CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

IPR Pérola – Dwarf Arabica coffee cultivar with high resistance to leaf rust and large beans

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Abstract: *IPR Pérola is a Coffea arabica cultivar developed from a cross between IAPAR 59 and Mundo Novo IAC 376-4. It features a dwarf-medium size, high yield, excellent cup quality, a medium-early ripening cycle, and large beans. Additionally, it boasts high resistance to coffee leaf rust.*

Keywords: *Coffea arabica, Hemileia vastatrix, IAPAR 59, Sarchimor, Timor Hybrid*

INTRODUCTION

Most Brazilian coffee plantations are planted with varieties from the Catuaí and Mundo Novo groups, both of which are considered pure Arabica coffees (*Coffea arabica*). Catuaí varieties are dwarf-to-medium in size, have a late ripening cycle, and produce medium-sized beans, while Mundo Novo varieties are tall-to-medium in size, have a medium ripening cycle, and produce medium-sized beans (Carvalho et al. 2008, Sera et al. 2022b). Despite their high average yield, these cultivars are susceptible to several biotic factors, including coffee leaf rust (CLR) (Sera et al. 2022a, Sera et al. 2022b), caused by the fungus *Hemileia vastatrix* Berk. et Br.

In response, Brazilian breeding programs have focused on incorporating resistance genes to biotic stresses from *C. canephora* into Arabica coffee germplasm, such as the Sarchimor derivatives derived from a hybridization between Villa Sarchi CIFC 971/10 and Híbrido de Timor CIFC 832/2, some *C. arabica* cultivars with *C. canephora* introgression have been developed with high-yielding traits and resistance to CLR (Pereira et al. 2022, Sera et al. 2022a), bacterial-halo-blight (Ito et al. 2008, Sera et al. 2017), and nematodes such as *Meloidogyne paranaensis*, *M. incognita*, and *M. exigua* (Sera et al. 2020, Botelho et al. 2021).

Of the 124 cultivars listed in the Brazilian federal database (Brasil 2024), eight dwarf *C. arabica* cultivars are the result of hybridization between Sarchimor and Mundo Novo germplasm (Sera et al. 2022b). According to the Brazilian Ministry of Agriculture, Livestock, and Supply (Ministério da Agricultura Pecuária e Abastecimento [MAPA]), five of these cultivars were developed by the Fundação Procafé and are named Acauã, Acauãma, Acauãnovo, Asabranca, and Graúna. The Instituto de Desenvolvimento Rural do Paraná - IAPAR-EMATER (IDR-Paraná) developed and registered the other three: IPR 107, IPR Alvorada, and IPR Pérola. These cultivars are characterized

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by high yields in different coffee growing regions and high resistance to CLR (Sera and Sera 2013, Botelho et al. 2021, Sera et al. 2022a, Pereira et al. 2022).

IPR 107, released in 2010, has shown average yields comparable to Catuaí Vermelho IAC 81 and Mundo Novo IAC 376-4. In addition, IPR 107 is highly resistant to CLR, produces larger fruits and has an earlier ripening cycle than Catuaí varieties (Sera and Sera 2013, Sera et al. 2022b, Pereira et al. 2022). In Paraná (PR), coffee growers have widely adopted IPR 107 to replace older cultivars such as Catuaí Vermelho IAC 99, Mundo Novo IAC 376-4, and Sarchimor cultivars such as Tupi IAC 1669-33 and IAPAR 59. To meet the continuing demand for varieties with traits similar to IPR 107 - such as high yield, CLR resistance and larger fruit and bean sizes - IDR-Paraná has developed a new variety: IPR Pérola.

PEDIGREE AND BREEDING METHODS

The IPR Pérola variety was developed by IDR-Paraná using the pedigree method after artificial crosses between IAPAR 59 and Mundo Novo IAC 376-4 in 1988. While both parents are *C. arabica* cultivars, only Mundo Novo IAC 376-4 is considered a pure Arabica coffee cultivar, originating from crosses between Sumatra and Bourbon Vermelho (Sera et al. 2022b). In contrast, IAPAR 59 is an Arabica coffee variety from the Sarchimor group, derived from a cross between Villa Sarchi CIFC 971/10 (a pure *C. arabica*) and Híbrido de Timor CIFC 832/2 (a *C. arabica* with *C. canephora* introgression).

Hybrids from the F_1 generation, named H8818, were planted in 1990 in an experimental field in Londrina, PR, Brazil. Seeds from this F1 population were harvested in 1993 and advanced to the F_2 generation in 1994 in Tamarana, PR. In 1997, the F_2 plant (R8C12) was selected, and its seeds were harvested to advance to the F_3 generation in 1998 in Londrina. In 2002, the F_3 plant (E9803 17-2) was selected and in 2003, the F_4 generation was created in Londrina. Thus, IPR Pérola is derived from the same F_3 plant as the IPR 107 variety. In 2009, the F_4 plant (E0319 6-1-9), which had larger fruits than IPR 107, was selected and its F_5 seeds advanced to the next self-pollinated generation.

