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SCS443 ISADORA: late ripening apple cultivar with very high fruit storage ability

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Abstract: The objective of this study is to describe the agronomic attributes of the SCS443 Isadora apple tree cultivar and to highlight its potential use in Brazil. Obtained by the hybridization made at Epagri in 2001 between 'Imperatriz' and 'Cripps Pink', after 20 years of agronomic evaluations carried out in Caçador-SC and Fraiburgo-SC, 'SCS443 Isadora' was originated. This cultivar has a wide plasticity of adaptation to the southern Brazilian climate due to the medium chilling requirement to overcome dormancy. It has greater resistance to the main apple diseases than cv. Gala and fruit harvest is later than cv. Fuji. Its apples have a red skin and firm flesh (≥18 lb), with high sugar content (≥ 14.5 %) and very crunchy and juicy texture, as well as high storage ability in post-harvesting. 'SCS443 Isadora' apples can be stored for 8 months, even in refrigerated air atmosphere chambers (21% O_2) with inhibition of the ethylene response by the use of 1-methylcyclopropene (1-MCP). Even stored for long periods of time, the indices of quality loss, physiological disorders and fruit rotting in 'SCS443 Isadora' apples are lower than on Gala and Fuji apples.

Index terms: apple breeding, harvest time, long-life apples, sweet apples

SCS443 Isadora: cultivar de macieira de maturação tardia e de altíssimo potencial de conservação dos frutos

Resumo: O trabalho tem como objetivo descrever os atributos agronômicos da cultivar de macieira SCS443 Isadora e evidenciar suas potencialidades de uso no Brasil. Obtida pela hibridação realizada na Epagri, em 2001, entre 'Imperatriz' e 'Cripps Pink', após 20 anos de avaliações agronômicas realizadas em Caçador-SC e Fraiburgo-SC, originou-se a 'SCS443 Isadora'. Esta cultivar é de ampla plasticidade de adaptação ao clima sul-brasileiro, em função do médio requerimento de frio hibernal, para superação da dormência das gemas. Possui maior resistência às principais doenças da macieira que a cv. Gala, e a maturação dos frutos é mais tardia que da cv. Fuji. As suas maçãs são de epiderme vermelha e de polpa firme (≥18 lb.),

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com alto teor de açúcares (≥ 14,5 %) e de textura muito crocante e suculenta, bem como de muito alta capacidade de conservação em câmara fria. Maçãs 'SCS443 Isadora' podem ser armazenadas por 8 meses, mesmo em câmaras de atmosfera do ar refrigerado (21% de O_2), com a inibição da resposta ao etileno pelo uso do 1-methylcyclopropene (1-MCP). Mesmo armazenadas por longos períodos de tempo, os índices de perda de qualidade, de distúrbios fisiológicos e de podridões são inferiores aos das maçãs 'Gala' e 'Fuji'.

Termos para indexação: melhoramento de macieira, época de maturação, maçãs longa vida, maçãs doces.

Introduction

Brazil, the third largest fruit producer in the world, in the last five years has produced an average of 1.15 million tons of apples annually, occupying the 12th position among the largest countries producing this fruit in the world (FAOSTAT, 2022). From this volume of apples produced in the country, more than 90% come only from the cultivars Gala and Fuji groups (KIRST, 2019).

Although the cultivation of apple trees of these two groups of cultivars is currently the most increasing in the world due to the high quality of their fruits (BELROSE, 2018), in the southern Brazil great difficulties have been observed in the cultivation of apples. It is due mainly to poor climatic adaptation of the main cultivars used, to the high susceptibility of 'Gala' to the glomerella leaf spot - GLS (*Colletrotrichum* spp.) and to the very restricted period for harvesting a too large amount of fruits, being these problems especially more severe in regions below 1,200 m of altitude (KVITSCHAL et al., 2019).

Compared to the largest apple growers in countries of both hemispheres, the Southern Region of Brazil has longer hot seasons and shorter winters, which consequently promote a longer vegetative period for apple grow. But, as a negative point, the short-winters in the southern Brazil do not allow accumulation of sufficient amount of chilling for an adequate 'Gala' and 'Fuji' budbreak. This promotes an erratic and deficient bud sprouting, mainly for cultivars that require high chilling accumulation to budbreak, such as those of Gala and Fuji groups (PETRI, 2002). However, this peculiarity of the Brazilian climate allows the use of a longer period of time for harvesting apples, being possible the production of apples since before Gala, considered an early ripening cultivar, up to Fuji which is considered a late ripening cultivar. The use of cultivars with late fruit maturation period for diversifying the harvesting of Gala and Fuji, allows the expansion of apple cultivars used in apple farms, which can be a very economically interesting strategy, mainly in those farms that depends on family labor hand (KVITSCHAL et al., 2019).

