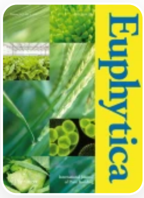
Biometric analyses of drought tolerance in populations of *Coffea canephora*

Research Published: 14 June 2024

Volume 220, article number 105, (2024) Cite this article



Euphytica

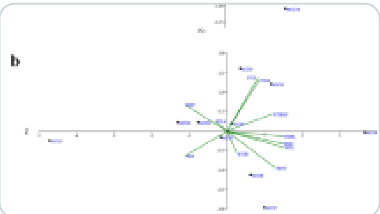
Aims and scope

Submit manuscript

Francisco Davi da Silva, Franciele Barros de Souza Sobreira, Edilson Marques, Cássio Fernandes Torres, Paulo Sérgio Volpi, Paulo Cezar Cavatte, Maria Amélia Gava Ferrão & Taís Cristina Bastos Soares

Abstract

Coffee is one of Brazil's main commodities. Among the goals of crop improvement, the search for drought-tolerant materials has stood out, mainly due to the water scarcity of the producing regions. The knowledge of genetic diversity and the morphophysiological analysis of plants allow the identification of genotypes with potential use in genetic improvement. Thus, this study aimed to evaluate the diversity, by morphophysiological characteristics, in 173 genotypes of *Coffea canephora*, from populations of contrasting crosses regarding the drought tolerance of the breeding program of Incaper, and to identify the relative importance of traits, subsidizing the selection for drought tolerance, based on the factor analysis index (FAI). The experiment was conducted in three evaluation periods, under field conditions without irrigation at the Incaper Experimental Farm of Marilândia, in the state of Espírito Santo. There was great variability between and within populations, which was affected by the evaluation season. Based on the traits of greater relative importance identified in this work (LL, LW, SLA, LAR, LT, TLA, PBL, CHL, NO_3^-, TSP, PRO, A, and iWUE), the FAI identified the genotypes 76 × 48 – 1, 76 × 48 – 10, 76 × 48 – 16, 76 × 48 – 76, 76 × 48 – 77, 76 × 48 – 83, 76 × 48 – 90, 76 × 48 – 128, 76 × 04 – 1, and 76 × 04 – 32 as more promising, from the ideotype of lower LL, LW, SLA, and LAR, and higher LT, TLA, PBL, CHL, NO_3^-, TSP, PRO, A, and iWUE.



Estimates of genetic parameters and correlation of morphological and...

Article 14 August 2022

Genetic variation and relationship of traits related to drought tolerance in cocoa...

Article 09 August 2014

Improving adaptation to drought stress in small red common bean: phenotypic...

Article 02 September 2014

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on request.

References

Adams MV, Wiersma JV (1978) An adaptation of principal component analysis to an assessement of genetic distance. Res Rep 347:2–7

Google Scholar

Anderson MJ (2001) A new method for non-parametric multivariate analysis of variance. Austral Ecol 26:32–46. https://doi.org/10.1111/j.1442-9993.2001.01070.pp.x

Article Google Scholar

Anderson MJ, Ellingsen KE, Mcardle BH (2006) Multivariate dispersion as a measure of beta diversity. Ecol Lett 9:683–693. https://doi.org/10.1111/j.1461-0248.2006.00926.x

Article PubMed Google Scholar

Andrade CA, Costa CK, Bora K, Miguel MD, Miguel OG, Kerber VA (2007) Determinação do conteúdo fenólico e avaliação da atividade antioxidante de *Acacia podalyriifolia* A. Cunn. ex G. Don. Leguminosae-Mimosoideae Rev Bras Farmacogn 17:231–235. https://doi.org/10.1590/S0102-695X2007000200017

Article Google Scholar

Bassett CL (2013) Water use and drought response in cultivated and wild apples. In: Vahdati K, Leslie C (eds) Abiotic Stress-Plant Responses and Applications in Agriculture. InTech, London, pp 249–275

Google Scholar

Bates LS, Waldren RP, Teare ID (1973) Rapid determination of free proline for water-stress studies. Plant Soil 39:205–207. https://doi.org/10.1007/BF00018060

Article CAS Google Scholar

Berthaud J (1980) L'incompatibilité chez *Coffea canephora*: méthode de test et déterminisme génétique. Café Cacao Thé 24:167–174

