XVIII International Colloquium on Plant Ecophysiology

Katalapi Park,
January 13-16, 2025

Organizers: Patricia L. Sáez - Lohengrin Cavieres - León A. Bravo

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Parque Katalapi, Puerto Montt, Chile; January 13-16, 2025

The **International Colloquium on Plant Ecophysiology** has, since its beginnings, been an event that fosters open, engaging, and relaxed scientific conversations, where discussions on ecophysiology flow naturally. In this way, we maintain our goal of cultivating a welcoming environment that promotes the exchange of ideas, sharing of experiences, and the building of valuable relationships between students and professors in the field of Plant Ecophysiology.

To honor your important contributions, we have compiled your participation in the XVIII International Colloquium on Plant Ecophysiology 2024, which included 4 Keynote Lectures, 6 Mini-Lectures, and 17 short communications.

The organizing committee extends heartfelt gratitude to our participants, both national and international. We truly appreciate your enthusiasm, your valuable feedback, and the time you dedicated to fostering meaningful discussions. It is thanks to the collective commitment of individuals like you that our community continues to grow, advancing the field of plant ecophysiology and establishing this Colloquium as a unique event in its field. We especially appreciate the commitment of our regular participants, who are now recognized as "*Katalapiers*." We look forward to continuing this collaborative journey in the study of Plant Ecophysiology.

Thank you!

Special recognition goes to the event sponsors whose support has been invaluable:
Universidad de Concepción, Universidad de La Frontera, Instituto de Ecología y Biodiversidad & Parque Katalapi.

Organizing Committee
Patricia Sáez (UFRO), patricia.saez@ufrontera.cl
León A. Bravo (UFRO), leon.bravo@ufrontera.cl
Lohengrin Cavieres (UdeC), lcaviere@udec.cl

Katalapi Administration & Logistics:
Luis J. Corcuera, Ana María Vliegenthart.

Links of interest:
www.parquekatalapi.cl
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GENERAL PROGRAM

Time	Monday 13th	Time	Tuesday 14th	Time	Wednesday 15th	Time	Thursday 16th
		8:00-9:00	**Breakfast**	**8:00-9:00**	**Breakfast**	**8:00-9:00**	**Breakfast**
		9:00-9:40	**Conference 1** Marilyn Ball	**9:00-9:40**	**Conference 3** Jaume Flexas		
		9:40-10:25	**Short Communications 1**	**9:40-10:25**	**Short Communications 4**	**9:40-9:55**	**Short Communications 7**
		9:40-9:55	Pere Aguiló-Nicolau	9:40-9:55	Dariel López	9:40-9:55	Enrique Ostria-Gallardo
		9:55-10:10	Andrea Arredondo	9:55-10:10	Carolina Álvarez-Maldini	**9:55-10:55**	**Mini-Conferences 5**
		10:10-10:25	Enrique Ostria-Gallardo	10:10-10:25	Fabián Pereira	9:55-10:25	Gerardo Alejo
		10:30-11:00	**Coffee Break**	**10:30-11:00**	**Coffee Break**	10:25-10:55	Daniela Aro
		11:00-11:40	**Conference 2** Bruce Osborne	**11:00-11:40**	**Conference 4** Jie Liang	10:55-11:25	**Coffee Break**
		11:40-12:10	**Mini-Conferences 1**	**11:40-12:10**	**Mini-Conferences 3**		
		11:40-12:10	Tomás Fuenzalida	11:40-12:10	Beatriz Fernández-Marin		
		12:10-12:40	**Short Communications 2**	**12:10-12:40**	**Short Communications 5**		
		12:10-12:25	Carolina Sanhueza	12:10-12:25	Eliana Bustos		
		12:25-12:40	Gabriela Castillo Estrada	12:25-12:40	Rodrigo G. Viveros		
		13:00-14:30	**Lunch**	**13:00-14:30**	**Lunch**	**13:00-14:30**	**Lunch**
		15:00-15:30	**Mini-Conferences 2**	**15:00-15:30**	**Mini-Conferences 4**	15:00-17:00	**Departures**
15:00	**Arrivals and accommodation**	15:00-15:30	Ignacio García Plazaola	15:00-15:30	Marely Cuba		
		15:30-16:15	**Short Communications 3**	**15:30-16:15**	**Short Communications 6**		
		15:30-15:45	Catalina Castro	15:30-15:45	Pedro B. Ferreira		
		15:45-16:00	Flavia Cresta-Recasens	15:45-16:00	Carolina Hernández		
		16:00-16:15	Karina Acuña	16:00-16:15	Carla Sandoval		
19:00	**"*Cata en Kata*"/Dinner**	**16:15-16:45**	**Coffee Break**	**16:15-16:45**	**Coffee Break**		
		16:45	**Relax time**	**16:45-18:00**	**"Bats, our friends in the forest"**		
		19:00-20:00	**Dinner**	19:00-20:00	**Dinner**		

ABSTRACTS BOOKLET

CONFERENCES

"Foliar water uptake makes similar contributions to water/carbon balances in an arid mangrove forest and a rainforest"

Jie Liang[1*], John Finnigan[1], Ken W. Krauss[2], Maurizio Mencuccini[3], Lawren Sack[4], Rafael S. Oliveira[5], Catherine E. Lovelock[6] and **Marilyn C. Ball[1]**
[1.]Plant Science Division, Research School of Biology, Australian National University, Acton, ACT 2601, Australia. [2]U.S. Geological Survey, Wetland and Aquatic Research Center, Lafayette, LA 70506, USA. [3]CREAF, Universidad Autonoma de Barcelona, Cerdanyola del Valles 08193, Barcelona, Spain. [4]Department of Ecology and Evolution, University of California Los Angeles, Los Angeles, CA 90095, USA. [5]Department of Plant Biology, Institute of Biology, University of Campinas – UNICAMP, Campinas, São Paulo CP6109, Brazil. [6]School of Biological Sciences, The University of Queensland, St Lucia, Qld 4072, Australia. marilyn.ball@anu.edu.au

Foliar water uptake (FWU) and associated carbon benefits are not considered in land surface models, despite being shown in over 200 species worldwide. We developed a framework combining a rate-duration model to quantify FWU amounts (ΔE) from fog/rain, dew and deliquescence, and a stomatal optimization model to evaluate carbon gain from ΔE. Use of this framework revealed that ΔE contributed an average of 6% of daily transpiration that supported a 2% increase in daily carbon gain in an arid mangrove and a moist rainforest. Carbon gain (ΔA) estimates using $\partial A/\partial E$ were one-fifth of those using A/E (assimilation/transpiration) for rainforests and one-third for mangroves. The ΔE from dew in the rainforest and from deliquescence plus dew in the mangrove elevated foliage water potentials above those in soil up to full turgor with a 4-7% increase in foliage water content. This framework can be incorporated into land surface models to improve drought impact predictions.
Acknowledgments: Australian Research Council Discovery Project Grant (DP180102969).

