

Phenotypic Reaction of Traditional Arabica Coffee Germplasm to Coffee Leaf Rust (*Hemileia vastatrix*) and Their Cup Quality at TaCRI, Lyamungu, Tanzania

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Abstract Preserving the coffee's genetic resources through seeds is insufficient due to its short longevity. The coffee germplasm is conserved in the field gene banks or in cold storage (cryopreservation), ensuring the genetic resources' longevity. The repeated occurrence of new virulent races of the coffee leaf rust caused by *Hemileia vastatrix* Berk et Br, and the breakdown of the resistance have challenged breeders to keep searching for other sources of resistance to CLR. This study aimed to identifying coffee accessions resistant to CLR under natural infestation and documenting their cup profile for genetic resource conservation and sustainable utilization. Thirteen coffee accessions were evaluated for their response to CLR and cup scores were documented. The experiment was laid out in a complete randomized block design with six replications. The CLR was assessed using a scale of 1 to 6 based on disease symptoms. The 250g of seed from each accession was collected to establish its cup profile using the Sensory method. Significant differences in the reaction to CLR and variation of cup score were observed. Coffee accession I5, AC98, and R3 were observed to be tolerant to CLR with excellent cup scores while KP532, N197, N110, and M95 were observed to be susceptible to CLR with cup scores ranging from good to excellent. The screened accessions with tolerance to CLR can be utilized in the breeding program. However, molecular characterization to identify and confirm the gene of resistance is important following more field and laboratory evaluation.

Keywords: coffee leaf rust, coffee germplasm, resistance, susceptible

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1. Introduction

Improving coffee is key to sustainable coffee cultivation and export [1,2]. The coffee germplasm acts as the base for the future of crop security and manipulation [3,4]. In Tanzania, coffee is grown and acts as a source of daily income, and along its value chain coffee provides thousands of employment opportunities to people [5]. Two types of coffee are grown in Tanzania, *Coffea arabica* L. and *Coffea canephora* Pierre ex A. Froehner. *C. arabica* is grown in Kilimanjaro, Mbeya, Songwe, Ruvuma, Tarime, and Kigoma while *C. canephora* is grown in Kagera, some parts of Morogoro, and Kigoma (Kibondo and Kakonko districts). *C. arabica* fetches good market price and consumers' preference as compared to *C. canephora*. *C. arabica* accounts for 75% of the total country's coffee production while *C. canephora* accounts for 25% of coffee production [6]. Coffee production is

constrained by both abiotic and biotic factors—abiotic factors including; climatic conditions, poor soil drainage and fertility, rainfall, and temperature—which have influences on coffee cup quality and production [7]. Biotic factors include; diseases and insect pests [8]. Diseases affecting coffee production in Tanzania are fungal diseases while insect pests range from coffee berry borer to weevils, leaf miners, and others. *C. canephora* is affected most by coffee wilt disease caused by *Fusarium xylarioides* Steyaert while *C. arabica* being affected with *Fusarium stilboides* Steyaert the causative agent of Fusarium bark disease. Moreover, Arabica coffee is also affected by Coffee berry disease caused by *Colletotrichum kahawae* J. M. Walker & Bridge, and coffee leaf rust caused by *Hemileia vastatrix* Berk. & Broome [9].

Coffee leaf rust (CLR) caused by *Hemileia vastatrix* is among the most devastating diseases in coffee worldwide [10,11]. Its symptoms appear on the leaf as small yellow-brown, oily spots on the upper leaf surface that expand into larger round spots that turn bright orange to red and

finally brown with a yellow border, early shedding of leaves, and reduced photosynthesis capacity of the coffee plant [12]. The rust spots are powdery and orange-yellow under the leaf surface. Later the spots turn black [13]. Rusted leaves drop, causing significantly lower coffee yield up to 70 percent, and may lead to tree death [14,15]. There are different approaches to control diseases in coffee ranging from traditional, biological, and chemical. Coffee leaf rust can be partially controlled by the timely application of fungicide sprays during wet seasons [16]. Due to climate changes, disease incidence is expected to spread further to regions with higher and cooler altitudes. However, the use of chemical control is not an effective remedy, economically sound, and eco-friendly practice [17]. Understanding CLR tolerance behavior among accessions may help to produce/ identify new CLR-resistant *Coffea arabica* varieties which may be utilized to enhance CLR resistance hybrids by the breeding program [18,19]. For sustainable and profitable crop production, detection and quantification of genetic variation among plant species for successful conservation of genetic material and enhanced plant breeding are important. These can be achieved by employing different techniques ranging from traditional, and morphological to modern molecular marker techniques [20,21].

