Abstract Book

1st Alpe Adria Plant Physiology Meeting

Udine - Rauscedo

5th - 6th March

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ALPE ADRIA
PLANT PHYSIOLOGY

INDEX

KEYNOTE SPEAKERS

Kristina Gruden – National Institute of biology, Slovenia

5th of March – 9:15 Library auditorium University of Udine

Using knowledge networks to decipher mechanisms of potato tolerance to abiotic stress

Stress Knowledge Map (SKM, https://skm.nib.si) is a publicly available resource containing two complementary knowledge graphs describing current knowledge of molecular interactions in plants: a highly curated model of plant stress signaling (PSS, 543 reactions) and a large comprehensive knowledge network of molecular interactions (CKN, 488,390 interactions).
Both were constructed by domain experts through the systematic curation of diverse literature and database resources. SKM provides a single-entry point for plant stress response investigations and the related growth trade-offs, through interactive exploration of current knowledge, as well as integration of experimental omics data. We will here present the data how these knowledge networks can be used to decipher responses of potato to multiple stresses, drought, heat, waterlogging and combined stresses.
The samples were analysed on multiple omics levels, from chromatin remodeling, transcriptomics, metabolomics and proteomics, to high throughput phenotyping. Knowledge networks offer a unique way to integrate these data and identify regulatory hubs.

Tomas Morosinotto – University of Padua, Italy

5th of March – 11:10 Library auditorium University of Udine

Response of photosynthesis to environmental light dynamics

Photosynthesis is a fundamental process in the biosphere, essential for primary production in all ecosystems. Environmental conditions have a strong impact on photosynthetic reactions, requiring complex modulation, specific to various species depending on their ecological niche. Photosynthesis is thus finely regulated, and plants employ photoprotective mechanisms to modulate electron pathways to dissipate excess energy and avoid potential damage from over-excitation and over-reduction.

Different plant species grown outdoors and monitored across different seasons show substantial diversity in photosynthetic properties, enabling their response to variable environmental conditions. Only a small fraction of this diversity is associated with phylogenetic distance, while the largest component is linked to the ability of each individual plant to modulate its photosynthetic performance. These results suggest that the ability to modulate photosynthetic reactions is an essential feature for plants resilience to environmental dynamics and ecological success.

Considering the impact of photosynthesis in biomass there is a strong interest in understanding if optimization of photosynthesis regulation also opens the possibility of improving light-use efficiency in crops, increasing their biomass productivity and ultimately yield.

Giuliana Tromba – Elettra-Sincrotrone Trieste S.C.p.A, Italy

5th of March – 14:05 Library auditorium University of Udine

Phase contrast micro-CT for plant physiology research: lessons learned and upcoming upgrades at Elettra

SYRMEP (SYnchrotron Radiation for MEdical Physics), the hard X-ray imaging beamline of the Elettra synchrotron light source (Trieste, I), has been operating for over 30 years offering advanced full-field X-ray imaging techniques and multiscale micro- tomography in phase-contrast mode. Powered by a standard bending magnet, SYRMEP had a relatively low X-ray flux and an energy range limited to 8.5-40 keV. This focused its application fields to relatively small samples.

The beamline is supported by two dedicated microfocus sources for conventional micro-tomography experiments (known as 'Tomolab') offering a complementary setup, given their wide X-ray spectrum and large beam, capable of studying bulky samples in a single scan. Being independent setups, access to these sources is always available also during the Elettra shutdown period.

The next generation of SYRMEP, currently under construction as part of the Elettra 2.0 upgrade program, is designed to overcome the limitations of the present beamline and offer state-of-the-art phase contrast imaging techniques with significant advancements, including an extended X-ray energy range, a higher flux and enhanced achievable spatial resolution. In its final configuration, the new setup will operate in an energy range between 10 and 130 keV for monochromatic imaging. This range will be further extended to about 300 keV when using pink beam modality. The broader energy interval will allow to encompass the study of bulky and denser samples and to expand the research horizons to paleontology, paleo-anthropology, materials science and medical research. This talk will present the outcomes achieved by the beamline in the field of plant imaging and the perspectives offered by the instrumental upgrade.

Stefan Mayr – University of Innsbruck, Austria

5th of March - 16:30 Library auditorium University of Udine

Under pressure - insights into xylem and its hydraulics

Plant water relations are frequently under pressure. Water transport is passively driven by transpiration, which generates negative pressure (i.e. negative water potential), transduced from leaves to the roots and to the soil via the water columns in the transport system. Negative water potentials also develop when the stomata are closed but soil water supply is limited.

Trees, due to long transport pathways from the soil to the crown, can reach remarkably low water potentials. The stability of water columns under these conditions is only possible due to optimized structures, enabling both, sufficient transport capacities (hydraulic efficiency) and prevention of interruptions in water columns (hydraulic safety). In the xylem, various structural features of the transport conduits, including their connections via bordered pits, contribute to maintaining hydraulic efficiency and safety.

Under climate change, tree water relations are increasingly under pressure, when drought intensities and frequencies as well as temperatures (and thus water vapor deficits) increase. This leads to lower water potentials, which may exceed species- specific thresholds in hydraulic safety and thereby critically reduce hydraulic efficiency.

Juan Jiménez – University of Copenhagen, Denmark

6th of March - 09:15 Auditorium VCR Research center

Root responses to soil flooding

Flooded soils, where pore spaces are saturated with water for transient or prolonged periods, impose stress conditions for plant growth. During flooding, oxygen (O_2) is rapidly depleted by root respiration and microbial activity, leaving the soil practically devoid of O_2. Prolonged flooding also alters redox conditions in rhizosphere, leading to the reduction and accumulation of micro-nutrients such as iron, manganese and sulfur, to phytotoxic levels for plant growth.

This presentation will address the principal stress factors plants experience under flooding and the root traits associated with flooding adaptation. I will emphasize the root anatomical, morphological and physiological characteristics that enhance O_2 diffusion from shoots to roots and the efficient use under hypoxic conditions.

In addition, I will discuss the chemical characterization and location of apoplastic barriers that restrict radial O_2 loss from roots to rhizosphere and limit the entry of toxic compounds form the rhizosphere into the root. Together, these mechanisms illustrate how roots balance internal aeration and protection in flooded environments, providing key insights for crop resistance to flooding conditions.

Andrea Pitacco – University of Padua, Italy

6th of March - 11:10 Auditorium VCR Research center

Fluxes across boundaries: plants shaping their own environment

Plants can survive in very variable and diverse environments, facing strong physical forcings like heavy radiation loads, extreme temperature and discontinuous water availability. Exploiting their position at the soil−atmosphere interface and leveraging basic thermodynamical processes, they can successfully handle their metabolism, growth and development in a broad spectrum of conditions. Exposed to rhythmic gradients (of temperature, moisture, carbon dioxide, etc.), they respond by establishing strong fluxes of heat and matter with the surrounding atmosphere, themselves altering local microclimate. While the physiological control of water vapor and carbon dioxide have been classical research themes of plant ecophysiologists for a long time, they have seldom focused on the relevance of external factors affecting – and possibly "regulating" – these fluxes.

External factors are mostly related to the variable conductance of the air around leaves, linked to the kinematics of the boundary−layers which can be irregularly dominated by laminar or turbulent regimes as wind gusts penetrate and interact with the canopies. The dynamic partitioning of kinematic regime has huge consequences on air mixing and therefore on boundary−layer conductance and transport processes. While any analysis of flux−gradient relationships– at any scale (leaf, plant, plot) – is usually performed at the steady−state, transient conditions can lead to an enhanced variability in the local microenvironment, including plant organs.

Starting from a thorough analysis of physical principles determining leaf and canopy energy−budget partitioning, the presentation will deal with fundamental properties of canopy microclimate as measured in a properly instrumented vineyard belonging to the Integrated Carbon Observation System network, operated for 10 years by the University of Padua.

ORAL PRESENTATIONS

Pietro Furnari – University of Messina, Italy

So, we've been measuring membrane stability wrong all along?

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Membrane integrity is a key cellular trait linked to plant vitality, and its loss is among the earliest indicators of stress-induced dysfunction. Relative electrolyte leakage (REL) is widely used as a simple and cost-effective proxy to assess membrane damage and to compare plant vulnerability or resistance to biotic and abiotic stresses. However, REL protocols vary substantially among studies, particularly in incubation time and membrane disruption procedures, potentially affecting measurement accuracy and comparability.

We compared three commonly used REL protocols to assess how methodological variation influences REL measurements. We hypothesized that leaf mass per unit area (LMA), as a proxy of leaf structural investment and mechanical toughness, modulates electrolyte leakage by affecting water penetration and ion diffusion kinetics. This effect is expected to be particularly pronounced under shorter incubation times or milder membrane disruption procedures. REL was measured in two species with contrasting LMA: *Feijoa sellowiana* O. Berg (184 $g \cdot m^{-2}$) and *Phaseolus vulgaris* L. (21 $g \cdot m^{-2}$).

Our results confirmed that REL responses depend on the interaction between leaf structural traits and protocol-specific parameters. High-LMA leaves exhibited slower electrolyte release and greater sensitivity to incubation time and membrane disruption methods. These patterns were consistently supported by independent analyses of cell vitality, confirming the biological relevance of REL measurements. Overall, our findings indicate that while REL is a powerful and accessible tool for assessing plant stress vulnerability, its comparative application across species with contrasting leaf traits requires careful methodological calibration.

Rebeka Strah – National institute of biology, Slovenia

How Cabernet Volos and Fleurtai respond to water deficits – integrating transcriptomic and metabolomic data

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Recurrent drought events during the summer are threatening the sustainability of viticulture around the world. The changing environment can also influence the incidence of plant diseases. In this context, two new fungus-resistant grapevine genotypes, Cabernet Volos and Fleurtai were investigated, with emphasis on their response to water deficits. We examined the grapevine response to water stress on the transcriptomic and metabolomic level by combining the analysis of high-throughput RNA-Seq and metabolite accumulation data with the data of plants' stem water potential. The expression of approximately 800 genes and nine metabolites was found to be changed due to the decreased water potential in at least one of the cultivars. Most of the changes were common in both cultivars, which included accumulation of amino acids, heat shock proteins, and ABA response and signaling. Moreover, correlation was found between stress-responsive metabolites and their biosynthetic genes. Smaller groups of genes with different expressions in Cabernet Volos and Fleurtai were also identified.