Google Scholar

Blum A (2009) Effective use of water (EUW) and not water-use efficiency (WUE) is the target of crop yield improvement under drought stress. F Crop Res 112:119–123. https://doi.org/10.1016/j.fcr.2009.03.009

Article Google Scholar

Blum A (2017) Osmotic adjustment is a prime drought stress adaptive engine in support of plant production. Plant Cell Environ 40:4–10. https://doi.org/10.1111/pce.12800

Article CAS PubMed Google Scholar

Cataldo DA, Haroon MH, Schrader LE, Youngs VL (1975) Rapid colorimetric determination of nitrate in plant tissue by nitration of salicylic acid. Commun Soil Sci Plant Anal 6:71–80. https://doi.org/10.1080/00103627509366547

Article CAS Google Scholar

Cavatte PC, Oliveira ÁAG, Morais LE, Martins SCV, Sanglard LMVP, DaMatta FM (2012) Could shading reduce the negative impacts of drought on coffee? A morphophysiological analysis. Physiol Plant 144:111–122. https://doi.org/10.1111/j.1399-3054.2011.01525.x

Article CAS PubMed Google Scholar

CONAB (2015) Acompanhamento da safra brasileira de café 2(4). Companhia Nacional de Abastecimento, Brasilia. https://www.conab.gov.br/info-agro/safras/cafe/boletim-da-safra-de-cafe. Acessed 31 October 2023

CONAB (2016) Acompanhamento da safra brasileira de café 3(4). Companhia Nacional de Abastecimento, Brasilia. www.conab.gov.br/info-agro/safras/cafe/boletim-da-safra-de-cafe. Acessed 31 October 2023

CONAB (2023) Acompamento da safra brasileira de café 9(4). Companhia Nacional de Abastecimento, Brasilia. https://www.conab.gov.br/info-agro/safras/cafe/boletim-da-safra-de-cafe. Acessed

Conagin CHTM, Mendes AJT (1961) Pesquisas citológicas e genéticas em três espécies de *Coffea*: auto-incompatibilidade em *Coffea canephora*. Bragântia 20:787–804. https://doi.org/10.1590/S0006-87051961000100034

Article Google Scholar

Cruz CD (2016) Programa Genes—Ampliado e integrado aos aplicativos R, Matlab e Selegen. Acta Sci - Agron 38:547–552. https://doi.org/10.4025/actasciagron.v38i4.32629

Article Google Scholar

Cruz CD, Regazzi AJ, Carneiro PCS (2012) Modelos Biométricos Aplicados ao Melhoramento Genético. UFV, Viçosa

Google Scholar

Cubry P, De Bellis F, Pot D, Musoli P, Leroy T (2013) Global analysis of *Coffea canephora* Pierre ex Froehner (Rubiaceae) from the Guineo-Congolese region reveals impacts from climatic refuges and migration effects. Genet Resour Crop Evol 60:483–501. https://doi.org/10.1007/s10722-012-9851-5

Article Google Scholar

DaMatta FM, Ramalho JDC (2006) Impacts of drought and temperature stress on coffee physiology and production: a review. Brazilian J Plant Physiol 18:55–81. https://doi.org/10.1590/S1677-04202006000100006

Article CAS Google Scholar

DaMatta FM, Chaves ARM, Pinheiro HA, Ducatti C, Loureiro ME (2003) Drought tolerance of two field-grown clones of *Coffea canephora*. Plant Sci 164:111–117. https://doi.org/10.1016/S0168-9452(02)00342-4

Article CAS Google Scholar

Davis AP, Tosh J, Ruch N, Fay MF (2011) Growing coffee: *Psilanthus* (Rubiaceae) subsumed on the basis of molecular and morphological data; implications for the size, morphology, distribution and evolutionary history of *Coffea*. Bot J Linn Soc 167:357–377. https://doi.org/10.1111/j.1095-8339.2011.01177.x

Article Google Scholar

El-Soda M, Malosetti M, Zwaan BJ, Koornneef M, Aarts MGM (2014) Genotype × environment interaction QTL mapping in plants: lessons from *Arabidopsis*. Trends Plant Sci 19:390–398. https://doi.org/10.1016/j.tplants.2014.01.001

Article CAS PubMed Google Scholar

Ferrão RG, Fonseca AFA, Ferrão MAG (2000) Emcapa 8141-Robustão Capixaba: variedade clonal de café conilon tolerante a seca. Rev Ceres 48:555–559

