Crop Breeding and Applied Biotechnology 14: 88-93 2014
Brazilian Society of Plant Breeding. Printed in Brazil

ARTICLE

http://dx.doi.org/10.1590/1984-70332014v14n2a16

Selection of Arabic coffee progenies with rust resistance

Luciana Harumi Shigueoka[1,2*], Gustavo Hiroshi Sera[1], Tumoru Sera[1], Inês Cristina de Batista Fonseca[2], Valdir Mariucci Junior[1], Elder Andreazi[1,2], Filipe Gimenez Carvalho[1,2], Cristiane Gonçalves Gardiano[2] and Fernando Cesar Carducci[2]

Received 06 December 2012

Accepted 16 August 2013

Abstract – *The aim of this study was to select high-yielding coffee progenies with resistance to coffee leaf rust for the State of Paraná (Brazil). Field experiments in a randomized block design were carried out in Itaguajé and Congonhinhas. Yield, vegetative vigor and rust resistance of nine progenies of Arabic coffee and three check cultivars were evaluated. Many genotypes derived from "Sarchimor" and "Catucaí" were susceptible. Three coffee genotypes of Sarchimor germplasm and the F_6 generation of genotype "Catuaí x (Catuaí x BA-10 coffee)" were selected to advance generations and are promising to become new cultivars for being higher-yielding than 'IAPAR 59' and 'Tupi IAC 1669-33' and having a large number of plants with complete rust resistance*.

Key words: Coffea arabica*, coffee breeding, cultivars,* Hemileia vastatrix*, Sarchimor.*

INTRODUCTION

Among the diseases of coffee, coffee leaf rust, caused by *Hemileia vastatrix* Berk. et Br, is one of the most deleterious, in view of the damage it causes to coffee yield and the increased production costs of coffee plantations.

Defoliation caused by leaf rust before floral induction or during fruit development results in reduced flowering and poor coffee bean formation (Godoy et al. 1997). On a two-year average, rust can cause yield losses of 35 to 50%, depending on the susceptibility of the cultivar, humidity, crop load, and nutritional status of the plant (Zambolim et al. 1997).

The use of resistant cultivars is the most economical and environmentally friendly way to control this disease, because the chemical control, although effective when used adequately, is costly for growers. Many coffee cultivars are resistant to most rust races, such as IAPAR 59, IPR 98, Tupi IAC 1669-33, and others, derived from Catimor and Sarchimor germplasm (Sera et al. 2007b, Sera et al. 2010a). However, the resistance to leaf rust has been broken by the frequent appearance of new races of the fungus, making it difficult to breed cultivars with complete and durable resistance (Várzea et al. 2002).

The goal of coffee breeding is to obtain cultivars with durable resistance by combining major and minor genes. The known major genes that confer rust resistance are *SH1* to *SH9* (Rodrigues-Junior et al. 1975, Bettencourt 1981, Bettencourt and Rodrigues-Junior 1988). The genes *SH1*, *SH2*, *SH4,* and *SH5* were identified in *Coffea arabica* L. accessions native to Ethiopia. The *SH3* is supposedly derived from *C. liberica* W. Bullex Hiern, while *SH6*, *SH7*, *SH8* and *SH9* are derived from *Coffea canephora* Pierre ex A. Froehner, one of the parents of "Híbrido de Timor" (HDT) and from other interspecific hybrids such as "Icatu" (Noronha-Wagner and Bettencourt 1967, Bettencourt and Noronha-Wagner 1971, Rodrigues-Junior et al. 1975, Bettencourt and Rodrigues-Junior 1988). Several HDT plants have at least the genes *SH5* to *SH9* (Bettencourt et al. 1992). The existence of other major genes has been confirmed in lines derived from HDT (Rodrigues-Junior et al. 2000). Studies on the inheritance of "Icatu" plants and HDT-derived lines with different levels of incomplete resistance indicated the presence of one or few partially dominant alleles, different from the *SH* genes. These genetic factors, in homozygosis or associated confer nearly complete resistance (Eskes et al. 1990).

