 c	226.74 b	29.46 a
1294	36.18 c	31.78 c	175.93 c	128.49 c	257.36 a	25.78 b
370	36.15 c	20.86 d	140.12 d	75.94 d	265.73 a	27.83 a
1178	35.81 c	34.84 b	156.69 c	146.19 c	236.72 b	29.08 a
940	35.09 c	25.98 c	138.81 d	104.17 d	245.90 b	29.34 a
1286	34.61 c	30.71 c	200.62 b	151.74 c	209.77 b	29.49 a
632	30.70 d	27.30 c	191.36 b	138.89 c	196.70 b	22.70 c
147	30.66 d	17.80 d	165.13 c	87.16 d	211.43 b	27.02 b
418	29.55 d	17.65 d	130.86 d	76.98 d	228.30 b	24.81 b
1349	27.23 d	20.04 d	129.88 d	92.89 d	214.30 b	25.43 b
1323	26.79 d	17.91 d	87.03 d	64.41 d	288.36 a	26.39 b
922	26.56 d	22.82 d	174.69 c	125.64 d	184.39 b	27.41 a
Londrina	22.52 d	21.40 d	83.21 d	72.23 d	304.31 a	27.97 a
CV (%)	14.90	15.98	17.82	19.7	14.7	5.96

Means followed by the same letter in the columns are not significantly different from each other by the Scott-Knott test at 5% probability of error.

clones, with absence of equal phenotypes, reinforcing the diversity originated from the parents.

In experiment 2, the genotypes were divided into three groups based on their total yields (**Table 4**). The group with the highest yield included the parent Uruguaiana and other four genotypes and their yields varied from 71.61 to 62.34 Mg ha^{-1}. The second group was composed of the parent Londrina and eight genotypes. The group with the lowest yield included 13 genotypes.

The commercial yield of the genotypes presented high differences, with formation of six groups for this variable (Table 4). The most productive materials were 1308, 1424, and Uruguaiana, with a mean yield of 56.51 Mg ha^{-1}. The group with the lowest yield was composed of six genotypes, with a mean yield of 14.58 Mg ha^{-1}. The genotype 968 stood out, with a high total yield, but a low commercial yield. This is due to the high percentage of tuberous roots with visual appearance different from that desired by consumers. These characteristics are evaluated and considered according to the purpose of the selection; for example, when the purpose is to meet industrial demands, visual appearance may not be important.

The genotypes were grouped into three groups based on their tuberous root fresh weights (Table 4). The parents Uruguaiana and Londrina and 14 genotypes presented the lowest individual fresh weights of tuberous roots.

The materials presented no difference regarding length to diameter ratio. However, the length and diameter of tuberous roots were different (Table 4). The genotypes were divided into two groups based on tuberous root length and diameter; the parents Uruguaiana and Londrina were in the same group for both

Table 3. Length to diameter ratio, length, and diameter of tuberous roots of sweet-potato genotypes and their parents (genotypes Londrina and Uruguaiana)

Genotype	Length to diameter ratio	Length (cm)	Diameter (cm)
1346	6.10 a	20.02 a	3.37 b
370	5.48 a	21.27 a	4.17 b
620	5.44 a	18.41 a	3.54 b
1308	5.21 a	20.23 a	4.12 b
147	5.13 a	19.04 a	3.91 b
Uruguaiana	4.97 a	19.37 a	4.01 b
1005	4.89 a	19.15 a	4.03 b
198	4.83 a	16.33 b	4.17 b
1294	4.80 a	18.41 a	4.01 b
1238	4.78 a	18.04 a	4.03 b
968	4.76 a	20.38 a	4.48 a
1349	4.61 a	18.23 a	4.16 b
1232	4.60 a	18.20 a	4.22 b
1178	4.53 a	18.32 a	4.01 b
272	4.21 b	16.33 b	4.63 a
323	4.49 b	18.06 a	4.47 a
922	4.12 b	16.93 b	4.35 b
1262	4.12 b	16.20 b	4.21 b
1286	4.17 b	16.19 b	4.00 b
1409	4.07 b	19.76 a	5.10 a
Londrina	4.00 b	17.66 a	4.49 a
862	3.98 b	16.61 b	4.13 b
632	3.97 b	15.28 b	4.12 b
418	3.94 b	16.47 b	4.34 b
939	3.92 b	18.01 a	4.89 a
526	3.90 b	16.61 b	4.63 a
1424	3.90 b	17.25 b	4.63 a
940	3.74 b	16.40 b	4.51 a
308	3.70 b	17.73 a	4.93 a
1315	3.40 b	16.02 b	4.86 a
782	3.37 b	15.79 b	4.95 a
1358	3.12 b	14.36 b	4.98 a
1323	2.86 b	14.44 b	5.27 a
CV (%)	15.41	11.7	8.71

Means followed by the same letter in the columns are not significantly different from each other by the Scott-Knott test at 5% probability of error.

characteristics (longest length and smallest diameter).