Google Scholar

Ferrão MAG, Fonseca AFA, Ferrão RG, Barbosa WM, Souza EMR (2009) Genetic divergence in conilon coffee revealed by RAPD markers. Crop Breed Appl Biot 9:67–74

Article Google Scholar

Ferrão RG, Fonseca AFA, Ferrão MAG et al (2012) Café conilon: técnicas de produção com variedades melhoradas, 4th edn. Incaper, Vitória

Google Scholar

Ferrão LFV, Caixeta ET, Souza FF, Zambolim EM, Cruz CD, Zambolim L, Sakiyama NS (2013) Comparative study of different molecular markers for classifying and establishing genetic relationships in *Coffea canephora*. Plant Syst Evol 299:225–238. https://doi.org/10.1007/s00606-012-0717-2

Article CAS Google Scholar

Ferrão RG, Moreira SO, Ferrão MAG, Riva EM, Arantes LO, Costa AFS, Carvalho PLPT, Galvêas PAO (2016) Genética e melhoramento: desenvolvimento e recomendação de cultivares com tolerância à seca para o Espírito Santo. Incaper Em Rev 6:51–71

Google Scholar

Ferrão RG, Volpi PS, Ferrão MAG, Verdin Filho AC, Fonseca AFA, Ferrão LMV, Ferrão LFV (2018) Melhoramento genético para obtenção da cultivar Marilândia ES 8143, variedade clonal de café conilon tolerante a seca. Multi-Science Res 1:1–18

Google Scholar

Ferrão MAG, Romario GF, Fonseca AFA, Verdim Filho AC, Volpi OS (2019) Origin, geographical dispersion, taxonomy and genetic diversity of *Coffea canephora*. In: Ferrão RG et al (eds) Conilon Coffee, 3rd edn. Incaper, Vitoria, pp 85–110

Google Scholar

Galili T (2015) dendextend: an R package for visualizing, adjusting and comparing trees of hierarchical clustering. Bioinformatics 31(22):3718–3720. https://doi.org/10.1093/bioinformatics/btv428

Article CAS PubMed PubMed Central Google Scholar

Gill SS, Tuteja N (2010) Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol Biochem 48:909–930. https://doi.org/10.1016/j.plaphy.2010.08.016

Article CAS PubMed Google Scholar

Gupta PK, Balyan HS, Gahlaut V (2017) QTL analysis for drought tolerance in wheat: present status and future possibilities. Agronomy 7(5):7010005. https://doi.org/10.3390/agronomy7010005

Article CAS Google Scholar

INCAPER (2015a) Boletim Climatológico Trimestral do Espírito Santo Jul-Set 2015 1(3). Incaper, Vitória. https://meteorologia.incaper.es.gov.br/boletim-agroclimatico-do-Espirito-Santo. Acessed 31 October 2023

INCAPER (2015b) Boletim Climatológico Trimestral do Espírito Santo Out-Dez 2015 1(4). Incaper, Vitória. https://meteorologia.incaper.es.gov.br/boletim-agroclimatico-do-Espirito-Santo. Acessed 31 October 2023

INCAPER (2016) Boletim Climatológico Trimestral do Espírito Santo Abr-Jun 2016 2(6). Incaper, Vitória. https://meteorologia.incaper.es.gov.br/boletim-agroclimatico-do-Espirito-Santo. Acessed 31 October 2023

Inman-Bamber NG, Smith DM (2005) Water relations in sugarcane and response to water deficits. F Crop Res 92:185–202. https://doi.org/10.1016/j.fcr.2005.01.023

Article Google Scholar

Inman-Bamber NG, Bonnett GD, Spillman MF, Hewitt ML, Jackson J (2008) Increasing sucrose accumulation in sugarcane by manipulating leaf extension and photosynthesis with irrigation. Aust J Agric Res 59:13–26. https://doi.org/10.1071/AR07167

Article CAS Google Scholar

Jolliffe IT (1972) Discarding variables in a principal component analysis. I: artificial data. Appl Stat 21:160–173. https://doi.org/10.2307/2346488

Article Google Scholar

Lang CA (1958) Simple microdetermination of kjeldahl nitrogen in biological materials. Anal Chem 30:1692–1694. https://doi.org/10.1021/ac60142a038

Article CAS Google Scholar

Lichtenthaler HK (1987) Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. Methods Enzymol 148:350–382. https://doi.org/10.1016/0076-6879(87)48036-1