"Giant rhubarb at home and abroad"

Bruce Osborne[1]
[1]UCD School of Agriculture and Food Science and UCD Earth Institute, University College Dublin, Belfield, Dublin 4, Ireland. Bruce.Osborne@ucd.ie

Rather surprisingly we often know more requires species in its introduced range than we do in its native range, even though many of the theories that have been used to account for the success of invasive species explicitly require information from both ranges. To emphasise the importance of this I report on an analysis of the ecological impacts of giant rhubarb (*Gunnera tinctoria*) at home and abroad and provide information on a related species, *G. manicata,* and the newly discovered hybrid, *G. cryptica*. Home, for *G. tinctoria,* is the Andean and coastal ranges of Chile, Argentina and Brazil, where it occupies a variety of habitats, as it does in its introduced range, with a distribution dependent largely on water availability. In its native range *G. tinctoria* has relatively small and subtle impacts on coastal dune plant communities in comparison to the invasive species *U. europaeus*. In contrast *G. tinctoria* is associated with significant increases in soil C, N, and available nitrogen, while the alien *U. europaeus* had no significant impacts. Abroad, almost the opposite scenario is found with invasions by *G. tinctoria* resulting in major changes in taxonomic and functional diversity and the formation of almost monospecific stands, but little impact on soil nutrients. Taken together these results indicate the difficulty of predicting impacts based on information from the native range and that range expanding species may have as great an impact on ecosystems as introduced species, when the totality of effects above and below ground are accounted for.

Acknowledgements: UCD, EPA, Science Without Borders, ANID 1211652, 1171239, 21201558.

"Measuring photosynthesis in climatically extreme environments"

Jaume Flexas[1]

[1]Department of Biology, Universitat de les Illes Balears-INAGEA, Spain. jaume.flexas@uib.es

Commercially available devices for measuring photosynthesis are designed mostly for measuring standard plants with flat (and better if large!) leaves. In this talk, I will discuss some of the most important problems faced when attempting to measure very small, often fully prostrated plants, with either tiny or fused leaves, in their native habitats in extreme environments. Common problems include the proper estimation of the enclosed leaf area, the issue of how to clamp petiole-less leaves with increasingly large cuvettes and the inherent problem of equipment being designed for working within a given range of environments (e.g. temperature, atmospheric pressure, etc.). Also, I will show a few examples on how we have overcome these limitations, and I will detail how a simple parameter, the ETR/An ratio, is extremely useful under remote field conditions to ascertain either the plant status or the proper functioning of the instruments and their underlying assumptions.

"What water use strategy does plants adopt under varying spatiotemporal environmental conditions?"

Jie Liang[1], Ken W. Krauss[2], John Finnigan[1], Hilary Stuart-Williams[1], Graham D. Farquhar[1] and Marilyn C. Ball[1]

[1] Plant Science Division, Research School of Biology, Australian National University, Acton, ACT 2601, Australia. [2] U.S. Geological Survey, Wetland and Aquatic Research Center, Lafayette, LA 70506, USA. JIE.LIANG@anu.edu.au

Limitations and utility of three measures of water use characteristics were evaluated: water-use efficiency (WUE), intrinsic water-use efficiency (IWUE), and marginal water cost of carbon gain ($\partial E/\partial A$) estimated, respectively, as ratios of assimilation (A) to transpiration (E), of A to stomatal conductance (g_s), and of sensitivities of E and A with variation in g_s. Theoretical relationships among these terms were explored and tested with published data. WUE and IWUE vary with environmental perturbations. Only the measure $\partial E/\partial A$ remains relatively stable across temporal and organisational scales from leaves to communities. $\partial E/\partial A$ therefore, estimates water use strategy in a way that integrates carbon gain relative to water use under varying environmental conditions. We provide updated and simplified ways of estimating $\partial E/\partial A$. Using this parameter adds depth to understanding ways that plants balance water expenditure against carbon gain, uniquely providing a mechanistic means of predicting water use characteristics under changing environmental scenarios.

Acknowledgments: Australian Research Council Grants DP180102969 and DP210103186.

MINI CONFERENCES

"Evolution of vegetative desiccation tolerance: Role of gene family rearrangements and priming"

Gerardo Alejo-Jacuinde[1], Ricardo A. Chávez Montes[1], Cristian D. Gutiérrez Reyes[2], Lenin Yong-Villalobos[1], June Simpson[3], and Luis Herrera-Estrella[1,4]
[1]Department of Plant and Soil Science, Institute of Genomics for Crop Abiotic Stress Tolerance (IGCAST), Texas Tech University, Lubbock, TX 79409, United States. [2] Department of Chemistry and Biochemistry, Texas Tech University, Lubbock, TX 79409, United States. [3]Department of Genetic Engineering, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, 36824 Irapuato, Guanajuato, Mexico.[4]Unidad de Genómica Avanzada/Langebio, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Irapuato, Gto. 36824, México. galejoja@ttu.edu.

Extreme water loss, such as desiccation, is lethal for most plants. However, there is a small group of species known as resurrection plants which can survive almost complete cellular water loss and subsequently activate their metabolism upon rehydration. Several studies have pointed out that these species evolved vegetative desiccation tolerance (VDT) by activating genes commonly present in most plants. To better understand the evolution of VDT, we generated chromosome-level assemblies and improved genome annotations of two *Selaginella* species with contrasting abilities to survive desiccation. We identified genomic features and critical mechanisms associated with VDT through sister-group comparative genomics, integrating multi-omics data. Our findings indicate that *Selaginella* evolved VDT through the expansion of some stress protection-related gene families and the contraction of senescence-related genes. Metabolic data also provided important insights into the difference between desiccation-tolerant and desiccation-sensitive species, such as the maintenance of significantly high levels of flavones derivatives as a constitutive protection strategy. During water loss, the resurrection *Selaginella* induces processes such as phospholipids metabolism, responses that are missing in the desiccation-sensitive species. Additionally, gene regulatory network analyses indicate the suppression of growth processes as a major component of VDT. This study presents novel perspectives on how gene dosage impacts crucial protective mechanisms and the regulation of central processes to survive extreme dehydration.
Acknowledgements: National Science Foundation (Award Number 2243690).

“Do CAM ferns really exist?”

Aros-Mualin, Daniela[*1]; McAdam, Scott[1]
[1]Purdue Center for Plant Biology, Department of Botany and Plant Pathology, Purdue University, West Lafayette, Indiana 47907, USA. darosmua@purdue.com

Crassulacean acid metabolism (CAM) photosynthesis has evolved independently multiple times as an adaptation to conserve water, with CAM plants opening stomata at night for CO_2 uptake, instead of the day. While CAM is well-studied in angiosperms, its occurrence in other plant groups remains underexplored. We examined whether CAM ferns, exclusively epiphytic and predominantly in Polypodiaceae, exhibit inverted stomatal rhythms. We also investigated potential mechanistic explanations for diurnal stomatal regulation in this group. We measured canopy conductance over four days under natural light conditions in 12 epiphytic Polypodiaceae species, and found that CAM ferns do not display fully inverted stomatal rhythms, like CAM angiosperms. Instead, all epiphytic ferns have stomata that are highly sensitive to vapor pressure deficit (VPD), with even minor increases in VPD leading to near-complete daytime stomatal closure. These results suggest that high VPD sensitivity, rather than an angiosperm-like, inversion of stomatal rhythms drives diurnal stomatal regulation in epiphytic ferns. The evolution of facultative CAM photosynthesis in epiphytic ferns may have been necessary for carbon gain in plants with stomata under such strong passive regulation by water status.

