RESISTANCE TO LEAF RUST IN COFFEE CULTIVARS

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ABSTRACT: All the *Coffea arabica* L. cultivars developed by IAPAR were resistant to rust (*Hemileia vastatrix*) when registered. However, with the appearance of new rust species these cultivars now present different resistance levels. The aim of this work was to assess the resistance to rust in coffee cultivars developed by IAPAR. Resistance to the local leaf rust species was assessed in high disease intensity field conditions in August 2007. Twelve coffee cultivars, from IPR 97 to IPR 108, were evaluated. 'IAPAR 59' and 'Catuaí Vermelho IAC 81' were used as resistance and susceptibility standards, respectively. The experimental design was in randomized blocks with nine replications and plots with seven plants. A scale from 1 to 5, based on rust severity, was used to evaluate resistance. Yield evaluation was based on the harvest carried out in June 2007. The cultivars IAPAR 59, IPR 97, IPR 98, IPR 104 and IPR 105 were almost 100 % rust resistant, while IPR 99, IPR 101, IPR 102 and IPR 107 presented approximately 75% of plants with complete resistance. Thus, the resistance gene(s) is probably in heterozygous condition. The cultivars IPR 103 and IPR 108 may present incomplete resistance, while the IPR 100 presented similar susceptibility to 'Catuaí Vermelho IAC 81' and IPR 106 may also be susceptible.

Key words: *Coffea*, *Hemileia vastatrix*, incomplete resistance, partial resistance, S_H genes.

RESISTÊNCIA À FERRUGEM ALARANJADA EM CULTIVARES DE CAFÉ

RESUMO: *As cultivares de café Coffea arabica L. obtidas pelo Iapar eram resistentes à ferrugem Hemileia vastatrix quando foram registradas, mas com o surgimento de novas raças, essas cultivares apresentam, atualmente, diferentes níveis de resistência. Neste trabalho objetivou-se avaliar a resistência à ferrugem em 12 cultivares de café desenvolvidas pelo Iapar. A avaliação da resistência foi para a população local de raças de ferrugem em condições de alta intensidade da doença em campo e foi realizada em agosto de 2007 em Londrina - PR. Avaliaram-se 12 cultivares, desde IPR 97 a IPR 108. Como padrões de resistência e suscetibilidade, foram avaliados, respectivamente, 'Iapar 59' e 'Catuaí Vermelho IAC 81'. O delineamento experimental foi em blocos ao acaso com nove repetições e parcelas de sete plantas. Para a avaliação da resistência, foi utilizada uma escala de notas que variava de 1 a 5, baseada na severidade da ferrugem. A avaliação da produtividade foi com base na colheita realizada em junho de 2007. As cultivares Iapar 59, IPR 97, IPR 98, IPR 104 e IPR 105 apresentaram resistência completa à ferrugem; 'IPR 99', 'IPR 101', 'IPR 102' e 'IPR 107' apresentaram cerca de 75% das plantas com resistência completa, assim, provavelmente, gene(s) de resistência estão em condição heterozigótica. As cultivares IPR 103 e IPR 108 podem ter resistência incompleta. A cultivar IPR 100 apresentou suscetibilidade similar ao da cultivar Catuaí Vermelho IAC 81; a 'IPR 106' também pode ser suscetível.*

Palavras-chave: Coffea, genes S_H, Hemileia vastatrix, resistência incompleta, resistência parcial.

1 INTRODUCTION

Leaf rust, whose etiological agent is the fungus *Hemileia vastatrix* Berk. et Br., is one of the main the impairments of coffee production (*Coffea* spp.), causing losses in crop yield and quality.

Although chemical control of rust is efficient, spraying with fungicides is costly. When leafall caused by rust occurs before flower induction or during the development of the fruits, reduced flowering and bean malformation occur (GODOY et al., 1997). In coffee production, leaf rust may cause mean biennium losses between 35% to 50%, depending on the cultivar's susceptibility, moisture levels, fruit load and plant nutrition (ZAMBOLIM et al., 1997).