The coffee breeding program of the Agricultural Research Institute of Paraná (IAPAR) has been developing coffee cultivars since 1972. In this period, several coffee

[1] Agricultural Research Institute of Paraná (IAPAR), Rodovia Celso Garcia Cid, km 375, C.P. 481, 86.047-902, Londrina, PR, Brazil. *E-mail: lucianashigueoka@yahoo.com.br
[2] State University of Londrina (UEL), Rodovia Celso Garcia Cid, km 445, C.P. 600111, 86.057-970, Londrina, PR, Brazil

cultivars with complete rust resistance and some with partial resistance were released. Currently, several IAPAR coffee progenies are being selected in order to obtain cultivars with high yield and rust resistance. The aim of this study was to select coffee progenies with high yield and rust resistance at two locations in the State of Paraná.

MATERIAL AND METHODS

The field experiments were carried out in December 2005, in the municipalities of Itaguajé (lat 22° 37' 04" S, long 51° 57' 57" W, alt 349m asl) and Congonhinhas (lat 23° 33' 03" S, long 50° 33' 14" W, alt 753m asl), in the State of Paraná, Brazil. The mean annual temperature is 23 °C and 20 °C, respectively.

The relative air humidity is between 65 and 70% in Itaguajé and 75 - 80% in Congonhinhas. The average annual rainfall ranges from 1200 to 1400 mm in Itaguajé, and from 1400 to 1600 mm in Congonhinhas.

The experimental design was in randomized blocks with three replications and 15 plants, spaced 3.0 x 1.0 m in Itaguajé and 2.5 x 1.0 m in Congonhinhas.

The following progenies were evaluated: "F_7 of Sarchimor E9602 2-19-1", "F_4 of Piatã x Catuaí", "F_6 of Catuaí x (Catuaí x BA-10 coffee)", "F_7 of Catuaí Vermelho IAC-81 x Catucaí", "F_7 of Sarchimor E9702 3-1-9", "F_4 of Sarchimor x Catucaí", "F_7 of Sarchimor E9601 1-7-34", "PR 05101", "PR 04323", 'IAPAR 59', 'Tupi IAC 1669-33', 'Catuaí vermelho IAC 99'. 'IAPAR 59' was used as rust-resistant and 'Catuaí vermelho IAC 99' as susceptible check.

The yield and plant vigor were evaluated between June 2008 and 2011. Rust resistance was evaluated in June 2008 (30 months after planting).

The yield was visually assessed by scores based on the volume (in L) of fruits per plant. Yield data were converted into processed bags of 60 kg ha^{-1} (Y), based on the plant spacing, by the formula: $Y = V.N/500$, where V is the average volume (in L) of fruits per plant and N the number of plants per hectare, calculated based on the plant spacing. In this formula, the factor 500 was used, since according to Bártholo et al. (1989), 450-500 liters of coffee fruits yield around 60 kg of processed coffee.

The plant vigor of the coffee plants was assessed on a 1 - 10 scale, from the most depleted to the plants with best development, respectively. These grades were based on the overall vegetative aspect of the plants, using the criteria plant height, branch diameter, canopy diameter, leafiness, secondary plagiotropic branches, and leaf color and thickness. Grades 1-3 were assigned to small, stunted plants, with low leafiness and little branching, very thin plagiotropic branches and yellowish leaves. Grades 4-6 were assigned to below average-sized plants, and low leafiness, few plagiotropic branches, and yellowish and yellowish-green leaves. Grades 7-8 were given to normal-sized coffee plants with average intensity of leafiness and plagiotropic branches and yellowish-green to light green leaf color. Grades 9-10 were assigned to the strongest coffee trees with above-average size, high intensity of leafiness and plagiotropic branches, and with thick, dark green leaves.

The severity of rust resistance was assessed in local populations of rust races by natural infection on a 1 - 5 scale (Table 1). Plants with grades 1 and 2 were considered completely resistant and those with grades 3, 4 and 5 were considered susceptible. The percentage of plants with the respective scores of disease severity was estimated.

For the analysis of variance of yield, plant vigor and disease severity we used the statistical program Genes (Cruz 2001). The treatment means were grouped by the Scott-Knott test at 5% probability.

The coffee trees with yields statistically equal to the check 'Catuaí Vermelho IAC 99' or statistically superior to the check cultivars IAPAR 59 and Tupi IAC 1669-33 and with complete rust resistance (grades 1 and 2) of at least 80% of the plants assessed were selected in successive generations.