In 2010, F_5 plants were planted in field experiments in Londrina and Congonhinhas, both in the state of Paraná. From 2013 to 2016, agronomic traits were evaluated in these experiments, showing that IPR Pérola had a yield similar to IPR 107 and Catuaí Vermelho IAC 99, while producing larger fruits and beans than IPR 107. In 2016, seeds from all F_5 plants were harvested to create a composite sample for the genetic seed field at IDR-Paraná in Londrina. These F_6 seeds were also used for the distinctability, Homogeneity and Stability test in 2017, as part of the variety protection process for MAPA.

IPR Pérola was officially registered with MAPA in 2021, and its cultivar protection rights were granted on November 16, 2021, set to expire on November 16, 2039.

YIELD, RIPENING CYCLE, RESISTANCE TO COFFEE LEAF RUST, AND BEAN SIZE

The evaluation of yield, resistance to CLR and ripening cycle of IPR Pérola was performed in two field experiments using seeds from the F_4 plant (E0319 6-1-9), selected in 2010 for advancement to the F_5 generation. These experiments were conducted in the state of Paraná with a planting distance of 2.5 × 0.50 m. Planting took place in September 2010 in Londrina (lat 23º 21’ 41.46” S, long 51º 09’ 44.35” W, alt 583 m asl) and in October 2010 in Congonhinhas (lat 23º 30’ 22.74” S, long 50º 33’ 12.37” W, alt 758 m asl). The mean annual temperatures were 21.2 ºC in Londrina and 20.1 ºC in Congonhinhas. Relative humidity at both sites ranged from 70.1% to 75%, and annual precipitation varied from 1600 to 1800 mm in Londrina and 1400 to 1600 mm in Congonhinhas. Both sites had dystrophic red latosol soils, and the climate was classified as Cfa according to the Köppen system.

Both experiments followed a randomized block design with four replications and 10 plants per plot. Fungicides, insecticides, and acaricides were applied as recommended for coffee crops (Matiello et al. 2016), and fertilization was based on soil analysis and recommendations for Paraná (Chaves 2002). Catuaí Vermelho IAC 99 and IPR 107 were used as controls in both experiments.

Yield was assessed by harvesting coffee cherries from 2013 to 2016 in June in Londrina and July in Congonhinhas. A 2 kg sample of harvested coffee from each plot was used to determine the weight of green coffee. Based on the plant spacing, the number of plants per hectare was calculated and the average yield was estimated in bags of 60 kg of green coffee beans per hectare.

The fruit ripening cycle was evaluated during the 2013 to 2016 harvests, when 80% of the fruits of IPR 107 were in the ripe, overripe, and dry stages. In each harvest season, a single evaluation was performed based on the proportion of ripe, overripe, and dry fruits exhibited by each plant compared to the control cultivars using a score scale from 1 to 5, as described by Andreazi et al. (2017). Plants with lower scores showed a later ripening cycle, while those with higher scores ripened earlier.

The severity of CLR was assessed in June of the 2013 and 2015 crops by natural infection, using a grading scale from 1.0 to 5.5 (Table 1). Plants with scores of 1.0 and 1.5 were considered highly resistant, while those with scores ≥ 2.0 were considered susceptible. The percentage of plants with each disease severity grade was estimated. IPR 107 and Catuaí Vermelho IAC 99 were used as resistant and susceptible controls, respectively.

Table 1. Grade scale used to evaluate the coffee leaf rust severity to the local population of races in Paraná, Brazil

Grade	Description[1]
1	Leaves without lesions
1.5	Leaves with lesions ranging from "flecks" to more or less intense chlorosis, accompanied by small necrosis, but without sporulation
2	Chlorotic lesions with sporulation, located in the lower third with very slight (0.1 – 5.0% of the leaves) severity
2.5	Chlorotic lesions with sporulation, located in the lower third with slight (5.01 – 10.0% of the leaves) severity
3	Chlorotic lesions with sporulation, located in the lower and middle thirds, respectively, with moderate-slight (10.01 – 20.0% of the leaves) and very slight severity
3.5	Chlorotic lesions with sporulation, located in the lower and middle thirds, respectively, with moderate (20.01 – 30.0% of the leaves) and slight severity
4	Chlorotic lesions with sporulation, located in the lower, middle and upper thirds, respectively, with moderate-high (30.01 – 40.0% of the leaves), moderate and very slight severity
4.5	Chlorotic lesions with sporulation, located in the lower, middle and upper thirds, respectively, with high (40.01 – 60.0% of the leaves), moderate-high and slight severity
5	Chlorotic lesions with sporulation, located in the lower, middle and upper thirds, respectively, with very high (> 60.0% of the leaves), high and moderate severity
5.5	Chlorotic lesions with sporulation, located in the lower, middle and upper thirds, respectively, with very high, very high and high severity

[1] levels of severity based on percentage of leaves with sporulation: very slight = 0.1 – 5.0%; slight = 5.01 - 10%; moderate-slight = 10.01 - 20%; moderate = 20.01 - 30%; moderate-high = 30.01 – 40%; high = 40.01 - 60%; very high = > 60%.