“Are Antarctic populations of *Colobanthus quitensis* the most salinity tolerant?: a field analysis”

Marely Cuba-Díaz[1,2], Darío Navarrete-Campos[1], Rogelio Najera-González[3], Gustavo Cabrera[4], Eduardo Fuentes-Lillo[5,6], Marjorie Reyes[7], Yadiana Ontivero[1,8], Touhidur Rahman Anik[3], Gerardo Alejo-Jacuinde[3], Luis Herrera-Estrella[3].
[1]Laboratorio de Biotecnología y Estudios Ambientales, Departamento de Ciencias y Tecnología Vegetal, Escuela de Ciencias y Tecnologías, Universidad de Concepción Campus Los Ángeles, Los Ángeles, Chile. [2]Programa de Ciencia Antártica y Subantártica (PCAS), Universidad de Concepción, Concepción, Chile. [3]Institute of Genomics for Crop Abiotic Stress Tolerance, Department of Plant and Soil Science, Texas Tech University, Lubbock, Texas, 79409, USA.[4]Facultad de Ciencias Para el Cuidado de la Salud, Universidad San Sebastián, Lientur 1439, Concepción, Chile.[5]Laboratorio de Invasiones Biológicas, Facultad de Ciencias Forestales, Universidad de Concepción, Concepción, Chile.[6]Institute of Ecology and Biodiversity (IEB), Santiago, Chile. [7]Laboratorio de Ecofisiología Molecular y Funcional de Plantas. Departamento de Ciencia Químicas y Recursos Naturales, Facultad de Ingeniería y Ciencias, Universidad de La Frontera, Temuco, Chile. [8]Programa de Doctorado

en Ciencias de la Agronomía, Facultad de Agronomía, Universidad de Concepción Campus Chillán, Chillán, Chile. mcuba@udec.cl.

Soil salinity causes major economic losses worldwide and affects food security in areas vulnerable to climate change. Salinity tolerance is a complex response involving mechanisms from the cellular level to abiotic and biotic interactions of plants. In Antarctica, an extreme environment with low terrestrial plant diversity, plants face severe abiotic conditions, with salinity being a key factor due to strong winds and the influence of marine fauna on coastal vegetation. However, research on this topic is limited. It has been shown that, in some species, such as halophytes, tolerance mechanisms depend on the type of exposure in their habitats. *Colobanthus quitensis*, the only native dicotyledon in Antarctica, is found in different salinity conditions throughout its wide distribution range, both within and outside the continent. This plant faces diverse sources of salinity, such as sea spray, high tides and waves. It is proposed that populations exposed to high tides have a greater tolerance to salinity, since they respond constitutively to it. The evaluation of biochemical and metabolomic variables in different populations of *C. quitensis* supports this hypothesis, suggesting that this species may be useful for studying the mechanisms of differential response to salinity.
Acknowledgment: Projects INACH RT_17_22 and ANID FOVI 230049

"Green tissues in the white season: potential cross-tolerance to freezing and desiccation in ferns"

Beatriz Fernández-Marín[1], Lucía Herrero-Quintanilla[1], Miren Irati Arzac[1], Alicia Victoria Perera-Castro[1], Soniya Firoozi[1], Enara Alday, José Ignacio García-Plazaola[1]
[1]Department of Plant Biology and Ecology, University of the Basque Country (UPV/EHU), Leioa, Spain.Beatriz.fernandezm@ehu.eus.

Ferns, which evolved around 400 million years ago, are a vital plant lineage bridging bryophytes and seed plants. Their unique life cycle, involving distinct gametophyte and sporophyte generations with differing ecological requirements, offers a valuable model for studying plant adaptability and resilience over geological time. While many ferns avoid freezing by inhabiting tropical climates or shedding fronds, wintergreen species in temperate and cold regions endure repeated freezing and thawing cycles, exposing them to risks like photooxidative stress, xylem embolism, and freeze-induced cell dehydration. Despite their ecological significance, knowledge of freezing tolerance mechanisms in ferns remains limited. We hypothesize that, desiccation-tolerant ferns, which can equilibrate water potential with the atmosphere and resume normal metabolism upon rehydration, may have inherent advantages in mitigating freezing/thawing damage. To address these gaps of knowledge, we studied the fronds of several wintergreen fern species naturally growing in Spain and with

diverse ecological requirements. We assessed freezing and desiccation tolerances in all of them. For some selected species we additionally evaluated ice nucleation temperature, gas exchange, xylem anatomy, and glass transition temperature. The preliminary results reveal notable interspecies differences in freezing tolerance, photosynthetic capacity, xylem traits, and ice nucleation temperatures. Data support a side-effect protection against freezing/thawing damage in desiccation-tolerant species, although some specific physiological adaptations are also needed. Overall, this study underscores the ecophysiological complexity of ferns, highlighting their resilience and unique strategies for surviving in harsh environments.
Acknowledgments: Research funded by POPEYE research grant (PID2022-139455NB-C32) funded by MCIN/AEI/10.13039/501100011033 and by “ERDF A way of making Europe.

“Here comes the sun…: xanthophylls as components of light memory”

José Ignacio García-Plazaola[1]; Miren Irati Arzac[1]; Águeda González-Rodríguez[2]; Laura Díaz-Jiménez[2]; Alicia Perera-Castro[2]; Beatriz Fernández-Marín[1].
[1] Dpt. Plant Biology and Ecology, University of the Basque Country (UPV/EHU), Spain. [2]Dpt. Botany, Ecology and Plant Physiology, University of La Laguna (ULL), Spain. joseignacio.garcia@ehu.eus

Plants are sessile organisms that live in a constantly fluctuating environment to which they adapt thanks to great phenotypic plasticity and acclimation capacity. As a result, plants can measure environmental factors, perform sophisticated calculations, store information and, based on this, apply decision-making algorithms. Whether this is a reflection of cognitive abilities is largely a philosophical question, but there is no doubt that it can be considered a type of "memory." This storage of information has a genetic, epigenetic or metabolic basis. Among the physical factors, the light environment is particularly important for photosynthetic organisms, as it is a necessary resource and at the same time the main source of environmental stress. For this reason, plants have developed the ability to protect from the excess of light but also to measure qualitative and quantitative variations in light. Among photoprotection mechanisms, the so-called non-photochemical quenching plays a pivotal role. This mechanism is partly controlled by the operation of xanthophyll cycle, which involves the reversible interconversion of violaxanthin, antheraxanthin and zeaxanthin. We postulate that this cycle also provides the metabolic support for the measurement and memory of the light dose that a plant receives in a given time, later affecting the physiological responses. This memory works in the medium-term (hours: interconversions of xanthophylls) and in the long-term (days: total pool of xanthophylls), but it is also the basis of "traumatic events" (irreversible accumulation of zeaxanthin). In the present case-study we have

quantified the dependence of the xanthophyll cycle on the radiation dose in different species and functional groups.

Acknowledgment: The research leading to these results has received funding from the European Union's Horizon 2020 project INTERACT, under the grant agreement No 730938, and from POPEYE research grant (PID2022-139455NB-C32) funded by MCIN/AEI/10.13039/501100011033 and by "ERDF A way of making Europe.