RESULTS AND DISCUSSION

Table 1. Grade scale used to evaluate the rust resistance to the local population of rust races in Paraná (Brazil)

Grade	Description
1	Plants without chlorotic lesions on leaves
2	Plants with lesions that vary from "flecks" to chlorosis in the infected area, but without formation of uredospores
3	Uredospore pustules in small quantities on the plant (on 1-25% of the leaves), usually in the lower third and low severity in the middle third
4	Uredospore pustules on 26 - 50% of the leaves, usually in the lower and middle third
5	Uredospore pustules on more than 50% of the leaves, from the lower to the upper third

The coffee plants of "PR 04323", "F_7 of Sarchimor E9602 2-19-1" and "F_6 of Catuaí x (Catuaí x BA-10 coffee)" did not differ statistically for yield, compared with the check 'Catuaí Vermelho IAC 99' and were significantly higher-yielding than the check 'IAPAR 59' and 'Tupi IAC 1669-33', both in Itaguajé and in Congonhinhas. The plant vigor of the same coffee plants was also statistically superior to that of the cultivars IAPAR 59 and Tupi IAC 1669-33 in Itaguajé. In Congonhinhas, no statistical differences in plant vigor were observed, although the vigor of "PR 05101" plants was relatively higher (Table 2).

The genotypes "F_7 of Sarchimor E9601 1-7-34" and "F_7 of Sarchimor E9702 3-1-9" did not differ statistically in yield from 'Catuaí Vermelho IAC 99' and were more productive than 'IAPAR 59' and 'Tupi IAC 1669-33' in Congonhinhas only.

Plants of "PR 04323", "F_4 of Piatã x Catuaí" and "F_4 of Sarchimor x Catucaí" did not differ statistically in vigor from 'Catuaí Vermelho IAC 99', but had lower yields, not differing significantly from IAPAR 59 and Tupi IAC 1669-33 plants.

In Congonhinhas, 100% of the 'Catuaí Vermelho IAC 99' plants were susceptible and the average grade of disease severity was 4.80, whereas 95.56% and 100% of the plants of 'Tupi IAC 1669-33' and 'IAPAR 59', respectively, were completely resistant. Of the plants of the genotypes "F_7 of Sarchimor E9602 2-19-1", "F_7 of Sarchimor E9601 1-7-34", "F_6 of Catuaí x (Catuaí x BA-10 coffee)", "F_7 of Sarchimor E9702 3-1-9", "F_7 of Catuaí Vermelho IAC-81 x Catucaí", "F_4 of Sarchimor x Catucaí", and "F_4 of Piatã x Catuaí", respectively, 86.67%, 81.82%, 80.02%, 91.12%, 82.23%, 75.57% and 31.12% were completely rust resistant. Of "PR 05101" and "PR 04323", respectively, 100% and 97.78% of the plants were susceptible (Table 3).

In Itaguajé, 'Catuaí Vermelho IAC 99' had 95.46% susceptible plants and an average disease severity grade of 4.22, while 100% of the plants of the resistant checks 'Tupi IAC 1669-33' and 'IAPAR 59' had complete resistance and an average disease severity grade of 1.00. In this municipality, the genotypes "F_7 of Sarchimor E9602 2-19-1", "F_7 of Sarchimor E9601 1-7-34", "F_6 of Catuaí x (Catuaí x BA-10 coffee)", "F_7 of Sarchimor E9702 3-1-9", "F_7 of Catuaí Vermelho IAC-81 x Catucaí", "F_4 of Sarchimor x Catucaí", "F_4 of Piatã x Catuaí" had, respectively, 97.78%, 100%, 90.71%, 100%, 95.46%, 85.38%, and 9.10% of plants with complete rust resistance. "PR 050101" and "PR 04323" had, respectively 90.8% and 100% of susceptible plants (Table 4).

It was observed that several genotypes with nearly 100% completely resistant plants in Itaguajé had more than 10% of susceptible plants in Congonhinhas. The greatest difference was observed for progeny "F_4 Piatã x Catuaí", with 85.36% resistant plants in Itaguajé and 31.12% in Congonhinhas. Therefore, it is likely that there are rust races with a greater number of virulence genes in Congonhinhas and for this reason the plants for successive generation selection were chosen in this municipality.

