



Supplementary Material

Morphological Variation of *Theobroma cacao* L. Affected by Increasing Doses of Heavy Metals

Robinson Torres Ronquillo¹, Manuel Carrillo Zenteno², Wuellins Durango Cabanilla², Diego Franco Ochoa¹, César Quinaluisa Morán¹, Seyed Mehdi Jazayeri^{3,4}, Gregorio Vásconez Montufar⁵, E. Rajasekhar⁶, Naga Raju Maddela^{7*} and Ronald Villamar-Torres^{1,5*}

¹Instituto Superior Tecnológico, Ciudad de Valencia, Sector El Pital #1, Predios Universidad Técnica de Babahoyo-Extensión Quevedo, Ecuador; ²Instituto Nacional de Investigaciones Agropecuarias-INLAP. Estación Experimental Tropical Pichilingue, cantón Mocache, Los Ríos. Ecuador; ³Universidad Nacional de Colombia, Facultad de Ciencias, Departamento de Biología, Bogotá, Colombia; ⁴Department of Biology, Faculty of Sciences, University of Tehran, Iran; ⁵Universidad Técnica Estatal de Quevedo, Facultad de Ciencias Agropecuarias, Finca Experimental La María, Cantón Quevedo, Los Ríos. Ecuador; ⁶Department of Physics, Rayalseema University, Kurnool-518007, India; ⁷Departamento de Ciencias Biológicas, Facultad de Ciencias de la Salud, Universidad Técnica de Manabí, Portoviejo-130105. Ecuador.

Received | September 22, 2023; Accepted | December 5, 2024; Published | February 10, 2025

*Correspondence | Ronald Villamar-Torres and Naga Raju Maddela, Facultad de Ciencias Agropecuarias, Universidad Técnica Estatal de Quevedo, Los Ríos, Ecuador; Departamento de Ciencias Biológicas, Facultad de Ciencias de la Salud, Universidad Técnica de Manabí, Portoviejo-130105. Ecuador; Email: rvillamart@uteq.edu.ec, raju.maddela@utm.edu.ec

Citation | Ronquillo, R.T., M.C. Zenteno, W.D. Cabanilla, D.F. Ochoa, C.Q. Morán, S.M. Jazayeri, G.V. Montufar, E. Rajasekhar, N.R. Maddela and R. Villamar-Torres. 2024. Morphological variation of *Theobroma cacao* L. affected by increasing doses of heavy metals. *Sarhad Journal of Agriculture*, 39(Special issue 2): 139–144.

DOI | <https://dx.doi.org/10.17582/journal.sja/2023/39/s2.139.144>

Keywords | Heavy elements, Cocoa, Toxicity, Chlorophyll



Copyright: 2025 by the authors. Licensee ResearchersLinks Ltd, England, UK.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).



Supplementary Figure S1: Greenhouse plantation of cacao.



Supplementary Figure S2: Cacao plants irrigation (a), determination of stem diameter (b) and chlorophyll content in cacao leaves (c).

Supplementary Table S1: Increasing doses of heavy metals (e.g. Hg, Pb, Cu and Cd) applied in cocoa seedlings in greenhouse, EET Pichilingue. INIAP.

Treatments	Increasing doses (mg kg^{-1})			
	Hg	Pb	Cu	Cd
T1	0.00	0.00	0.00	0.00
T2	3.75	2.50	2.50	0.50
T3	7.50	5.00	5.00	1.00
T4	11.25	7.50	7.50	1.50
T5	15.00	10.00	10.00	2.00
T6	18.75	12.50	12.50	2.50
T7	22.50	15.00	15.00	3.00