In the 1960s, different arabica coffee cultivars were collected from the coffee growing regions and planted to evaluate agronomic performances and lately preserved as germplasm materials at Field 18z at Tanzania Coffee Research Institute (TaCRI), Lyamungu station since the coffee seeds' longevity is insufficient to be used to preserve genetic resources.

However, the level of resistance of these germplasms to CLR under field conditions and cup quality is not well known. Therefore, this study aimed to identify accessions that are resistant to natural disease infestation and document their cup scores for genetic resource conservation and sustainable utilization.

2. Material and Methods

2.1. Location of the Study

This study was conducted under field conditions at Field 18Z at TaCRI, Lyamungu, Hai district, Kilimanjaro region in Tanzania. The area is located at 03.24°14.35'S, 37.24°14.38'E and with an altitude of 1268m above sea level with an average rainfall of 1500mm annually, and temperature of 25°C and 15°C for maximum and minimum temperature respectively. This area consists of nitisol soil with an average pH of 6.8.

2.2. Methods

2.2.1. Coffee Leaf Rust Severity Score

Thirteen cultivars namely; I5, AC98, R3, N205, I235, R11, KP532, N197, N110, M95, N218, KP683, and M197 of *Coffea arabica* were assessed for CLR under natural infestation during March and July 2022 in a Complete Randomized Block Design with six replications. The disease severity followed a scale of 1 to 6 as described by

[16] at which 1-2.4 was considered resistant, 2.5-3.4 moderately resistant, 3.5-4.4 tolerant, 4.5-5.4 moderately susceptible and 5.5-6 susceptible [16].

2.2.2. Coffee Cup Profiling

The cup quality score of these sixteen cultivars was cupped at the Liquefying Laboratory at TaCRI, Lyamungu. The ripened cherries were harvested following the fully washed processed and dried to acquire the moisture content of 12°C. The dried parchment was hulled and the green beans were graded using the grading sieves. Coffee beans weighed 250g of each coffee accession were medium-level roasted using the Probat-Werke at the temperature of 250°C for seven (7) minutes. The roasted beans were ground to coarse particles and cupping analyses were performed. The cup profile followed the cup descriptor; Fragrance/aroma, acidity, flavor, body, aftertaste, and flavor taints/faults. The cup scores were calibrated and recorded following the sensory method.

2.3. Data Analysis

Data collected were subjected to GENSTAT software Version 16 to generate means, variance, standard error, and coefficient of variation. Means were separated using Tukey's HSD at $p \leq 0.05$. The correlation coefficient between the coffee leaf rust and the cup score of the coffee accession was generated using the Microsoft Excel application, 2018.

3. Results and Discussion

3.1. Coffee accession Reaction to Coffee Leaf Rust

There were highly significant differences in coffee leaf rust reaction among the 13 accessions. The accessions I5, AC98, and R3 were observed to have scores of 4.06, 4.22, and 4.26 respectively, qualifying as tolerant under natural infestation. The accessions N218, N205, KP683, M197, I235, and R11 had disease score of 4.67, 5.00, 5.18, 5.33, 5.41, and 5.43 respectively (moderately susceptible) while KP532, N197, N110, and M95 had reaction score of 5.53, 5.56, 5.70, and 5.85 respectively, qualifying as susceptible to CLR disease under natural infestation (Table 1). However, [1,22] described the Ethiopian Arabica accession containing SH1, SH2, SH4, and SH5 genes as being known to confer resistance to some rust races. The accession I235 which is native Ethiopian arabica coffee was observed to be moderately susceptible under field conditions. Moreover, the materials observed to be tolerant to CLR under this study have not been utilized in the breeding program and there was no information about their gene of resistance. they possess- There was also no information on the rest of the accessions; they probably have not been characterized. The good field tolerance of I5, AC98, and R3 would require further laboratory evaluation and screening to confirm whether they have resistance or escapes.