Irene Luzzi – University of Padua, Italy

Unraveling chromatin-mediated mechanisms shaping drought stress memory in tomato

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Drought is a major environmental stressor that limits plant growth and productivity. To cope with water deficit, plants modulate gene expression through molecular and epigenetic mechanisms. To dissect drought-induced memory, we investigated physiological, transcriptomic and chromatin-based responses to mild and severe-recurrent drought in two tomato genotypes, M82 and Lucariello, using a multi-omics approach. In M82, mild-drought reduced stomatal conductance and transpiration while increasing chlorophyll content, indicative of a drought-avoidance strategy that was fully reversible upon rehydration. Transcriptomic analyses revealed extensive gene-expression reprogramming under drought and an attenuated response after rewatering, outlining a two-phase adaptive strategy. Subsets of genes displayed positive and negative transcriptional memory, suggesting mechanisms that enable plants to "remember'' prior stress exposure. The effects of drought on histone-mark distribution were examined through immunolocalization. Immunofluorescence revealed an enrichment of the H3K27me3 signal. Consistently, H3K27me3 ChIP-Seq profiling showed that this mark is negatively associated with dehydration-responsive memory genes. Furthermore, integrating transcriptomic and chromatin datasets provided insights into how Lucariello responds to severe-recurrent drought events followed by rewatering. The identification of transcriptional-memory targets, together with dynamic changes in H3K4me3, indicates that stress-memory mechanisms are gene-subset-specific. Three categories of stress-memory genes were identified: type-I, showing stable transcriptional and/or H3K4me3 changes upon a second dehydration event; type-II, initially repressed and later re-induced, displaying H3K4me3 enrichment during the second stress exposure; negative-delayed memory genes, characterized by hyperinduced transcriptional and chromatin responses after repeated stress. Overall, this work provides a genome-wide, integrative framework for understanding chromatin-mediated stress memory in tomato.

Anja Mavrič Čermelj – University of Ljubljana, Slovenia

Silicon supplementation mitigates PEG-induced drought stress in hydroponically grown barley

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Climate change threatens to reduce food production by intensifying drought stress and reducing crop productivity. Silicon (Si) supplementation is a promising approach to improve plant tolerance to abiotic stresses. This study evaluated the effects of Si supplementation on the morphological, physiological, and biochemical responses of barley (*Hordeum vulgare* L.) under drought stress. Barley seeds were sterilized, germinated, and grown in aerated nutrient solutions under controlled light and temperature conditions. Plants were supplied with either 0 mM Si (Si0) or 1 mM Si (Si+). Drought stress was subsequently induced in half of the treatments by adding 10% polyethylene glycol (PEG), resulting in four treatments: Si0, Si+, Si0PEG, and Si+PEG. After 46 days from germination, plant growth, physiological parameters, and biochemical traits were analyzed. Drought stress significantly reduced plant height, biomass, and the number of green leaves, while increasing proline accumulation and lipid peroxidation in leaves. Si supplementation mitigated these adverse effects by increasing the number of green leaves, maintaining leaf dry biomass, improving the potential photochemical efficiency of photosystem II (Fv/Fm), and reducing malondialdehyde content under drought conditions. Si-treated plants also exhibited higher α-tocopherol levels, indicating enhanced antioxidant protection. Although drought altered chloroplast pigment composition, the violaxanthin–antheraxanthin–zeaxanthin cycle was not fully activated. Si supplementation enhanced drought tolerance in barley by improving antioxidant defences and maintaining plant growth and biomass, suggesting its potential use as a sustainable strategy to mitigate drought stress in crops.

Azzurra Di Bonaventura - University of Udine, Italy

Extracellular vesicles from Coffea arabica L. cell suspension cultures: isolation and proteomic insights

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Beyond to their biological roles in plants, extracellular vesicles (EVs) are gaining relevance in biotechnological, medical and agricultural fields. In this study, we developed a protocol for isolating and characterizing EVs from *Coffea arabica* cell suspension cultures (CSCs), offering a scalable, non-disruptive production system. EVs were isolated via differential ultracentrifugation, resulting in two distinct fractions (100,000×g and 125,000×g). Transmission electron microscopy confirmed that both fractions contained vesicular structures with dimensions consistent with typical plant EVs. While morphologically similar, proteomic analysis revealed significant compositional differences. The 100,000×g fraction was enriched with the cell periphery and plasma membrane proteins, while the 125,000×g fraction predominantly contained extracellular region proteins. Both fractions exhibited established transmembrane, transport, and soluble EV-associated protein markers with negligible contamination from non-EV intracellular proteins.
These results demonstrate that coffee CSCs actively secrete EVs without requiring mechanical cell disruption. CSC-derived EVs therefore represent a reliable, high-purity and scalable platform for downstream functional studies and biotechnological applications.

Arianna Del Pino - University of Udine, Italy

Responses of Alpine grassland plants to heat wave are mediated by changes in functional traits, primary production and CO2 fluxes

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The Alps are facing more frequent summer heat waves that are threatening alpine ecosystems and their biodiversity. These events can greatly impact primary alpine grasslands, key providers of ecosystem services. Recent studies showed that combined drought and heat stress affects species and community-level responses, yet the role of stress timing and duration remains unclear. This study addresses this gap by examining heat wave effects on alpine grasslands at different growth stages, focusing on species representing the three main plant functional types: sedges, grasses, and forbs.

Heat waves were simulated using shelters that excluded rainfall and increased temperature. Treatments varied in timing and duration: (1) early and prolonged (start to peak of season, ~2 months), (2) early (1 month after growth resumed), (3) late (1 month before peak), and (4) control (no stress). Plant responses were evaluated through morphological and physiological traits analysis. Specifically, leaf traits and pigment concentrations (chlorophylls, flavonoids, carotenoids) were assessed. At the community level, the focus was on primary production (i.e. above ground biomass) and CO_2 fluxes.

We hypothesize that early stress may accelerate phenology and boost early growth, while prolonged or late exposure reduces productivity and induces early senescence. Our findings will improve understanding of alpine vegetation resilience under future climate extremes, guiding adaptive conservation strategies.

Luca Redivo – University of Trieste, Italy

Intraspecific variability of turgor loss point in *Carpinus betulus* L. populations

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Climate-induced drought is a major driver of forest decline. Understanding intraspecific variability of drought tolerance is crucial for sustainable forest management. We investigated the intraspecific variability of drought tolerance in 11 Northern Italian populations of *Carpinus betulus*, selected along an aridity gradient and grown in pots in a nursery under the same environmental conditions. A large-scale phenotypic screening was conducted on ~1,100 saplings to determine turgor loss point (TLP), specific leaf area and leaf dry matter content, as well as growth rate. Results showed significant inter-population variability in TLP, partly associated with summer climatic stressors at the seed source, as well as significant intra-population differences in drought tolerance. A controlled water-stress experiment performed in 2025 on a sub-set of 4 populations revealed that *C. betulus* displays an isohydric behavior, maintaining leaf water potential through strict stomatal control, while simultaneously showing significant capacity for osmotic adjustment (ΔTLP) to sustain turgor. The Sedico population displayed the highest physiological plasticity. These findings highlight the importance of local adaptation and phenotypic plasticity in shaping the response to drought of *C. betulus*.

Carlotta Musso – University of Innsbruck, Austria

Physiological responses of Alpine dwarf shrubs to the extreme green roof's conditions

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Green roofs enhance urban green spaces and biodiversity, when local, functionally diverse species are used. However, the harsh conditions on roofs necessitate careful species selection. This study investigated the suitability of four Alpine dwarf shrubs (*Arctostaphylos uva-ursi*, *Vaccinium myrtillus*, *V. vitis-idaea*, *Calluna vulgaris*) and, for comparison, the Mediterranean shrub *Salvia officinalis*, in experimental green roof plots with substrate depths of 10 cm (Plot10) and 30 cm (Plot30) under temperate climate. Microclimatic conditions were continuously monitored and seasonal and daily variations in leaf water potential, leaf temperature, transpiration, and photosynthesis were recorded during humid and dry periods. In Plot30, temperature changes were less extreme, and the substrate retained more water, resulting in lower drought stress than in Plot10. Nevertheless, species-specific physiological responses to substrate depth and drought intensity were observed. *A. uva-ursi* and *V. vitis-idaea* performed best: the former remained above its hydraulic vulnerability threshold (Ψ_{50}) in both plots, and the latter in Plot30. *S. officinalis* achieved the highest gas exchange and vigorous growth in Plot30 and maintained favourable water status in both plots. Conversely, despite strict stomatal control, *C. vulgaris* and *V. myrtillus* exceeded their Ψ_{50} during drought in Plot10 and experienced dieback. We conclude that Alpine dwarf shrubs can grow on green roofs, but preferably on deeper substrates, and can broaden the range of species used for temperate green roofs. We suggest alternating patches of low and high substrate depths to better support shrub survival and account for species-specific physiological responses, without necessarily increasing the overall weight on buildings.

Giai Petit – University of Padua, Italy

Axial scaling of xylem traits, water potential gradient, embolism vulnerability and phenotypic plasticity

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Xylem vascular elements vary in lumen and pit size along the soil–plant–atmosphere continuum, from transpiring leaves to absorbing roots. The axial variation of these traits determines the shape of the water potential gradient from leaves to roots, as well as embolism resistance at different positions along the hydraulic pathway. The axial scaling of conduit lumen diameter appears to be convergent among vascular plants, and pit traits may also follow convergent scaling, although empirical evidence remains limited. Although the overall range of variation is narrow, it may nonetheless encompass differences in the xylem hydraulic safety margin (i.e., the difference between the local xylem water potential and the local P50 - the water potential at which 50% of conductivity is lost) at different points along the pathway.

Here, I discuss how differences in axial anatomical scaling, even within this relatively narrow range of variation, may reflect distinct patterns of acclimation and adaptation to soil drought and high vapor pressure deficits.

Patrizia Merkel – University of Innsbruck, Austria

Seasonal dynamics of pigments and antioxidants and their response to recurrent drought in Picea abies and Larix decidua

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Forests provide vital ecosystem services, yet they are becoming increasingly vulnerable to climate change-related stressors, particularly recurring droughts. Our study investigated whether repeated summer droughts trigger distinct metabolic responses in montane conifers that could explain their species-specific sensitivity to or resilience against drought.
We examined *Picea abies* (L.) H. Karst. and *Larix decidua* Mill. at a long-term ecosystem research site in the Kaserstattalm forest (Tyrolean Alps), situated at an elevation of 1960 m. From 2016 to 2023, the trees were subjected to experimental summer droughts using rainout shelters. Needle samples were collected from two trees per plot in three drought-treated and three control plots. Concentrations of pigments and tocopherols, as well as the redox state of the glutathione pool (GSH/GSSG), were quantified by HPLC in combination with GC-MS-based metabolite profiling on eleven occasions for *P. abies* and eight for *L. decidua*, from summer 2023 to summer 2024 (i.e. the first year after drought cessation). Additionally, glutathione and pigments were analysed in control and drought-stressed trees at the Kranzberg forest (Bavaria) to investigate the legacy effects of drought.
Both species exhibited pronounced seasonal dynamics in all analyzed metabolites. However, no statistically significant differences in pigment, tocopherol or glutathione content were detected between drought-treated and control trees. Analysis of untargeted metabolites revealed only a few to be statistically significant out of a total of 147.
The absence of detectable differences in targeted metabolites between drought-exposed and control trees, despite previously reported reductions in growth induced by drought, suggests a substantial degree of metabolic acclimation following prolonged exposure to recurrent drought.