Table 2. Yield means in bags of processed coffee per hectare and plant vigor in the municipalities of Congonhinhas and Itaguajé (Paraná, Brazil), between 2008 and 2011

	Congonhinhas		Itaguajé	
Genotypes[1]	**Yield[2]**	**Vigor[2]**	**Yield[2]**	**Vigor[2]**
'Catuaí Vermelho IAC 99' (susceptible check)	29.07 a	8.22 a	40.27 a	8.40 a
PR 05101	32.27 a	8.55 a	40.13 a	8.45 a
F_7 of Sarchimor E9602 2-19-1	31.75 a	8.19 a	37.65 a	8.27 a
F_7 of Sarchimor E9601 1-7-34	31.67 a	8.04 a	30.37 b	7.72 b
F_6 of Catuaí x (Catuaí x BA-10 coffee)	29.19 a	7.95 a	36.97 a	8.05 a
F_7 of Sarchimor E9702 3-1-9	29.02 a	8.00 a	33.52 b	7.57 b
F_7 of Catuaí Vermelho IAC 81 x Catucaí	26.27 b	7.74 a	28.65 b	7.79 b
F_4 of Sarchimor x Catucaí	25.80 b	7.73 a	34.14 b	7.94 a
F_4 of Piatã x Catuaí	24.88 b	7.54 a	32.17 b	8.07 a
PR 04323	23.40 b	7.93 a	30.01 b	8.51 a
'Tupi IAC 1669-33'(resistant check)	24.73 b	7.24 a	27.25 b	7.30 b
'IAPAR 59' (resistant check)	23.51 b	7.28 a	29.60 b	7.26 b

[1] Genotypes in decreasing order, from the highest to the lowest-yielding, based on the yield means in the municipality of Congonhinhas. [2] Means followed by the same letter belong to the same group by the Scott-Knott test at 5%.

Table 3. Frequency of plants in each severity group, according to the grade scale of rust severity (R) and mean grades of rust severity in the municipality of Congonhinhas (Paraná, Brazil)

	Plant frequency (%) according to the R grades					Mean grade[2]
Genotype[1]	**1**	**2**	**3**	**4**	**5**	**R[3]**
'Catuaí Vermelho IAC 99' (susceptible check)	0.00	0.00	0.00	20.00	80.00	4.80 a
PR 05101	0.00	0.00	0.00	6.66	93.34	4.93 a
F_7 of Sarchimor E9602 2-19-1	75.55	11.12	2.22	6.66	4.45	1.53 c
F_7 of Sarchimor E9601 1-7-34	68.19	13.63	18.18	0.00	0.00	1.60 c
F_6 of Catuaí x (Catuaí x BA-10 coffee)	68.90	11.12	6.66	6.66	6.66	1.71 c
F_7 of Sarchimor E9702 3-1-9	82.23	8.89	8.88	0.00	0.00	1.27 d
F_7 of Catuaí Vermelho IAC 81 x Catucaí	64.45	17.78	11.12	2.21	4.44	1.64 c
F_4 of Sarchimor x Catucaí	62.23	13.34	15.56	2.22	6.65	1.78 c
F_4 of Piatã x Catuaí	17.78	13.34	15.56	20.00	33.32	3.38 b
PR 04323	2.22	0.00	2.22	35.56	60.00	4.51 a
'Tupi IAC 1669-33'(resistant check)	95.56	2.22	2.22	0.00	0.00	1.07 d
'IAPAR 59' (resistant check)	100.00	0.00	0.00	0.00	0.00	1.00 d

[1] Genotypes in decreasing order, from the highest to the lowest-yielding, based on the yield means in the municipality of Congonhinhas. [2] Means followed by the same letter belong to as same group by the Scott-Knott test at 5%. [3] Data from 2008.

Table 4. Frequency of plants in each severity group according to the grade scale of rust severity (R) and mean grades of rust severity in the municipality of Itaguajé (Paraná, Brazil)

	Plant frequency (%) according to the R grades					Mean grade[2]
Genotype[1]	**1**	**2**	**3**	**4**	**5**	**R[3]**
'Catuaí Vermelho IAC 99' (susceptible check)	4.56	0.00	4.54	50.00	40.90	4.22 a
PR 05101	0.00	0.00	4.54	36.37	59.09	4.54 a
F_7 of Sarchimor E9602 2-19-1	95.56	2.22	2.22	0.00	0.00	1.07 c
F_7 of Sarchimor E9601 1-7-34	100.00	0.00	0.00	0.00	0.00	1.00 c
F_6 of Catuaí x (Catuaí x BA-10 coffee)	90.71	0.00	2.32	2.32	4.65	1.30 c
F_7 of Sarchimor E9702 3-1-9	97.68	2.32	0.00	0.00	0.00	1.02 c
F_7 of Catuaí Vermelho IAC 81 x Catucaí	90.91	2.28	0.00	6.81	0.00	1.23 c
F_4 of Sarchimor x Catucaí	93.18	2.28	0.00	4.54	0.00	1.16 c
F_4 of Piatã x Catuaí	85.38	0.00	0.00	7.31	7.31	1.48 c
PR 04323	9.10	0.00	18.19	68.17	4.54	3.59 b
'Tupi IAC 1669-33' (resistant check)	100.00	0.00	0.00	0.00	0.00	1.00 c
'IAPAR 59' (resistant check)	100.00	0.00	0.00	0.00	0.00	1.00 c