The result of this study shows the potential of getting useful accession from germplasm fields at

TaCRI—Lyamungu which can be used in different breeding programs. [23] used germplasm materials to develop the coffee arabica hybrids which coffee growers are now adopting to enhance productivity.

Table 1. Coffee Arabica accession reaction to Coffee Leaf Rust under field conditions

Accession name	CLR score	Cup score
I5	4.06 a	80.02 bc
AC98	4.22 ab	82.53 cd
R3	4.26 ab	82.33 cd
N218	4.67 abc	85.67 e
N205	5.00 cd	83.48 de
KP683	5.18 cde	83.63 de
M197	5.33 bcde	84.39 de
I235	5.41 cde	84.77 de
R11	5.43 cde	75.5 a
KP532	5.53 de	77.72 ab
N197	5.56 de	84.73 de
N110	5.70 e	86.33 e
M95	5.85 e	77.72 ab
Grand mean	4.9969	82.22
s.e.d	0.2456	0.818
cv%	22.3	1.2
F prob.	<.001	<.001
Correl. CLR&CS		0.177

Note: Means with the same letter in the same column indicate no significant differences ($p \leq 0.05$) according to Tukey's Honestly Significance Difference. *CLR=coffee leaf rust; CS=coffee cup score; cv%=coefficient of variation; F prob.= F probability; Correl.= correlation coefficient; s. e. d= standard error of differences. *cup classification; 60-70= Good, 71-80= Very good, 81-90= Excellent and 91-100= Outstanding.

3.2. Cup Profiling

There were significant differences ($p \leq 0.001$) among the 13 coffee accessions on the coffee cup profiling. The coffee accession N110 and N218 showed high cup scores of 86.33 and 85.67 respectively followed by I235, N197, M197, KP683, N205, AC98, R3, and I5 with cup scores of 84.77, 84.73, 84.39, 83.63, 83.48, 82.53, 82.33, and 80.02, qualifying as excellent cup class. However, very good cup quality was observed in M95, KP532, and R11 with cup scores of 77.72, 77.72, and 75.5 respectively as shown in Table 1. Similar results were obtained by [12].

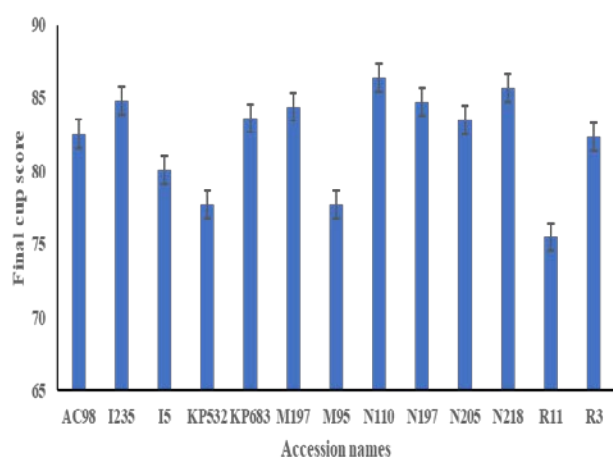


Figure 1. The cup profile of the tested arabica coffee accessions available at germplasm fields at TaCRI—Lyamungu

3.3. Correlation Between CLR Resistance and the Cup Profile

There was a zero correlation (0.177) between the coffee leaf rust reaction to the cup profile of the tested coffee accessions. However, coffee accession R11 qualified as moderately susceptible with a low cup score of 75.50 compared to KP532 and M95 which qualified as susceptible both had a low cup score of 77.72 (Table 1). Moreover, I5, AC98, and R3 fall displayed tolerance with excellent cup profiles as shown in Table 1. The correlation observed in this study is in agreement with those found by [24]. Similarly, a study conducted by [25] on the wilt-resistant Robusta varieties showed a significant correlation in which the cup profile ranged from 76 to 82%. They concluded that the improved and resistant varieties have a worth cup profile as compared to the traditional coffee [25]. Moreover, [25] and [26] suggested that with all environmental factors at the optimum level, disease resistance cultivars can produce a good cup profile as good as those from the traditional varieties.