Article CAS Google Scholar

Lima ALS, Zanella F, Schiavinato MA, Haddad CRB (2006) Nitrogenous compounds, phenolic compounds and morphological aspects of leaves: comparison of deciduous and semideciduous arboreal legumes. Sci Agric 63:40–45. https://doi.org/10.1590/S0103-90162006000100007

Article CAS Google Scholar

Lisar SYS, Motafakkerazad R, Hossain MM, Rahman IMM (2012) Water stress in plants: causes, effects and responses. In: Rahman IMM, Hasegawa H (eds) Water Stress. InTech, Rijeka, pp 1–15

Google Scholar

Machado Filho JA, Rodrigue WP, Baroni DF et al (2021) Linking root and stem hydraulic traits to leaf physiological parameters in *Coffea canephora* clones with contrasting drought tolerance. J Plant Physiol 258:153355. https://doi.org/10.1016/j.jplph.2020.153355

Article CAS PubMed Google Scholar

Marraccini P, Vinecky F, Alves GSC et al (2012) Differentially expressed genes and proteins upon drought acclimation in tolerant and sensitive genotypes of *Coffea canephora*. J Exp Bot 63:4191–4212. https://doi.org/10.1093/jxb/ers103

Article CAS PubMed PubMed Central Google Scholar

Menezes-Silva PE, Cavatte PC, Martins SCV et al (2015) Wood density, but not leaf hydraulic architecture, is associated with drought tolerance in clones of *Coffea canephora*. Trees 29:1687–1697. https://doi.org/10.1007/s00468-015-1249-5

Article CAS Google Scholar

Milligan GW, Cooper MC (1985) An examination of procedures for determining the number of clusters in a data set. Psychometrika 50:159–179. https://doi.org/10.1007/BF02294245

Article Google Scholar

Mofatto LS, Carneiro FA, Vieira NG et al (2016) Identification of candidate genes for drought tolerance in coffee by high-throughput sequencing in the shoot apex of different *Coffea arabica* cultivars. BMC Plant Biol 16:1–18. https://doi.org/10.1186/s12870-016-0777-5

Article CAS Google Scholar

Mojena R (1977) Hierarchical grouping methods and stopping rules: an evaluation. Comput J 20:359–363. https://doi.org/10.1093/comjnl/20.4.359

Article Google Scholar

Montagnon C, Cubry P, Leroy T (2012) Amélioration génétique du caféier *Coffea canephora* Pierre: connaissances acquises, stratégies et perspectives. Cah Agric 21:143–153. https://doi.org/10.1684/agr.2012.0556

Article Google Scholar

Montgomery DC, Peck EA (1981) Introduction to linear regression analysis. J Wiley, New York

Google Scholar

Musoli P, Cubry P, Aluka P et al (2009) Genetic differentiation of wild and cultivated populations: Diversity of *Coffea canephora* Pierre in Uganda. Genome 52:634–646. https://doi.org/10.1139/G09-037

Article CAS PubMed Google Scholar

Nóbrega NEF, Silva JGF, Ramos HEA, Pagung FS (2008) Balanço hídrico climatológico e classificação climática de Thornthwaite e Köppen para o município de Marilândia - ES. Anais do XVIII Congresso Nacional de Irrigação e Drenagem.

https://biblioteca.incaper.es.gov.br/digital/bitstream/item/247/1/1568-marilandia.pdf. Acessed 31 October 2023

Oksanen J, Simpson GL, Blanchet FG et al (2019) vegan: Community Ecology Package. R Package Version 2.5–6. https://cran.rstudio.com/web/packages/vegan/index.html. Acessed 31 October 2023

Paradis E, Schliep K (2019) Ape 5.0: an environment for modern phylogenetics and evolutionary analyses in R. Bioinformatics 35:526–528

Article CAS PubMed Google Scholar

Pinheiro HA, DaMatta FM, Chaves ARM, Loureiro ME, Ducatti C (2005) Drought tolerance is associated with rooting depth and stomatal control of water use in clones of *Coffea canephora*. Ann Bot 96:101–108. https://doi.org/10.1093/aob/mci154

Article PubMed PubMed Central Google Scholar

Poorter H, Villar R (1997) The fate of acquired carbon in plants: chemical composition and construction costs. In: Bazzaz FA, Grace J (eds) Plant resource allocation. Academic Press, Cambridge, pp 39–72

