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# Studies on salt and drought tolerance of endemic and rare species in Valencian salt marshes as a tool for reintroduction programmes

**Abstract**

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Plant growth under stress conditions depends on the effectiveness of tolerance mechanisms in each species. The strategy of conducting comparative studies on genetically related taxa with different degrees of tolerance is a valuable approach, especially for distinguishing tolerance-relevant responses. The results may help design and implement conservation, reinforcement or reintroduction programmes and manage threatened populations of such rare and endemic species in the area of interest, the Albufera Natural Park.

*Key words*: endemism, conservation, Mediterranean, climate change, abiotic stresses.

## Introduction

Drought and salinity are the environmental factors that affect the plants the most, although Mediterranean plants are generally well adapted to these adverse conditions. However, predictions estimate that, due to climate change, environmental conditions will become more stressful, especially in dry, semi-arid and arid areas. These changes could affect the occurrence of many wild species, particularly those that are already threatened, rare or endemic. Both drought and salt stress cause the activation of a series of defence or response mechanisms in plants, including control of ionic transport, accumulation of compatible solutes or osmolytes, and activation of antioxidant systems.

The study was performed in the Albufera Natural Park, a coastal area holding saline ecosystems of great ecological value and biodiversity. It is the most relevant protected area of Valencia Community (Spain) (Ballester & al. 2003). The study focused on two *Limonium* species (*Plumbaginaceae*) (*L. albuferae* P.P. Ferrer, Roselló, Rosselló & E. Laguna and *L. dufourii* (Girard) Kuntze), one *Thalictrum* species (*Ranunculaceae*) (*T. maritimum* Dufour) and two *Bupleurum* species (*Apiaceae*) (*B. tenuissimum* L. and *B. fruticosum* L.) (Fig.1).

The unique population of *L. albuferae*, a recently described endemic species, is found in the salt marsh complex of the Albufera Natural Park (Ferrer-Gallego & al. 2016), where-


Fig. 1. *Limonium albuferae* in 'Raco de l'Olla' (El Saler, Valencia) (A) and plant production at the Centre for Forestry Research and Experimentation (CIEF) (Valencia) (B); *Limonium dufourii* in El Saler (Valencia) (C) and plant production at the CIEF (D); *Thalictrum maritimum* in Torreblanca (E) and Almenara (F) (Castellón, Spain); *B. tenuissimum* in Marjal dels Moros (Sagunt, Valencia) (G), and at the end of treatments with 450 mM of NaCl and control conditions in the greenhouse of the Polytechnic University of Valencia (H); *B. fruticosum* in the Botanical Garden of Valencia (I).

as *L. dufourii* is present in a few other salt marshes outside this natural park (Navarro & al. 2006; Aguilella & al. 2010). Nevertheless, *L. dufourii* is one of the most threatened endemic species of *Limonium* in the Valencian territory (Aguilella & al. 2010). In the past, this species was more widely distributed along the coast and salt marshes of the provinces of Valencia and Castellón (Crespo & Lledó 1998). Nowadays, it is represented by only five separate natural populations restricted to small coastal areas.

On the other hand, *T. maritimum* is an eastern Iberian endemic, growing only in a few coastal areas (Ferrer-Gallego & al. 2015). Furthermore, the species occurs worldwide in only four sites, all of which are located in the Valencian Community, with its southern limit within the Albufera Natural Park (Ballester & al. 2003).

Finally, *B. tenuissimum* is a rare species in Spain, which has become extinct in recent decades in many localities, including the Albufera Natural Park. *B. fruticosum*, a congenic species, was included as comparative material. At present, all these species – except *B. fruticosum*– are included in conservation programmes aimed at their reintroduction in this territory.

This multidisciplinary research included the analysis of the selected species and the parameters affecting their distribution and growth in their natural habitats, as well as the evaluation of their tolerance limits to salt and water stress under controlled greenhouse conditions. The main physiological and biochemical mechanisms of tolerance to drought, salinity and other abiotic stresses are known for some of the structural species in this habitat type (Katschnig & al. 2013; Pardo-Domenech & al. 2015; Al Hassan & al. 2016). Nevertheless, little information is available on the stress responses of differential, often endemic, rare, and/or endangered species such as those included in this study.

The results obtained allowed us to establish the relative tolerance to water deficit and salt stress of the analysed species and their relationships with environmental factors such as climate, vegetation and soil. Therefore, the optimal areas for the establishment of the most interesting species can be determined based on this information. Furthermore, the relevant tolerance mechanisms to both types of stress were identified in each species analysed. All plants activate the same defence mechanisms in response to abiotic stress, but their contribution to tolerance differs by genus and even species. In general, an intensification of ion transport to aerial parts and the activation of enzymatic antioxidant systems to maintain redox balance were noticed. As a result, most of the species studied did not show oxidative stress, except for the two species of the genus *Bupleurum*.

The species of the genus *Limonium* showed the slightest growth inhibition under stress, especially under conditions of high salinity. Therefore, this genus is clearly the most tolerant of those studied; its defence against stress is mainly based on the activation of the transport of toxic ions to the aerial part, the accumulation of compatible solutes and the activation of enzymatic antioxidant systems. The data obtained indicate that salinity is not a limiting factor for reintroducing the two *Limonium* species of interest in the Albufera Natural Park (Valencia, Spain), as both tolerate much higher salinities under controlled conditions than those present in their natural habitats. However, water scarcity could be a problem for *L. albuferae*, whereas *L. dufourii* should not be introduced in areas prone to prolonged flooding (González-Orenga & al. 2019a, 2019b; González-Orenga & al. 2021a).