[1] Genotypes in decreasing order, from the highest to the lowest-yielding, based on the yield means in the municipality of Itaguajé. [2] Means followed by the same letter belong to the same group by the Scott-Knott test at 5%. [3] Data from 2008.

To date, over 45 physiological rust races have been identified worldwide, which are carriers of nine virulence alleles (v1 to v9), alone or in combinations. Some races have a wide virulence spectrum, e.g., race XXXIX, with seven virulence alleles (v2, 4, 5, 6, 7, 8, 9), isolated from samples from India (Várzea and Marques 2005). Seventeen races were detected in Brazil (I, II, III, VII, X, XIII, XIV, XV, XVI, XVII, XXI, XXII, XXIII, XXIV, XXV and XXXI, XXX, and XXXIII), between 1972 to 2002; these alleles carry v1, v2, v3, v4, v5, v6, v8, and v9, alone or in combinations. Since the most cultivated varieties in Brazil are germplasm Catuai and Mundo Novo, carriers of gene *SH5*, the geographical distribution of race II (v5) is the widest, being found in every State, in *C. arabica* as well as in other genotypes. Race III (v1, v5) was detected in the States of São Paulo, Espírito Santo, Minas Gerais, and Paraná and race XV (v4, v5) in the states of São Paulo, Espírito Santo and Minas Gerais. Complex races, such as XVI (v1, v2, v3, v4, v5) with several virulence genes, were identified only in coffee germplasm with complex combinations of resistance

genes in field trials, but with low virulence (Zambolim et al. 2005). Assessments in differential coffee plants of IAPAR in Londrina (Paraná, Brazil) indicated that there are races carrying the virulence alleles v1, v2, v4, v5, and v8, alone or in combinations (Sera et al. 2007a).

In this study we observed that plants of several genotypes derived from "Sarchimor" and "Catucaí" were rust-susceptible. In Brazil, it has also been observed that several coffee lines derived from Sarchimor, Icatu and Catucaí germplasm are losing the complete rust resistance. Some plants of 'Palma I' ("Catuaí" x "Catimor"), 'Palma II' ("Catuaí" x "Catimor") and 'Sabiá 398' ('Acaiá' x "Catimor") are being attacked by rust, though with reduced defoliation (Matiello et al. 2005). Some plants of 'IPR 107' ("Sarchimor" x 'Mundo Novo') were also rust-susceptible, but the frequency of plants with complete rust resistance was increased by new selections (Sera et al. 2010a, Sera et al. 2010b). The complete resistance was broken in several coffee plants of Catucaí germplasm, which are currently partially resistant (Matiello et al. 2005, Sera et al. 2010a) or susceptible (Sera et al. 2010a).

The genotype "F_6 of Catuaí x (Catuaí x BA-10 coffee)" is probably a carrier of gene *SH3*, since the series BA-10 is derived from *C. liberica;* more than 80% of plants of this genotype were completely resistant and *SH3* can be in heterozygosis. In Brazil, complete rust resistance has been observed in coffee carrying *SH3* (Conceição et al. 2005, Fazuoli et al. 2005, Pereira et al. 2005, Sera et al. 2007a, Sera et al. 2010a).

'Catuaí Vermelho IAC 99' is known for its wide adaptability in most coffee regions of Brazil, with good productivity. 'Tupi IAC 1669-33' and 'IAPAR 59', widely planted in the State of Paraná, have complete rust resistance and are high-yielding in dense coffee planting systems (Carvalho et al. 2008). The genotypes "F_7 of Sarchimor E9601 1-7-34", "F_7 of Sarchimor E9702 3-1-9", "F_7 of Sarchimor E9602 2-19-1", "F_6 of Catuaí x (Catuaí x BA-10 coffee)" had a high proportion of plants with complete rust resistance and were more productive than 'Tupi IAC 1669-33' and 'IAPAR 59'. The plants of these genotypes with complete rust resistance and highest yield in the municipality of Congonhinhas will be harvested and grown separately in the following generation to obtain genotypes with a higher yield potential than 'Tupi IAC 1669-33' and 'IAPAR 59'.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support of the Agricultural Research Institute of Paraná (IAPAR), National Council for Scientific and Technological Development (CNPq), Coffee Research Consortium / Embrapa Café and of the State University of Londrina.