In experiment 3, the cycle of the genotypes was longer due to a period of mild and dry weather, because of the choice of crop season (autumn-winter). The genotypes were divided into three groups based on their total yields (**Table 5**). The highest yield was found for the genotype 198, which reached 71.96 Mg ha^{-1} and was isolate in the first group; in the second group, genotypes 281 and 21 presented approximately 60 Mg ha^{-1}; the other genotypes formed a third group, along with the parents Londrina and Uruguaiana, presenting total yields varying from 43.98 to 51.61 Mg ha^{-1}.

The genotypes were classified into four groups based on their commercial yields (Table 5). The highest yield was obtained by the genotype 21, which produced 47 Mg ha^{-1}, corresponding to 78% of the total tuberous root yield of this material, which can be considered a high percentage. The second group was composed of the genotypes 198 and 281, with yields of 36.05 and 39.89 Mg ha^{-1}, respectively. The third group was formed by the genotypes 1168 and 223. The genotypes with the lowest yields formed a fourth group, which included the parents Londrina and Uruguaiana, which presented commercial tuberous root yields of 9.6 and 17.66 Mg ha^{-1}, corresponding to 22% and 36% of the total yields, respectively.

The high difference between total and commercial yields of some materials was due to the tortuous appearance that most tuberous roots developed. The genotype Londrina frequently presents tortuosity and, therefore, non-commercial appearance, when grown in the autumn-winter, explaining the low percentage of commercial tuberous roots in this experiment. Thus, the genotypes with high percentage of commercial tuberous roots are materials with lower susceptibility to tuberous root deformities under mild temperature conditions.

Regarding the individual fresh weight of commercial tuberous roots, the 10 genotypes were classified into two groups; genotypes 1168, 1086, and Londrina presented the lowest values (Table 5).

The genotypes were different regarding characteristics connected to shape and were divided into two groups based on length to diameter ratio (Table 5). Four materials were in the group with the highest length to diameter ratio, including two of the three most productive genotypes (198 and 21) and the parent Londrina. However, the parent Uruguaiana was in the group with the lowest values.

The genotypes that presented the longest tuberous roots were 618, 198, 21 and 1308. Five genotypes presented tuberous roots with large diameter, mainly the parent Uruguaiana. The parent Londrina was in the group with the smallest tuberous root diameters (Table 5).

The genotypes 21, 198, and 1308 were selected in the present work. These materials were approved as cultivars: IAC Lavínia, IAC Clara, and IAC Prudentina. All of them present purple skin, light-yellow flesh, tuberous roots with a uniform shape, and pleasant flavor and texture.

Genotype 21 stood out with the highest commercial yield in the autumn-winter and presented no deformities caused by mild temperatures. Genotypes 198 and 1308 presented high commercial yield, which was equal or higher than that of the parent Londrina, as well as excellent tuberous root shapes.

Table 4. Total and commercial yields, fresh individual weights, length to diameter ratio, and length and diameter of tuberous roots of sweet-potato genotypes and their parents (genotypes Londrina and Uruguaiana)