"Use of force-sensing clamps for passive monitoring of leaf thickness and turgidity via uniaxial compression"

Tomás I. Fuenzalida[1,2] and Jacques Dumais[1]

[1]Facultad de Ingeniería y Ciencias, Universidad Adolfo Ibáñez. [2]Plant Science Division Research School of Biology, The Australian National University. tifuenza@gmail.com

Many electromechanical devices use uniaxial compression to measure plant leaf thickness (h) or turgidity (P_t), but methods vary widely, lacking consensus. The imposition of constant mechanical stress or constant thickness to the leaf sample can be used to measure h or P_t, respectively. In this study, we designed and tested two passive sensors to measure h or P_t by varying the deflection and force range of the load cells. The more flexible sensor (with deflection 20 µm N^{-1}) was used to monitor h, while the more rigid sensor (0.7 µm N^{-1}) was used to monitor P_t. Under laboratory conditions, we found excellent linear agreement between leaf balancing pressure (BP) and P_t within the turgid range (R^2 = 0.99), and a hysteretic relationship between h and P_t during artificial rehydration. A field trial on a well-watered tree showed a linear relationship between BP and RWC to both h and P_t during dehydration, and a non-linear relationship during rehydration. The h and P_t sensors had thermal responses of 0.015% K^{-1} and 0.15% K^{-1}, which under field conditions can be neglected or corrected for, respectively. These open-source mechanical sensors enable unparalleled precision and accuracy at comparable cost and may also be adapted as dendrometers.

Acknowledgements: FONDECYT Postdoctorado 3230209.

SHORT COMUNICATIONS

“High temperature tolerance of photosynthetic tissues in high Andean plants”

Karina Acuña[1,4], Isabel Saavedra[1,4], Claudia Reyes[2,4], Benjamín Morong[1,4], Graciela Valencia[1,4], Maritza Mihoc[1,4], Patricia L. Sáez[3,4], León Bravo[3] and Lohengrin Cavieres[1,4]
[1]Departamento de Botánica, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Chile. [2]Millenium Nucleus of Patagonian Limit of Life (LiLi), Universidad de Talca, Chile. [3]Departamento de Ciencias Agronómicas y Recursos Naturales, Facultad de Ciencias Agropecuarias y Medioambiente, Universidad de La Frontera, Temuco, Chile. [4]Instituto de Ecología y Biodiversidad (IEB), Concepción, Chile. kacuna@gmail.com

One of the main effects of climate change on high-elevation ecosystems is the increase in temperature. This has caused shifts in the altitudinal ranges of alpine plant species, as well as increases and decreases in species richness depending on how wet or dry the growing seasons are. Extreme high-temperature events are also increasing in frequency and intensity in alpine habitats, but our knowledge of how tolerant alpine plant species are to these events is still scarce. The extensive alpine area of the Chilean Andes covers a large latitudinal and altitudinal gradient, resulting in marked variations in temperature and water availability. Ground-level temperatures as high as 45°C are frequent in these habitats. Our objective was to determine the susceptibility of high Andean species to high temperatures across both latitudinal and altitudinal gradients. The tolerance to high temperatures showed no changes across latitudes above the tree line (44.0±0.6°C) but slightly decreased with elevation in the Central Chilean Andes (2.6±0.04°C). Furthermore, in Central Chile, native species tolerated temperatures ±1.9°C higher than non-native species, with no observed relationship to plant stature. Overall, our results indicate that most high-elevation plant species of the Chilean Andes can withstand extreme high temperatures, regardless of their origin, plant stature, or latitude.
Acknowledgments: ACT 210038, FONDECYT 1211197, ANID FB210006

“Measuring Rubisco isotope fractionation *in vitro*”

Pere Aguiló-Nicolau[1], Reto S. Wijker[2], Madalina Jaggi[2], Concepción Iñiguez[1], Sebastià Capó-Bauçà[1], Heather Stoll[2], Jeroni Galmés[1]
[1]Research Group on Plant Biology under Mediterranean Conditions, INAGEA-University of the Balearic Islands, Palma, Balearic Islands, Spain. [2]Earth Science Department, ETH Zürich, Zürich, Switzerland. p.aguilo@uib.es

Rubisco catalyses the addition of inorganic carbon to organic compounds in the first step of the Calvin-Benson-Bassham (CBB) cycle, playing a pivotal role in global carbon fixation and producing biomass to sustain most trophic chains. Rubisco exhibits a kinetic isotope effect, preferentially fixing the lighter stable carbon isotope ($^{12}CO_2$) over the heavier one ($^{13}CO_2$), resulting in a ^{13}C depleted carboxylation product. Rubisco's carbon isotope fractionation (ε) has been applied in palaeoclimatological models to reconstruct ancient atmospheric compositions. Historically, these models assumed an ε of 25 ‰, yet evidence from coccolithophores has revealed that ε can be as low as 11 ‰. Despite its significance, ε has been successfully measured in only a limited number of model species, predominantly in higher plants. Furthermore, ε has been suggested to correlate with temperature-dependent Rubisco kinetic parameters. This work aims to improve the existing methodology for measuring ε, characterize it in non-plant species, and investigate the relationship between ε, Rubisco kinetic parameters and temperature. Our results represent an improved methodology based on a single device for the measurement of both dissolved inorganic carbon and isotope composition, a positive correlation between ε and Rubisco's specificity factor, and a negative correlation with Michaelis-Menten semisaturation constant for the CO_2 only in IB Rubisco forms. In addition, we found no effect of the temperature on ε in coccolithophores but large variations in spinach replicates. These findings evidence the need for further research to confirm the correlation between ε and Rubisco kinetic parameters and temperature, while exploring different phylogenetic groups and underrepresented Rubisco types.
Acknowledgements: Predoctoral fellowship (FPI/046/2020) granted by the government of the Balearic Islands to Pere Aguiló-Nicolau. Funding: Heather Stoll (ETH Zürich, ETH03-19-1) and UNRAVENAR to Jeroni Galmés (PID2023-148523NB-I00).

"Evidence of hydraulic vulnerability segmentation in *Prunus dulcis* cultivars during drought"

Carolina Álvarez-Maldini[1], Manuel Acevedo[2], Andrea Valero[1], Daniela Estay[3].
[1]Departamento de Silvicultura, Facultad de Ciencias Forestales, Universidad de Concepción, Concepción, Chile. [2]Centro Tecnológico de la Planta Forestal, Instituto Forestal, San Pedro de la Paz, Chile. [3] Instituto de Ciencias Agroalimentarias, Animales, y Ambientales (ICA3), Universidad de O´Higgins, Campus Colchagua, San Fernando, Chile. caalvarez@udec.cl

Almond cultivars have been previously characterized by its isohydric and anisohydric behavior through analysis of stomatal conductance (gs), pre-dawn (Ψ_{pd}) and mid-day (Ψ_{md}) leaf water potential during desiccation experiments. However, leaf abscission before the point of Ψ_{pd}=Ψ_{md} (i.e., limits of stomata control) and highly cavitation resistant stems evidenced the possible existence of hydraulic vulnerability segmentation (HVS) between leaves and stems of almond cultivars. This points towards the vulnerability of expendable organs such as leaves, to protect perennial and "costly" organs like the stem. Thus, through

a pot desiccation experiment, we assessed the above-mentioned hydraulic traits, leaf hydraulic conductance (K_{leaf}), and the embolism formation through optical vulnerability curves in iso- and anisohydric almond cultivars. In agreement to our hypothesis, loss of 50% K_{leaf} was the first event during drought (between -0.586 MPa in isohydric vs. -0.906 MPa in anisohydric cultivars) preceding stomatal closure, and the formation of the first embolism events in leaves (P_{12}) at -0.565 MPa in isohydric vs. -1.547 MPa in anisohydric cultivar; while stems were less vulnerable to cavitation events, displaying a water potential at 50% loss of stem hydraulic conductivity ($P_{50\text{-}stem}$) between -2.97 MPa in isohydric cultivar vs. -3.8 MPa in anisohydric cultivar. These results show a coordinated variation in embolism vulnerability between leaves and stems during drought. The occurrence of leaf shedding before the point of $\Psi_{pd}=\Psi_{md}$ protects the integrity of the hydraulic system of the perennial and more carbon costly stems. The role of roots in HVS remains unknown and should be further assessed.