Marianna Grohar – University of Ljubljana, Slovenia

Role of light and temperature in apple ripening: the case of preharvest pruning stress

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This study examined the effects of preharvest pruning on the physiological and biochemical stress responses of ‘Topaz’ apple fruit. Shaded, continuously sun-exposed, and previously shaded fruit suddenly exposed to full sunlight after pruning were compared. Summer pruning created abrupt light and temperature stress, with skin temperatures of exposed fruit reaching up to 40 °C. The sudden exposure of shaded fruit triggered notable stress responses, especially in phenolic compounds content. However, pigment levels in these fruits remained lower than in continuously sun-exposed fruit, indicating that while stress stimulates anthocyanin synthesis, it also imposes physiological limitations. These findings underscore the role of pruning-induced light and temperature stress in modulating apple ripening and highlight the importance of canopy management in balancing fruit quality and stress exposure.

Filippo Sanna – University of Udine, Italy

Exploring volatile compounds for the early detection of Neopestalotiopsis clavispora: emerging grape trunk disease

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This study aimed to characterise the volatile organic compounds (VOCs) profile of *Neopestalotiopsis clavispora*, an emerging grapevine trunk pathogen and to identify characteristic volatile fungal metabolites as potential infection biomarkers. *N. clavispora* was cultured on an agar medium containing grapevine wood sawdust (10%) derived from Cabernet Sauvignon and Sauvignon Blanc vines, in sterile vials (10 mL), for seven days at 25 °C. The VOCs in the vial headspace were analysed by SPME-GC–MS. For the *in vivo* assay, a fungal conidial suspension (20 µL, 1×10^5 conidia/mL) was inoculated into Sauvignon Blanc twigs by holes drilled with a wood bit. The twig roots were immersed in boxes containing tap water, and the inoculated top part was inserted into a sterile plastic box (94 x 94 x 352 mm) to concentrate the VOCs. The twigs were then maintained at 20 °C for 21 days, with a 12-hour light/dark cycle. After incubation, fibre DVB/CAR/PDMS was used to collect the VOCs, which were then analysed using GC–MS. In both the *in vitro* and *in vivo* experiments, the control group comprised agar media and twigs that were not inoculated with the pathogen. Multivariate analysis revealed distinct clustering of VOCs according to the growth medium, reflecting differences in grapevine cultivar and plant–pathogen interactions. However, the preliminary VOCs profile of grapevine twigs showed qualitative changes in volatile emissions following fungal infection. Overall, these findings provided a basis for identifying specific volatile metabolites as potential biomarkers of infection, emphasising the importance of VOCs in microorganism–plant interactions.

Kris Pirih – University of Ljubljana, Slovenia

At the Edge of Comfort "Plasticity of tomato under temperature stress"

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The ability of plants to continually adjust their growth and physiology enables them to survive harsh environmental situations. We investigated how tomato (*Solanum lycopersicum*) seedlings respond and recover from a four-day exposure to: low (15/5 °C), optimal (25/20 °C), and high (40/25 °C) temperatures. A comprehensive assessment was achieved by combining chlorophyll fluorescence imaging, multispectral and 3D phenotyping, and gas-exchange measurements. Both low and high temperatures induced transient decreases of Fv/Fm. However, full recovery occurred within three days, demonstrating a high PSII repair capacity. Fluorescence measurements conducted at a common temperature revealed contrasting acclimation strategies. Low temperature stress maintained higher Fq′/Fm′, ΦNPQ, qL, and NPQ(t), together with elevated anthocyanin accumulation, indicating a conservative photoprotective response. In contrast, high temperature stress reduced these parameters, increased ΦNO, and induced higher chlorophyll content, suggesting structural reinvestment in the photosynthetic apparatus following heat-induced impairment. Despite turbulent PSII responses under high temperature, net photosynthesis declined only under low temperature during stress, while high temperature did not limit photosynthesis relative to control. Respiration, stomatal conductance, and transpiration increased under high temperature and decreased under low temperature during stress, but fully recovered after stress removal. Despite rapid physiological recovery, both temperature extremes left a persistent morphological legacy. Plant volume remained reduced up to nine days after stress; high temperature primarily decreased leaf area, whereas low temperature reduced plant height and overall growth. Together, these results demonstrate that tomato phenotypic plasticity enables distinct, temperature-dependent strategies that sustain performance "at the edge of comfort".

Marta Sartor – University of Udine, Italy

Take a breath: relationship between oxygen consumption and carbon reserves in vine cuttings during cold storage

Sartor, Marta[1*]; *Nawaz, Ayesha Fazal*[1,2]; *Pedersen, Ole*[3]; *Pichierri, Alessandro*[4]; *Gargiulo, Sara*[1]; *De Luca, Elisa*[4]; *Zancani, Marco*[1]; *Zambon, Yuri*[4]; *Casolo, Valentino*[1]

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Preserving woody crop cuttings in cold storage rooms is critical to maintain their physiological viability and ensure optimal field performance upon transplanting. However, the effect of temperature on the cutting's metabolic activity during storage and on subsequent transplanting success and growth remains unknown. This study explores oxygen consumption, non-structural carbohydrate (NSC) dynamics, and antioxidant capacity as indicators of the physiological conditions of grapevine grafted cuttings stored in darkness at 2.5 °C, 4°C, and 10°C in controlled rooms. Measurements were conducted on freshly harvested grapevine grafted cuttings to investigate the influence of temperature on storage duration. We measured oxygen concentration in bud, rootstock, and root using an optical oxygen sensor embedded in a hypodermic needle. Oxygen consumption varies significantly across distinct tissues, with a gradual increase from 2.5°C to 10°C, suggesting altered respiratory activity during prolonged storage at higher temperatures. NSCs were analyzed on the same tissues, showing an initial sugar accumulation as a result of starch hydrolysis in roots. After 28 days of conservation, sugars gradually decreased over time in all organs, more rapidly at 10°C. Together with soluble NSC, we observed a reduction in antioxidant capacity, measured as Oxygen Radical Absorbance Capacity (ORAC), suggesting a loss of cryoprotection during long storage of vine cuttings. These findings enhance the understanding of tissue-specific metabolic responses during cold storage and provide valuable insights into the physiology of grapevine cuttings during cold storage conditions.

Valeria De Rosa – University of Trento, Italy

Lighting up resistance: UV-C reshapes secondary metabolism enhancing downy mildew tolerance in grapevine

Authors: De Rosa, Valeria[1*]; *Giovannini, Oscar*[2]; *Zini, Erica*[1]; *Bignardi, Alessandro*[1]; *Zanoni Giorgio*[2]; *Masuero, Domenico*[2]; *Berardinelli, Annachiara*[1,3]; *Faralli, Michele*[1]

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Plasmopara viticola, the causal agent of grapevine downy mildew, poses a significant threat to viticulture and is managed through intensive use of chemical fungicides. While downy mildew-tolerant varieties offer a sustainable alternative, their adoption remains limited and finding effective complementary control strategies is crucial. This study evaluates the efficacy of UV-C radiation as a potential elicitor of plant resistance under controlled conditions. Using a bespoke platform, ten experiments were conducted on leaf disks of a disease susceptible cultivar (*Vitis vinifera* cv. Pinot noir) and a tolerant hybrid (cv. Johanniter) to determine the threshold between UV-C-derived phytotoxicity and effective resistance induction. We show that UV-C radiation significantly reduced disease severity in both genotypes ($p < 0.001$), while exhibiting higher efficacy in Johanniter at lower dosages compared to those required in Pinot noir. This heightened efficacy in the tolerant genotype was linked to a superior basal concentration of defence-related stilbenes, whose accumulation was further increased by UV-C exposure. Metabolomic analyses revealed a tissue-specific modulation of secondary metabolites: UV-C induced an increase in flavonoids within the epidermis, while simultaneously shifting the metabolic flux toward stilbene production, presumably, in the mesophyll. These findings highlight a clear synergistic effect between UV-C treatments and genetically determined *P. viticola* tolerance, providing support for future field applications.

POSTERS

Adriano Losso – University of Innsbruck, Austria

Late-spring frost-induced xylem embolism can be fatal for newly established tree seedlings

Authors: Losso, Adriano[1*], *Stegner, Matthias*[1]. *Mayr, Stefan*[1] and *Beikircher, Barbara*[1]

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Freezing is one of the main factors that affect the survival of tree seedlings. However, due to the methodical difficulties posed by small and fragile newly established seedlings, research into the impact of freezing temperatures has focused primarily on the impairment of their living tissues, with the potential effects on their hydraulics remaining unexplored.

We investigated whether a single freeze-thaw cycle on the hypocotyls of 5-8-week-old *Acer pseudoplatanus*, *Sorbus aucuparia*, *Larix decidua* and *Pinus cembra* seedlings would affect whole-shoot hydraulic conductance (K_{shoot}). We also monitored embolism formation via ultrasonic acoustic emissions (AEs) of the hypocotyls during a freeze-thaw cycle, and determined the cold hardiness of leaves/needles exposed to different subzero temperatures.

A single freeze-thaw cycle significantly impaired angiosperms K_{shoot}, whereas the conifer hypocotyls showed greater resistance to freeze-thaw-induced xylem embolism. The maximum number of AEs was always observed when freezing happened, indicating that most xylem embolisms occurred during the initial formation of ice. Deciduous leaves and needles showed substantial damage at temperatures already below −2°C, while *P. cembra* needles remained unaffected even at −5°C.

The results suggest that freezing stress can heavily affect the fitness of newly emerging seedlings. Therefore, the increased frequency of spring frosts in European forests could threaten the survival of newly established tree seedlings. This will be important for our understanding of forest regeneration and restoration in the context of ongoing climate change.

Nicole Furlan – University of Padua, Italy

Auxin-based Treatments as Tools to Modulate Ripening Dynamics in Wine Grapes

Authors: Furlan, Nicole [1], Canton, Monica [1], Shmuleviz, Ron [2], Amato, Alessandra [2], Zenoni, Sara [2], Zamboni, Anita [2], Fasolil, Marianna [2], Tornielli, Govanni Battista [1]

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Increasing global temperatures are advancing grapevine phenology and shifting ripening to warmer periods. This negatively impacts grape and wine quality by altering the critical balance between sugars, acidity, phenolics, and aroma compounds. Plant growth regulators represent a promising strategy to delay ripening and mitigate these effects. This study assessed the impact of auxin-based treatments on grape ripening dynamics, berry composition, and molecular regulation across different grape cultivars. Field trials were conducted in commercial vineyards in the Veneto region of Italy. Clusters of the white cultivars Glera and Pinot Grigio, and the red cultivar Corvina were treated before veraison with 1-naphthaleneacetic acid (NAA). Ripening dynamics were monitored through weekly berry sampling from veraison to harvest. In selected trials, transcriptomic analyses were performed to investigate treatment-induced gene expression changes. NAA consistently delayed veraison and ripening progression, postponing sugar accumulation and slowing acid degradation, albeit with cultivar-dependent differences. In Glera and Pinot Grigio, the treatment resulted in a general delay in sugar accumulation, whereas in Corvina, it promoted a more balanced anthocyanin-to-sugar ratio. Transcriptomic analyses revealed a general postponement of the ripening program, with strong modulation of auxin-related genes and genes involved in other hormonal pathways, including ABA, ethylene, gibberellins, and brassinosteroids, highlighting the role of hormonal crosstalk in ripening regulation. These results support the use of auxin-based treatments as a promising adaptive vineyard management strategy to mitigate the effects of climate change and help preserve grape and wine quality.