The high respiratory rate and the high production of ethylene in 'Gala' apples are factors that usually reduce their longevity at storing, which hinder the apple supply on the market during the off-season (BRACKMANN, 1992). Since 'Gala' apples account for more than half of Brazilian apple production (DENARDI et al., 2017) but lose quickly the quality when storing at air cold chambers (BRACKMANN and SAQUET, 1999), the apple sector in the country also feel difficulties in the processes of fruit classification, packaging and storage. That is because keeping 'Gala' fruits stored for periods that allow supplying the market in the off-season implies a high storing costs, considerable post-harvest loss rates and gradual depreciation of apple quality to the consumers. Therefore, the production and supply of new apple cultivars with equivalent 'Gala' fruit quality, but with higher storage ability in post-harvest is a very important demand for apple growers in the country (KVITSCHAL et al., 2022).

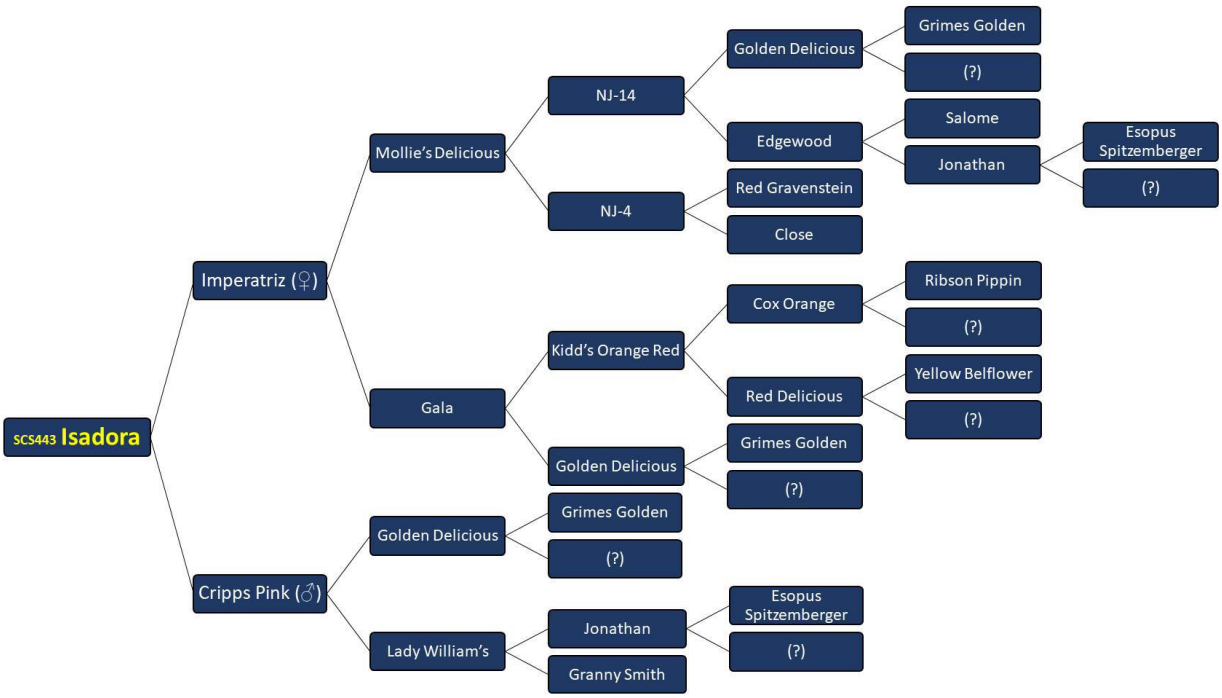
As a way to provide apple growers more technological options to mitigate or minimize several mentioned difficulties, Epagri in the State of Santa Catarina, Brazil, has been developing researches in Apple Breeding for

more than 50 years, having already released 21 cultivars (KVITSCHAL et al., 2022). Among the main objectives of this Epagri's Apple Breeding Program, in addition to the high fruit quality, are included the low to medium chilling requirement, resistance to the main apple diseases (GFS, scab, powdery mildew and fruit rots), fruit ripening in different periods than cultivars Gala and Fuji, apples with long cold storage and shelf-life ability (DENARDI et al., 2019).

Thus, this study aims to describe the agronomic attributes of the SCS443 Isadora apple cultivar and to highlight its potential for use in association with the traditional cultivars Gala and Fuji in Brazil.

Materials and methods

The breeding method used was using hybridizations in order to generate genetic variability followed by clonal selection and grafting as the propagation method. The SCS443 Isadora cultivar was obtained by crossing the cultivars Imperatriz and Cripps Pink, whose complete genealogy is illustrated in Figure 1.



(?) It means No parental information in literature

Figure 1 – Lineage of the SCS443 Isadora apple tree cultivar.

