Selection of Arabic coffee progenies with rust resistance

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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 F6 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 Coffea 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
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: “F₇ of Sarchimor E9602 2-19-1”, “F₄ of Piatã x Catuaí”, “F₆ of Catuaí x (Catuaí x BA-10 coffee)”, “F₅ of Catuaí Vermelho IAC-81 x Catucaí”, “F₄ of Sarchimor E9702 3-1-9”, “F₆ of Sarchimor x Catucaí”, “F₅ 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 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: \( Y = V \cdot N/500 \), 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 ‘Catuai 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>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Plants without chlorotic lesions on leaves</td>
</tr>
<tr>
<td>2</td>
<td>Plants with lesions that vary from “flecks” to chlorosis in the infected area, but without formation of uredospores</td>
</tr>
<tr>
<td>3</td>
<td>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</td>
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<tr>
<td>4</td>
<td>Uredospore pustules on 26 - 50% of the leaves, usually in the lower and middle third</td>
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<tr>
<td>5</td>
<td>Uredospore pustules on more than 50% of the leaves, from the lower to the upper third</td>
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Table 1. Grade scale used to evaluate the rust resistance to the local population of rust races in Paraná (Brazil)
The coffee plants of “PR 04323”, “F₇ of Sarchimor E9602 2-19-1” and “F₆ of Catuaí x (Catuaí x BA-10 coffee)” did not differ statistically for yield, compared with the check ‘Catuai 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 “F₇ of Sarchimor E9601 1-7-34” and “F₇ 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”, “F₄ of Piatã x Catuaí” and “F₄ of Sarchimor x Catucaí” did not differ statistically in vigor from ‘Catuai Vermelho IAC 99’, but had lower yields, not differing significantly from IAPAR 59 and Tupi IAC 1669-33 plants.

In Congonhinhas, 100% of the ‘Catuai 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 “F₇ of Sarchimor E9602 2-19-1”, “F₇ of Sarchimor E9601 1-7-34”, “F₆ of Catuaí x (Catuaí x BA-10 coffee)”, “F₇ of Sarchimor E9702 3-1-9”, “F₇ of Catuaí Vermelho IAC-81 x Catucaí”, “F₄ of Sarchimor x Catucaí”, “F₄ 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 “F₄ 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.

In Itaguajé, ‘Catuai 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.

The genotypes “F₇ of Sarchimor E9601 1-7-34” and “F₇ of Sarchimor E9702 3-1-9” did not differ statistically in yield from ‘Catuai Vermelho IAC 99’ and were more productive than ‘IAPAR 59’ and ‘Tupi IAC 1669-33’ in Congonhinhas only.

Plants of “PR 04323”, “F₄ of Piatã x Catuaí” and “F₄ of Sarchimor x Catucaí” did not differ statistically in vigor from ‘Catuai Vermelho IAC 99’, but had lower yields, not differing significantly from IAPAR 59 and Tupi IAC 1669-33 plants.

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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

| Genotypes¹ | Congonhinhas | | Itaguajé | | |
|------------|--------------|--------|------------|--------|
|            | Yield² | Vigor² | Yield² | Vigor² |
| ‘Catuai 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 |
| F₇ of Sarchimor E9602 2-19-1 | 31.75 a | 8.19 a | 31.67 a | 8.04 a | 30.37 b | 7.72 b |
| F₇ of Sarchimor E9601 1-7-34 | 31.67 a | 8.04 a | 30.19 a | 7.89 a |
| F₆ of Catuaí x (Catuaí x BA-10 coffee) | 29.19 a | 7.95 a | 29.02 a | 8.00 a | 29.02 a | 8.00 a |
| F₇ of Sarchimor E9702 3-1-9 | 29.02 a | 8.00 a | 26.27 b | 7.74 a | 26.27 b | 7.74 a |
| F₇ of Catuai Vermelho IAC 81 x Catucaí | 25.80 b | 7.73 a | 25.80 b | 7.73 a | 34.14 b | 7.94 a |
| F₇ of Sarchimor x Catucaí | 24.88 b | 7.54 a | 24.88 b | 7.54 a | 24.88 b | 7.54 a |
| PR 04323   | 23.40 b | 7.93 a | 23.40 b | 7.93 a | 32.17 b | 8.07 a |
| ‘Tupi IAC 1669-33’ (resistant check) | 24.73 b | 7.24 a | 24.73 b | 7.24 a |
| ‘IAPAR 59’ (resistant check) | 23.51 b | 7.28 a | 23.51 b | 7.28 a |

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%.
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, Espirito 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 “Catuaí” were rust-susceptible. In Brazil, it has also been observed that several coffee lines derived from Sarchimor, Icatu and Catuaí germplasm are losing the complete rust resistance. Some plants of “Palma I” (“Catuaí x “Catimor”), “Palma II” (“Catuaí x “Catimor”) and ‘Sabiá 398’ (“Acaíá 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 Catuaí germplasm, which are currently partially resistant (Matiello et al. 2005, Sera et al. 2010a) or susceptible (Sera et al. 2010a).

The genotype “F0 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).

“Catuai 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 “F0 of Sarchimor E9601 1-7-34”, “F0 of Sarchimor E9702 3-1-9”, “F6 of Sarchimor E9602 2-19-1”, “F6 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’.

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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 municípios 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 “Catuaí” apresentaram plantas suscetíveis. Três cafeeiros do germoplasma Sarchimor e uma progénie “F0 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.

Palavras-chave: Coffea arabica, cultivares, Hemileia vastatrix, melhoramento, Sarchimor.

REFERENCES


References continue...
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