Martina Tomasella – University of Trieste, Italy

Automated optical leaf pressure-volume curves for turgor loss point estimation

Authors:Tomasella, Martina[1*]; *Stella, Carlo*[2]; *Righele, Marco*[2]; *Biruk, Lucìa Nadia* [1,3] and *Nardini, Andrea*[1]

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Leaf water potential at turgor loss point (ΨTLP) is a pivotal drought tolerance parameter, but its proper determination can be time-consuming. We propose an automated method for leaf pressure-volume (P-V) analysis and we tested it for *Helianthus annuus*, *Arundo donax* and *Laurus nobilis* species.

P-V curves were obtained by continuously measuring water potentials (Ψ) with a leaf psychrometer and the "dehydration level" (DL) with an optical leaf sensor (pocket Leaf Water Meter, pLWM) while whole branches or sole leaves were dehydrating on the bench. DL is a parameter derived from photon attenuation during light transmission through the leaf and is strictly related to leaf water content. The obtained ΨTLP and the osmotic potential at full turgor (π0) were compared with those estimated from two currently used methods, i.e. the classical P-V curves (obtained by coupling Ψ measured with a Scholander pressure chamber with water content) and the osmometric method (based on determination of π0).

Optical P-V curves were similar in shape to the classical ones, showing a typical linear relationship between $-\Psi^{-1}$ and DL after turgor loss point. Moreover, the two methods were consistent in the estimation of ΨTLP and π0, while in some cases the osmometric method overestimated ΨTLP and/or π0. The proposed automated technique represents a promising alternative to classical, labor-intensive P-V curves for reliable ΨTLP determination.

Monica Canton – University of Padua, Italy

Physiological and molecular responses of grapevine to repeated water stress

Authors: <u>Canton, Monica</u> [1,2]; Meggio, Franco [1,2]; Mirone, Francesco[1]; Pichierri, Alessandro[3]; Casolo, Valentino[3]; Tornielli, Giovanni Battista [1,2]; Pitacco, Andrea [1,2]*

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The frequency of consecutive and even extreme drought events is increasing in the Mediterranean region, directly affecting grapevine physiology and shaping the molecular strategies that grapevine plants employ to cope with recurring water stress. This study evaluates the effects of two subsequent drought cycles, each followed by rewatering, applied on potted vines of Vitis vinifera L. cv. Sauvignon blanc, in a semi-controlled tunnel. Physiological assessments were combined with transcriptomic analysis, performed on leaf samples collected every six hours during the last day of drought cycle and subsequent rewatering. Chlorophyll fluorescence revealed persistent photoinhibition after severe drought. Variations in non-structural carbohydrates (NSC) concentrations across treatments and diurnal cycles indicated alterations in carbon metabolism. The study showed that NSC are mobilized differently depending on drought severity and that drought effects on photosynthesis and NSC are not fully reversible upon rewatering. RNA-Seq results showed temporal and cycle-dependent dynamics in genes associated with carbohydrate metabolism, abscisic acid metabolism and signaling, and photosynthesis during drought events. By analyzing gene expressions across the day in both drought cycles, we observed conserved and distinct transcriptional patterns, with different processes activated or repressed depending on the time of day and the cycle. Conserved genes such as galactinol synthase and dehydrin were present in both cycles most of the time. On the other hand, it was observed that plants change from immediate defense and stress mitigation in the first drought cycle to more centered on metabolic changes and adaptive adjustments during the second drought. These findings suggest that grapevines adjust their molecular responses after an initial drought episode, consistent with stress-priming mechanisms, and may "remember" prior stress to better cope with subsequent water deficits. This fine-scale temporal perspective provides insight into the strategies that grapevine uses to survive recurring drought, with relevance for viticulture under climate change.

Mateja Germ – University of Ljubljana, Slovenia

Silicon improves growth and photosynthetic performance in drought-stressed cucumber grown hydroponically

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Water deficit is one of the most critical environmental factors limiting plant growth and photosynthetic performance. Silicon (Si) has been shown to enhance structural, physiological, and biochemical mechanisms that improve plant tolerance to drought stress. The study examined the effects of Si on growth and physiological responses of cucumber (Cucumis sativus L.) under drought stress in a hydroponic system. Seeds were sterilized and germinated, and seedlings were transferred to hydroponics in growth chambers. Six treatments were established (Si+PEG, Si0PEG, PEG, Si+, Si0, nutrient solution (NS)) with six replicates per treatment. Si was supplied as sodium silicate, drought stress was induced using 10% PEG-6000 and sodium concentration was adjusted using NaCl. Morphological, physiological, and biochemical analyses were performed after two weeks of stress exposure. Under drought stress, plants treated with Si+PEG showed higher root and shoot dry weight compared with Si0PEG plants, indicating that silicon improved growth and enhanced water uptake capacity. Similarly, Si+PEG plants exhibited higher potential photochemical efficiency of PS II (Fv/Fm) and chlorophyll a content than Si0PEG, suggesting better preservation of the photosynthetic apparatus. Proline levels were also elevated in Si+PEG plants compared to Si0PEG, reflecting enhanced osmotic adjustment. Interestingly, the Si+ treatment (Si with NaCl, without PEG) showed the highest Fv/Fm and chlorophyll a content, the lowest proline concentration, and the highest shoot dry weight among all treatments. This suggests improved plant performance under mild salinity and indicates a beneficial contribution of Si to stress acclimation. Our results indicate that Si alleviated the negative effects of drought, indicating its role in enhancing plant tolerance under water-limited conditions.

Andrea Nardini – University of Trieste, Italy

Species-specific tree desiccation risk under hot drought correlates to hydraulic traits but not to thermal tolerance

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Extreme drought episodes coupled to heat waves are predicted to become more common and intense in the near future, leading to 'hot droughts'. High air temperatures rise atmospheric vapour pressure deficit, increasing the evaporative demand and worsening the effects of reduced soil water availability, and might cause tissue temperatures to surpass critical values leading to membrane disruption and tissue death. Hot droughts have produced massive effects on forest ecosystems, causing extensive canopy dieback and tree mortality on a global scale. The identification of tree species more tolerant to hot droughts is crucial for forest management, and requires an understanding of the physiological mechanisms and related functional traits underlying species-specific vulnerability to such events and to their drivers, namely water shortage and high temperatures. We leveraged the exceptional hot drought that occurred in the Classical Karst area in summer 2022 to investigate eventual correlations of species-specific desiccation patterns with physiological indicators of drought tolerance (turgor loss point, TLP; vulnerability to xylem embolism, P_{50}) vs thermal tolerance (critical temperature inducing damage to photosynthetic efficiency, T_{50}). Desiccation rates in populations of nine different woody species, based on visual estimates of the health status of more than 2400 individual trees, were strictly correlated to both TLP and P_{50}, but completely independent of T_{50}. We conclude that functional traits related to drought tolerance are better predictors of tree species vulnerability to hot drought episodes, compared to traits connected to thermal tolerance.

Lucia Biruk – University of Padua, Italy

No xylem phenotypic plasticity in branchwood of *Picea abies* across a soil water availability gradient

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It is widely accepted that under reduced water availability, plants typically produce xylem conduits more resistant to embolism formation, at the expense of hydraulic conductance, anatomically reflected in altered pit traits and reduced lumen diameters. However, most studies rely on single-point sampling at fixed stem positions, overlooking the progressive variation in conduit and pit traits with distance from the apex (DFA).
We investigated the effect of soil water availability on the axial patterns of xylem anatomical and hydraulic traits. We sampled top branches from five *Picea abies* trees at three sites along a soil water retention gradient. We measured the hydraulically weighted tracheid diameter (Dh) and the leaf-specific hydraulic conductance (K_L) at increasing DFA. Vulnerability curves (percent loss of xylem conductance –PLC– at different xylem water potentials) were constructed, and the P50 vulnerability index (water potential at PLC = 50%) was obtained from samples taken at fixed DFA. At the two driest sites, conduit widening was similar ($Dh = 0.96\ DFA^{0.13}$) and consistent with published data. Conversely, at the wettest site, the widening pattern strongly diverged from that commonly reported in literature ($Dh = 1.08\ DFA^{0.05}$), showing a significantly lower exponent and higher allometric constant. Regarding hydraulic traits, we obtained similar K_L ($\approx 0.004\ kg\ s^{-1}\ MPa^{-1}\ m^{-2}$) and P50 ($-4.75 \pm 0.22$ MPa) across sites.
Results indicate conservative axial anatomical and hydraulic traits, with negligible xylem phenotypic adjustment to soil water availability in *P. Abies*, underscoring the importance of considering DFA in future xylem trait studies.

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KEYNOTE SPEAKERS

Kristina Gruden – National Institute of biology, Slovenia

5th of March – 9:15 Library auditorium University of Udine

Using knowledge networks to decipher mechanisms of potato tolerance to abiotic stress

Stress Knowledge Map (SKM, https://skm.nib.si) is a publicly available resource containing two complementary knowledge graphs describing current knowledge of molecular interactions in plants: a highly curated model of plant stress signaling (PSS, 543 reactions) and a large comprehensive knowledge network of molecular interactions (CKN, 488,390 interactions).

Both were constructed by domain experts through the systematic curation of diverse literature and database resources. SKM provides a single-entry point for plant stress response investigations and the related growth trade-offs, through interactive exploration of current knowledge, as well as integration of experimental omics data. We will here present the data how these knowledge networks can be used to decipher responses of potato to multiple stresses, drought, heat, waterlogging and combined stresses.

The samples were analysed on multiple omics levels, from chromatin remodeling, transcriptomics, metabolomics and proteomics, to high throughput phenotyping. Knowledge networks offer a unique way to integrate these data and identify regulatory hubs.

Tomas Morosinotto – University of Padua, Italy

5th of March – 11:10 Library auditorium University of Udine

Response of photosynthesis to environmental light dynamics

Photosynthesis is a fundamental process in the biosphere, essential for primary production in all ecosystems. Environmental conditions have a strong impact on photosynthetic reactions, requiring complex modulation, specific to various species depending on their ecological niche. Photosynthesis is thus finely regulated, and plants employ photoprotective mechanisms to modulate electron pathways to dissipate excess energy and avoid potential damage from over-excitation and over-reduction.