Chapter Google Scholar

Praxedes SC, DaMatta FM, Loureiro ME, Maria MA, Cordeiro AT (2006) Effects of long-term soil drought on photosynthesis and carbohydrate metabolism in mature robusta coffee (*Coffea canephora* Pierre var. *kouillou*) leaves. Environ Exp Bot 56:263–273. https://doi.org/10.1016/j.envexpbot.2005.02.008

Article CAS Google Scholar

R Core Team (2021) R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/. Acessed 31 October 2023

Ribeiro WR, Pinheiro AA, Ferreira DS et al (2018) Water deficit as a limiting factor to the initial growth of coffee conilon variety diamante. Am J Exp Agric 22(5):1–11. https://doi.org/10.9734/JEAI/2018/41156

Article Google Scholar

Rocha JRASC, Machado JC, Carneiro PCS (2018) Multitrait index based on factor analysis and ideotype-design: proposal and application on elephant grass breeding for bioenergy. GCB Bioenergy 10:52–60. https://doi.org/10.1111/gcbb.12443

Article Google Scholar

Rodrigues WN, Tomaz MA, Ferrão MAG, Ferrão RG, Fonseca AFA (2015) Diversity among genotypes of conilon coffee selected in Espírito Santo state. Biosci J 31:1643–1650

Article Google Scholar

Rodrigues WP, Martins MQ, Fortunato AS et al (2016) Long-term elevated air [CO2] strengthens photosynthetic functioning and mitigates the impact of supra-optimal temperatures in tropical *Coffea* arabica and C. *canephora* species. Glob Chang Biol 22:415–431. https://doi.org/10.1111/gcb.13088

Article PubMed Google Scholar

Ronchi CP, DaMatta FM (2007) Aspectos fisiológicos do café conilon. In: Ferrão GF et al (eds) café conilon. Incaper, Vitória, pp 94–119

Google Scholar

Silva PEM, Cavatte PC, Morais LE, Medina EF, DaMatta FM (2013) The functional divergence of biomass partitioning, carbon gain and water use in *Coffea canephora* in response to the water supply: Implications for breeding aimed at improving drought tolerance. Environ Exp Bot 87:49–57

Article Google Scholar

Souza FF, Caixeta ET, Ferrão LFV et al (2013) Molecular diversity in *Coffea canephora* germplasm conserved and cultivated in Brazil. Crop Breed Appl Biotechnol 13:221–227. https://doi.org/10.1590/S1984-70332013000400001

Article CAS Google Scholar

Taques RC, Adalto GG (2019) Agroclimatic zoning for conilon coffee culture in the state of Espírito Santo. In: Ferrão RG et al (eds) Conilon Coffee, 3rd edn. Incaper, Vitoria, pp 71–84

Google Scholar

Tuberosa R (2012) Phenotyping for drought tolerance of crops in the genomics era. Front Physiol 3:347. https://doi.org/10.3389/fphys.2012.00347

Article PubMed PubMed Central Google Scholar

Velázquez-Márquez S, Conde-Martínez V, Trejo C et al (2015) Effects of water deficit on radicle apex elongation and solute accumulation in *Zea mays* L. Plant Physiol Biochem 96:29–37. https://doi.org/10.1016/j.plaphy.2015.07.006

Article CAS PubMed Google Scholar

Wickham H, Averick M, Bryan J, Chang W et al (2019) Welcome to the tidyverse. J Open Source Softw 4(43):1686

Article Google Scholar

Wilhelm C, Selmar D (2011) Energy dissipation is an essential mechanism to sustain the viability of plants: the physiological limits of improved photosynthesis. J Plant Physiol 168:79–87. https://doi.org/10.1016/j.jplph.2010.07.012

Article CAS PubMed Google Scholar

Acknowledgements

The authors thank M. Sc. Renan Köpp Hollunder (Instituto de Biologia da Universidade Federal do Rio de Janeiro) for his support in the permutational multivariate analysis of variance (PERMANOVA) and D. Sc. João Romero do Amaral Santos de Carvalho Rocha (Universidade Federal de Viçosa) for his support in the Factor Analysis Index. We also thank the Espírito Santo Research and Innovation Support Foundation (FAPES), the Coordination for the Improvement of Higher Education Personnel (CAPES), and the National Council for Scientific and Technological Development (CNPq) for the granting of scholarships and financial support for the development of this study. Moreover, we thank the Coffee Research Consortium of Embrapa for the financial support for the implementation and conduct of field experiments (Code: 02.13.02.047.00.07- Call 02, Macroprogram 2), and to the Capixaba Institute of Research, Technical Assistance and Rural Extension (Incaper) for the availability of genotypes and the experimental area for data collection.