The size of flat beans was evaluated in an experiment planted at 2.75 m × 0.60 m spacing in March 2017 in Londrina (lat 23º 21' 38.11" S, long 51º 09' 41.77" W, alt 582 m asl), PR. The experiment followed a randomized block design with four replications and eight plants per plot. In June 2020, samples of ripe cherry fruits were collected from the eight plants in each plot. The harvested fruits were dry processed by drying in full sun until a moisture content of approximately 11.4% was reached. After drying, the husks were removed by hulling and three 100 g samples of green coffee were taken from each plot. These samples were passed through a series of screens with rounded holes 19/64", 18/64", 17/64", 16/64", 15/64", and 14/64" in diameter. The last screen, with no holes, retained the Peaberry beans and any beans not retained by the 14/64" screen. The average of the three 100g samples was calculated to obtain the mean for each plot. IPR 107 and Catuaí Vermelho IAC 99 were used as controls for large and medium beans, respectively. Flat beans retained on the 19/64", 18/64" and 17/64" screens were classified as large (Fl-L), those retained on the 16/64" and 15/64" screens were classified as medium (Fl-M), and those retained on the 14/64" screen were classified as small (Fl-S).

Data transformation was necessary, as indicated by the Bartlett test for homogeneity of variances and the Shapiro-Wilk normality test. The data for yield and fruit ripening cycle variables were transformed using $\sqrt{x}$, while bean size data were transformed using $\sqrt{x+1}$. No transformation was applied to the CLR severity variable data. Analysis of variance (ANOVA) followed by Tukey's means test at 5% significance level was performed. Statistical analyses, including Bartlett's test for homogeneity of variances, Shapiro-Wilk normality test, ANOVA, and Tukey's test, were performed using R software version 3.3.0 (R Core Team 2016) with the agricolae package (Mendiburu 2015). A group comparison of experiments was performed for yield.

YIELD, RIPENING CYCLE, RESISTANCE TO COFFEE LEAF RUST, AND BEAN SIZE

For yield, no significant interaction was observed between cultivars and locations. In both Londrina and Congonhinhas, IPR Pérola showed no statistically significant differences compared to the check cultivars (Table 2), indicating its high yield potential in the tested environments.

In terms of fruit ripening cycle, IPR Pérola did not differ significantly from IPR 107 in either location. Both cultivars displayed an earlier ripening cycle compared to Catuaí Vermelho IAC 99 (Table 2). Sera et al. (2022b) classified IPR 107 as early-ripening, which suggests IPR Pérola shares the same cycle, similar to Bourbon Vermelho. However, further studies in other coffee-growing regions in Brazil are necessary to confirm the ripening cycle classification.

Both IPR Pérola and IPR 107 demonstrated high resistance to CLR, with no susceptible plants observed in either location. These results were statistically different from the susceptible control, Catuaí Vermelho IAC 99, where 100% of the plants were susceptible.

Regarding bean size, IPR Pérola outperformed both check cultivars, showing statistically significant differences. IPR Pérola had a higher percentage of large flat beans retained on the 19/64", 18/64", and 17/64" screens compared to IPR 107 and Catuaí Vermelho IAC 99 (Table 3). Notably, IPR Pérola exceeded IPR 107 in bean size, which itself is classified as a cultivar with large beans (Sera and Sera 2013).

OTHER TRAITS

IPR Pérola is well-suited for cultivation in regions favorable for Arabica coffee, particularly in the state of Paraná, where average annual temperatures range from 20 to 22 ºC. Like Catuaí cultivars, it has a dwarf-medium size and is recommended for both low- and high-density planting. IPR Pérola has moderate plagiotropic branching, similar to Mundo Novo cultivars.

Fruits of IPR Pérola are red and large, comparable to the Acaiá varieties, which facilitates manual and mechanical harvesting. Its cup quality is excellent, often scoring higher than Catuaí cultivars in the Specialty Coffee Association (SCA) classification.