Many coffee cultivars, such as Iapar 59, Obatã IAC 1669-20, Oeiras, Tupi IAC 1669-33, and others, mostly derived from Catimor and Sarchimor germoplasms, present complete resistance to most rust species. However, cultivars previously considered

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resistant, originating from Catimor germoplasm, for example, are becoming increasingly susceptible to infection by new rust species (VÁRZEA et al., 2002). Coffee genetic breeding studies, combining major and minor resistance genes, aim at obtaining cultivars with long-term rust resistance. The genes with the highest known rust resistance are S_H1 to S_H9, contrasting with the corresponding v1 to v9 *H. vastatrix* virulence genes (BETTENCOURT & RODRIGUES-JUNIOR, 1988; RODRIGUES-JUNIOR et al., 1975). The genes S_H1, S_H2, S_H4 and S_H5 have been identified in pure arabica (*Coffea arabica* L.) coffee from Ethiopia. S_H3 is supposedly derived from *Coffea liberica* W.Bull ex Hiern, while S_H6, S_H7, S_H8 and S_H9 originate from *Coffea canephora* Pierre ex A.Froehner, one of the parentals of "Híbrido de Timor" and of other, interspecific hybrids, such as "Icatu" (BETTENCOURT & NORONHA-WAGNER, 1971; BETTENCOURT & RODRIGUES-JUNIOR, 1988; NORONHA-WAGNER & BETTENCOURT, 1967; RODRIGUES-JUNIOR et al., 1975). The existence of other genes in "Híbrido de Timor" and other interspecific coffee hybrids has been confirmed by the increasing susceptibility to new *H. vastatrix* species (VÁRZEA & MARQUES, 2005). The S_H factors provide complete resistance in homozygous conditions and when specific to the rust species. However, when some S_H genes are broken, coffee trees may present incomplete or partial resistance to infection (ESKES, 1989). Incomplete rust resistance was also observed in function of other genes, apart from the known S_H, in "Icatu" and "Hibrido de Timor" coffee trees (ESKES et al., 1990).

The Genetic Breeding Program developed by the Instituto Agronômico do Paraná (Iapar) has been producing coffee cultivars adapted to the specific environmental conditions of Paraná state since 1972. During this time, 13 cultivars have been developed (Iapar 59, IPR 97, IPR 98, IPR 99, IPR 100, IPR 101, IPR 102, IPR 103, IPR 104, IPR 105, IPR 106, IPR 107 and IPR 108), of which four have been registered at the Ministry of Agriculture (IAPAR 59, IPR 98, IPR 99 and IPR 103) and made available to coffee producers. These cultivars originated from different rust resistance sources, such as "Icatu", "Híbrido de Timor CIFC 832/2" and "Catuaí S_H2, S_H3". Initially, the lineage of all these cultivars was resistant to rust but, in time, resistance has been undermined by new species.

Therefore, the aim of this work was to assess rust resistance in twelve new coffee cultivars developed by Iapar.

2 MATERIAL AND METHODS

The field experiment was set up in March 2003 at Iapar's experimental farm (23º 22' S, 51º 10' W), in Londrina, Paraná state, Brazil. The region's altitude is 585 m and mean annual precipitation, temperature and relative humidity are, respectively, 1610 mm, 20,8 ºC and 71%. In the experiment, chemical control of rust was not done in 2007.

Resistance to the local rust species was assessed in highly infectious conditions in August 2007 (54 months after planting).

The cultivars assessed were IPR 97, IPR 98, IPR 99, IPR 100, IPR 101, IPR 102, IPR 103, IPR 104, IPR 105, IPR 106, IPR 107 and IPR 108. Iapar 59 and Catuaí Vermelho IAC 81 were used as resistance and susceptibility standards, respectively. All the cultivars in the experiment originated from seeds resulting from natural self-pollination. The experimental design was in random blocks with nine replications and plots constituted by seven plants.

To assess rust severity, a scale from 1 to 5, attributed to the trees individually, (Table 1) was used. The coffee trees were assessed from the bottom third to the top third. Trees rated 1 and 2 were considered completely resistant. Trees presenting rust sporulation were rated 3, 4 and 5; the higher scores indicated a greater number of lesions.

Yield was assessed based on manual harvest in June 2007. The production data collected per plot were converted into processed sacks (60 kg)/hectare, based on the spacing of the trees.

The rust severity variable was assessed by log x transformation. Gens statistical program (CRUZ, 2001) was used to analyze rust severity and production variation and the Scott-Knott test was applied at 1% significance for assessment of the rust severity and production variables.

