Original Research Article

Screening of exotic collections of Arabica coffee genotypes for Coffee berry borer and Coffee leaf rust disease incidence

Abstract

In India, commercial cultivation of coffee relies upon two important species like *Coffea arabica* (Arabica coffee) and *Coffea canephora* (Robusta coffee). In the consumer market, arabica coffee is preferred for its fine beverage quality, aromatic characteristics and low caffeine content compared to robusta coffee. In India coffee is grown under natural agroecosystem offers arabica coffee to fetch premium price in the international market. In spite of the commercial importance and the appropriate environmental conditions, the drastic reduction of arabica coffee area in India is likely associated with lack of adaptability for each ecological zone of the region, susceptibility to coffee berry borer and leaf rust and increased cost of production coupled with low productivity (470 kg clean coffee/ha). Therefore to address the issues identification of resistance source is the important criteria in crop improvement programme. With this background the study was aimed at screening of exotic collections of Arabica coffee genotypes maintained at Central Coffee Research Institute (CCRI), Balehonnur, Karnataka, India against Coffee Berry Borer (CBB) and Coffee Leaf Rust (CLR). The experiment was laid out randomized block design with three replications. Results revealed that, the CLR disease severity infection was ranged from 1.34 to 32.67 per cent and the genotypes S.1495, S.1561, S.2504, S.2509, S.2510, S.2529, S.2602 and S.2724 exhibited moderately resistant to leaf rust disease infection based on mean per cent disease severity level (1-5%). Hence, these genotypes will be

valuable as new sources of resistance to these pathogens in the future and can be utilized in coffee breeding programmes in India. Similarly, all the genotypes utilized in the study were established low to least infestation of coffee berry borer (1.03 to 5.03 %).

Keywords: Arabica coffee, Coffee berry borer, Coffee leaf rust, Infestation and Resistance

Introduction

Coffee is an important beverage crop of India and is the second most important export commodity next to the petroleum products. In India, 70 per cent of the total coffee produces is meant for export only (Anon, 2014). There are two important species of Coffea which are being commercially cultivated in India and across the world are Arabica coffee (*Coffea arabica* L.) and Robusta coffee (*Coffea canephora*). Among these two species, Arabica coffee fetches highest price in the international market when compared with Robusta coffee as Arabica coffee produces finest cup quality than Robusta coffee. However, Arabica coffee is highly susceptible to major pests like coffee white stem borer and coffee berry borer and diseases such as coffee leaf rust and black rot of coffee, respectively compared to Robusta coffee which is highly tolerant (Gichuru *et al*., 2008; Kathurima *et al*., 2009; Gimase *et al*., 2014). Coffee genotypes respond differently to biotic factors mainly coffee leaf rust (CLR) and coffee berry borer (CBB) (Anon, 2014).

Coffee Berry Borer (CBB) (*Hypothenemus hampei*) is an important major and monophagous pests of coffee in which both the species of coffee were susceptible. This pests known to cause 30-40% yield loss in coffee (Annon, 2014). In addition, berry borer attacks coffee in field and even at the time of storage. Although there are many studies on chemical, biological and cultural control, coffee breeding for this pest has not been studied yet due to lack of resistance sources in the *Coffea* genus and related species (Vijayalakshmi *et al.*, 2014).

Similarly, CLR is a fungal disease caused by *Hemileia vastatrix* and is one of the major diseases of coffee. It causes premature leaf fall, yield loss and even death of the tree in severe cases. 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 (Sera *et al.,* 2007b and 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 (Varzea *et al.,* 2002). The susceptibility and poor adaptability nature of arabica coffee to major pests and diseases and adverse environmental conditions is mainly attributed to low genetic diversity when compared with that of robusta coffee due to its narrow genetic base. This necessitated the systematic breeding efforts for selection of genotypes with respect to leaf rust resistance, high yielding potential, wide adaptability and superior quality. Therefore identification and selection of tolerant or resistant sources of Arabica coffee genotypes for pests and diseases is at most important. Hence, the present study was aimed at screening of exotic collections of Arabica coffee genotypes maintained at Central Coffee Research Institute (CCRI), Balehonnur, Karnataka, India against CBB and CLR.