Acknowledgment: Fondecyt n° 112007807.

"Treeline formation of *Nothofagus pumilio* and its relationship with bark yeasts"

Andrea Arredondo Aracena[1], Frida I. Piper[1] and Claudia Reyes[2]
[1]Instituto de Ciencias Biológicas, Universidad de Talca, Chile.[2]Instituto de Investigación Interdisciplinaria (I^3). andrea98arredondo@gmail.com

Climatic treelines represent natural boundaries where tall trees are replaced by smaller vegetation, often corresponding to the 6.4°C isotherm during the growing season. To explore the physiological processes influencing treeline formation, we studied *Nothofagus pumilio* (Lenga) at Termas de Chillán, Chile, sampling the internal bark of trees at the treeline and 300 m below. Trees with contrasting architectures were analyzed to assess their coupling to atmospheric conditions. The deciduous nature of Lenga, compared to evergreen species, has sparked debate regarding its growth response to temperature, aligning with the Growth Limitation Hypothesis (GLH). However, previous studies have also supported the Carbon Limitation Hypothesis (CLH), which posits that photosynthesis is more sensitive to low temperatures than growth. We quantified nonstructural carbohydrates (NSC), photosynthetic rates, growth, and yeast abundance—specifically *Saccharomyces* spp., which ferment soluble sugars—at the beginning, midpoint, and end of the growing season. Using linear and mixed models, we observed a weak negative correlation between soluble sugars and yeast abundance. Treeline trees exhibited reduced growth but maintained NSC concentrations and photosynthetic rates like trees below the treeline, offering limited support for GLH or CLH. Notably, dwarfed trees demonstrated higher photosynthetic rates but lower growth and NSC concentrations than erect trees, potentially reflecting differences in sink activity. These findings suggest that dwarfed architectures may represent adaptations to colder environments. However, their implications under global warming remain uncertain. As taller

trees potentially migrate upwards, the reduced resources in dwarfed trees could influence yeast abundance and ecosystem dynamics at higher elevations.

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"Allocation of photoassimilates in *Quillaja saponaria* after a period of carbon deprivation"

Eliana Bustos[1], D. A. Diaz-Muñoz[1], Frida I. Piper[1,2,3] & Claudia Reyes-Bahamonde[1,2,3]
[1]Laboratory of Plant Ecophysiology, Institute of Biological Sciences, Campus Talca, Universidad de Talca, Chile. [2]Millenium Nucleus of Patagonian Limit of Life (LiLi), Chile. [3]Instituto de Ecología y Biodiversidad (IEB), Casilla 653, Santiago, Chile. eliana_b@outlook.es

Growth has been considered the main sink of photoassimilates in plants. However, drought-adapted plant species could prioritize the allocation of photoassimilates to other sinks before growth, such as storage. For example, in sclerophyll species from Mediterranean regions, prioritizing the allocation of photoassimilates to storage instead of growth could be more advantageous to sustain the metabolic requirements of the plant under prolonged stomatal closure caused by the summer drought. On the other hand, these species could prioritize the allocation of photoassimilates to the formation of osmolytes since these compounds promote tolerance to dehydration by decreasing the osmotic potential and, consequently, increasing the cell turgor. The objective of this study is to evaluate the carbon (C) allocation to storage, osmoregulation, and growth after C deprivation in saplings of *Quillaja saponaria,* a tree species from the Mediterranean forests in Chile. For that purpose, 48 saplings were randomly assigned to two light conditions: full light over the whole experiment (control) and 80% light reduction (shade) for 4 weeks. Shade plants were subsequently transferred to the light conditions of the control plants and the leaf osmotic potential at maximum turgor (π_{100}), growth, biomass, and non-structural carbohydrates (NSC, as starch and soluble sugars) concentrations were periodically measured for 1 month.
NSC concentrations, growth and the π_{100} were all significantly lower in shade than in control plants. Concentrations of starch and soluble sugars in leaves and stems of shade plants, and of soluble sugars in roots, were recovered to control values 7 days after re-illumination. The osmotic potential began to be restored after the re-establishment of NSC concentration in aboveground organs. Finally, 14 days after re-illumination, diameter growth and root starch concentration achieved control values. It is concluded that saplings of *Quillaja saponaria* prioritize the formation of C reserves in aboveground tissues over any other sink after a period of C deprivation, with growth and belowground starch being the least prioritized sinks. We suggest that plants that require a high amount of osmolytes may also require high levels of carbohydrate reserves to support their osmotic requirements. In this study, leaf osmotic

demands were covered only after the reestablishment of aboveground C reserves, suggesting that the dehydration tolerance is supported by storage.

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"Improving HMW DNA Extraction: A Key to Successful Long-Read Sequencing"

Lenin Yong-Villalobos[1], **Gabriela Castillo Estrada[2],** Damar Lopez-Arredondo[1] and Luis Herrera-Estrella[1].

[1]Institute of Genomics for Crop Abiotic Stress Tolerance, Plant and Soil Science Department. Texas Tech University, Lubbock, Texas. [2]Center for Biotechnology & Genomics, Texas Tech University, Lubbock, Texas. cas81977@ttu.edu

With the development of long-read sequencing technologies, such as the PacBio and Oxford Nanopore platforms, the study of complex genomes has been significantly facilitated. These technologies allow for the sequencing of thousands—sometimes even hundreds of thousands—of bases from a single read, in contrast to the average 300 bases generated by short-read sequencing methods. This advancement is particularly transformative for assembling whole genomes and analyzing highly repetitive regions, such as telomeres and centromeres. Furthermore, these platforms can sequence native DNA, which enables epigenetic studies by investigating DNA modifications, such as methylation. The success of a long-read sequencing run is highly dependent on starting with high-quality, high-molecular-weight (HMW) DNA. However, extracting such DNA from plant tissues, particularly from non-model species, remains a significant challenge. Although there are several commercial kits available for extracting high-quality HWM DNA, most of them are optimized to work with blood or mammalian tissue, which often results in significantly lower yields when applied to plants, and their cost can be prohibitive. In this study, we combined a nuclei extraction method with a modified CTAB DNA extraction protocol to obtain high-quality HMW DNA from different non-model algae tissues. The quality of the HMW DNA samples was assessed using a DeNovix DS-11 Spectrophotometer/Fluorometer and an Agilent TapeStation 4200 Automated Electrophoresis System. The samples obtained using this combination of methods were successfully sequenced using the Oxford Nanopore platform, demonstrating the effectiveness of this approach for long-read sequencing of non-model plant species.