3 RESULTS AND DISCUSSION

Application of the Scott-Knott test resulted in the formation of four rust severity groups and two production groups.

IPR 100 presented the same rust severity (SF) level as the susceptibility standard 'Catuaí Vermelho IAC 81' (Table2). The cultivar is resistant to species II (gene v5) of *H. vastatrix*, while the Catuaí germoplasm cultivars, which have only the S_H5 gene, are susceptible to rust (CAPUCHO et al., 2007). Therefore, any resistance gene in IPR 100 that differed from Catuaí Vermelho IAC 81 S_H5 was completely supplanted (without incomplete resistance) by some rust species other than II.

The mean SF levels of the cultivars IPR 106, IPR 103 and IPR 108 were significantly lower than the susceptibility standard (Table 2). Most of the IPR 103 (69,85 %) and IPR 108 (67,74 %) trees were scored 3 (few lesions with sporulation), indicating incomplete resistance (Table 3).

Rust resistance of IRP 103 ("Catuaí" x "Icatu") is probably derived from "Icatu", as different incomplete resistance levels have been frequently found in plants originating from this germoplasm (ESKES et al., 1990; ESKES & CARVALHO, 1983; ESKES & COSTA, 1983; MONACO & CARVALHO, 1975).

Incomplete resistance may occur due not to the action of minor genes but to the incomplete annulment of S_H genes by *H. vastatrix* (VÁRZEA et al., 2002). Minor resistance genes control quantitative traits and may once have been major genes broken by a pathogen (NELSON, 1978). In 'IPR 108' ['Iapar 59' x ("Catuaí" x "Icatu")], incomplete resistance of genes originating from 'Iapar 59' or "Híbrido de Timor CIFC 832-2" may have been supplanted by the local rust species. "Híbrido de Timor" plants have, at least, the major genes S_H5 to S_H9 (BETTENCOURT et al., 1992). Apart from those already known, it is likely that other genes appear in these genotypes (VÁRZEA & MARQUES, 2005). 'IPR 108'was not completely resistant, as it probably does not have one or more 'Iapar 59' S_H gene. It is also possible that the incomplete resistance in 'IPR 108' was caused by minor genes originating from 'Icatu'.

The score 4 attributed to IPR 103 and IPR 108 trees (Table 3) may be due to the high inoculation pressure or high production of some of the cultivars' trees. On the other hand, lack of inoculation or low production may have occurred in IPR 100, IPR 103, IPR 106 and IPR 108 trees, which presented complete resistance (scores 1 and 2) (Table 3). In years of low productivity, *H. vastatrix* infection severity decreases in imcompletely resistant coffee trees (COSTA et al., 2007; ESKES, 1983). Low yield arabica coffee, such as Rume Sudan" and "Tafarikella", classified by CIFC in susceptibility group E, have been presenting a high level of incomplete field resistance for many years (VÁRZEA et al., 2002). The cultivars IPR 103 and IPR 108 had good incomplete resistance levels as, even when production was high (significantly higher than the standard susceptibility 'Iapar 59'), their mean SF score was significanlty lower than the standard (Table 2). 'IPR 106' ("Icatu") was classified in the same SF group as cultivars IPR 103 and IPR 108; however, the cultivar presented low yield (Table 2) and most of its trees received score 4, similar to the cultivars Catuaí Vermelho IAC 81 and IPR 100 (Table 3). If yield had been higher, it is likely that more trees rated 4 and 5 would have been found. Therefore, IPR 106 could be classified as susceptible to rust, as the standard 'Catuaí Vermelho IAC 81' and 'IPR 100'.

The cultivars IPR 99, IPR 101, IPR 102 and IPR 107 presented significantly lower SF means than

Table 1 – Resistance scale to the local rust populations (Londrina, Paraná state, Brazil).

Score	Description
1	Trees without clorotic lesions in the leaves.
2	Trees with clorotic lesions in the leaves, without rust sporulation.
3	Number of lesions with spores per leaf between 1 and 10 and frequency of leaves with sporulation between 1% and 10%.
4	Number of lesions with spores per leaf between 11 and 20 and frequency of leaves with rust sporulation between 11% and 35%.
5	Over 20 lesões with spores per leaf and over 35% of leaves with rust sporulation

Table 2 – Mean rust severity and production (60 kg processed sacks / hectare) scores of coffee cultivars assessed for the local rust populations at Iapar.