Materials and Methods

CCRI is situated in Southern hill zone of Karnataka state at 13^{0} 22" North latitude and 75^{0} 28" East longitudes and at an altitude of 885 m above the mean sea level. During the study, about forty one Arabica coffee genotypes (Table 1) comprising of exotic collections such as World collections (14), Costa Rica collections (15), Ethiopian collections (10) and check varieties of CCRI (Cauvery and Chandragiri) maintained at CCRI germplasm of uniform age groups (16 years old) were selected for assessment against coffee leaf rust and coffee berry borer. The experiment was conducted in randomized complete block design (RCBD) with two replications. Four randomly selected plants from each replication were tagged for recording observations on coffee leaf rust and coffee berry borer and cup quality parameters. Further, the regular calendar of operations like weeding, fertilizer application, harvesting and processing were carried out during the course of investigation. Genotypes were screened for their response to CBB and CLR incidence under natural field conditions of one acre area at CCRI research farm during 2020-21 and 2021-2022 when the CBB and CLR incidence pressure was at peak (September and November, respectively).

The weather data was recorded during the year 2020 and 2021 at the meteorological observatory of CCRI. The average rainfall of area was 2645 mm and distributed over a period of five to six months (June-October). During 2020-21 and 2021-22, the average monthly maximum (27.01 and 26.97^{o}C) and minimum (18.58 and 18.45^{o}C) mean temperatures, the average mean monthly maximum (94.92 and 93.67%) and minimum (64.75 and 69.58%) relative humidity was recorded. The total rain fall received during 2020 and 2021 was 2755 and 2433 mm, respectively. The minimum and maximum bright sunshine hours per day varied from 1.0 to 8.1 hrs in 2020-21 and 3.0 to 7.0 hrs in 2021-22, respectively and the same is presented in Table 2.

Observations on incidences of following CBB and CLR was recorded.

a. **Coffee berry borer infestation (%):** The infestation of coffee berry borer (CBB), *Hypothenemus hampei* was recorded in all the genotypes. Random sampling method was followed to enumerate the CBB infestation within the berries. The sampling was carried out before the crop harvest. The berries with CBB damage were counted and converted to per cent infestation by using the following formula. The incidence level of CBB was measured using the scale >1% (1-9%) (Low) and >10% (High) by Irulandi *et al.* (2007).

$$\text{CBB infestation (\%)} = \frac{\text{Total number of berries infested}}{\text{Total number of berries examined}} \times 100$$

b. **Leaf rust disease severity (%):** The coffee leaf rust (CLR), *Hemileia vastatrix* was recorded at the end of post monsoon season (October and November). The leaves with CLR infection were observed and converted to per cent severity. The leaf rust disease severity was calculated by grading the leaf rust infected area based on the following disease 0-5 grade scale given by (Muthappa, 1974 and Kushalappa, 1989).

Rust disease severity scale can be obtained by using the formula developed by Muthappa (1974) and Kushalappa (1989)

$$\text{RDS (\%)} = \frac{\text{Sum of numerical disease rating recorded}}{\text{Total number of leaves examined x Maximum disease rating}} \times 100$$

Chart 1 : Grade wise Distribution

Grade	Per cent infected leaf area	Reaction type	Reaction type
G_0	0	Healthy	Immune
G_1	1-5	Mild	Moderately resistant
G_2	6-10	Medium	Tolerant
G_3	11-20	Severe	Moderately susceptible
G_4	21-50	Very severe	Susceptible
G_5	>50	Destructive	Highly susceptible

The data recorded for various characters were subjected to statistical analysis for variability at 5% and 1% level of significance using statistical package "Windostat Version 9.2 from Indostat services, Hyderabad" available at department of Crop Improvement and Biotechnology (CIB), Kittur Rani Channamma College of Horticulture, Arabhavi .