The hybridization was performed at Epagri /Caçador Experimental Station (CdES), Caçador, Santa Catarina, Brazil, in the spring of 2001. The hybrid seeds were collected from ripe fruits harvested in the subsequent summer. The seeds were germinated at 4°C to overcome dormancy and subsequently transplanted to substrate in greenhouse environment, as described by Denardi et al. (2013). At the 6-8 leaf phase, the seedlings were inoculated with a mixture of isolates of the fungus *Colletotrichum* spp. (glomerella leaf spot – GLS) according to the methodology described by Furlan et al. (2010).

The seedlings that did not shown symptoms of GLS were transplanted to the nursery where they were submitted to evaluations for short juvenility and resistance to powdery mildew (*Podosphaera leucotricha*) according to the methodology described in Denardi et al. (2013). All pre-selected seedlings from the original segregating population were grafted onto the dwarfing rootstock M.9 in order to accelerate the fruit crop.

The experimental orchard was planted in 2005 at Epagri - CdES, representing a single plant for each pre-selected hybrid. The

plants were submitted to the evaluation of the following traits: a) budbreak ability of the trees after submitted to a winter chilling, using a numerical scale ranging from 1 to 5, whose methodology is described by Denardi et al. (2012); b) precocity of fruiting characterized by the time in which the transition between the juvenile and reproductive phases of the plants occurs; c) resistance to diseases at field conditions, prioritizing scab, powdery mildew, GLS, bitter rot (*Glomerella cingulata*), marssonine (*Marssonina mali*) and eventual secondary diseases, according to methodology described by Denardi et al. (2019); d) vigor and typical architecture of the trees; e) fruit appearance (color, size, shape) and presence of physiological disorders (russeting, bitter pit, cork spot, fruit cracks, sunburn, etc...); f) fruit flesh quality (sugar content, acidity, crispness, juiciness, aroma, etc...); g) time of fruit ripening and fruit harvesting; h) yield potential of the trees on consecutive years of evaluations.

Each hybrid selection, identified in the original plant population, was propagated again to make up plant collections performed by five trees of each hybrid, where advanced studies were conducted at Epagri - CdES. The selections that highlighted because their agronomic advantages over the traditional cultivars Gala and Fuji, were also evaluated in an experimental orchard located at Fischer Agroindústria Farm, in Fraiburgo – SC, Brazil. The experimental design was randomized blocks with 3 replications of 4 plants per plot, cultivated under central leader system training. This orchard was planted under an anti-hail screen (18% shading), grafted on the Geneva® apple rootstock G.814. The population density was of 1,667 trees.ha^{-1} (4.0m x 1.5m) using Galaxy and Fuji Suprema cultivars as controls. In this experiment, additionally to the traits already mentioned, were also evaluated: a) phenology of buds sprouting (beginning) and the flowering (beginning, full and final); (b) onset date of fruit ripening; c) annual fruit production (Kg.tree^{-1}); d) cumulative fruit production throughout the evaluation seasons, estimated by the sum of annual fruit productions (Kg.tree^{-1}); e) regularity of fruit production, measured by the presence or absence of flowering/production alternation. More details about the evaluation methodologies of the apple hybrids are reported by Denardi et al. (2019).

Additionally, a total of 15,240 fruits of SCS443 Isadora cultivar were evaluated for different categories of fruit size and red skin color coverage. The trial was carried out with apples sampled randomly in 10 replicates of 1,524 fruits each. The fruits were harvested in the 2020/2021 season in a nine years old experimental orchard in Epagri - CdES, grafted on the M.9 rootstock with a planting density of 2,500 tree.ha^{-1} (4.0m x 1.0m).

The chilling requirement to overcome the buds dormancy was also estimated for cv. SCS443 Isadora, whose trait is directly related to the local adaptation of the genotype in the different subtropical climatic conditions (HAUAGGE; CUMMINS, 1991), typical in the Southern Region of Brazil. The chilling requirement was obtained by comparing the budbreak levels and dates of 'SCS443 Isadora' with IAPAR-75 Eva and Epagri 408 Condessa low chilling cultivars, and Gala and Fuji as high-chilling cultivars. These comparisons were made from information obtained in the field over all the years of evaluation. The cv. IAPAR-75 Eva requires chilling accumulation (≤ 7.2ºC) between 250 and 450 hours (HAUAGGE; TSUNETA, 1999), while cv. Epagri 408 Condessa requires around 350 hours of winter chilling accumulation annually (PUTTI et al., 2003). For the Gala and Fuji cultivars, at least 1,000 hours of winter chilling accumulation are required to overcome buds dormancy (HAUAGGE; CUMMINS, 1991).