Cultivar (Description) [1]	Rust [2]	Production [2]
Catuaí Vermelho IAC 81 (‘Caturra’ x ‘Mundo Novo’)	4,233 a	39,36 a
IPR 100 (“Catuaí S_H2, S_H3”)	3,677 a	37,62 a
IPR 106 (“Icatu”)	3,413 b	20,09 b
IPR 103 (‘Catuaí’ x “Icatu”)	3,096 b	40,66 a
IPR 108 (‘IAPAR 59’ x “Catucaí”)	3,037 b	33,80 a
IPR 102 (‘Catuaí’ x “Icatu”)	2,032 c	45,58 a
IPR 107 (‘Iapar 59’ x ‘Mundo Novo IAC 376-4’)	1,810 c	34,55 a
IPR 99 (V. Sarchi x H. Timor)	1,778 c	27,40 b
IPR 101 (“Catuaí S_H2, S_H3”)	1,540 c	27,45 b
IPR 97 (V. Sarchi x H. Timor)	1,318 d	21,81 b
IPR 104 (V. Sarchi x H. Timor)	1,079 d	26,33 b
IPR 98 (V. Sarchi x H. Timor)	1,037 d	21,15 b
IPR 105 (“Catuaí S_H2, S_H3”)	1,016 d	27,78 b
Iapar 59 (V. Sarchi x H. Timor)	1,016 d	30,35 b
Variation coefficient (%)	34,91	32,83

[1] V. Sarchi = ‘Villa Sarchi CIFC 971/10’; H. Timor = “Híbrido de Timor CIFC 832/2”.

[2] Means followed by the same letter did not differ in the Scott-Knott test at 1%. The rust severity variable data were transformed into log x.

IPR 106, IPR 103 and IPR 108 (Table 2). In IPR 99, IPR 101, IPR 102 and IPR 107, 75% of the trees were completely resistant (Table 3), indicating that the resistance gene(s) is probably heterozygous. ‘IPR 99’ originates from the same crossing as ‘Iapar 50’, which has at least four S_H “Híbrido de Timor CIFC 832-2” genes (S_H6, S_H7, S_H8, S_H9) (CARDOSO et al., 1996) and has been presenting long term rust resistance for over 30 years. Also, ‘Iapar 59’ is one of the parentals of ‘IPR 107’. In this way, both ‘IPR 99’ and ‘IPR 107’ could have the same S_H genes as ‘Iapar 59’, but they must be heterozygous. Another hypothesis is that ‘IPR 99’ and ‘IPR 107’ have less resistance genes than ‘Iapar 59’ and that these are heterozygous. In the many self-pollinating generations resultingi that resulted in cultivars IPR 99 and IPR 107, S_H genes were segregated. Thus, the chances of identifying ‘Iapar 59’ trees with more than four S_H genes are low. It is possible to identify progenies with the same number of genes as ‘Iapar 59’ if the progenies with a high frequency of resistant plants are adequately selected. Sera et al. (2007b) have identified IPR 107 cultivar progenies with a frequency of resistant plants similar to ‘Iapar 59’.

The 75% frequency of resistant plants found for ‘IPR 102’ could be explained by the presence of heterozygous resistance gene(s) originating from “Icatu”. CIFC studies with “Icatu” have found coffee trees classified in physiological group A, that is resistant to all known rust species (BETTENCOURT & CARVALHO, 1968; MARQUES & BETTENCOURT, 1979). The complete resistance in ‘IPR 102’ may also have

been caused by partially dominant minor genes originating from "Icatu". These genetic factors, associated or in homozygous conditions, confer almost complete rust resistance (ESKES et al., 1990).

As 'IPR 101' originates from the Catuaí S_H2, S_H3 germoplasm, it is likely that only S_H3 is heterozygotic, as the gene has been confering complete resistance in Iapar. Sera et al. (2007a) found that rust species infected Iapar coffee trees with gene S_H2 but did not infect trees with gene S_H3.

If IPR 99, IPR 101, IPR 102 and IPR 107 trees rated 1 and 2 are selected, and their progenies are almost 100% resistant, the degree of resistance will probably be similar to the Iapar 59 cultivars IPR 97, IPR 98, IPR 104 and IPR 105.