Results and Discussion

To identify the sources of resistance, forty one genotypes were screened and categorized based on reaction type against coffee leaf rust disease infection and coffee berry borer infestation (Table 3) under natural epiphytic conditions during 2020-21, 2021-22 and pooled average over years. The data on incidence and their grouping as per the reaction type of each Arabica coffee genotypes for leaf rust disease infection and coffee berry borer infestation during 2020-21, 2021-22 and pooled average over years are presented in Table 4 and 5. Genotypes showing moderately resistant and susceptibility against coffee leaf rust are depicted in Plate 1 and 2.

Table 1: List of Arabica coffee genotypes evaluated during this study

Sl. No.	Name of the genotypes	Source
1.	S.1477	World collections
2.	S.1482	
3.	S.1484	
4.	S.1493	
5.	S.1495	
6.	S.1496	
7.	S.1497	
8.	S.1500	
9.	S.1502	
10.	S.1561	
11.	S.1565	
12.	S.1572	
13.	S.1573	
14.	S.1655	
15.	S.2501	Costa Rica collections
16.	S.2502	
17.	S.2503	
18.	S.2504	
19.	S.2505	
20.	S.2506	
21.	S.2507	
22.	S.2508	
23.	S.2509	
24.	S.2510	
25.	S.2511	
26.	S.2529	
27.	S.2532	
28.	S.2724	
29.	S.2725	
30.	S.2601	Ethiopian collections
31.	S.2602	
32.	S.2606	
33.	S.2608	
34.	S.2613	
35.	S.2616	
36.	S.2659	
37.	S.2660	

38.	S.2671	
39.	S.2672	
40.	Cauvery - Check	**CCRI, selections**
41.	Chandragiri - Check	

Table 2: Meteorological data recorded during experimental period (2020-21 and 2021-22) at Central Coffee Research Institute, Balehonnur

Months	Temperature (ºC)				RH (%)				Rainfall (mm)		Sunshine (hrs)	
	2020-21		2021-22		2020-21		2021-22		2020-21	2021-22	2020-21	2021-22
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.				
January	28.5	17.5	25.3	16.5	96	51	75	98	-	135.6	7.5	6.0
February	30.0	17.0	26.0	16.3	87	35	95	82	-	72.4	8.1	4.5
March	30.8	18.8	29.7	16.7	90	53	95	46	23.2	5.6	6.5	6.5
April	31.0	20.0	29.8	19.5	95	44	92	63	72.2	87.6	6	6.5
May	28.3	21.0	27.8	19.5	98	70	92	55	218.6	230.8	4.5	6.0
June	26.5	19.5	26.3	20.0	97	80	96	49	269.6	353.4	4.0	4.5
July	24.8	19.5	26.3	19.5	96	79	96	66	439.9	782.2	1.5	3.0
August	23.0	19.0	25.4	17.4	96	78	97	78	1057.4	297.4	1.0	3.5
September	24.3	19.5	26.0	19.0	96	79	97	82	465.6	186.4	1.0	3.5
October	24.8	18.5	27.0	21.8	97	72	95	80	163.2	284.6	3.5	4.5
November	25.8	16.3	26.0	19.2	95	63	97	78	44.0	195.6	4.0	4.0
December	26.3	16.3	28.0	16.0	96	73	97	58	1.4	9.8	5.0	7.0
Max – Maximum, Min – Minimum, RH – Relative humidity												