Different plant species grown outdoors and monitored across different seasons show substantial diversity in photosynthetic properties, enabling their response to variable environmental conditions. Only a small fraction of this diversity is associated with phylogenetic distance, while the largest component is linked to the ability of each individual plant to modulate its photosynthetic performance. These results suggest that the ability to modulate photosynthetic reactions is an essential feature for plants resilience to environmental dynamics and ecological success.

Considering the impact of photosynthesis in biomass there is a strong interest in understanding if optimization of photosynthesis regulation also opens the possibility of improving light-use efficiency in crops, increasing their biomass productivity and ultimately yield.

Giuliana Tromba – Elettra-Sincrotrone Trieste S.C.p.A, Italy

5th of March – 14:05 Library auditorium University of Udine

Phase contrast micro-CT for plant physiology research: lessons learned and upcoming upgrades at Elettra

SYRMEP (SYnchrotron Radiation for MEdical Physics), the hard X-ray imaging beamline of the Elettra synchrotron light source (Trieste, I), has been operating for over 30 years offering advanced full-field X-ray imaging techniques and multiscale micro- tomography in phase-contrast mode. Powered by a standard bending magnet, SYRMEP had a relatively low X-ray flux and an energy range limited to 8.5-40 keV. This focused its application fields to relatively small samples.

The beamline is supported by two dedicated microfocus sources for conventional micro-tomography experiments (known as 'Tomolab') offering a complementary setup, given their wide X-ray spectrum and large beam, capable of studying bulky samples in a single scan. Being independent setups, access to these sources is always available also during the Elettra shutdown period.

The next generation of SYRMEP, currently under construction as part of the Elettra 2.0 upgrade program, is designed to overcome the limitations of the present beamline and offer state-of-the-art phase contrast imaging techniques with significant advancements, including an extended X-ray energy range, a higher flux and enhanced achievable spatial resolution. In its final configuration, the new setup will operate in an energy range between 10 and 130 keV for monochromatic imaging. This range will be further extended to about 300 keV when using pink beam modality. The broader energy interval will allow to encompass the study of bulky and denser samples and to expand the research horizons to paleontology, paleo-anthropology, materials science and medical research. This talk will present the outcomes achieved by the beamline in the field of plant imaging and the perspectives offered by the instrumental upgrade.

Stefan Mayr – University of Innsbruck, Austria

5th of March - 16:30 Library auditorium University of Udine

Under pressure - insights into xylem and its hydraulics

Plant water relations are frequently under pressure. Water transport is passively driven by transpiration, which generates negative pressure (i.e. negative water potential), transduced from leaves to the roots and to the soil via the water columns in the transport system. Negative water potentials also develop when the stomata are closed but soil water supply is limited.

Trees, due to long transport pathways from the soil to the crown, can reach remarkably low water potentials. The stability of water columns under these conditions is only possible due to optimized structures, enabling both, sufficient transport capacities (hydraulic efficiency) and prevention of interruptions in water columns (hydraulic safety). In the xylem, various structural features of the transport conduits, including their connections via bordered pits, contribute to maintaining hydraulic efficiency and safety.

Under climate change, tree water relations are increasingly under pressure, when drought intensities and frequencies as well as temperatures (and thus water vapor deficits) increase. This leads to lower water potentials, which may exceed species- specific thresholds in hydraulic safety and thereby critically reduce hydraulic efficiency.

Juan Jiménez – University of Copenhagen, Denmark

6th of March - 09:15 Auditorium VCR Research center

Root responses to soil flooding

Flooded soils, where pore spaces are saturated with water for transient or prolonged periods, impose stress conditions for plant growth. During flooding, oxygen (O_2) is rapidly depleted by root respiration and microbial activity, leaving the soil practically devoid of O_2. Prolonged flooding also alters redox conditions in rhizosphere, leading to the reduction and accumulation of micro-nutrients such as iron, manganese and sulfur, to phytotoxic levels for plant growth.

This presentation will address the principal stress factors plants experience under flooding and the root traits associated with flooding adaptation. I will emphasize the root anatomical, morphological and physiological characteristics that enhance O_2 diffusion from shoots to roots and the efficient use under hypoxic conditions.

In addition, I will discuss the chemical characterization and location of apoplastic barriers that restrict radial O_2 loss from roots to rhizosphere and limit the entry of toxic compounds form the rhizosphere into the root. Together, these mechanisms illustrate how roots balance internal aeration and protection in flooded environments, providing key insights for crop resistance to flooding conditions.

Andrea Pitacco – University of Padua, Italy

6th of March - 11:10 Auditorium VCR Research center

Fluxes across boundaries: plants shaping their own environment

Plants can survive in very variable and diverse environments, facing strong physical forcings like heavy radiation loads, extreme temperature and discontinuous water availability. Exploiting their position at the soil‒atmosphere interface and leveraging basic thermodynamical processes, they can successfully handle their metabolism, growth and development in a broad spectrum of conditions. Exposed to rhythmic gradients (of temperature, moisture, carbon dioxide, etc.), they respond by establishing strong fluxes of heat and matter with the surrounding atmosphere, themselves altering local microclimate. While the physiological control of water vapor and carbon dioxide have been classical research themes of plant ecophysiologists for a long time, they have seldom focused on the relevance of external factors affecting – and possibly "regulating" – these fluxes.

External factors are mostly related to the variable conductance of the air around leaves, linked to the kinematics of the boundary‒layers which can be irregularly dominated by laminar or turbulent regimes as wind gusts penetrate and interact with the canopies. The dynamic partitioning of kinematic regime has huge consequences on air mixing and therefore on boundary‒layer conductance and transport processes. While any analysis of flux‒gradient relationships– at any scale (leaf, plant, plot) – is usually performed at the steady‒state, transient conditions can lead to an enhanced variability in the local microenvironment, including plant organs.

Starting from a thorough analysis of physical principles determining leaf and canopy energy‒budget partitioning, the presentation will deal with fundamental properties of canopy microclimate as measured in a properly instrumented vineyard belonging to the Integrated Carbon Observation System network, operated for 10 years by the University of Padua.

ORAL PRESENTATIONS

Pietro Furnari – University of Messina, Italy

So, we've been measuring membrane stability wrong all along?

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Membrane integrity is a key cellular trait linked to plant vitality, and its loss is among the earliest indicators of stress-induced dysfunction. Relative electrolyte leakage (REL) is widely used as a simple and cost-effective proxy to assess membrane damage and to compare plant vulnerability or resistance to biotic and abiotic stresses. However, REL protocols vary substantially among studies, particularly in incubation time and membrane disruption procedures, potentially affecting measurement accuracy and comparability.
We compared three commonly used REL protocols to assess how methodological variation influences REL measurements. We hypothesized that leaf mass per unit area (LMA), as a proxy of leaf structural investment and mechanical toughness, modulates electrolyte leakage by affecting water penetration and ion diffusion kinetics. This effect is expected to be particularly pronounced under shorter incubation times or milder membrane disruption procedures. REL was measured in two species with contrasting LMA: *Feijoa sellowiana* O. Berg (184 $g \cdot m^{-2}$) and *Phaseolus vulgaris* L. (21 $g \cdot m^{-2}$).
Our results confirmed that REL responses depend on the interaction between leaf structural traits and protocol-specific parameters. High-LMA leaves exhibited slower electrolyte release and greater sensitivity to incubation time and membrane disruption methods. These patterns were consistently supported by independent analyses of cell vitality, confirming the biological relevance of REL measurements. Overall, our findings indicate that while REL is a powerful and accessible tool for assessing plant stress vulnerability, its comparative application across species with contrasting leaf traits requires careful methodological calibration.

Rebeka Strah – National institute of biology, Slovenia

How Cabernet Volos and Fleurtai respond to water deficits – integrating transcriptomic and metabolomic data

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Recurrent drought events during the summer are threatening the sustainability of viticulture around the world. The changing environment can also influence the incidence of plant diseases. In this context, two new fungus-resistant grapevine genotypes, Cabernet Volos and Fleurtai were investigated, with emphasis on their response to water deficits. We examined the grapevine response to water stress on the transcriptomic and metabolomic level by combining the analysis of high-throughput RNA-Seq and metabolite accumulation data with the data of plants' stem water potential. The expression of approximately 800 genes and nine metabolites was found to be changed due to the decreased water potential in at least one of the cultivars. Most of the changes were common in both cultivars, which included accumulation of amino acids, heat shock proteins, and ABA response and signaling. Moreover, correlation was found between stress-responsive metabolites and their biosynthetic genes. Smaller groups of genes with different expressions in Cabernet Volos and Fleurtai were also identified.

Irene Luzzi – University of Padua, Italy

Unraveling chromatin-mediated mechanisms shaping drought stress memory in tomato

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Drought is a major environmental stressor that limits plant growth and productivity. To cope with water deficit, plants modulate gene expression through molecular and epigenetic mechanisms. To dissect drought-induced memory, we investigated physiological, transcriptomic and chromatin-based responses to mild and severe-recurrent drought in two tomato genotypes, M82 and Lucariello, using a multi-omics approach. In M82, mild-drought reduced stomatal conductance and transpiration while increasing chlorophyll content, indicative of a drought-avoidance strategy that was fully reversible upon rehydration. Transcriptomic analyses revealed extensive gene-expression reprogramming under drought and an attenuated response after rewatering, outlining a two-phase adaptive strategy. Subsets of genes displayed positive and negative transcriptional memory, suggesting mechanisms that enable plants to "remember'' prior stress exposure. The effects of drought on histone-mark distribution were examined through immunolocalization. Immunofluorescence revealed an enrichment of the H3K27me3 signal. Consistently, H3K27me3 ChIP-Seq profiling showed that this mark is negatively associated with dehydration-responsive memory genes. Furthermore, integrating transcriptomic and chromatin datasets provided insights into how Lucariello responds to severe-recurrent drought events followed by rewatering. The identification of transcriptional-memory targets, together with dynamic changes in H3K4me3, indicates that stress-memory mechanisms are gene-subset-specific. Three categories of stress-memory genes were identified: type-I, showing stable transcriptional and/or H3K4me3 changes upon a second dehydration event; type-II, initially repressed and later re-induced, displaying H3K4me3 enrichment during the second stress exposure; negative-delayed memory genes, characterized by hyperinduced transcriptional and chromatin responses after repeated stress. Overall, this work provides a genome-wide, integrative framework for understanding chromatin-mediated stress memory in tomato.