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“Effect of nitrogen deficiency stress in *Chenopodium quinoa* mother plants on growth and physiology of their offspring”

Catalina Castro[1], Rodrigo Sanhueza-Lepe[1], José Ortiz[1], María Paz Jerez[1], Elizabeth Escobar[1], Teodoro Coba de la Peña[2], Enrique Ostria-Gallardo[1], Luisa Bascuñan-Godoy[1]
[1]Laboratorio de Fisiología Vegetal, Departamento de Botánica, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Concepción, Chile. [2]Laboratorio de Recursos Naturales y Fitorremediación, Centro de Estudios Avanzados en Zonas Áridas (CEAZA), La Serena, Chile. catalinacastro@udec.cl

Plants have developed various strategies to deal with abiotic stresses throughout their lifetimes. However, environmental stresses can have long lasting effects, positively modifying plant physiological responses to subsequent stress episodes, a phenomenon known as pre-conditioning or stress memory. Intriguingly, this memory can even be transmitted to off-spring, referred to as “inter- or transgenerational memory”. *Chenopodium quinoa* is a pseudocereal that is resistant to many abiotic stresses, including nitrogen (N) limitation. Our work studied the influence of maternal N on the physiological and metabolic responses of the offspring. At LN, offspring seedlings from mothers grown at low N (LNF0LNF1) showed a significant increase in root number, which was correlated with an improvement in net photosynthesis, stomatal conductance, transpiration and starch, suggesting greater CO2 assimilation. Transcriptomics of daughter and granddaughter seedlings reveal that maternal conditions, rather than offspring growth conditions, mark the differences between treatments. Differentially expressed genes between treatments that are common in both daughter and granddaughter seedlings include: NRT1.1 (high affinity nitrate transporter) and some methyltransferases. Our findings suggest that quinoa transmits maternal environmental stress to its offspring, modulating their resilience. This work underscores the potential of utilizing maternal environmental conditions as a natural priming tool to enhance crop resilience against nutritional stress, in line with the efforts towards sustainable agriculture and food security.
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“Nursery techniques to improve water stress resistance traits in two shrub species from Mediterranean central Chile”

Flavia Cresta-Recasens[1], Carolina Álvarez-Maldini[1], Manuel Acevedo[2], Manuel Sánchez-Olate[1].
[1]Departamento de Silvicultura, Facultad de Ciencias Forestales, Universidad de Concepción, Concepción. [2] Centro Tecnológico de la Planta Forestal, Instituto Forestal, San Pedro de la Paz. flaviacresta@gmail.com

Nursery production techniques aim to modify morpho-physiological traits to improve performance during water stress after field establishment. Techniques such as chemical root pruning and irrigation based on plant water demand are applied for such purpose, but often lack scientific evidence in shrub species. Thus, we researched the effect of above-mentioned techniques during nursery production of *Escallonia pulverulenta* and *Azara dentata*, two native shrubs from Mediterranean central Chile. We tested two irrigation schemes: based on plant demand (CR50%) and systematic (SIS), and two root pruning treatments: control without root pruning (WoRP) and root pruning with cupper oxychloride application (WRP). We measured growth, nutritional status, biomass distribution, relative chlorophyll concentration (RCC), and pressure-volume (PV) relationship. In *E. pulverulenta*, the CR50% treatment reduced plant size (diameter and length) but increased the root-to-shoot ratio. In *A. dentata*, interaction between root pruning and irrigation affected plant size; higher stem diameter and length was observed in the CR50% *x* WRP treatment combination. In both species, WRP decreased root biomass. As expected, in both species, the CR50% treatment increased leaf nitrogen concentration and RCC. After a frost event, we observed that irrigation scheme affected survival in both species, where plants in the CR50% treatment had higher survival. Regarding PV traits, only absolute capacitance (C_{abs}) was affected in *A. dentata*, where C_{abs} was higher in systematic irrigation. Consequently, the CR50% was the treatment that mostly induced changes in morpho-physiological traits related to drought resistance in both species. However, this is currently being confirmed through a drought stress experiment.

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"Unveiling Resilience: Transcriptomic Insights into Desiccation-Tolerant Extremophile Plant Species"

Pedro B. Ferreira[1], Karla Villena[2], Humberto Gajardo[2], Olman Gomez-Espinosa[2], Giovana C. D. Saito[1], Felipe G. Scola[1], Leon Bravo[2], Helaine Carrer[1]

[1]Departamento de Ciências Biológicas, Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo - Piracicaba, São Paulo, Brasil. [2]Laboratorio de Fisiología y Biología Molecular Vegetal, Departamento de Ciencias Agronómicas y Recursos Naturales, Facultad de Ciencias Agropecuarias y Forestales & Scientific and Technological Bioresource Nucleus, Universidad de La Frontera, Temuco, Chile. pedrobf@usp.br

The climate is warming, environments are shifting, and extreme events are more frequent. Plants in both natural and agricultural ecosystems face numerous stresses, threatening productivity and ecosystem stability. However, certain extremophile plants, such as *Strombocarpa tamarugo* (Atacama Desert) as well as *Colobanthus quitensis* and *Deschampsia antarctica* (maritime Antarctica), maintain relatively high photosynthetic capacity even after desiccation stress, positioning them as outliers in the trade-off between

productivity and stress tolerance. Their closely related species - *Neltuma alba*, *Colobanthus apetalus*, and *Deschampsia cespitosa* - exhibit the expected trade-off, providing valuable ecophysiological contrasts. We hypothesized that these outlier species share genetic components driving their tolerance traits. We compared the transcriptomes of outlier/non-outlier pairs qualitatively and quantitatively under a controlled water stress experiment. In the differential expression analysis, mostly species-specific responses emerged, but remarkably, certain gene families were still shared among the outliers. Several candidate genes were cloned for functional characterization in a heterologous system. Notably, *S. tamarugo PHYTOCHROME INTERACTING FACTOR 3* (*StPIF3*) enhanced photosynthetic efficiency in T0 transgenic tobacco (13.63 ± 0.52 vs. 10.52 ± 0.11 μmol CO_2 m^{-2} s^{-1} under well-watered conditions; 8.23 ± 0.91 vs. 6.46 ± 0.67 μmol CO_2 m^{-2} s^{-1} under moderate stress). Although preliminary, these results illustrate the potential contribution of extremophile-derived genes to sustaining photosynthetic performance. Additional candidate genes are also being transformed and assessed. Collectively, these findings provide molecular and genomic insights into plant stress tolerance, contributing to the study and management of plant resilience under a changing climate.
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“Red color as a plant quality indicator in Eucalyptus: myth or reality?”

Hernández-Fuentes C.[1], Gonzalez R.[1] and Muñoz X.[1]
[1]Subgerencia de Viveros y Biotecnología. ARAUCO, Chile. carolina.hernandez@arauco.com

In the forestry industry the red color of Eucalyptus leaves has been used as an indicator of plant quality. This is because the red color in leaves is associated with greater resistance to freezing temperature in the field. However, it has been observed that plants with high levels of red color in their leaves tend to have slow growth. In this study we asked: what is the appropriate range of red color to withstand freezing temperature without losing plant quality? We selected 4 genotypes of Eucalyptus species, and 3 visual range of red color in leaves for each genotype: low (green leaves), medium (two pairs of leaves red) and high (more of two pairs of leaves red). Then, half of the plants were exposed to freezing temperature (-6°C) whilst the other half (control plants) were maintained to control temperature (20°C day and 8°C night). We found that plants with high levels of red color in leaves do not perform better after frost than control plants. Further, the recovery after freezing in plants with red leaves was slower than control plants. Thus, the red color in leaves is not a good indicator of plant quality.