During 2020-21 and 2021-22 (Table 3), the mean per cent rust disease severity infection ranged from 1.33 to 33.00 per cent and 1.34 to 32.34 per cent, respectively. The genotype S.2724 was manifested minimum rust disease severity infection followed by S.2504, while the rust disease severity infection was maximum in case of check variety Cauvery during both the years of study. The same trend of leaf rust disease severity infection also followed in pooled average over years. Results revealed that, the mean per cent rust disease severity infection ranged from 1.34 to 32.67 per cent. The genotype S.2724 was manifested minimum rust disease severity infection of 1.34 per cent followed by S.2504 (2.73%), while the rust disease severity infection was maximum in case of check variety Cauvery (32.67%) on pooled average over years. Based on mean per cent disease severity infection level (1-5%), genotypes S.1495, S.1561, S.2504, S.2509, S.2510, S.2529, S.2602 and S.2724 exhibited moderately resistant to leaf rust disease infection (Table 4). While the genotypes S.1497, S.2501, S.1655, S.2507, S.2506, S.2506, S.2505, S.2503, S.2508, S.2613 and Chandragiri manifested tolerant (6-10%) to leaf rust disease infection. However, the genotypes S.1493, S.1484, S.1482, S.1477, S.1496, S.1502, S.1565, S.1573, S.2502, S.2511, S.2532, S.2725, S.2608, S.2606, S.2672, S.2671 and S.2660 established moderately susceptible (11-20%) to leaf rust disease infection. Very few of the genotypes *viz*., S.1500, S.1572, S.2601, S.2659, S.2616 and Cauvery had shown susceptibility (21-50%) to leaf rust disease infection during 2020-21, 2021-22 and pooled over the years. This study has shown that it is possible to transfer desirable genes for resistance to the most important coffee pathogens to new genotypes. These genotypes will be valuable as new sources of resistance to these pathogens in the future and can be utilized in coffee breeding programmes in India but there was no information about the resistance genes they contain. There was also no information about the rest of the genotypes and probably they have not been characterized. This confirmed the report by Gichimu (2012) and Shigueoka *et al.* (2014).

Data on mean per cent infestation of coffee berry borer infestation was recorded during 2020-21, 2021-22 and pooled over the years (Table 3) and it ranged from 1.08 to 4.98 per cent (2020-21) and 0.98 to 5.08 per cent (2021-22) and 1.03 to 5.03 per cent (pooled over the years). The mean per cent infestation of coffee berry borer was found to be low (1-9%) in all the genotypes studied (S.1477, S.1482, S.1484, S.1493, S.1495, S.1496, S.1497, S.1500, S.1502, S.1561, S.1565, S.1572, S.1573, S.1655, S.2501, S.2502, S.2503, S.2504, S.2505, S.2506, S.2507, S.2508, S.2509, S.2510, S.2511, S.2529, S.2532, S.2724, S.2725, S.2601, S.2602, S.2606, S.2608, S.2613, S.2616, S.2659, S.2660, S.2671, S.2672, Cauvery, Chandragiri) (Table 5). The genotype S.2671 had the least per cent infestation of coffee berry borer that (1.08% in 2020-21, 0.98% in 2021-22 and 1.03% in pooled over years). While, the higher mean per cent infestation of coffee berry borer was observed in genotype S.1561 (4.98, 5.08 and 5.03%, respectively) during 2020-21, 2021-22 and pooled over years. From the present study, it can be inferred that all the genotypes utilized in the study established low to least infestation of coffee berry borer (tolerant), this might be due to the occurrence of natural rain (act as a natural barrier for suppressing the infestation of coffee berry borer) during the month of September (peak infestation) in both the years (2020-21 and 2021-22) brought down the infestation level of coffee berry borer on all the genotypes studied. However, this study was focused only on mean per cent infestation of coffee berry borer and no economic loss assessment have been made. Similar results were obtained by Irulandi *et al.* (2007), Samuel *et al.* (2013) and Garbaba and Garedew (2019).