Evaluations about the best time to harvest the 'SCS443 Isadora' fruits were also performed in post-harvest, as well as trials to evaluate the storage ability of the fruits in both air atmosphere (AA) (21% O_2) and controlled atmosphere (CA) storing conditions, according to the methodology described

by Argenta et al. (2022). The experiment was conducted with apples harvested on 03/25/2014, from 100 apple trees, in an experimental orchard located in Fraiburgo-SC, under a completely randomized block design, with 4 replicates of 20 fruits per treatment and per storing period. The fruits were harvested with a starch degradation index higher than 5.0 (scale 1 to 9), and the following experimental conditions were considered: a) refrigerated storing (~0.8 ºC) on air atmosphere (AA: 21% O_2); b) controlled atmosphere (CA: ~0.8°C, 1.5% O_2 and 1.5% CO_2), with and without ethylene inhibition by applying 1-MCP (1-Methylcycloprene).

The data set about budbreaking potential of the three cultivars evaluated (Galaxy, Fuji Suprema and SCS433 Isadora) in five different growing seasons (2012/13, 2014/15, 2015/16, 2016/17 and 2017/18) was analyzed in a 3 x 5 factorial scheme. The annual fruit production data set (Kg.tree^{-1}) followed factorial scheme 3 x 7 (2012/13, 2013/14, 2014/15, 2015/16, 2016/17, 2018/19 and 2019/20). The cumulative fruit production (Kg.tree^{-1}) was analyzed only for the sum of the fruit production over the seven seasons. Variance analysis (Anova) was applied to data and the means were compared by the Tukey and Scott-Knott tests ($p<0.05$).

Results and discussion

A total of 2,400 seeds were obtained from the cross that originated the SCS443 Isadora cultivar. After cold treatment to overcome seeds dormancy, 2,290 seedlings were obtained which, after inoculation with spore suspension of the fungus *Colletotrichum* spp., resulted in 1,270 seedlings (55.5%) resistant to glomerella leaf spot (GLS). After evaluations of juvenility and reaction to scab and powdery mildew, 232 pre-selections were preserved, which were then grafted on M.9 rootstock to start the first stage of fruit quality evaluation. After four subsequent years of evaluating the plants of this hybrid population, five selections were obtained, including the selection identified by the code M.10/09, later registered by Epagri in 2021 under the name SCS443 Isadora.

One of the main attributes of cv. SCS443 Isadora is its best climate adaptation in most apple growing regions in the southern Brazil when compared to traditional Gala and Fuji cultivars. This is potentially due to its lower winter chilling requirement to overcome buds dormancy. Its winter chilling requirement is higher than Epagri 408 Condessa and IAPAR75 Eva cultivars, but lower than Gala and Fuji cultivars, thus suggesting a medium chilling requirement to budbreak (estimated between 500 and 650 hours ≤ 7.2°C). This is confirmed by its higher bud sprouting rate observed in the climatic conditions of Fraiburgo-SC, even after winters with less chilling accumulation, as observed in 2014/15, 2015/16 and 2017/18 seasons (Table 1). Additional results obtained in the climatic conditions of Caçador-SC evaluations, at 960m of altitude, involving 40 trees/cultivar in the 2014/2015 season (chilling accumulation of only 271 hours ≤ 7.2ºC), with chemical treatment to induce sprouting (0.7% Dormex + 3.5% Mineral Oil), showed 93.8% of sprouted buds in 'SCS443 Isadora' while in the Galaxy cultivar the sprouting rate was only 54.3%. This characteristic gives to 'SCS443 Isadora' good adaptation plasticity to the most diverse climatic environments in the South Region of Brazil, with altitudes above 900 m. The use of spraying chemicals induction for buds sprouting can improves the budbreak rates, in addition to standardizing the trees flowering period, especially in seasons with low chilling accumulation during the winter, in which cultivars with high chilling requirements may not respond very well to this technology. Therefore, the 'SCS443 Isadora' has greater predictability of phenological response than cultivars such as Gala and Fuji in mild winter climatic conditions, with the occurrence of high temperature amplitudes, which are typical of southern Brazil.

Table 1 - Budbreak index of Galaxy, Fuji Suprema and SCS443 Isadora cultivars in five evaluation cycles in Fraiburgo-SC. Caçador-SC, 2022

Cultivar	Budbreak index / Season [2/]				
	2012/2013	2014/2015	2015/2016	2016/2017	2017/2018
Galaxy	3.63 b	2.75 b	2.25 b	2.63 b	1.50 c
Fuji Suprema	3.50 b	2.45 b	2.00 b	3.50 a	2.13 b
SCS443 Isadora	4.55 a	4.08 a	3.88 a	4.00 a	2.88 a
Average Index	3.89	3.09	2.71	3.38	2.58
C.V. (%)	7.97	10.02	11.42	9.15	11.99
CUaccumulated [/1]	1,108	678	504	1,019	562

[/1] Number of chilling units (CU) accumulated, according North Caroline Modified model (EBERT et al., 1986); [2/] Numeric scale from 1 (≤ 20%) to 5 (100%) according the proportion of sprouted buds (DENARDI et al., 2012); Means followed by the same letter in the column do not differ by the Tukey test (P > 0.05); C.V.(%) = coefficient of variation.