“Using leaf manganese concentrations to estimate root carboxylate exudation strategies in South-American temperate rainforests on phosphorus-impoverished soils”

Dariel López[1,2], Patricio Barra[3,2], Mabel Delgado[2]
[1]Laboratorio de Fisiología y Biología Molecular Vegetal, Departamento de Ciencias Agronómicas y Recursos Naturales, Facultad de Ciencias Agropecuarias y Medioambiente, Universidad de La Frontera, Temuco, Chile. [2]Scientific and Technological Bioresource Nucleus, Universidad de La Frontera, Temuco, Chile. [3]Laboratorio de Biocontrol, Universidad de La Frontera, Temuco, Chile. dariel.lopez@gmail.com

South-American temperate rainforests primarily grow on volcanic soils rich in total phosphorus (P); however, P availability is limited for most plants due to its frequent sorption by metallic oxides and hydroxides. To overcome this, certain plant species release root carboxylates to mobilize P from the soil. However, studying root exudates in the field is challenging, leading to the recent suggestion that leaf manganese concentration ([Mn]) can serve as a proxy for root carboxylate exudation. In this study, we used leaf [Mn] to identify plant species potentially utilizing root carboxylates for P mobilization. We collected leaf and soil samples from 50 plant families across four sites, analyzing leaf [Mn] to estimate exudation patterns, with fern species as negative references and species with high leaf [Mn] (≈500 mg kg^{-1}) as positive references. The plant community leaf [Mn] was highest at the Rucamanque and Oncol sites compared to Conguillio and V.P. Rosales. All species from the families Bromeliaceae, Myrtaceae, Nothofagaceae, and Winteraceae consistently exhibited high leaf [Mn], as did *Podocarpus* and *Maytenus* trees. Trees, shrubs, and epiphytes generally had higher leaf [Mn] than ferns, mosses, and herbs. Our findings suggest that plants in P-limited soils show a greater frequency and higher average of leaf [Mn] compared to those in more P-rich soils, indicating their potential use of carboxylate exudation for P acquisition.
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“Physiological responses of two contrasting populations of *Araucaria araucana* to heat stress”

Amaranta Herrera[1], José Ortíz[1], Elizabeth Escobar[1], José Retamal[1], Luisa Bascuñán-Godoy[1], Lohengrin Cavieres[2,3], **Enrique Ostria-Gallardo**[1].
[1] Laboratorio de Fisiología Vegetal, Departamento de Botánica, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Concepción, Chile. [2]Laboratorio de Ecología, Biogeografía y Sistemática Vegetal, Departamento de Botánica, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Concepción, Chile. [3] Instituto de Ecología y Biodiversidad, Santiago, Chile. eostria@udec.cl

Araucaria araucana (Molina) Koch is the oldest conifer in South America. In Chile it inhabits the Andes Range (AR), with cold climates, and the Coastal Range (CR), with more temperate climates. In the context of climate change, an increase in the frequency and intensity of extreme temperature events (e.g. heat waves) are projected for these habitats. In the Andes, a higher frequency of heat waves is expected, while in the Coastal Range a greater thermal variability and episodes of extreme cold are expected. The objective of this work was to determine the effect of thermal stress due to high temperatures on the photochemical and physiological response of *A. araucana* plants from the Andes Mountains (Lonquimay) and the Coastal Mountains (Nahuelbuta). Under growth chamber conditions, a heat wave was simulated and physiological traits (e.g. chlorophyll *a* fluorescence, electrolyte leakage, total soluble proteins, relative water content, LT_{50}) were studied in young plants from both populations. The results of the analyzed traits show a differential capacity, particularly in the parameters of chlorophyll a fluorescence (F_v/F_m, V_j, PI), with the plants from Lonquimay (AR) being less photochemically affected by the heat wave. On the other hand, those *A. araucana* from Nahuelbuta (CR) showed higher relative water content (RWC) after the heat wave. These preliminary results suggest different mechanisms of response of *A. araucana* to heat waves depending on its origin.

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"Metabolic responses of *Chenopodium quinoa* and *Amaranthus cruentus* to heatwaves"

Felipe Asalgado[1], Estrella Zúñiga-Contreras[2], Catalina Bustamante[2], Catalina Castro-Oñate[1], José Ortíz[1], Teodoro Coba de la Peña[2], Luisa Bascuñán-Godoy[1], Lohengrin Cavieres[3,4], **Enrique Ostria-Gallardo[1]**.

[1]Laboratorio de Fisiología Vegetal, Departamento de Botánica, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Concepción, Chile. [2]Centro de Estudios Avanzados en Zonas Áridas-CEAZA, La Serena, Chile. [3] Laboratorio de Ecología, Biogeografía y Sistemática Vegetal, Departamento de Botánica, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Concepción, Chile. [4.]Instituto de Ecología y Biodiversidad, Santiago, Chile. eostria@udec.cl

Chenopodium quinoa and *Amaranthus cruentus* are key crops for global food security. They have great resilience to adverse environmental conditions, such as water deficit or salinity, being ideal crops for regions with poor soils and extreme climates. Despite the above, their metabolic responses to extreme temperature events, such as heat waves, has been poorly studied. The objective of this work was to study the global metabolic changes of *C. quinoa* and *A. cruentus* in response to a simulated heat wave event. The metabolome of plants under room temperature was compared with plants subjected to 3 days of simulated heat wave. The results show a species-specific response to the heat wave. For *C. quinoa*, a significant effect is seen in metabolic pathways related to sulfur metabolism, alanine, aspartate and glutamate metabolism, and glyoxylate metabolism. In addition, a high accumulation of osmolytes and polyamines is observed. On the other hand, *A. cruentus* is affected by metabolic pathways associated with starch and sucrose metabolism, glutathione, and the pentose pathway. Furthermore, one of the metabolites that was shown to be a central node in the metabolic networks after the heat wave was beta-mannosylglycerate. This metabolite is key for thermotolerance in extremophylle bacteria, and in plants it has only been described for *Selaginella moellendorffii*. Taken together, these preliminary results provide a broad overview of the dynamics of the most important metabolite networks and metabolic pathways in response to the heat, probably associated with their C_3 (*C. quinoa*) and C_4 (*A. cruentus*) photosynthetic metabolisms.

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“Identification of plant species from southern South America that potentially use a carboxylate-releasing strategy to mobilize phosphorus from soil”

Fabián Pereira[1], Dariel López[2], Patricio Barra[3], Diego Valdebenito[2,3], María de la Luz Mora[2,3], Marjorie Reyes-Díaz[4], Mabel Delgado [2,3].