Only IPR 97, IPR 98, IPR 104 and IPR 105 were completely resistant to rust, as their mean SF was similar to 'Iapar 59' (Table 2) and the frequency of completely resistant trees varied from 91 to 100% (Table 3). The standard resistance (Iapar 59), IPR 98 and IPR 105 cultivars presented 100% completely resistant trees. IPR 97, IPR 98 and IPR 104 may have the same resistance genes as 'Iapar 59', as they all originate from the same F_3 progenie ('Villa Sarchi CIFC 971/10' x "Híbrido de Timor CIFC 832/2"). The frequency of plants with rust sporulation found in IPR 97 and IPR 104, 8,07% and 1,59%, respectively, could be explained by the fact that some of their trees are classified in physiological group A (resistant to all rust species). This is also observed in 'Iapar 59', in which 94% of the trees are classified in group A and the remaining 6% in other groups, according to Cardoso et al. (1996).

Table 3 – Plant frequency (%), according to the rust severity (SF) scale (1 to 5), in coffee cultivars (*Coffea arabica* L.) assessed for the local rust populations at Iapar.

Cultivar [1]	Plant frequency (%) according to SF[2]				
	1	2	3	4	5
Catuaí Vermelho IAC 81 [3]	---	---	---	79,66	20,34
IPR 100	---	4,84	27,42	62,90	4,84
IPR 106	6,35	1,59	36,51	55,55	---
IPR 103	4,76	3,17	69,85	22,22	---
IPR 108	3,23	9,68	67,74	19,35	---
IPR 102	50,79	15,87	19,05	7,94	6,35
IPR 107	52,38	19,05	23,81	4,76	---
IPR 99	58,73	12,70	20,63	7,94	---
IPR 101	76,19	4,76	9,52	7,94	1,59
IPR 97	82,25	9,68	3,23	3,23	1,61
IPR 104	93,65	4,76	1,59	---	---
IPR 98	96,61	3,39	---	---	---
IPR 105	98,41	1,59	---	---	---
Iapar 59	98,41	1,59	---	---	---

[1] Treatments listed in a decreasing order based on the mean rust severity score. [2] (—) indicates a lack of plants with the respective rust severity score. [3] Standard susceptibility.

The complete resistance of 'IPR 105', derived from "Catuaí S_H2, S_H3", was probably due to the S_H3 gene as, in Iapar coffee, trees with gene S_H3 were resistant while trees with gene S_H2 were susceptible to rust (SERA et al., 2007a). F_3 coffee progenies originating from "Catuaí" plants and genotypes carrying S_H3 gene have been presenting rust resistance (CONCEIÇÃO et al., 2005).

S_H3 and certain *C. canephora* genes, such as the Híbrido de Timor and Icatu germoplasms, may be more efficient in promoting long term resistance, especially if combined (BERGAMIN-FILHO, 1976; ESKES, 1989; RAMACHANDRAN & SRINIVASAN, 1979; SRINIVASAN & NARASIMHASWAMY, 1975). Crossings of 'IPR 105' x "Híbrido de Timor" derivates, such as 'Iapar 59', 'IPR 97', 'IPR 98' and 'IPR 104', and with "Icatu" derivates, such as 'IPR 102' and 'IPR 103', may provide durable resistance due to the combination of minor and major, complete or incomplete resistance genes.

As rust resistance and production were assessed in only one year, further studies are perhaps necessary to confirm this work's preliminary results. The cultivars assessed in this work should be sent to the Centro de Investigação das Ferrugens do Cafeeiro (CIFC), in Portugal, for inoculation with rust species with virulence genes from v1 to v9 to accurately determine which S_H genes occur in them.

4 CONCLUSIONS

The cultivars Iapar 59, IPR 97, IPR 98, IPR 104 and IPR 105 are completely resistant to the local rust populations found at Iapar.

75% of the IPR 99, IPR 101, IPR 102 and IPR 107 trees were completely resistant to rust and the resistance gene(s) is probably heterozygous.

IPR 100 presented rust susceptibility similar to Catuaí Vermelho IAC 81. IPR 106 is probably as susceptible to rust as 'IPR 100' and 'Catuaí Vermelho IAC 81'.

The cultivars IPR 103 and IPR 108 may be incompletely resistant to rust.

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