Genotype	Total yield (Mg ha^{-1})	Commercial yield (Mg ha^{-1})	Fresh weight (g)	Length to diameter ratio	Length (cm)	Diameter (cm)
968	71.61 a	14.14 f	288.30 b	3.40 a	17.36 a	5.39 b
1308	69.33 a	58.61 a	376.19 a	3.33 a	18.89 a	5.92 a
1424	67.51 a	57.38 a	256.59 c	3.41 a	17.14 a	5.22 b
Uruguaiana	64.24 a	53.54 a	262.19 c	3.10 a	15.92 a	5.36 b
676	62.34 a	45.21 c	221.30 c	3.03 a	15.18 b	5.16 b
958	55.18 b	27.80 e	290.79 b	2.93 a	16.74 a	5.90 a
198	54.04 b	48.23 b	295.63 b	3.55 a	17.67 a	5.27 b
1220	53.94 b	42.88 c	340.12 a	3.13 a	17.38 a	5.79 a
1315	53.39 b	42.66 c	285.52 b	3.15 a	16.55 a	5.46 b
Londrina	52.73 b	47.90 b	257.62 c	3.48 a	16.60 a	4.98 b
618	52.42 b	47.11 b	288.99 b	3.04 a	16.18 a	5.53 a
298	50.92 b	36.29 d	272.32 c	2.47 a	13.86 b	5.91 a
913	50.90 b	27.15 e	229.91 c	3.11 a	15.07 b	4.97 b
526	49.78 b	39.18 c	224.02 c	3.41 a	16.23 a	4.93 b
632	46.74 c	11.72 f	292.32 b	2.47 a	14.27 b	6.02 a
350	45.81 c	34.74 d	229.90 c	2.14 a	12.40 b	5.98 a
252	44.14 c	30.01 e	233.83 c	2.77 a	14.20 b	5.28 b
1232	44.08 c	42.06 c	229.58 c	2.82 a	14.29 b	5.27 b
1086	41.70 c	14.73 f	246.73 c	2.57 a	14.20 b	5.61 a
1168	41.66 c	20.31 f	339.11 a	3.06 a	16.83 a	5.89 a
176	40.57 c	31.13 e	246.29 c	2.96 a	15.52 b	5.44 b
223	40.39 c	35.55 d	234.40 c	3.71 a	16.92 a	4.76 b
571	40.02 c	12.51 f	262.30 c	4.89 a	20.17 a	4.60 b
316	39.27 c	14.09 f	305.17 b	2.36 a	14.50 b	5.95 a
308	39.24 c	27.39 e	367.87 a	2.97 a	17.44 a	6.11 a
21	37.06 c	34.03 d	263.05 c	3.04 a	15.69 b	5.33 b
1404	28.23 c	23.22 e	174.44 c	3.47 a	14.70 b	4.36 b
CV (%)	11.68	14.56	13.12	17.08	9.97	10.38

Means followed by the same letter in the columns are not significantly different from each other by the Scott-Knott test at 5% probability of error.

Table 5. Total and commercial yields, fresh individual weight, length to diameter ratio, length, and diameter of tuberous roots of sweet-potato genotypes and their parents (genotypes Londrina and Uruguaiana)

Genotype	Total yield (Mg ha^{-1})	Commercial yield (Mg ha^{-1})	Fresh weight (g)	Length to diameter ratio	Length (cm)	Diameter (cm)
198	71.96 a	36.05 b	382.68 a	2.83 a	17.42 a	6.36 a
281	61.78 b	39.89 b	347.30 a	2.44 b	15.44 b	6.45 a
21	59.92 b	47.00 a	358.79 a	2.90 a	17.00 a	5.98 b
1168	51.61 c	28.30 c	249.87 b	2.58 b	14.83 b	5.88 b
Uruguaiana	49.51 c	17.66 d	330.02 a	2.30 b	15.22 b	6.70 a
1308	49.10 c	20.24 d	328.92 a	2.71 b	16.88 a	6.49 a
618	46.39 c	7.84 d	348.13 a	3.19 a	18.04 a	5.75 b
1086	45.39 c	17.75 d	269.77 b	2.46 b	14.28 b	6.03 b
223	44.58 c	25.54 c	313.45 a	2.56 b	16.04 b	6.42 a
Londrina	43.98 c	9.60 d	226.27 b	2.94 a	15.44 b	5.39 b
CV (%)	8.27	12.32	12.76	10.46	7.10	6.61

Means followed by the same letter in the columns are not significantly different from each other by the Scott-Knott test at 5% probability of error.

Conclusions

Thirteen of the 49 genotypes evaluated presented higher commercial yields than the parent Londrina and 19 presented similar commercial yields.

Twelve genotypes presented higher commercial yield than the parent Uruguaiana and 22 presented similar commercial yields.

Genotype 21 stood out in the autumn-winter season by presenting lower susceptibility to tuberous root deformities, which is a problem for plants grown in this season.

Considering the superior genotypes recommended for the region of Presidente Prudente, SP, Brazil, the materials 21, 198, and 1308 were selected and approved as cultivars (IAC Lavínia, IAC Clara, and IAC Prudentina, respectively), all presenting purple skin, light-yellow flesh, and a long elliptical shape.