Anja Mavrič Čermelj – University of Ljubljana, Slovenia

Silicon supplementation mitigates PEG-induced drought stress in hydroponically grown barley

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Climate change threatens to reduce food production by intensifying drought stress and reducing crop productivity. Silicon (Si) supplementation is a promising approach to improve plant tolerance to abiotic stresses. This study evaluated the effects of Si supplementation on the morphological, physiological, and biochemical responses of barley (*Hordeum vulgare* L.) under drought stress. Barley seeds were sterilized, germinated, and grown in aerated nutrient solutions under controlled light and temperature conditions. Plants were supplied with either 0 mM Si (Si0) or 1 mM Si (Si+). Drought stress was subsequently induced in half of the treatments by adding 10% polyethylene glycol (PEG), resulting in four treatments: Si0, Si+, Si0PEG, and Si+PEG. After 46 days from germination, plant growth, physiological parameters, and biochemical traits were analyzed. Drought stress significantly reduced plant height, biomass, and the number of green leaves, while increasing proline accumulation and lipid peroxidation in leaves. Si supplementation mitigated these adverse effects by increasing the number of green leaves, maintaining leaf dry biomass, improving the potential photochemical efficiency of photosystem II (Fv/Fm), and reducing malondialdehyde content under drought conditions. Si-treated plants also exhibited higher α-tocopherol levels, indicating enhanced antioxidant protection. Although drought altered chloroplast pigment composition, the violaxanthin–antheraxanthin–zeaxanthin cycle was not fully activated. Si supplementation enhanced drought tolerance in barley by improving antioxidant defences and maintaining plant growth and biomass, suggesting its potential use as a sustainable strategy to mitigate drought stress in crops.

Azzurra Di Bonaventura - University of Udine, Italy

Extracellular vesicles from Coffea arabica L. cell suspension cultures: isolation and proteomic insights

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Beyond to their biological roles in plants, extracellular vesicles (EVs) are gaining relevance in biotechnological, medical and agricultural fields. In this study, we developed a protocol for isolating and characterizing EVs from *Coffea arabica* cell suspension cultures (CSCs), offering a scalable, non-disruptive production system. EVs were isolated via differential ultracentrifugation, resulting in two distinct fractions (100,000×g and 125,000×g). Transmission electron microscopy confirmed that both fractions contained vesicular structures with dimensions consistent with typical plant EVs. While morphologically similar, proteomic analysis revealed significant compositional differences. The 100,000×g fraction was enriched with the cell periphery and plasma membrane proteins, while the 125,000×g fraction predominantly contained extracellular region proteins. Both fractions exhibited established transmembrane, transport, and soluble EV-associated protein markers with negligible contamination from non-EV intracellular proteins.
These results demonstrate that coffee CSCs actively secrete EVs without requiring mechanical cell disruption. CSC-derived EVs therefore represent a reliable, high-purity and scalable platform for downstream functional studies and biotechnological applications.

Arianna Del Pino - University of Udine, Italy

Responses of Alpine grassland plants to heat wave are mediated by changes in functional traits, primary production and CO2 fluxes

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The Alps are facing more frequent summer heat waves that are threatening alpine ecosystems and their biodiversity. These events can greatly impact primary alpine grasslands, key providers of ecosystem services. Recent studies showed that combined drought and heat stress affects species and community-level responses, yet the role of stress timing and duration remains unclear. This study addresses this gap by examining heat wave effects on alpine grasslands at different growth stages, focusing on species representing the three main plant functional types: sedges, grasses, and forbs.

Heat waves were simulated using shelters that excluded rainfall and increased temperature. Treatments varied in timing and duration: (1) early and prolonged (start to peak of season, ~2 months), (2) early (1 month after growth resumed), (3) late (1 month before peak), and (4) control (no stress). Plant responses were evaluated through morphological and physiological traits analysis. Specifically, leaf traits and pigment concentrations (chlorophylls, flavonoids, carotenoids) were assessed. At the community level, the focus was on primary production (i.e. above ground biomass) and CO_2 fluxes.

We hypothesize that early stress may accelerate phenology and boost early growth, while prolonged or late exposure reduces productivity and induces early senescence. Our findings will improve understanding of alpine vegetation resilience under future climate extremes, guiding adaptive conservation strategies.

Luca Redivo – University of Trieste, Italy

Intraspecific variability of turgor loss point in *Carpinus betulus* L. populations

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Climate-induced drought is a major driver of forest decline. Understanding intraspecific variability of drought tolerance is crucial for sustainable forest management. We investigated the intraspecific variability of drought tolerance in 11 Northern Italian populations of *Carpinus betulus*, selected along an aridity gradient and grown in pots in a nursery under the same environmental conditions. A large-scale phenotypic screening was conducted on ~1,100 saplings to determine turgor loss point (TLP), specific leaf area and leaf dry matter content, as well as growth rate. Results showed significant inter-population variability in TLP, partly associated with summer climatic stressors at the seed source, as well as significant intra-population differences in drought tolerance. A controlled water-stress experiment performed in 2025 on a sub-set of 4 populations revealed that *C. betulus* displays an isohydric behavior, maintaining leaf water potential through strict stomatal control, while simultaneously showing significant capacity for osmotic adjustment (ΔTLP) to sustain turgor. The Sedico population displayed the highest physiological plasticity. These findings highlight the importance of local adaptation and phenotypic plasticity in shaping the response to drought of *C. betulus*.

Carlotta Musso – University of Innsbruck, Austria

Physiological responses of Alpine dwarf shrubs to the extreme green roof's conditions

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Green roofs enhance urban green spaces and biodiversity, when local, functionally diverse species are used. However, the harsh conditions on roofs necessitate careful species selection. This study investigated the suitability of four Alpine dwarf shrubs (*Arctostaphylos uva-ursi, Vaccinium myrtillus, V. vitis-idaea, Calluna vulgaris*) and, for comparison, the Mediterranean shrub *Salvia officinalis*, in experimental green roof plots with substrate depths of 10 cm (Plot10) and 30 cm (Plot30) under temperate climate. Microclimatic conditions were continuously monitored and seasonal and daily variations in leaf water potential, leaf temperature, transpiration, and photosynthesis were recorded during humid and dry periods. In Plot30, temperature changes were less extreme, and the substrate retained more water, resulting in lower drought stress than in Plot10. Nevertheless, species-specific physiological responses to substrate depth and drought intensity were observed. *A. uva-ursi* and *V. vitis-idaea* performed best: the former remained above its hydraulic vulnerability threshold (Ψ_{50}) in both plots, and the latter in Plot30. *S. officinalis* achieved the highest gas exchange and vigorous growth in Plot30 and maintained favourable water status in both plots. Conversely, despite strict stomatal control, *C. vulgaris* and *V. myrtillus* exceeded their Ψ_{50} during drought in Plot10 and experienced dieback. We conclude that Alpine dwarf shrubs can grow on green roofs, but preferably on deeper substrates, and can broaden the range of species used for temperate green roofs. We suggest alternating patches of low and high substrate depths to better support shrub survival and account for species-specific physiological responses, without necessarily increasing the overall weight on buildings.

Giai Petit – University of Padua, Italy

Axial scaling of xylem traits, water potential gradient, embolism vulnerability and phenotypic plasticity

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Xylem vascular elements vary in lumen and pit size along the soil–plant–atmosphere continuum, from transpiring leaves to absorbing roots. The axial variation of these traits determines the shape of the water potential gradient from leaves to roots, as well as embolism resistance at different positions along the hydraulic pathway. The axial scaling of conduit lumen diameter appears to be convergent among vascular plants, and pit traits may also follow convergent scaling, although empirical evidence remains limited. Although the overall range of variation is narrow, it may nonetheless encompass differences in the xylem hydraulic safety margin (i.e., the difference between the local xylem water potential and the local P50 - the water potential at which 50% of conductivity is lost) at different points along the pathway.
Here, I discuss how differences in axial anatomical scaling, even within this relatively narrow range of variation, may reflect distinct patterns of acclimation and adaptation to soil drought and high vapor pressure deficits.

Patrizia Merkel – University of Innsbruck, Austria

Seasonal dynamics of pigments and antioxidants and their response to recurrent drought in Picea abies and Larix decidua

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Forests provide vital ecosystem services, yet they are becoming increasingly vulnerable to climate change-related stressors, particularly recurring droughts. Our study investigated whether repeated summer droughts trigger distinct metabolic responses in montane conifers that could explain their species-specific sensitivity to or resilience against drought.
We examined *Picea abies* (L.) H. Karst. and *Larix decidua* Mill. at a long-term ecosystem research site in the Kaserstattalm forest (Tyrolean Alps), situated at an elevation of 1960 m. From 2016 to 2023, the trees were subjected to experimental summer droughts using rainout shelters. Needle samples were collected from two trees per plot in three drought-treated and three control plots. Concentrations of pigments and tocopherols, as well as the redox state of the glutathione pool (GSH/GSSG), were quantified by HPLC in combination with GC-MS-based metabolite profiling on eleven occasions for *P. abies* and eight for *L. decidua*, from summer 2023 to summer 2024 (i.e. the first year after drought cessation). Additionally, glutathione and pigments were analysed in control and drought-stressed trees at the Kranzberg forest (Bavaria) to investigate the legacy effects of drought.
Both species exhibited pronounced seasonal dynamics in all analyzed metabolites. However, no statistically significant differences in pigment, tocopherol or glutathione content were detected between drought-treated and control trees. Analysis of untargeted metabolites revealed only a few to be statistically significant out of a total of 147.
The absence of detectable differences in targeted metabolites between drought-exposed and control trees, despite previously reported reductions in growth induced by drought, suggests a substantial degree of metabolic acclimation following prolonged exposure to recurrent drought.

Marianna Grohar – University of Ljubljana, Slovenia

Role of light and temperature in apple ripening: the case of preharvest pruning stress

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This study examined the effects of preharvest pruning on the physiological and biochemical stress responses of ‘Topaz’ apple fruit. Shaded, continuously sun-exposed, and previously shaded fruit suddenly exposed to full sunlight after pruning were compared. Summer pruning created abrupt light and temperature stress, with skin temperatures of exposed fruit reaching up to 40 °C. The sudden exposure of shaded fruit triggered notable stress responses, especially in phenolic compounds content. However, pigment levels in these fruits remained lower than in continuously sun-exposed fruit, indicating that while stress stimulates anthocyanin synthesis, it also imposes physiological limitations. These findings underscore the role of pruning-induced light and temperature stress in modulating apple ripening and highlight the importance of canopy management in balancing fruit quality and stress exposure.

Filippo Sanna – University of Udine, Italy

Exploring volatile compounds for the early detection of Neopestalotiopsis clavispora: emerging grape trunk disease

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This study aimed to characterise the volatile organic compounds (VOCs) profile of *Neopestalotiopsis clavispora*, an emerging grapevine trunk pathogen and to identify characteristic volatile fungal metabolites as potential infection biomarkers. *N. clavispora* was cultured on an agar medium containing grapevine wood sawdust (10%) derived from Cabernet Sauvignon and Sauvignon Blanc vines, in sterile vials (10 mL), for seven days at 25 °C. The VOCs in the vial headspace were analysed by SPME-GC–MS. For the *in vivo* assay, a fungal conidial suspension (20 µL, 1×10^5 conidia/mL) was inoculated into Sauvignon Blanc twigs by holes drilled with a wood bit. The twig roots were immersed in boxes containing tap water, and the inoculated top part was inserted into a sterile plastic box (94 x 94 x 352 mm) to concentrate the VOCs. The twigs were then maintained at 20 °C for 21 days, with a 12-hour light/dark cycle. After incubation, fibre DVB/CAR/PDMS was used to collect the VOCs, which were then analysed using GC–MS. In both the *in vitro* and *in vivo* experiments, the control group comprised agar media and twigs that were not inoculated with the pathogen. Multivariate analysis revealed distinct clustering of VOCs according to the growth medium, reflecting differences in grapevine cultivar and plant–pathogen interactions. However, the preliminary VOCs profile of grapevine twigs showed qualitative changes in volatile emissions following fungal infection. Overall, these findings provided a basis for identifying specific volatile metabolites as potential biomarkers of infection, emphasising the importance of VOCs in microorganism–plant interactions.