*Thalictrum maritimum* was more tolerant than expected to saline stress but less resistant to water stress, which caused greater growth inhibition. Its defence mechanisms seem to be more related to active ion transport to the aerial part and maintenance of foliar $K^+$ homeostasis, as well as activation of enzymatic antioxidant systems. Consequently, this species behaved as a moderate halophyte, with optimal growth in the absence of salt, but tolerating much higher concentrations than its natural habitats; however, it was sensitive to water deficit (González-Orenga & al. 2020).

The two species of the genus *Bupleurum* showed a clear difference; the relevant endangered species, *B. tenuissimum*, is more tolerant of salinity, whereas the one used as comparative material, *B. fruticosum*, is more drought tolerant but susceptible to salinity even at low concentrations. Their primary defence mechanisms are related to immobilisation of toxic ions in the roots, accumulation of proline and activation of enzymatic and non-enzymatic antioxidant systems (González-Orenga & al. 2021b).

The results obtained in this study provide critical information for the reintroduction and conservation or maintenance of the species of interest, and allowing the understanding of the population reduction in recent years. On the other hand, the results may also contribute to a better knowledge of water and stress tolerance mechanisms in the studied genera, providing information on stress responses in species that have not been previously analysed.

**References**

Aguilella, A., Fos, S. & Laguna, E. (eds) 2010: Catálogo Valenciano de Especies de Flora Amenazadas. − Valencia.

Al Hassan, M., Chaura, J., López-Gresa, M. P., Borsai, O., Daniso, E., Donat-Torres, M.P., Mayoral, O., Vicente, O. & Boscaiu, M. 2016: Native-invasive Plants vs. Halophytes: Stress Tolerance Mechanisms in Two Related Species. − Front. Pl. Sci.**7:** 473. https://doi.org/10.3389/fpls.2016.00473

Ballester, J. A., Díes, B., Hernández Muñoz, J. A., Laguna, E., Oltra, C., Palop, S. & Urios, G. 2003: Parques Naturales de la Comunidad Valenciana/Natural Parks of the Valencian Community; Generalitat Valenciana. − Valencia.

Crespo, M. & Lledó, M. 1998: El género *Limonium* en la Comunidad Valenciana. − Valencia.

Ferrer-Gallego, P. P., Laguna, E. & Mateo, G. 2015: Neotipificación de *Thalictrum maritimum* Dufour (*Ranunculaceae*), Planta Endémica y Amenazada del Este Peninsular Ibérico. − Fl. Montiberica **59:** 83-87. https://doi.org/10.11646/phytotaxa.252.2.3

−−, Roselló, R., Rosato, M., Rosselló, J. A. & Laguna, E. 2016: *Limonium albuferae* (*Plumbaginaceae*), a New Polyploid Species from the Eastern Iberian Peninsula. Phytotaxa **252:** 114-122. https://doi.org/10.1016/j.jbiotec.2019.05.081

González-Orenga, S., Vicente, O., Laguna, E., Ferrer-Gallego, P. P., Llinares, J. V. & Boscaiu, M. 2019a: Physiological and Biochemical Responses to Salinity in Two Endemic *Limonium* Species from Spain. − J. Biotechnol. **305:** S20. https://doi.org/10.1016/j.jbiotec.2019.05.081

−−, Ferrer-Gallego, P. P., Laguna, E., López-Gresa, M. P., Donat-Torres, M. P., Verdeguer, M., Vicente, O. & Boscaiu, M. 2019b: Insights on Salt Tolerance of Two Endemic *Limonium* Species from Spain. − Metabolites **9**: 294. https://doi.org/10.3390/metabo9120294

−−, Trif, C., Donat-Torres, M. P., Llinares, J.V., Collado, F., Ferrer-Gallego, P. P., Laguna, E., Boscaiu, M.& Vicente, O. 2020: Responses to Increased Salinity and Severe Drought in the Eastern Iberian Endemic Species *Thalictrum maritimum* (*Ranunculaceae*), Threatened by Climate Change. Plants **9:** 1251. https://doi.org/10.3390/plants9101251

−−, Donat-Torres, M., Llinares, J. V., Navarro, A., Collado, F., Ferrer-Gallego, P. P., Laguna, E., Vicente, O. & Boscaiu, M. 2021a: Multidisciplinary Studies Supporting Conservation Programmes of Two Rare, Endangered *Limonium* Species from Spain. – Pl. Soil **466:** 505-524. https://doi.org/10.1007/s11104-021-05059-9

−−, Leandro, M.E.D.A., Tortajada, L., Grigore, M.N., Llorens, J.A., Ferrer-Gallego, P.P., Laguna, E., Boscaiu, M. & Vicente, O. 2021b: Comparative studies on the stress responses of two *Bupleurum* (*Apiaceae*) species in support of conservation programmes. − Environ. Exp. Bot. **191:** 104616. https://doi.org/10.1016/j.envexpbot.2021.104616

Katschnig, D., Broekman, R. & Rozema, J. 2013: Salt Tolerance in the Halophyte *Salicornia dolichostachya* Moss: growth, morphology and physiology- Enviro. − Exp. Bot. **92:** 32-42. https://doi.org/10.1016/j.envexpbot.2012.04.002

Navarro, A., Ferrando, I. & Laguna, E. 2006: Censo y Riesgo de Extinción de *Limonium dufourii*. − Toll Negre **8**: 38-49.

Pardo-Domenech, L. L., Tifrea, A., Grigore, M. N., Boscaiu, M. & Vicente, O. 2015: Proline and Glycine Betaine Accumulation in Two Succulent Halophytes Under Natural and Experimental conditions. – Pl. Biosyst. **150(5)**: 904-915. https://doi.org/10.1080/11263504.2014.990943

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