IOCAG 2025 Conference

The 3rd International Online Conference on Agriculture

22–24 October 2025 | Online

agriculture MDPI

Resilience Strategies of Carob (*Ceratonia siliqua* L.) to Salt Stress: Multivariate Approaches and Artificial Intelligence for Sustainable Agriculture

Yassine Mouniane [1], Mohamed El Bakkali [2], Issam El-Khadir [1], Ahmed Chriqui [1], Yassine Kadmi [3,4], Driss Hmouni [1]

[1] Laboratory of Natural Resources and Sustainable Development, Faculty of Sciences, Ibn Tofaïl University, Morocco
[2] Higher Institute of Nursing and Health Techniques, Kenitra, Morocco
[3] LASIRE, Equipe Physico-Chimie de l'Environnement, CNRS UMR 8516, Université Lille, Sciences et Technologies, CEDEX, 59655 Villeneuve d'Ascq, France
[4] Department of Chemistry, Université d'Artois, IUT de Béthune, 62400 Béthune, France

INTRODUCTION

In arid and semi-arid regions, soil salinity and water scarcity limit agricultural productivity. *Ceratonia siliqua* L. (carob) is a promising species due to its drought and salt tolerance. However, understanding the physiological and biochemical mechanisms underlying its resilience requires integrated analytical approaches combining multivariate statistics and artificial intelligence.

OBJECTIVES

- Evaluate the physiological and biochemical responses of *C. siliqua* under NaCl-induced stress.
- Identify key determinants of salt tolerance using multivariate and AI-based models (PLS-SEM, Bayesian inference).
- Determine the most resilient provenances for sustainable agroecological applications.

METHODS

Experimental design:

6 provenances (Ouazzane, Safi, Aït Attab, Berkane, Khemissat, etc.)

Treatments: Control (0 g/L NaCl) and Salinity (10 g/L NaCl)

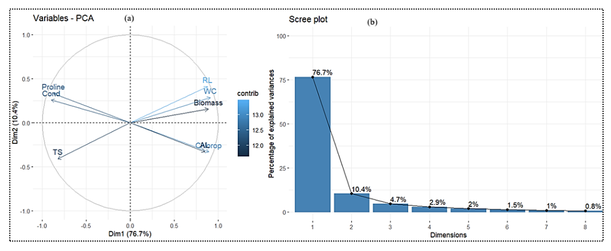
Co-cultivation with Spergularia salina tested.

Measured parameters: Biomass, water content, chlorophyll, root length, ion content.

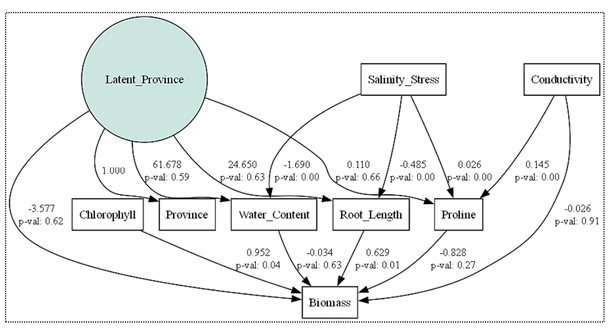
Statistical and AI tools: MANOVA → PCA → PLS-SEM → Bayesian inference.

RESULTS & DISCUSSION

Salt stress ($F(5,30)=7.36$, $p<2.2e-16$) and ecotype ($F(5,30)=16.49$, $p<2.2e-16$) significantly affected physiological traits.PCA clearly separated stressed vs. control plants (PC1=76.66% variance).Key contributors: root length, biomass, water content.

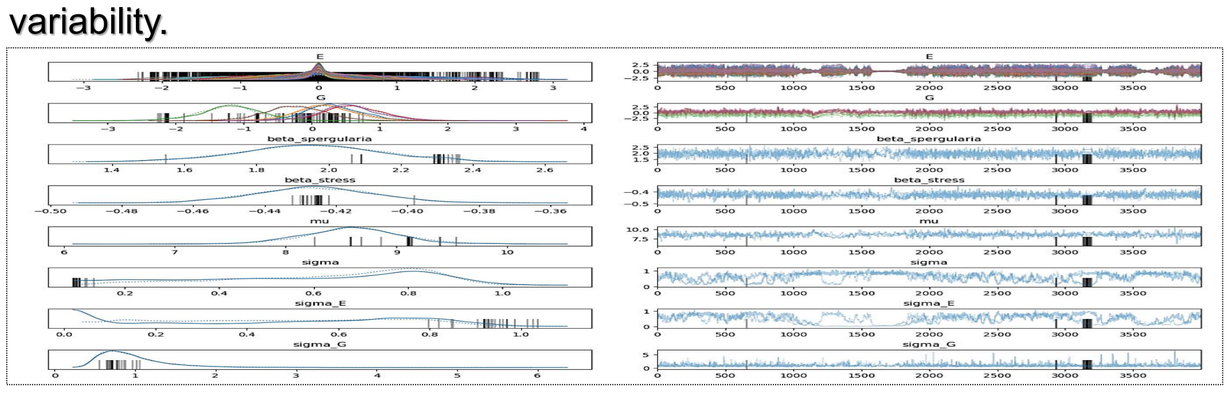


Root length had the highest direct effect on biomass ($\beta = 0.629$, $p < 0.05$), while chlorophyll and water content showed indirect contributions.



Ouazzane and Aït Attab provenances exhibited the strongest resilience; Khemissat was the most sensitive.

Bayesian posterior distributions revealed significant intra-population variability.



CONCLUSION

Carob exhibits remarkable resilience under saline stress, driven primarily by root development and genotype-specific adaptation. The integration of multivariate and AI-based models provides new insights for selecting salt-tolerant varieties, promoting sustainable agriculture in saline and arid ecosystems.