Due to its wide budbreak potential, there is a tendency for plants to develop a large number of branches along the trunk after planting the young trees in the orchard, in addition of having a tendency to develop branches with a low opening angle in relation to the trunk. Therefore, thinning and bending of the branches along the central leader is required for a good training of the trees, especially during the first years of the orchard (Figure 2a). It has also been observed that the use of growth inhibitors (e.g. prohexadione calcium) during the trees structural formation in young orchards facilitates management of the canopy. The temporary suppression of vegetative growth at the apex of the branches as a result of the application of this type of chemical (MILLER, 2002) reduces the intervention with green pruning in the trees, which also implies a reduction in the demand for labor hand and provide opportunities for plants training with less-density canopy, more airy and better lit.

Figure 2 – Illustration of (a) budbreak ability of the plants, (b) yield potential, (c) details of the peduncular and calyceal cavities of the fruits, (d) fruit shape and skin coloration and (e) flesh coloration of 'SCS443 Isadora' apples.

The SCS443 Isadora cultivar is characterized by its high ability to differentiate flower buds. Although, the fruit production is mainly on brindles with apical fruiting buds predominate, the trees also develop a large number of fruiting spur buds. The architec-

ture of the trees and the pattern of their predominant reproductive structures also guarantee to 'SCS443 Isadora' good adaptation to high density training systems, with compact trees, with shorter branches, whose canopy is more airy and better lit. This training system allows improving fruit production and the fruit quality.

Another differential advantage of this cultivar is the good spectrum of genetic resistance to diseases such as the high resistance (immunity) to GLS, which is currently the main summer disease for apple trees in Brazil. In addition, only mild symptoms of scab (*Venturia inaequalis*), powdery mildew and marssonine spot (*Marssonina mali*) were observed over another 15 years of field evaluations, characterizing its medium resistance to these diseases (Table 2). 'SCS443 Isadora' has also shown high resistance to pre-harvest fruit rots (Table 2), with symptoms generally being observed only in parts of the fruits with some type of mechanical damage or in conditions of accentuated fruit fly (*Anastrepha fraterculus*) attacks.

All these resistances guarantee to 'SCS443 Isadora' lower costs of production and easier phytosanitary control for trees in the orchard, especially when compared to cv. Gala, which is typically very susceptible to GLS. This is reflected as saving resources at apple farms, as environmental protection and as food security, because growing SCS443 Isadora trees makes it possible to reduce the amount of pesticides sprayed in the orchard throughout the production season.

Table 2 – Main agronomic and phenological data of the plants and physicochemical data of the fruits for Galaxy, Fuji Suprema and SCS443 Isadora growing up at Epagri - Caçador Experimental Station, Midwest region of Santa Catarina, seasons from 2009 to 2022.

	Trait	Cultivar		
		Galaxy	Fuji Suprema	SCS443 Isadora
1. Trees:	Chilling requirement (CH) [1/]	>1,000 [3/]	>1,000 [3/]	500-650
	Resistance to Scab	None	None	Medium
	Resistance to GLS	None	High	High
	Resistance to fruit rot	Low	Low	High
	Beginning of flowering	Sep. 25th	Sep. 23rd	Sep. 15th
	Flowering intensity	High	High	Very High
	Fruit set	Medium	High	Very High
2. Fruits:	Fruit maturation (beginning)	Early February	End of March	Mid April
	Flesh firmness (lb.)	16.5-17.0	16.0-16.5	18.0-22.0
	Soluble Solids Content (%)	12.5-13.0	13.5-14.5	14.5-15.5
	Titratable Acidity (% malic acid)	0.40-0.45	0.35-0.40	0.35-0.40
	Storage ability [2/]	3 months	5 months	≥ 8 months

[1/] CH = chilling hours ≤ 7.2°C required to satisfy the dormancy of the buds.
[2/] Storage in Air Atmosphere chamber (21% O_2) without application of 1-MCP ethylene inhibitor.
[3/] Source: Hauagge and Cummins (1991)

The typical dates for budbreaking and the beginning of flowering for 'SCS443 Isadora' trees occur about seven to fifteen days before the usual periods for Gala or Fuji cultivars, varying according to the prevailing climatic conditions in winter and spring seasons. The earlier flowering combined with late fruit maturation results in a long period between anthesis and fruit maturation which, according to Denardi and Camilo (1996), is correlated with greater flesh firmness and, consequently, greater fruit storage ability in post-harvest.