Seleção de progênies de café arábica com resistência à ferrugem alaranjada

Resumo – *O objetivo desse estudo foi selecionar progênies de café produtivas e com resistência à ferrugem em dois locais do Estado do Paraná (Brasil). Os experimentos de campo foram instalados no delineamento experimental em blocos ao acaso nos município de Itaguajé e Congonhinhas. Foram avaliadas as características produção, vigor vegetativo e resistência à ferrugem em nove progênies de café arábica e em três cultivares padrões. Vários genótipos derivados do "Sarchimor" e do "Catucaí" apresentaram plantas suscetíveis. Três cafeeiros do germoplasma Sarchimor e uma progênie "F_6 de Catuaí x (Catuaí x cafeeiro da série BA-10)" foram selecionados para avanço de geração e têm potencial para se tornarem novas cultivares, pois apresentaram produção maior que 'IAPAR 59' e 'Tupi IAC 1669-33' e muitas plantas apresentaram resistência completa à ferrugem.*

P**alavras-chave:** Coffea arabica*, cultivares,* Hemileia vastatrix*, melhoramento, Sarchimor.*

REFERENCES

Bártholo GF, Magalhães-Filho AAR, Guimarães PTG and Chalfoun SM (1989) Cuidados na colheita, no preparo e no armazenamento do café. **Informe Agropecuário 14**: 33-44.

Bettencourt AJ and Noronha-Wagner M (1971) Genetic factors conditioning resistance of *Coffea arabica* L. to *Hemileia vastatrix* Berk. et Br. **Agronomia Lusitana 31**: 285-292.

Bettencourt AJ (1981) **Melhoramento genético do cafeeiro: transferência de fatores de resistência à *Hemileia vastatrix* Berk. & Br. para as principais cultivares de *Coffea arabica* L.** Junta de investigações cientificas do ULTRAMARC/Centro de Investigação das Ferrugens do Cafeeiro, Oeiras, 93p.

Bettencourt AJ and Rodrigues-Junior CJ (1988) Principles and practice of coffee breeding for resistance to rust and other diseases. In Clarke RJ and Macrae R (eds.) **Coffee.** Agronomy Elseviers Applied Science, London, 4, p. 199-235.

Bettencourt AJ, Lopes J and Palma S (1992) Fatores genéticos que condicionam a resistência às raças de *Hemileia vastatrix* Berk. et Br. dos clones-tipo dos grupos 1, 2 e 3 de derivados de Híbridos de Timor. **Brotéria Genética 13**: 185-194.

Carvalho CHS, Fazuoli LC, Carvalho GR, Guerreiro-Filho O, Pereira AA, Almeida SR, Matiello JB, Bartholo GF, Sera T, Moura WM, Mendes ANG, Rezende JC, Fonseca AFA, Ferrão MAG, Ferrão RG, Nacif AP, Silvarolla MB, Toma-Braghini M and Sera GH (2008) Cultivares de café arábica de porte baixo. In Carvalho CHS (ed) **Cultivares de**

café: origem, características e recomendações. Embrapa Café, Brasília, p. 157-226.

Conceição AS, Fazuoli LC and Toma-Braghini M (2005) Avaliação de progênies de F3 de cafeeiros de porte baixo com gene *SH3* de resistência a *Hemileia vastatrix* Berk. et Br. **Bragantia 64**: 547-599.

Cruz CD (2001) **Programa Genes: versão Windows; aplicativo computacional em genética e estatística.** UFV, Viçosa, 648p.

Eskes AB, Hoogstraten JGJ, Toma-Braghini M, Carvalho A (1990) Race-specificity and inheritance of incomplete resistance to coffee leaf rust in some Icatu coffee offspring and derivatives of Híbrido de Timor. **Euphytica 47**: 11-19.

Fazuoli LC, Oliveira ACB, Toma-Braghini M and Silvarolla MB (2005) Identification and use of sources of durable resistance to coffee leaf rust at the IAC. In Zambolim L, Zambolim EM, Várzea VMP (eds) **Durable resistance to coffee leaf rust.** UFV, Viçosa, p. 137-185.