Kris Pirih – University of Ljubljana, Slovenia

At the Edge of Comfort "Plasticity of tomato under temperature stress"

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The ability of plants to continually adjust their growth and physiology enables them to survive harsh environmental situations. We investigated how tomato (*Solanum lycopersicum*) seedlings respond and recover from a four-day exposure to: low (15/5 °C), optimal (25/20 °C), and high (40/25 °C) temperatures. A comprehensive assessment was achieved by combining chlorophyll fluorescence imaging, multispectral and 3D phenotyping, and gas-exchange measurements. Both low and high temperatures induced transient decreases of Fv/Fm. However, full recovery occurred within three days, demonstrating a high PSII repair capacity. Fluorescence measurements conducted at a common temperature revealed contrasting acclimation strategies. Low temperature stress maintained higher Fq′/Fm′, ΦNPQ, qL, and NPQ(t), together with elevated anthocyanin accumulation, indicating a conservative photoprotective response. In contrast, high temperature stress reduced these parameters, increased ΦNO, and induced higher chlorophyll content, suggesting structural reinvestment in the photosynthetic apparatus following heat-induced impairment. Despite turbulent PSII responses under high temperature, net photosynthesis declined only under low temperature during stress, while high temperature did not limit photosynthesis relative to control. Respiration, stomatal conductance, and transpiration increased under high temperature and decreased under low temperature during stress, but fully recovered after stress removal. Despite rapid physiological recovery, both temperature extremes left a persistent morphological legacy. Plant volume remained reduced up to nine days after stress; high temperature primarily decreased leaf area, whereas low temperature reduced plant height and overall growth. Together, these results demonstrate that tomato phenotypic plasticity enables distinct, temperature-dependent strategies that sustain performance "at the edge of comfort".

Marta Sartor – University of Udine, Italy

Take a breath: relationship between oxygen consumption and carbon reserves in vine cuttings during cold storage

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Preserving woody crop cuttings in cold storage rooms is critical to maintain their physiological viability and ensure optimal field performance upon transplanting. However, the effect of temperature on the cutting's metabolic activity during storage and on subsequent transplanting success and growth remains unknown. This study explores oxygen consumption, non-structural carbohydrate (NSC) dynamics, and antioxidant capacity as indicators of the physiological conditions of grapevine grafted cuttings stored in darkness at 2.5 °C, 4°C, and 9°C in controlled rooms. Measurements were conducted on freshly harvested grapevine grafted cuttings to investigate the influence of temperature on storage duration. We measured oxygen concentration in bud, rootstock, and root using an optical oxygen sensor embedded in a hypodermic needle. Oxygen consumption varies significantly across distinct tissues, with a gradual increase from 2.5°C to 9°C, suggesting altered respiratory activity during prolonged storage at higher temperatures. NSCs were analyzed on the same tissues, showing an initial sugar accumulation as a result of starch hydrolysis in roots. After 28 days of conservation, sugars gradually decreased over time in all organs, more rapidly at 9°C. Together with soluble NSC, we observed a reduction in antioxidant capacity, measured as Oxygen Radical Absorbance Capacity (ORAC), suggesting a loss of cryoprotection during long storage of vine cuttings. These findings enhance the understanding of tissue-specific metabolic responses during cold storage and provide valuable insights into the physiology of grapevine cuttings during cold storage conditions.

Valeria De Rosa – University of Trento, Italy

Lighting up resistance: UV-C reshapes secondary metabolism enhancing downy mildew tolerance in grapevine

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Plasmopara viticola, the causal agent of grapevine downy mildew, poses a significant threat to viticulture and is managed through intensive use of chemical fungicides. While downy mildew-tolerant varieties offer a sustainable alternative, their adoption remains limited and finding effective complementary control strategies is crucial. This study evaluates the efficacy of UV-C radiation as a potential elicitor of plant resistance under controlled conditions. Using a bespoke platform, ten experiments were conducted on leaf disks of a disease susceptible cultivar (*Vitis vinifera* cv. Pinot noir) and a tolerant hybrid (cv. Johanniter) to determine the threshold between UV-C-derived phytotoxicity and effective resistance induction. We show that UV-C radiation significantly reduced disease severity in both genotypes ($p < 0.001$), while exhibiting higher efficacy in Johanniter at lower dosages compared to those required in Pinot noir. This heightened efficacy in the tolerant genotype was linked to a superior basal concentration of defence-related stilbenes, whose accumulation was further increased by UV-C exposure. Metabolomic analyses revealed a tissue-specific modulation of secondary metabolites: UV-C induced an increase in flavonoids within the epidermis, while simultaneously shifting the metabolic flux toward stilbene production, presumably, in the mesophyll. These findings highlight a clear synergistic effect between UV-C treatments and genetically determined *P. viticola* tolerance, providing support for future field applications.

Rachele Gamba – University of Turin, Italy

Drought priming treatment and drought intensity effects on physio-anatomical traits of Nebbiolo vines

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Recently, investigation of plant memory phenomena in response to abiotic stresses has become a subject of interest due to increasingly intense and frequent drought events. It has been suggested that plants can "remember" past stress occurrence. Grapevine, one of the most economically important crops worldwide, is particularly vulnerable to environmental stressors impacting growth and fruit quality. Although physio-anatomical adjustments were observed in grapevines after recurrent drought exposures in the same growing season, little is known about persistent plant memory occurring years after recurrent drought.

To unravel this mechanism, plants of Vitis vinifera cv Nebbiolo (CVT 185) grafted onto the SO4 rootstock were subjected to a priming treatment consisting in repeated cycles of mild drought and recovery imposed over three years. Then, primed plants were exposed to severe drought, concomitantly with a group of unprimed vines in the fourth year. Hydraulic and anatomical measurements performed on current year sprouts of fifth year, scion and rootstock (at 5 cm above and below the grafting point, respectively) revealed no significant differences between drought-primed and unprimed plants, but they showed changes depending on the applied drought intensity (mild vs. severe). In conclusion, drought priming treatment has no effect on the studied plant physio-anatomical characteristics, while drought intensity turns out to be the main factor modulating wood anatomical growth of grapevine.

POSTERS

Adriano Losso – University of Innsbruck, Austria

Late-spring frost-induced xylem embolism can be fatal for newly established tree seedlings

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Freezing is one of the main factors that affect the survival of tree seedlings. However, due to the methodical difficulties posed by small and fragile newly established seedlings, research into the impact of freezing temperatures has focused primarily on the impairment of their living tissues, with the potential effects on their hydraulics remaining unexplored.
We investigated whether a single freeze-thaw cycle on the hypocotyls of 5-8-week-old *Acer pseudoplatanus*, *Sorbus aucuparia*, *Larix decidua* and *Pinus cembra* seedlings would affect whole-shoot hydraulic conductance (K_{shoot}). We also monitored embolism formation via ultrasonic acoustic emissions (AEs) of the hypocotyls during a freeze-thaw cycle, and determined the cold hardiness of leaves/needles exposed to different subzero temperatures.
A single freeze-thaw cycle significantly impaired angiosperms K_{shoot}, whereas the conifer hypocotyls showed greater resistance to freeze-thaw-induced xylem embolism. The maximum number of AEs was always observed when freezing happened, indicating that most xylem embolisms occurred during the initial formation of ice. Deciduous leaves and needles showed substantial damage at temperatures already below −2°C, while *P. cembra* needles remained unaffected even at −5°C.
The results suggest that freezing stress can heavily affect the fitness of newly emerging seedlings. Therefore, the increased frequency of spring frosts in European forests could threaten the survival of newly established tree seedlings. This will be important for our understanding of forest regeneration and restoration in the context of ongoing climate change.

Nicole Furlan – University of Padua, Italy

Auxin-based Treatments as Tools to Modulate Ripening Dynamics in Wine Grapes

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Increasing global temperatures are advancing grapevine phenology and shifting ripening to warmer periods. This negatively impacts grape and wine quality by altering the critical balance between sugars, acidity, phenolics, and aroma compounds. Plant growth regulators represent a promising strategy to delay ripening and mitigate these effects. This study assessed the impact of auxin-based treatments on grape ripening dynamics, berry composition, and molecular regulation across different grape cultivars. Field trials were conducted in commercial vineyards in the Veneto region of Italy. Clusters of the white cultivars Glera and Pinot Grigio, and the red cultivar Corvina were treated before veraison with 1-naphthaleneacetic acid (NAA). Ripening dynamics were monitored through weekly berry sampling from veraison to harvest. In selected trials, transcriptomic analyses were performed to investigate treatment-induced gene expression changes. NAA consistently delayed veraison and ripening progression, postponing sugar accumulation and slowing acid degradation, albeit with cultivar-dependent differences. In Glera and Pinot Grigio, the treatment resulted in a general delay in sugar accumulation, whereas in Corvina, it promoted a more balanced anthocyanin-to-sugar ratio. Transcriptomic analyses revealed a general postponement of the ripening program, with strong modulation of auxin-related genes and genes involved in other hormonal pathways, including ABA, ethylene, gibberellins, and brassinosteroids, highlighting the role of hormonal crosstalk in ripening regulation. These results support the use of auxin-based treatments as a promising adaptive vineyard management strategy to mitigate the effects of climate change and help preserve grape and wine quality.

Martina Tomasella – University of Trieste, Italy

Automated optical leaf pressure-volume curves for turgor loss point estimation

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Leaf water potential at turgor loss point (ΨTLP) is a pivotal drought tolerance parameter, but its proper determination can be time-consuming. We propose an automated method for leaf pressure-volume (P-V) analysis and we tested it for *Helianthus annuus*, *Arundo donax* and *Laurus nobilis* species.
P-V curves were obtained by continuously measuring water potentials (Ψ) with a leaf psychrometer and the "dehydration level" (DL) with an optical leaf sensor (pocket Leaf Water Meter, pLWM) while whole branches or sole leaves were dehydrating on the bench. DL is a parameter derived from photon attenuation during light transmission through the leaf and is strictly related to leaf water content. The obtained ΨTLP and the osmotic potential at full turgor (π0) were compared with those estimated from two currently used methods, i.e. the classical P-V curves (obtained by coupling Ψ measured with a Scholander pressure chamber with water content) and the osmometric method (based on determination of π0).
Optical P-V curves were similar in shape to the classical ones, showing a typical linear relationship between $-\Psi^{-1}$ and DL after turgor loss point. Moreover, the two methods were consistent in the estimation of ΨTLP and π0, while in some cases the osmometric method overestimated ΨTLP and/or π0. The proposed automated technique represents a promising alternative to classical, labor-intensive P-V curves for reliable ΨTLP determination.