4. Conclusion and Recommendation

This study successfully identified the I5, AC98 and R3 coffee arabica had tolerance to coffee leaf rust under natural infestation with good cup profile. These materials demonstrated field tolerance and can be used as a resistance source of CLR in breeding programs. We also identified and documented the cup profile of the thirteen Arabica accessions named in this study. These materials can be adopted and utilized for cup quality improvement of the arabica coffee. Since this study was the first attempt to evaluate the reaction of the germplasm accession available at TaCRI to coffee leaf rust under natural infestation, more studies have to be done using artificial inoculation to observe their response. Laboratory screening of these accessions is very essential to confirm their level of reaction to CLR and to find out their sensitivity to the disease. Furthermore, the genes of resistance for all the materials identified as tolerant are not yet known. Therefore, molecular biology tests should be studied in the future to characterize their resistance pattern.

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References

- [1] Sera, G. H., Sera, T., Fonseca, I. C. D. B., and Ito, D. S. (2010). Resistance to leaf rust in coffee cultivars. *Coffee science*, 5(1), 59-66. 2010.

- [2] Jibat, M. Review on resistance breeding methods of coffee leaf rust in Ethiopia. *International Journal of Research in Agriculture and Forestry*, 7(6), 32-41. 2020.
- [3] Gichimu, B. M. Field screening of selected *Coffea arabica* L. genotypes against coffee leaf rust. 10(7). 2012.
- [4] Várzea, V., Pereira, A. P., and Silva, M. D. C. L. D. (2023). Screening for Resistance to Coffee Leaf Rust. In *Mutation Breeding in Coffee with Special Reference to Leaf Rust: Protocols* Berlin, Heidelberg: Springer Berlin Heidelberg. 209-224. 2023.
- [5] Kilambo, D. L., Mtenga, D. J., Ng'Homa, N. M., Ng'omuo, R., Teri, J., and Mlwilo, B. A decade of contributing to a profitable and sustainable coffee industry in Tanzania: the arabica and robusta improvement programmes. *American Journal of Research Communication*, 3(1), 31-35. 2015.
- [6] Kiwelu, L., Damas, P., and Mpenda, Z. Profitability Analysis of Coffee Production among Adopters and Non-Adopters of Improved Coffee Varieties in Mbinga and Mbozi Districts. 2021.
- [7] Maro, G., Mbwambo, S., Kilambo, D., and Kiwelu, L. Integrated Soil Fertility Management Practices for Coffee in Tanzania: A Review. *World*, 12(1), 8-17. 2024.
- [8] Aryal, L. N., Basnet, S., & Aryal, S. Field screening of arabica coffee genotypes against coffee white stem borer (*Xylotrechus quadripes*) and leaf rust (*Hemileia vastatrix*) infestation in Kaski, Nepal. *Journal of Agriculture and Environment*, 156-165. 2022.
- [9] Gokavi, N., Gangadharappa, P. M., Prakash, N. S., Hiremath, J. S., Sathish, D., Nishani, S., and Koulagi, S. Screening of Exotic Collections of Arabica Coffee Genotypes for Coffee Berry Borer and Coffee Leaf Rust Disease Incidence. *International Journal of Environment and Climate Change*, 12(10), 238-246. 2022.
- [10] Dias, R. A., Ribeiro, M. R., Carvalho, A. M. D., Botelho, C. E., Mendes, A. N. G., Ferreira, A. D., and Fernandes, F. C. Selection of coffee progenies for resistance to leaf rust and favorable agronomic traits. 2019.
- [11] Rojas-Chacón, J. A., Echeverría-Beirute, F., and Gatica-Arias, A. Evaluation of Coffee (*Coffea arabica* L. var. Catuai) Tolerance to Leaf Rust (*Hemileia Vastatrix*) using inoculation of Leaf discs under controlled conditions. In *Mutation Breeding in Coffee with Special Reference to Leaf Rust: Protocols*. Berlin, Heidelberg: Springer Berlin Heidelberg. 233-242. 2023.