Acknowledgments

The authors thank the Sao Paulo State Foundation for Research Support (FAPESP) for the financial support (Process 2017/03298-1).

References

Andrade, M.I., Ricardo, J., Naico, A., Alvaro, A., Makunde, G.S., Low, J., Ortiz, R., Grüneberg, W.J. 2017. Release of orange-fleshed sweetpotato (*Ipomoea batatas* [l.] Lam.) cultivars in Mozambique through an accelerated breeding scheme. *The Journal of Agricultural Science* 155: 919–929.

Austin, D.F. 1977. Hybrid haploids in Ipomoea section batatas. *Journal of Heredity* 68: 259-260.

Austin, D.F., Huamán, Z.A. 1996. Synopsis of Ipomoea (Convolvulaceae) in Americas. *Taxon* 45: 3-38.

Azevedo, A.M., Andrade Júnior, V.C., Fernandes, J.S.C., Pedrosa, C.E., Oliveira C.M. 2015. Desempenho agronômico e parâmetros genéticos em genótipos de batata-doce. *Horticultura Brasileira* 33: 084-090.

Carmona, P.A.O., Peixoto, J.R., Amaro, G.B., Mendonça, M.A. 2015. Divergência genética entre acessos de batata-doce utilizando descritores morfoagronômicos das raízes. *Horticultura Brasileira* 33: 241-250.

FAO. Food and Agriculture Organization of the United Nations. 2021. Disponível em: https://www.fao.org/faostat/en/#data/QCL <Acesso em 25 Abr. 2023>

IBGE. Sistema IBGE de recuperação automática. 2021. Disponível em: https://sidra.ibge.gov.br/tabela/1612#resultado <Acesso em 25 Abr. 2023>

Jones, A. 1986. Sweet potato breeding. In: BASSET, M.J. *Breeding Vegetable Crops*. AVI, Westport, USA. 35 p.

Kwak, S.S. 2019. Biotechnology of the sweetpotato: ensuring global food and nutrition security in the face of climate change. *Plant Cell Report* 38: 1361–1363.

Massaroto, J.A., Maluf, W.R., Gomes, L.A.A., Franco, H.D., Gasparino, C.F. 2014. Desempenho de clones de batata-doce. *Ambiência* 10: 73-81.

Melo, R.A.C., Silva, G.O., Vendrame, L.P.C., Pilon, L., Guimarães, J.A., Amaro, G.B. 2020. Evaluation of purple-fleshed sweetpotato genotypes for root yield, quality and pest resistance. *Horticultura Brasileira* 38: 439-444.

Montes, S.M.N.M. 2013. *Cultura da batata-doce: do plantio à comercialização*. Agronomic Institute, Campinas, Brazil. 80 p.

Narasimhamurthy, P.N., Patel, N.B., Patel, A.I., Koteswara, Rao G. 2018. Genetic variability, heritability and genetic advance for growth, yield and quality parameters among sweet potato [*Ipomoea batatas* (L.) lam.] genotypes. *International Journal of Chemical Studies* 6: 2410-2413.

Neiva, I.P., Andrade Júnior, V.C., Viana, D.J.S., Figueiredo, J.A., Mendonça Filho, C.V., Parrella, R.A.C., Santos, J.B. 2011. Caracterização morfológica de acessos de batata-doce do banco de germoplasma da UFVJM, Diamantina. *Horticultura Brasileira* 29: 537-541.

Nóbrega, D.S. 2015. *Desempenho agronômico, parâmetros genéticos e reação de clones de batata-doce aos insetos de solo e aos nematoides das galhas (Meloidogyne spp.)*. University of Brasília, Brasília, Brazil. 129 p.

Nóbrega, D.S., Peixoto, J.R., Vilela, M.S., Nóbrega, A.K.S., Santos, E.C., Costa, A.P., Carmona, R. 2019.Yield and soil insect resistance in sweet potato clones. *Bioscience Journal* 35: 1773-1779.

Okada, Y., Monden, Y., Nokihara, K., Shirasawa, K., Isobe, S., Tahara, M. 2019. Genome-wide association studies (gwas) for yield and weevil resistance in sweet potato (Ipomoea batatas (L.) Lam). *Plant Cell Reports* 38: 1383–1392.