[1]Facultad de Ciencias Agropecuarias y Medio Ambiente, Universidad de la Frontera, Temuco, Chile. [2]Laboratorio de Suelo y Planta, Instituto de Agroindustrias, Universidad de La Frontera, Temuco, Chile. [3]Center of Plant -Soil Interaction and Natural Resources Biotechnology, Scientific and Technological Bioresource Nucleus (BIOREN), Universidad de La Frontera, Temuco, Chile. [4]Departamento de Ciencias Químicas y Recursos Naturales, Facultad de Ingeniería y Ciencias, Universidad de La Frontera, Temuco, Chile. f.pereira03@ufromail.cl

Phosphorus (P) is a macronutrient limiting plant growth worldwide. Plants have developed a variety of strategies to adapt to soils with low P availability, including the exudation of carboxylates by their roots. Measuring root carboxylate exudation in the field is challenging due to its invasiveness and high costs. As an indirect measurement, leaf manganese concentration ([Mn]) has been proposed, as it has shown a positive correlation with root carboxylate exudation. Our objective was to identify plant species from southern South America that may use a carboxylate-releasing strategy to mobilize P from the soil, using foliar [Mn] as an indicator in two contrasting seasons. The research was conducted in the Ecological and Cultural Park Rucamanque, belonging to the Universidad de la Frontera, Temuco, Chile. Mature leaves were collected in several plant species and foliar [Mn] was

quantified in winter and spring. Our results suggest an active exudation of carboxylates by the species with higher [Mn] are *Caldcluvia paniculata, Maytenus boaria and Eucryphia cordifolia*. Besides, the species with lower [Mn] are *Luma apiculata, Blechnum hastatum* and *Aristotelia chilensis*. The foliar [Mn] maintains a similar trend between winter and spring for the different species evaluated, although in general, the foliar [Mn] was higher in winter season. This study provides valuable information on the nutrient acquisition strategies of native species, highlighting those that probably exude carboxylates as a strategy to access P. Understanding plant strategies to grow in P-poor soils has important implications for proposing these in future reforestation plans or agricultural polycultures.

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Biochemical characterization of aluminum-tolerant bacteria isolated from roots of *Gevuina avellana* growing in acidic soils with high aluminum bioavailability

C. Sandoval[1], C. Rabert[4], M. Astorga[5], J. Sandoval[6], G. Berríos[2,3]
[1]Facultad de Ciencias Agropecuarias y Medioambiente, Universidad de la Frontera, Temuco, Chile.[2] Departamento de Ciencias Químicas y Recursos Naturales, Facultad de Ingeniería y Ciencias, Universidad de La Frontera, Temuco, Chile. [3]Laboratorio de Suelo y Planta, instituto de Agroindustrias, Universidad de La Frontera, Temuco, Chile. [4]Instituto de Ciencias Aplicadas, Universidad Autónoma, Temuco, Chile. [5]Grupo de Investigación en nutrición y alimentación humana, Facultad de Ciencias de la Salud, Universidad Autónoma, Temuco, Chile.6Instituto de Ciencias Biomédicas, Universidad Autónoma, Temuco, Chile. c.sandoval25@ufromail.cl

Acidic soils in Chile have high bioavailability of aluminum (Al) and low availability of essential nutrients for plants such as phosphorus (P). Soluble Al (Al^{3+}) can be toxic to plants, inhibiting root growth and reducing nutrient uptake. In response, plants have developed tolerance mechanisms such as Al exclusion, accumulation and chelation. One example is *Gevuina avellana*, a native species that forms a root adaptation known as proteoid roots to capture nutrients from poor soils and is known as an Al hyperaccumulator. These roots are associated with a rich bacterial community, whose interaction could improve plant growth in acidic soils through various mechanisms. This study suggests that Al-tolerant bacteria, isolated from the rhizosphere of *G. avellana*, have growth-promoting capacities that contribute to plant tolerance in acidic soils. Fourteen bacterial strains based on repetitive intergenic DNA sequences were identified using the ERIC-PCR(enterobacterial repetitive intergenic consensus polymerase chain reaction) technique, phosphate-solubilizing and nitrogen-fixing strains were isolated using specific culture media, and the activity of the 1-aminocyclopropane-1-carboxylic acid deaminase enzyme(ACCD) was quantified by measuring alpha-keto butyrate production and indole-3-aceticacid (IAA) production using High-Performance Liquid Chromatography (HPLC). The results showed that 35% of the

strains produced IAA, 60% solubilized phosphates, which improves P bioavailability, 20% produced ACCD, which contributes to reducing ethylene levels, and 0% has the capacity for biological nitrogen fixation. These findings suggest that the bacterial community associated with *G. avellana* works in a complementary manner to promote plant growth and contributes to the plant's tolerance to Al in acidic soils.

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"Early development under low salinity improves growth and stimulates antioxidant metabolism in *Colobanthus quitensis* (Kunth) Bartl."

Carolina E. Sanhueza[1], Diego Reyes[1], Darío Navarrete[1] and Marely Cuba[1].
[1]Departamento de Ciencias y Tecnología Vegetal, Escuela de Ciencias y Tecnología. Universidad de Concepción Campus Los Ángeles. Juan Antonio Coloma 0201, Los Ángeles.
e-mail: csanhuez@udec.cl

Elevated temperatures driven by climate change have intensified global salinity, especially in coastal zones. In plants, enhanced evapotranspiration contributes to increasing salt concentrations comprising the development and inducing osmotic, ionic and oxidative stress. *Colobanthus quitensis* is a moderate salt tolerant species, and different populations of this species can withstand different salinity levels. We hypothesized that at early development, plant sensitization to low salinity could improve the development and induce a more robust antioxidant system. The experimental approach was performed under *in vitro* conditions using a population from the King George. Individuals were cultured under low salinity treatment (50 mM NaCl) and control NaCl-free for 16 weeks. After this period morphophysiological parameters and conductivity were determined. We found that the relative water content and total biomass was higher in plants developed under low salinity. Furthermore, electrolyte leakage was higher under salinity conditions, reflecting some cellular damage by osmotic pressure or ion toxicity. Analysis of antioxidant enzymes will allow us to identify the defense mechanisms of these species to face salinity stress. With the development of this research, we aim to contribute to explain mechanisms underlying responses to salt plant responses.

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"Effects of Growth Temperature on Photosynthesis in Plants from the Andes of Central Chile"

Rodrigo G. Viveros[1], Patricia L. Sáez[2], and Lohengrin A. Cavieres[1,3]

[1]ECOBIOSIS, Departamento de Botánica, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Barrio Universitario n/n, Concepción, Chile. [2]Laboratorio de Fisiología y Biología Molecular Vegetal, Instituto de Agroindustria, Departamento de Ciencias Agronómicas y Recursos Naturales, Facultad de Ciencias Agropecuarias y Medioambiente, Universidad de la Frontera, Temuco, Chile. [3]Instituto de Ecología y Biodiversidad-IEB, Concepción, Chile. cortinablanca01@gmail.com

Temperature is a key factor influencing morphology and photosynthesis in high mountain plants, driving altitudinal patterns. At higher elevations, lower temperatures often increase leaf mass per area (LMA), potentially limiting CO_2 diffusion in the mesophyll (gm) and reducing photosynthetic rates (A_N). However, most studies supporting this claim are field-based, where factors like partial gas pressure, water, and light availability vary with elevation. Additionally, observed photosynthetic changes may reflect adaptations of ecotypes to specific altitudes. Plant types also play a role, as plants in wetlands (azonal) may respond differently to temperature shifts due to water's buffering effect on air temperature. To isolate these variables, we conducted a controlled experiment using plants from two elevations (2600 and 3550 m a.s.l.), grown at daytime temperatures mimicking field conditions (15 and 20 °C). We assessed the effects of temperature on LMA, gm, and A_N. Results indicate that temperature changes did not significantly alter LMA but did affect gm and photosynthesis. Altitudinal origin and plant type (zonal vs. azonal) also influenced outcomes. This study highlights that elevation-related temperature changes impact mountain plant photosynthesis through mesophyll diffusion mechanisms, independent of LMA. It also underscores the role of plant adaptations to specific altitudes and environments, such as wetlands, in shaping physiological responses.

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