The SCS443 Isadora trees have intense flowering and also has shown high fruit set (Table 2). The trees also start the fruit production very early (2nd season age), indicating a high yield potential (Figure 2b). In the trials carried out in Fraiburgo-SC, in addition to 'SCS443 Isadora' starting fruit production as early as

'Galaxy' and 'Fuji Suprema', its productive performance was never lower than both control cultivars, and it was even higher in some of the evaluation seasons (Table 3). It is important to point out that 'SCS443 Isadora' is sensitive to biennial bearing, requiring good management of fruit thinning, under the risk of alternating flowering in the trees for next season if the excess of fruits are not removed at the right time (fruits with diameter < 14 mm) or at the required intensity. This is observed in Table 3, whose fruit production was reduced drastically in the 2013/2014 and 2015/2016, possibly due to slim thinning in the previous seasons (2012/2013 and 2014/2015). Over seven seasons, 'SCS443 Isadora' had cumulative fruit production of 161.5 Kg.tree^{-1}, do not differing from cv. Fuji Suprema (138.6 Kg.tree^{-1}). However, the cumulative fruit production of 'SCS443 Isadora' was significantly higher than that of 'Galaxy' (93.9 Kg.tree^{-1}), whose difference is mainly due to adaptive restrictions and to 'Galaxy' susceptibility to GLS (Table 2).

Table 3 – Annual fruit production (Kg.tree^{-1}) for Galaxy, Fuji Suprema and SCS443 Isadora cultivars, and cumulative fruit production (Kg.tree^{-1}) over seven seasons of evaluation in Fraiburgo-SC.

Cultivar	Annual fruit production (Kg.tree^{-1}) / Season							Cumulative Production[1/]
	2012/13	2013/14	2014/15	2015/16	2016/17	2018/19	2019/20	
Galaxy	9.13 Ca	7.92 Ca	17.84 Ba	5.29 C b	13.54 Bb	14.89 Bb	25.30 Aa	93.9 b
Fuji Suprema	4.25 Ca	4.30 Ca	23.70 Ba	7.86 Cab	38.86 Aa	33.95 Aa	25.69 Ba	138.6 ab
SCS443 Isadora	13.75 Ca	6.84 Da	25.11 Ba	16.65 Ca	39.15 Aa	38.14 Aa	21.88 Ba	161.5 a
Average	9.04	6.35	22.21	9.93	30.52	28.99	24.29	131.34
C.V.(%)	54.6 %	77.7 %	22.2 %	49.7 %	16.2 %	17.0%	20.3 %	12.14 %

[/1] Cumulative fruit production (Kg.tree^{-1}) along seven seasons of evaluation (from 2012/13 to 2019/20); Means followed by the same lowercase letter in the column do not differ by the Tukey test (P > 0.05); Means followed by the same uppercase letter in the row do not differ by the Scott-Knott test (P > 0.05) C.V. (%) = coefficient of variation.

'SCS443 Isadora' apples fruits are typically small to medium sized, globose and slightly flattened, with a red skin color and a greenish-yellow background color (Figures 2c, 2d). Additional results about evaluations of red skin color coverage and caliber of 'SCS443 Isadora' apples in an automatic sorting machine at 2019/2020 season also showed a predominance of small to medium-sized fruits. Apples weighing between 87g and 157g accounted for 75.8% of the 15,240 evaluated apples, with 110.9g average weight (Figure 3b). This indicates that 'SCS443 Isadora' requires careful fruit thinning, in terms of avoiding biennial bearing, and in the sense of avoiding the production of very small-sized fruits. In terms of red skin color fruit coverage, it was observed that 77.7% of the 'SCS443 Isadora' apples had more than 75% of the surface area of the fruit red coloring, and only 3.9% of the apples produced red pigments in less than half of the fruits skin surface (Figure 3a), which typifies its high potential for red fruit coloration. The stripes on the fruit skin are discrete (Figures 2c, 2d), with clearly visible lenticels (Figure 2d) and pronounced russeting but restricted to the peduncle cavity (Figure 2c). The flesh is cream colored (Figure 2e), firm (18-22 lb.), very crunchy and very juicy. The taste is quite sweet (14.5-15.5 %) with a very subtle acidity (0.35-0.40% malic acid), similar to 'Fuji' apples (Table 2).

Considering the requirements related to the appearance and physical-chemical quality of the fruits required by IN No. 5 of the Brazilian Ministry of Agriculture, Livestock and Supply about apples classification in Brazil (MAPA, 2006), it is observed that 'SCS443 Isadora' has high potential for fruit production of Cat I and Extra categories, which are the best price fruits for apple growers.

The fruit maturation and harvesting is typically late (mid-April, after the 'Fuji' harvest), which is another major competitive advantage of 'SCS443 Isadora' (Table 2), as it enables the optimization of the labor hand use available in the harvesting and extending the apple harvest period on apple farms.

This benefit is mainly important on small apples farms that basically rely on family labor hand. On the eve of harvest, during fruit maturation in the orchard, the ethylene production rate range from 5 to 20 ηMol kg^{-1} h^{-1} and the firmness loss rate is quite low, being less than 0.5 lb. per week. Since the fruit maturation evolution on the tree is slow and the fruit flesh firmness is high, it is suggested that 'SCS443 Isadora' apples be harvested at advanced maturation stages (starch degradation index > 8) to optimize redness coloration in the fruit skin and attenuate the flesh firmness indices.