Table 3: Screening of forty one Arabica coffee genotypes for coffee leaf rust infection and coffee berry borer infestation during 2020-21, 2021-22 and pooled average over years

Genotypes	RDS (%)			CBB (%)		
	2020-21	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
S.1477	12.53	12.44	12.49	1.64	1.27	1.46
S.1482	16.40	16.68	16.54	2.40	2.30	2.35
S.1484	12.42	12.38	12.40	4.16	4.28	4.22
S.1493	14.55	14.63	14.59	4.26	4.54	4.40
S.1495	4.43	4.28	4.36	2.00	1.92	1.96
S.1496	19.65	19.31	19.48	2.50	3.00	2.75
S.1497	8.01	8.17	8.09	3.14	3.19	3.17
S.1500	28.68	29.10	28.89	3.38	3.82	3.60
S.1502	10.30	10.20	10.25	1.24	1.18	1.21
S.1561	4.51	4.55	4.53	4.34	4.55	4.45
S.1565	12.91	12.76	12.84	3.33	3.64	3.49
S.1572	20.49	20.12	20.31	3.17	3.26	3.22
S.1573	18.75	18.64	18.70	2.29	2.58	2.44
S.1655	7.13	7.06	7.10	1.62	1.19	1.41
S.2501	7.14	7.20	7.17	3.77	4.01	3.89
S.2502	13.31	13.69	13.50	3.73	4.13	3.93
S.2503	5.38	5.32	5.35	3.85	4.27	4.06
S.2504	2.69	2.76	2.73	2.84	3.08	2.96
S.2505	6.86	8.17	7.52	4.19	4.33	4.26
S.2506	6.59	6.36	6.48	2.30	2.49	2.40
S.2507	8.37	8.21	8.29	3.20	3.27	3.24
S.2508	5.81	5.95	5.88	3.78	4.26	4.02
S.2509	3.64	3.66	3.65	3.22	3.49	3.36
S.2510	4.88	4.75	4.82	3.85	4.38	4.12
S.2511	16.84	16.36	16.60	3.16	3.64	3.40
S.2529	4.44	4.39	4.42	2.12	2.31	2.22
S.2532	10.01	10.12	10.07	3.85	3.73	3.79
S.2724	1.33	1.34	1.34	3.24	3.38	3.31
S.2725	14.40	14.20	14.30	3.32	3.73	3.53
S.2601	27.51	28.01	27.76	1.92	1.80	1.86
S.2602	4.91	4.97	4.94	2.96	3.48	3.22
S.2606	14.95	14.83	14.89	3.88	4.03	3.96
S.2608	18.91	18.64	18.78	2.07	2.18	2.13
S.2613	9.16	9.03	9.10	2.07	2.07	2.07
S.2616	20.01	19.87	19.94	1.10	1.19	1.15
S.2659	29.70	29.53	29.62	4.98	5.08	5.03
S.2660	15.15	15.05	15.10	4.11	4.07	4.09
S.2671	18.36	17.86	18.11	1.08	0.98	1.03
S.2672	17.78	17.92	17.85	1.90	1.84	1.87
Cauvery - Check	33.00	32.34	32.67	3.77	4.09	3.93
Chandragiri - Check	8.45	8.52	8.49	3.10	3.01	3.06
Mean	**12.69**	**12.36**	**12.48**	**2.99**	**3.07**	**3.00**
S.Em±	0.25	0.30	0.27	0.29	0.07	0.15
C.D. @ 5%	0.72	0.86	0.81	0.84	0.20	0.45

RDS – Rust disease severity, **CBB** – Coffee berry borer

Table 4: Grouping of forty one Arabica coffee genotypes based on rust disease scoring on pooled average over years

Rust disease grades	Rust disease severity scale	Reaction type	Genotypes
G_0	0	Immune	-
G_1	1-5	Moderately resistant	S.1495, S.1561, S.2504, S.2509, S.2510, S.2529, S.2602, S.2724
G_2	6-10	Tolerant	S.1497, S.2501, S.1655, S.2507, S.2506, S.2505, S.2503, S.2508, S.2613, Chandragiri
G_3	11-20	Moderately susceptible	S.1477, S.1482, S.1484, S.1493, S.1496, S.1502, S.1565, S.1573, S.2502, S.2511, S.2532, S.2725, S.2608, S.2606, S.2672, S.2671 S.2660
G_4	21-50	Susceptible	S.1500, S.1572, S.2601, S.2616, S.2659, Cauvery
G_5	>51	Highly susceptible	-