Okada, Y., Nishiguchi, M., Saito, A., Kimura, T., Mori, M., Hanada, K., Sakai, J., Matsuda, Y., Murata, T. 2002. Inheritance and stability of the virus-resistant gene in the progeny of transgenic sweet potato. *Plant Breeding* 121: 249-253.

Pedrosa, C.E., Andrade Junior, V.C., Pereira, R.C., Dornas, M.F.S., Azevedo, A.M. 2015. Yield and quality of wilted sweet potato vines and its silages. *Horticultura Brasileira* 33: 283-289.

Peressin, V.A., Feltran, J.C. 2022. Introdução. In: Peressin, V.A., Feltran, J.C., Rós, A.B., Fernandes, A.M. (ed.). *A cultura da batata-doce*. Agronomic Institute, Campinas, Brazil. 3 p.

Peressin, V.A., Rós, A.B., Feltran, J.C., Bernacci, L.C., Gonçalves, C., Fabri, E.G., Piotto, F.A., Doná, S. 2022. Introdução. In: Peressin, V.A., Feltran, J.C., Rós, A.B., Fernandes, A.M. (ed.). *A cultura da batata-doce*. Agronomic Institute, Campinas, Brazil. 3 p.

Placide, R., Shimelis, H., Laing, M., Gahakwa, D. 2015. Phenotypic characterisation of sweetpotato genotypes grown in East and Central Africa. *South African Journal of Plant and Soil* 32: 77–86.

Rós, A.B. 2017. Sistemas de preparo do solo para o cultivo da batata-doce. *Bragantia* 46: 113-124.

Rós, A.B., Araújo, H.S., Narita, N., Tavares Filho, J. 2011. Uso de fertilizante e tempo de permanência de mudas de batata-doce produzidas em bandejas. *Pesquisa Agropecuária Brasileira* 46: 845-851.

Rós, A.B., Fernandes, A.M., Montes, S.M.N.M., Fischer, I.H., Leonel, M., Franco, C.M.L. 2015. Batata-doce (*Ipomoea batatas*). In: Leonel, M., Fernandes, A.M., Franco, C.M.L. (coord). *Culturas amiláceas: batata-doce, inhame, mandioca e mandioquinha-salsa*. CERAT/UNESP, Botucatu, Brazil. 120 p.

Rós, A.B., Hirata, A.C.S., Santos, H.S. 2012. Avaliação da produtividade de plantas de batata-doce oriundas de matrizes livres de vírus. *Revista Brasileira de Ciências Agrárias* 7: 434-439.

Santos, H.G., Jacomine, P.K.T, Anjos, L.H.C., Oliveira, V.A., Lumbreras, J.F., Coelho, M.R., Almeida, J.A., Araujo Filho, J.C., Oliveira, J.B., Cunha, T.J.F. 2018. *Brazilian Soil Classification System*. Embrapa, Brasília, Brasil. 303 p.

Senff, S.E., Milcheski, V.F., Konkol, A.C.B., Fioreze, A.C.L. 2021. Genotype × environment effects on morphological and productive components ofsweet potato (*Ipomoea batatas* L.). *Colloquium Agrariae* 17: 7-15.

Silva, G.O., Suinaga, F.A., Ponijaleki, R., Amaro, G.B. 2015. Desempenho de cultivares de batata-doce para caracteres relacionados com o rendimento de raiz. *Ceres* 62: 379-383.

Solankey, S.S., Singh, P.K., Singh, R.K. 2015. Genetic diversity and interrelationship of qualitative and quantitative traits in sweet potato. *International Journal of Vegetable Science* 21: 236-248.

Visalakshi, C., Anil, S.R., Sheela, M.N., Hegde, V., Jyothi, A.N., Sreekumar, J. 2021. Genetic variation for important processing traits and identification of potential parents for developing hybrid clones suitable for processing in sweet potato (*Ipomoea batatus* L Lam). *South African Journal of Botany* 141: 255–264.

Wera, B., Yalu, A., Ramakrishna, A., Deros, M. 2014. Genotypic variability estimates of agronomic traits for selection in a sweetpotato (*Ipomoea batatas*) polycross population in Papua New Guinea. *Journal of Plant Breeding and Genetics* 02: 131-136.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

All the contents of this journal, except where otherwise noted, is licensed under a Creative Commons Attribution License attribuition-type BY.