Godoy CV, Bergamin-Filho A and Salgado CL (1997) Doenças do cafeeiro (*Coffea arabica* L.). In Kimati H, Amorim L, Bergamin-Filho A, Camargo LEA and Rezende JAM (eds) **Manual de fitopatologia.** 3rd ed., 2nd vol., Agronômica Ceres, São Paulo, p. 184-200.

Matiello JB, Almeida SR and Carvalho CHS (2005) Resistant cultivars to coffee leaf rust. In: Zambolim L, Zambolim EM and Várzea VMP (eds) **Durable resistance to coffee leaf rust.** UFV, Viçosa, p. 443-450.

Noronha-Wagner M and Bettencourt AJ (1967) Genetic study of resistance of *Coffea* sp. to leaf rust. In: Identification and behavior of four factors conditioning disease reaction in *Coffea arabica* to twelve physiologic races of *Hemileia vastatrix*. **Canadian Journal of Botany 45**: 2021-2031.

Pereira AA, Sakiyama NS, Zambolim L, Moura WM, Zambolim EM and Caixeta ET (2005) Identification and use of sources of durable resistance to coffee leaf rust in the UFV/EPAMIG breeding program. In Zambolim L, Zambolim EM and Várzea VMP (eds) **Durable resistance to coffee leaf rust.** UFV, Viçosa, p. 215-232.

Rodrigues-Junior CJ, Bettencourt AJ and Rijo L (1975) Races of pathogen and resistance to coffee rust. **Annual Review of Phytopathology 13**: 49-70.

Rodrigues-Junior CJ, Várzea VMP, Silva MC, Guerra-Guimarães L, Rocheta M and Marques DV (2000) Recent advances on coffee leaf rust. In **Proceedings of the international scientific symposium on coffee.** Central Coffee Research Institute, Bangalore, p. 179-193.

Sera GH, Sera T, Ito DS, Azevedo JA, Mata JS, Doi DS and Ribeiro-Filho C (2007a) Resistance to leaf rust in coffee carrying *SH3* gene and others *SH* genes. **Brazilian Archives of Biology and Technology 50**: 753-757.

Sera GH, Sera T, Ito DS, Azevedo JA, Mata JS, Doi DS and Ribeiro-Filho C (2007b) Selection for durable resistance to leaf rust using test-crosses on IAPAR-59 and Tupi IAC 1669-33 cultivars of *Coffea arabica*. **Brazilian Archives of Biology and Technology 50**: 565-570.

Sera GH, Sera T, Fonseca ICB and Ito DS (2010a) Resistência à ferrugem alaranjada em cultivares de café. **Coffee Science 5**: 59-66.

Sera GH, Sera T, Fonseca ICB, Ito DS, Del Grossi L, Shigueoka LH and Kanayama FS (2010b) Seleção para a resistência à ferrugem em progênies das cultivares de café IPR 99 e IPR 107. **Bragantia 69**: 547-554.

Várzea VMP, Rodrigues-Junior CJ, Silva MCML, Gouveia M, Marques DV, Guerra-Guimarães L and Ribeiro A (2002) Resistência do cafeeiro a *Hemileia vastatrix*. In Zambolim L. (ed.) **O Estado da arte de tecnologias na produção de café.** UFV, Viçosa, p. 297-320.

Várzea VMP and Marques DV (2005) Population variability of *Hemileia vastatrix* vs. coffee durable resistance. In Zambolim L, Zambolim EM, Várzea VMP (eds) **Durable Resistance to Coffee Leaf Rust.** UFV, Viçosa, p. 53-74.

Zambolim L, Vale FXR, Pereira AA and Chaves GM (1997) Café (*Coffea arabica* L.). Controle de doenças causadas por fungos, bactérias e vírus. In: Vale FXR and Zambolim L (eds.) C**ontrole de doenças de plantas.** UFV/Ministério da Agricultura e do Abastecimento, Viçosa, p. 83-180.

Zambolim L, Zambolim EM, Vale FXR, Pereira AA, Sakiyama NS and Caixeta ET (2005) Physiological races of *Hemileia vastatrix* Berk. et Br. In Brazil-Physiological variability, current situation and future prospect. In Zambolim L, Zambolim EM and Várzea VMP (eds) **Durable resistance to coffee leaf rust.** UFV, Viçosa, p. 75-98.