Table 5: Grouping of forty one Arabica coffee genotypes based on coffee berry borer incidence scale on pooled average over years

Coffee berry borer incidence scale	Reaction type	Genotypes

>1-9	Tolerant	S.1477, S.1482, S.1484, S.1493, S.1495, S.1496, S.1497, S.1500, S.1502, S.1561, S.1565, S.1572, S.1573, S.1655, S.2501, S.2502, S.2503, S.2504, S.2505, S.2506, S.2507, S.2508, S.2509, S.2510, S.2511, S.2529, S.2532, S.2724, S.2725, S.2601, S.2602, S.2606, S.2608, S.2613, S.2616, S.2659, S.2660, S.2671, S.2672, Cauvery, Chandragiri
>10	Susceptible	-

Conclusion

Forty one Arabica coffee genotypes were evaluated for their response to coffee leaf rust infection and coffee berry borer infestation under field conditions. Significant variation for moderately resistant to tolerance of CLR infection was observed among the genotypes such as S.1495, S.1561, S.2504, S.2509, S.2510, S.2529, S.2602 and S.2724, S.1497, S.2501, S.1655, S.2507, S.2506, S.2506, S.2505, S.2503, S.2508, S.2613. These genotypes will be valuable as new sources of resistance to these pathogens in the future and can be utilized in coffee breeding programmes in India. Similarly, all the genotypes utilized in the study were established low to least infestation of coffee berry borer. The low genetic diversity among the Arabica coffee genotypes evaluated was expected. This was due to the process of autogamy and narrow genetic base, resulting from the process of homozygosis and the successive selection cycles. This was also confirmed by the fact that the Arabica genetic materials were probably derived from a few seeds that survived the efforts of expanding the Yemen borders for the cultivation of coffee plants, reaching the present cultivation sites.

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Conflict of interest

This is to declare that authors have NO conflict of interest with regard to publication of tis manuscript or research data. Hence, this paper may be consider for possible publication in your esteemed journal.

Author's contribution

Dr. P. M. Gangadharappa, Dr. Sumangala Koulagi and Mr. J. S. Hiremath guided in characterizing the genotypes.

Dr. N. Suryapraksh Rao and Dr. Sathish D. has experts in breeding aspects and analyzing data and interpretation of results.

Dr. Sandhyarani Nishani an expert in Biotechnology aspects and guiding in molecular characterization.