Table 2. Yield (60 kg of green coffee bags ha^{-1}), coffee leaf rust (CLR) severity, ripening cycle means, of the cultivars IPR Pérola, IPR 107 and Catuaí Vermelho IAC 99 (Catuaí V.), planted in Londrina (Lond.) and Congonhinhas (Cong.), both in Paraná State, Brazil

Cultivar	Yield[1,2]	Overall	Relative Yield (%)[3]	CLR severity[1,4]		Ripening cycle[1,2]	
				Londr.	Cong.	Londr.	Cong.
IPR Pérola	61.10 a	60.32 a	102.60	1.32 b	1.38 b	3.69 a	3.54 a
IPR 107	59.33 a	58.79 a	99.51	1.30 b	1.45 b	3.66 a	3.53 a
Catuaí V.	58.66 a	59.08 a	100.00	4.11 a	4.24 a	2.79 b	2.63 b
Overall	59.40			2.24	2.36	3.38	3.23
CV (%)	5.35			2.80	6.25	1.60	3.21

[1] Means followed by the same letters did not differ from each other by the Tukey means test at 5% significance. [2] Means of the 2013 to 2016 crops. Data were transformed in $\sqrt{X}$. [3] Yield in relation to Catuaí Vermelho IAC 99 and considering the average yield of Londrina and Congonhinhas. [4] Mean of CLR severity of the 2013 and 2015 crops.

Table 3. Percentage of flat beans size 19 (Fl-19), 18 (Fl-18), 17 (Fl-7), large (Fl-L), 16 (Fl-16), 15 (Fl-15), medium (Fl-M) and 14 or small (Fl14-S) of the cultivars IPR Pérola, IPR 107 and Catuaí Vermelho IAC 99, from 2020 crop, from a field experiment installed in Londrina, PR, at 2.75 x 0.60 m spacing in March 2017

Cultivar	Percentage of flat beans according to size[1]							
	Fl-19	Fl-18	Fl-17	Fl-L[2]	Fl-16	Fl-15	Fl-M[3]	Fl14-S
IPR Pérola	3.53 a	20.83 a	39.19 a	63.55 a	18.61 c	4.55 c	23.16 c	4.07 b
IPR 107	1.23 b	12.94 b	30.82 b	44.99 b	28.38 b	11.26 b	39.64 b	7.28 a
Catuaí	0.00 c	3.06 c	20.11 c	23.17 c	41.25 a	20.58 a	61.83 a	5.87 a
Overall	1.59	12.28	30.04	43.90	29.41	12.13	41.54	5.74
CV (%)	3.21	3.27	1.14	1.06	2.03	3.70	2.21	4.53

[1] Means followed by the same letters did not differ from each other by the Tukey means test at 5% significance. Data were transformed in $\sqrt{x+1}$. [2] Fl-L refers to the sum of beans Fl-19, Fl-18 and Fl-17. [3] Fl-M refers to the sum of beans Fl-16 and Fl-15.

Table 4. Morphological traits of IPR Pérola with the respective descriptions

Traits	Descriptions
Canopy architecture	Cylindrical (~ Catuaí)
Plant height	Medium (~ Catuaí)
Plant canopy diameter	Medium-small (between Catuaí and IAPAR 59)
Position of plagiotropic branches in relation to orthotropic branches	Horizontal (~ Catuaí)
Internode lenght	Medium (~ Catuaí)
Leaf length	Medium-long (between Mundo Novo and Obatã)
Leaf width	Medium-large (between Mundo Novo and Obatã)
Leaf shape	Elliptical
Undulation of the leaf margin intensity	Medium wavy (~ Catuaí)
Fruit shape	Elliptical
Color of leaves not fully expanded	Bronze
Bean length	Long (~ Acaiá)
Bean width	Large (~ Catuaí)
Bean thickness	Medium (~ Mundo Novo)

The recommended planting spacing within rows ranges from 0.5 to 0.6 m, depending on the average annual temperature of the cultivation site and the technologies employed, such as fertilizers, irrigation, and pruning. The inter-row spacing should be determined based on farm size and the machinery used, similar to planting recommendations for Catuaí cultivars.

IPR Pérola is susceptible to the nematodes *Meloidogyne paranaensis* and *M. incognita*. Its resistance to *M. exigua* has not yet been tested. Other traits, as listed in the coffee descriptors from the MAPA, are detailed in Table 4.

SEED MAINTENANCE AND DISTRIBUTION

IPR Pérola is registered with the National Cultivar Registry (Registro Nacional de Cultivares [RNC]) of MAPA under number 48402 in Brazil. It was granted protection in November 2021 by the National Cultivar Protection Service (Serviço Nacional de Proteção de Cultivares [SNPC]), under protection number 20220060. The Instituto de Desenvolvimento Rural do Paraná – IAPAR-EMATER (IDR-Paraná) is responsible for maintaining the genetic and basic seeds, while certified seeds are distributed by private seed producers registered with MAPA.

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DATA AVAILABILITY

The datasets generated and/or analyzed during the current research are available from the corresponding author upon reasonable request.

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