Funding

Espírito Santo Research and Innovation Support Foundation,Coordination for the Improvement of Higher Education Personnel,Coffee Research Consortium of Embrapa,02.13.02.047.00.07- Call 02,Macroprogram 2,02.13.02.047.00.07- Call 02,Macroprogram 2,02.13.02.047.00.07- Call 02,Macroprogram 2,02.13.02.047.00.07- Call 02,Macroprogram 2,02.13.02.047.00.07- Call 02,Macroprogram 2,02.13.02.047.00.07- Call 02,Macroprogram 2,02.13.02.047.00.07- Call 02,Macroprogram 2,02.13.02.047.00.07- Call 02,Macroprogram 2,Capixaba Institute of Research,Technical Assistance and Rural Extension

Author information

Authors and Affiliations

Natural History Museum and Botanical Garden, Federal University of Minas Gerais, Rua Gustavo da Silveira, 1035, Belo Horizonte, Minas Gerais, 31080-010, Brazil

Francisco Davi da Silva

Center for Exact, Natural and Health Sciences, Federal University of Espírito Santo, Alto Universitário, y/n, Alegre, Espírito Santo, 29500-000, Brazil

Franciele Barros de Souza Sobreira

Department of Agronomy, Federal University of Viçosa, Campus Universitário, Avenida da Agronomia, y/n, Viçosa, Minas Gerais, 36570-900, Brazil

Edilson Marques

Department of Agronomy, Center for Agricultural Sciences and Engineering, Federal University of Espírito Santo, Alto Universitário, y/n, Alegre, Espírito Santo, 29500-000, Brazil

Cássio Fernandes Torres

Capixaba Institute of Research, Technical Assistance and Rural Extension, Incaper, Fazenda de Marilândia, Marilândia, Espírito Santo, 29725-000, Brazil

Paulo Sérgio Volpi

Department of Biology, Center for Exact, Natural and Health Sciences, Federal University of Espírito Santo, Alto Universitário, y/N, Alegre, Espírito Santo, 29500-000, Brazil

Paulo Cezar Cavatte

Brazilian Agricultural Research Corporation, Embrapa, Incaper, Rua Afonso Sarlo, 160, Vitória, Espírito Santo, 29052010, Brazil

Maria Amélia Gava Ferrão

Department of Pharmacy and Nutrition, Center for Exact, Natural and Health Sciences, Federal University of Espírito Santo, Alto Universitário, y/N, Alegre, Espírito Santo, 29500-000, Brazil

Taís Cristina Bastos Soares

Contributions

F.D.S. and F.B.S.S. worked together in data collection and manipulation, statistical analysis, interpretation of results, and writing of the study. E.M.Jr. and C.F.T. contributed to the collection of morphophysiological data in field and laboratory. P.S.V. contributed to the conduction and field evaluations of the experiment, as well as supporting the collection of morphophysiological data. P.C.C. contributed with the orientation in the evaluation methodology of the morphophysiological characteristics, in the statistical analyses, and in the interpretation of the results. M.A.G.F. conceived and designed the study, contributed to the development of the object of study, orientation in the evaluation methodology statistical analyses, and interpretation of the results. T.C.B.S. planned and conceived the study, contributed with the orientation in the evaluation methodology, in the interpretation of the results, and in the writing of the study. All authors read and approved the manuscript.

Corresponding author

Correspondence to Francisco Davi da Silva.

Ethics declarations

Competing interests

The authors declare no competing interests.

Additional information

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Rights and permissions

Reprints and permissions

About this article

Cite this article

da Silva, F.D., de Souza Sobreira, F.B., Marques, E. *et al.* Biometric analyses of drought tolerance in populations of *Coffea canephora*. *Euphytica* **220**, 105 (2024). https://doi.org/10.1007/s10681-024-03365-8

Received	Accepted	Published
03 November 2023	03 June 2024	14 June 2024

DOI

https://doi.org/10.1007/s10681-024-03365-8

Keywords

Coffee · Characterization · Water deficit · Genetic improvement