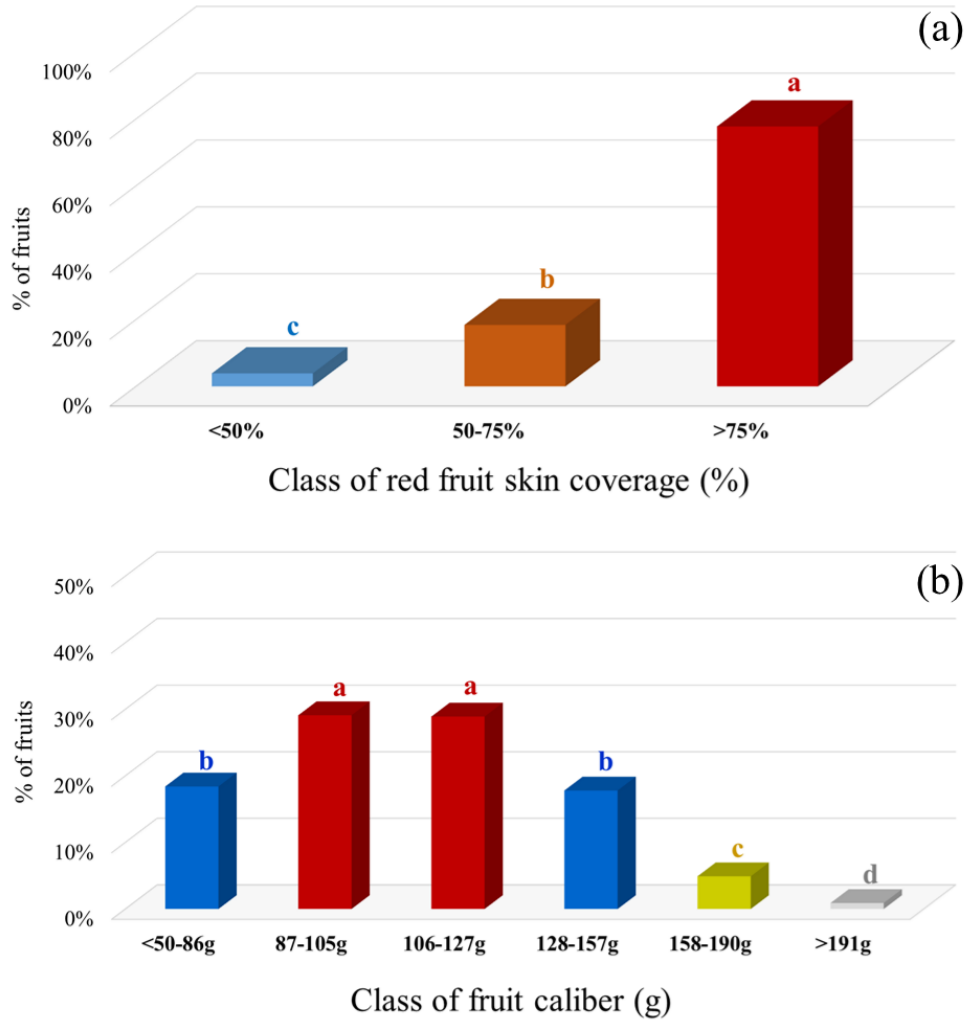


Figure 3 – Frequency distribution of 'SCS443 Isadora' apples by classes of (a) coverage with red coloring on the fruit skin and (b) caliber, 2020/2021 season, Caçador-SC. Columns flowed by the same letter do not differ by the Scott-Knott test (P > 0.05).

The storage ability of 'SCS443 Isadora' apples is very high (Figure 4). Flesh firmness of stored fruits does not decrease, even over eight months of cold storage plus seven days of shelf-life environment (22°C), regardless of the type of storage atmosphere and treatment with the ethylene inhibitor 1-MCP (Figure 4). The combination of CA storage and 1-MCP treatment is the most effective postharvest practice to inhibit the loss of titratable acidity (TA) of 'SCS443 Isadora' apples during storage. An increase in the soluble solids (SS) content of the fruits of this cultivar during storage is common, with higher values for fruits stored in CA. In most postharvest studies carried out at Epagri - Caçador Experimental Station, wilting and bitter pit symptoms were not observed after long-term storage of 'SCS443 Isadora' apples. Superficial fruit scald can occur, but with low

severity and only in apples stored in an air atmosphere (AA) after a period higher than 8 months. Both CA and 1-MCP effectively prevent superficial scald of 'SCS443 Isadora' fruits. The incidence of fruit rots was always below 12%, even after eight months of storage, not being significantly affected by the storage atmosphere or by the treatment with 1-MCP, although more studies on this subject are being carried out at Epagri. After long periods of storage, the incidence of fruit rots is similar to that of 'Gala' apples, but lower than that of 'Fuji' apples (ARGENTA et al., 2021). Therefore, due to the high storage ability of apples and the post-harvest technology currently available, it is possible to preserve and offer 'SCS443 Isadora' apples to the consumers throughout all the apple off-season in Brazil, without changing their appearance and physical-chemical attributes that may depreciate the quality of its fruits.