- [12] Echeverría-Beirute, F. *Plant Performance and Bean Quality of Coffee (Coffea arabica L.) under Rust (Hemileia vastatrix Berk. et Br.) Control and Fruit Thinning Treatments* (Doctoral dissertation). 2018.
- [13] Várzea, V. M. P., Pedro, J. N. M., Rodrigues, Jr. C. J., and Marques, D. V. Cultural variants in *Colletotrichum kahawae* In: Proceedings of the 11th Congress of the Mediterranean Phytopathological Union and 3rd Congress of the Sociedade Portuguesa de Fitopatologia, Évora, Portugal, 269-271. 2001.
- [14] Voegelé, R. T., and Mendgen, K. (2003) Rust haustoria: nutrient uptake and beyond. *New Phytol.* 159:93-100. 2003.
- [15] Silva, M. D. C., Várzea, V., Guerra-Guimarães, L., Azinheira, H. G., Fernandez, D., Petitot, A. S., and Nicole, M. Coffee resistance to the main diseases: leaf rust and coffee berry disease. *Brazilian journal of plant physiology*, 18, 119-147. 2006.
- [16] Kilambo, D. L., Mabagala, R. B., Varzea, V. M. P., Haddad, F., Loureiro, A., and Teri, J. M. Characterization of *Colletotrichum kahawae* strains in Tanzania. *International Journal of Microbiology Research*, 5(2), 382-389. 2013.
- [17] Kilambo, D. L., Mlwilo, B., Mtenga, D., and Maro, G. Effect of soils properties on the quality of compact arabica hybrids in Tanzania. *American Journal of Research Communication*, 3(1), 15-19. 2015.
- [18] Reichel, T., de Resende, M. L. V., Monteiro, A. C. A., Freitas, N. C., and dos Santos Botelho, D. M. Constitutive defense strategy of coffee under field conditions: A comparative assessment of resistant and susceptible cultivars to rust. *Molecular Biotechnology*, 64(3), 263-277. 2022.
- [19] Viana, M. T. R., Azevedo, H. P. A. D., Pereira, F. A. C., Carvalho, M. A. D. F., and Guimarães, R. J. Coffee genotypes morphophysiological adaptation under coffee leaf rust biotic stress. 2021.
- [20] Missio, R. F., Caixeta, E. T., Zambolim, E. M., Pena, G. F., Zambolim, L., Dias, L. A. S., and Sakiyama, N. S. Genetic characterization of elite coffee germplasm assessed by gSSR and EST-SSR markers. In *Embrapa Café-Artigo-manais de congresso (ALICE). Genetics and Molecular Research*, v. 10(4), 2366-2381, 2011.
- [21] Gimase, J. M., Thagana, W. M., Kirubi, D. T., Gichuru, E. K., and Gichimu, B. M. Genetic characterization of Arabica coffee hybrids and their parental genotypes using molecular markers. 2015.
- [22] Sera, G. H., Sera, T., Ito D. S., Azevedo, J. A., da Mata, J. S., Dóí, D. S., Filho, C.R., and Kanayama, F.S. Resistance to Leaf Rust in Coffee Carrying SH3 Gene and others SH Genes. *Brazilian Archives of Biology and Technology* 50(5): 753-757. 2007.
- [23] Nyange, N. E., Kipokola, T. P., Mtenga, D. J., Kilambo, D. L., Swai, D. J., Charmentant, P. Creation and Selection of *Coffea arabica* Hybrids in Tanzania. *Proceedings of 18th International Colloquium Association for Science and Information on Coffee, Helsinki, Finland, August 1999*. 2000.
- [24] Van der Vossen, H. A. M. The cup quality of disease-resistant cultivars of Arabica coffee (*Coffea arabica*). *Experimental agriculture*, 45(3), 323-332. 2009.
- [25] Mulindwa, J., Kaaya, A. N., Muganga, L., Paga, M., Musoli, P., Sseremba, G., and Bitalo, D. N. Cup quality profiles of Robusta coffee wilt disease resistant varieties grown in three agro-ecologies in Uganda. *Journal of the Science of Food and Agriculture*, 102(3), 1225-1232. 2022.
- [26] Filete, C. A., Moreira, T. R., dos Santos, A. R., dos Santos Gomes, W., Guarçoni, R. C., Moreli, A. P., and Pereira, L. L. The New standpoints for the terroir of *Coffea canephora* from Southwestern Brazil: Edaphic and sensorial perspective. *Agronomy*, 12(8), 1931. 2022.