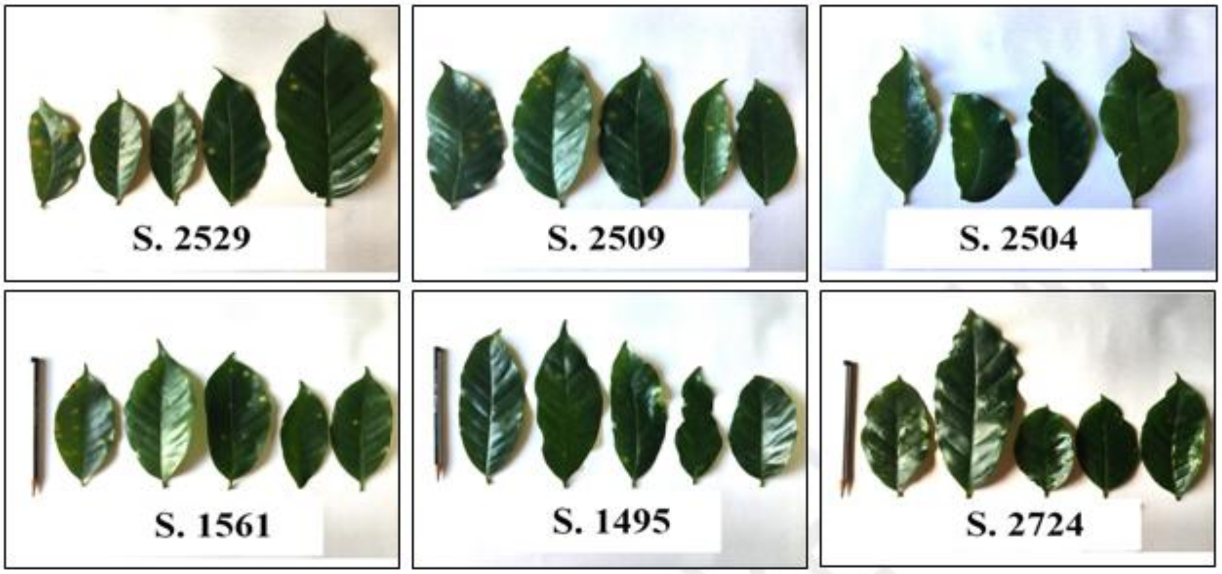

Plate 1: Genotypes established moderately resistant to coffee leaf rust disease

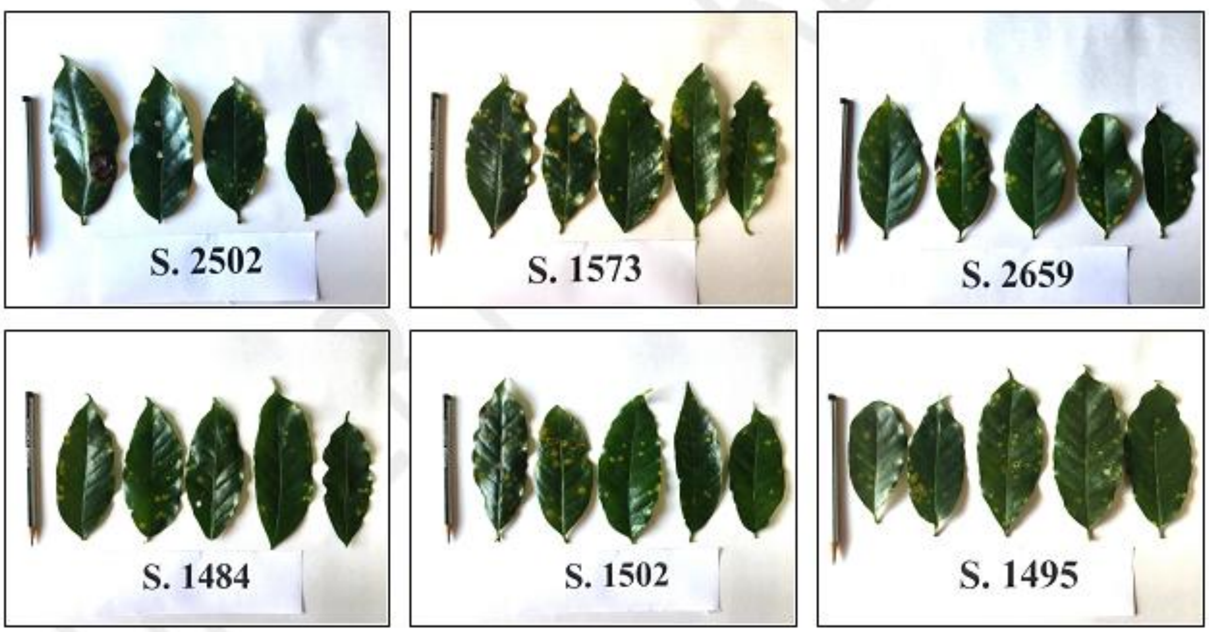

Plate 2: Genotypes showing susceptibility to coffee leaf rust disease

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