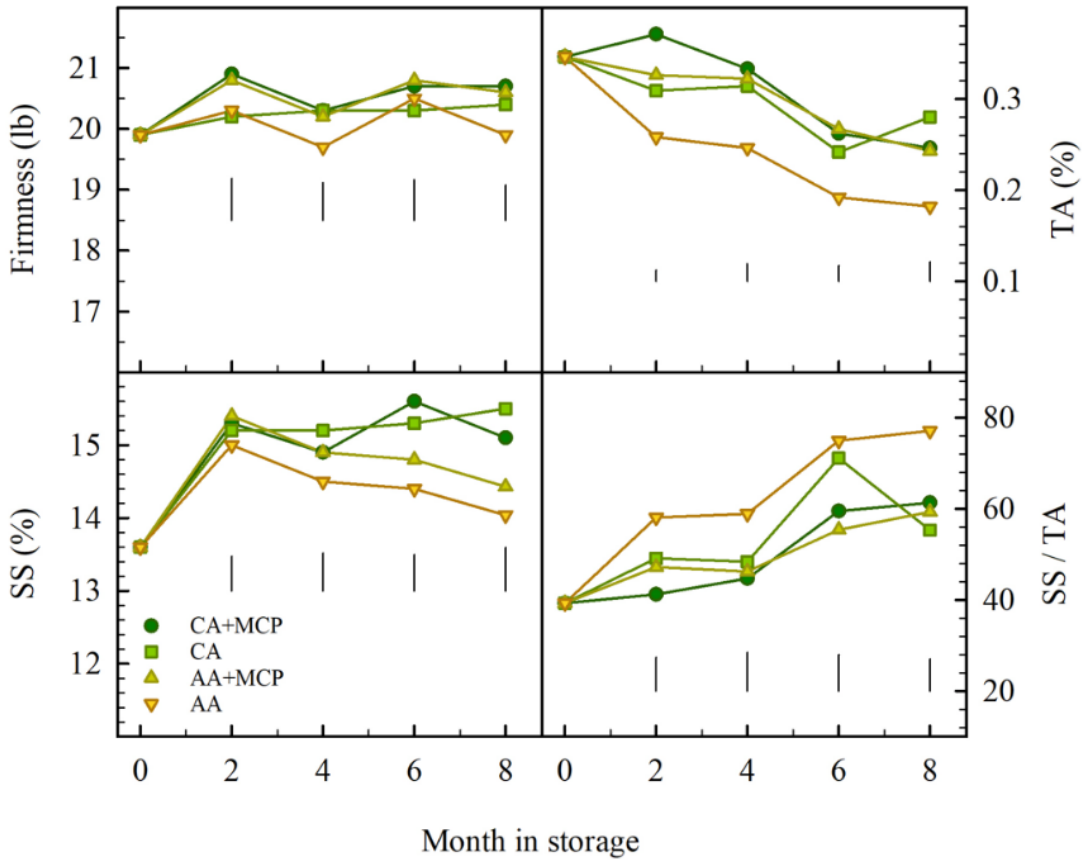


Figure 4. Flesh firmness, titratable acidity (TA), soluble solids content (SS) and SS/TA ratio of 'SCS443 Isadora' apples at harvest (month zero) and after storing. The fruits were treated (+MCP) or not treated with 1-MCP, and then stored at 0.8°C under air atmosphere (AA) or controlled atmosphere (CA), from two to eight months. Fruits were kept 7 days at 22°C after refrigerated storing before evaluation. Vertical lines represent LSD values (Fisher's test, $\alpha = 0.05$) for treatment effects at each assessment date. Data from experiment carried out in 2014.

Conclusion

'SCS443 Isadora' apple cultivar has medium chilling requirement to satisfy the dormancy of the buds and, therefore, with good adaptation to most apple growing regions in the southern Brazil. It has high resistance to glomerella leaf spot and fruit rots, and has some horizontal resistance to apple scab. It has a high yield potential, produces small to medium sized fruits, red skin fruits with discreet stripes and a very typical russeting in the peduncle cavity. The fruits flesh is very firm (>18 lb.), with a very

sweet flavor (>14.5 %) and a very crunchy and juicy texture. Ripening and harvesting is quite late, typically occurring after the end of the Fuji harvest. The storage ability of its apples in a cold chamber is more than 8 months, enabling the supply of high quality apples during the apple off-season in the country.

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