Monica Canton – University of Padua, Italy

Physiological and molecular responses of grapevine to repeated water stress

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The frequency of consecutive and even extreme drought events is increasing in the Mediterranean region, directly affecting grapevine physiology and shaping the molecular strategies that grapevine plants employ to cope with recurring water stress. This study evaluates the effects of two subsequent drought cycles, each followed by rewatering, applied on potted vines of Vitis vinifera L. cv. Sauvignon blanc, in a semi-controlled tunnel. Physiological assessments were combined with transcriptomic analysis, performed on leaf samples collected every six hours during the last day of drought cycle and subsequent rewatering. Chlorophyll fluorescence revealed persistent photoinhibition after severe drought. Variations in non-structural carbohydrates (NSC) concentrations across treatments and diurnal cycles indicated alterations in carbon metabolism. The study showed that NSC are mobilized differently depending on drought severity and that drought effects on photosynthesis and NSC are not fully reversible upon rewatering. RNA-Seq results showed temporal and cycle-dependent dynamics in genes associated with carbohydrate metabolism, abscisic acid metabolism and signaling, and photosynthesis during drought events. By analyzing gene expressions across the day in both drought cycles, we observed conserved and distinct transcriptional patterns, with different processes activated or repressed depending on the time of day and the cycle. Conserved genes such as galactinol synthase and dehydrin were present in both cycles most of the time. On the other hand, it was observed that plants change from immediate defense and stress mitigation in the first drought cycle to more centered on metabolic changes and adaptive adjustments during the second drought. These findings suggest that grapevines adjust their molecular responses after an initial drought episode, consistent with stress-priming mechanisms, and may "remember" prior stress to better cope with subsequent water deficits. This fine-scale temporal perspective provides insight into the strategies that grapevine uses to survive recurring drought, with relevance for viticulture under climate change.

Mateja Germ – University of Ljubljana, Slovenia

Silicon improves growth and photosynthetic performance in drought-stressed cucumber grown hydroponically

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Water deficit is one of the most critical environmental factors limiting plant growth and photosynthetic performance. Silicon (Si) has been shown to enhance structural, physiological, and biochemical mechanisms that improve plant tolerance to drought stress. The study examined the effects of Si on growth and physiological responses of cucumber (Cucumis sativus L.) under drought stress in a hydroponic system. Seeds were sterilized and germinated, and seedlings were transferred to hydroponics in growth chambers. Six treatments were established (Si+PEG, Si0PEG, PEG, Si+, Si0, nutrient solution (NS)) with six replicates per treatment. Si was supplied as sodium silicate, drought stress was induced using 10% PEG-6000 and sodium concentration was adjusted using NaCl. Morphological, physiological, and biochemical analyses were performed after two weeks of stress exposure. Under drought stress, plants treated with Si+PEG showed higher root and shoot dry weight compared with Si0PEG plants, indicating that silicon improved growth and enhanced water uptake capacity. Similarly, Si+PEG plants exhibited higher potential photochemical efficiency of PS II (Fv/Fm) and chlorophyll a content than Si0PEG, suggesting better preservation of the photosynthetic apparatus. Proline levels were also elevated in Si+PEG plants compared to Si0PEG, reflecting enhanced osmotic adjustment. Interestingly, the Si+ treatment (Si with NaCl, without PEG) showed the highest Fv/Fm and chlorophyll a content, the lowest proline concentration, and the highest shoot dry weight among all treatments. This suggests improved plant performance under mild salinity and indicates a beneficial contribution of Si to stress acclimation. Our results indicate that Si alleviated the negative effects of drought, indicating its role in enhancing plant tolerance under water-limited conditions.

Andrea Nardini – University of Trieste, Italy

Species-specific tree desiccation risk under hot drought correlates to hydraulic traits but not to thermal tolerance

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Extreme drought episodes coupled to heat waves are predicted to become more common and intense in the near future, leading to ‘hot droughts’. High air temperatures rise atmospheric vapour pressure deficit, increasing the evaporative demand and worsening the effects of reduced soil water availability, and might cause tissue temperatures to surpass critical values leading to membrane disruption and tissue death. Hot droughts have produced massive effects on forest ecosystems, causing extensive canopy dieback and tree mortality on a global scale. The identification of tree species more tolerant to hot droughts is crucial for forest management, and requires an understanding of the physiological mechanisms and related functional traits underlying species-specific vulnerability to such events and to their drivers, namely water shortage and high temperatures. We leveraged the exceptional hot drought that occurred in the Classical Karst area in summer 2022 to investigate eventual correlations of species-specific desiccation patterns with physiological indicators of drought tolerance (turgor loss point, TLP; vulnerability to xylem embolism, P_{50}) vs thermal tolerance (critical temperature inducing damage to photosynthetic efficiency, T_{50}). Desiccation rates in populations of nine different woody species, based on visual estimates of the health status of more than 2400 individual trees, were strictly correlated to both TLP and P_{50}, but completely independent of T_{50}. We conclude that functional traits related to drought tolerance are better predictors of tree species vulnerability to hot drought episodes, compared to traits connected to thermal tolerance.

Andrea Ganthaler – University of Innsbruck, Austria

Intraspecific variation in growth and stem anatomical traits in Norway spruce seedlings: a comparison of ten provenances

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Norway spruce (*Picea abies*) is one of the most important tree species in Central European forests, but is strongly affected by increasingly frequent and intense summer droughts. Therefore, identifying intraspecific variability and selecting seed sources that perform best under water-limited conditions could help to mitigate the negative effects of climate change.

In a large-scale phenotyping experiment, we conducted stem anatomical measurements of a few weeks old seedlings from ten different provenances, to gain novel insights into the growth and anatomical variability of spruce. The effect of two conditions (well-watered and severe drought) on the growth and width of the xylem, phloem, bark and epidermis, the number of tracheid rows formed, and the mean radial tracheid diameter was analysed.

Spruce provenances exhibited pronounced differences in growth under both well-watered and drought conditions. The variability of the analysed traits ranged from high values for bark and phloem thickness (CV >15%) to low values for tracheid diameter (CV 2%). On average, drought stress reduced the phloem (-40%) much stronger than the xylem and the bark (-32% and -33%), and had little effect on the epidermis (-5%) and tracheid diameters (±0%).

The results show that intraspecific variation in stem anatomical traits and drought responses can be detected at an early developmental stage, accelerating the selection of resistant plants. While xylem, phloem and bark dimensions scaled (to a different degree) with radial growth, tracheid size was unaffected. Further investigations are needed to clarify why seed material from arid regions showed highest growth reductions under drought.

Lucia Biruk – University of Padua, Italy

No xylem phenotypic plasticity in branchwood of *Picea abies* across a soil water availability gradient

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It is widely accepted that under reduced water availability, plants typically produce xylem conduits more resistant to embolism formation, at the expense of hydraulic conductance, anatomically reflected in altered pit traits and reduced lumen diameters. However, most studies rely on single-point sampling at fixed stem positions, overlooking the progressive variation in conduit and pit traits with distance from the apex (DFA).
We investigated the effect of soil water availability on the axial patterns of xylem anatomical and hydraulic traits. We sampled top branches from five *Picea abies* trees at three sites along a soil water retention gradient. We measured the hydraulically weighted tracheid diameter (Dh) and the leaf-specific hydraulic conductance (K_L) at increasing DFA. Vulnerability curves (percent loss of xylem conductance –PLC– at different xylem water potentials) were constructed, and the P50 vulnerability index (water potential at PLC = 50%) was obtained from samples taken at fixed DFA. At the two driest sites, conduit widening was similar ($Dh = 0.96\ DFA^{0.13}$) and consistent with published data. Conversely, at the wettest site, the widening pattern strongly diverged from that commonly reported in literature ($Dh = 1.08\ DFA^{0.05}$), showing a significantly lower exponent and higher allometric constant. Regarding hydraulic traits, we obtained similar K_L (≈ 0.004 kg s^{-1} MPa^{-1} m^{-2}) and P50 (-4.75 ± 0.22 MPa) across sites.
Results indicate conservative axial anatomical and hydraulic traits, with negligible xylem phenotypic adjustment to soil water availability in *P. Abies*, underscoring the importance of considering DFA in future xylem trait studies.

Annual rings and carbon reserves in trees: a new frontier in dendrochronology

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The wood of trees can tell a long-life story through the analysis of xylem architecture and dendrochronology. Xylem features are affected by circadian rhythms and environmental conditions, which determine the dimensions and thickness of the cell walls, as well as their composition in terms of cellulose, hemicellulose, and pectin. Less is known about the non-structural carbohydrate content of parenchymatic rays, mainly because of the difficulty of measuring sugars and starch in the wood core. This is further complicated by the challenge of relating non-structural carbon to tree lifespan in non-vital heartwood or in living tissue crossing sapwood in both crosswise and lengthwise directions.
However, since carbon fate in a plant depends on the balance between growth, metabolism, and reserves, and the use of stored carbohydrates is driven by environmental constraints that limit carbon assimilation through photosynthesis, the evaluation of non-structural carbohydrates in wood parenchyma could be important to verify whether reserves are consistent with dendrochronological outputs or, conversely, respond differently. In particular, the relationship between dendrochronology and carbohydrates could help highlight and explain possible long-lasting legacies in wood formation and priming for future stress.
This paper reviews the literature linking wood anatomy and dendrochronology with measured carbohydrate content, aiming to identify current limitations, evaluate possible solutions, and suggest new experimental approaches. The ultimate goal is to better understand the relationship between structural and non-structural carbohydrates in deciphering tree responses to changing climatic conditions and other abiotic constraints.

Rachele Gamba – University of Turin, Italy

Evaluating the Efficacy of Dendrosurgery in Esca Disease Control: A Vineyard Case Study on Barbera grapevines

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Grapevine (*Vitis vinifera* L.) is affected by several fungal diseases, including esca, a severe trunk vascular disease that leads to leaf stripes, wood decay, disrupting vine physiology and, in severe cases, plant death.

Esca disease causes economic losses due to reduced yields and the costs associated with replacing diseased or dead grapevines. Therefore, the removal of infected wood is crucial to limiting the spread of the disease. Recently, alongside the use of preventive strategies, such as selected tolerant rootstocks, a new approach has been introduced: the dendrosurgery (DDC). This practice involves the mechanical removal of necrotic wood. Uncertainties remain regarding the short and long-term effects of the DDC treatment on the productivity, symptom occurring and physiological performance of treated grapevines.

This study focused on *Vitis vinifera* cv. Barbera vines (Azienda Braida, Rocchetta Tanaro, AT, Italy) showing esca symptoms. Some symptomatic vines had been treated 3–4 years earlier using dendrosurgery (DDC). These DDC-treated vines have shown no esca disease symptoms since the treatment. Additional symptomatic vines were treated with DDC in March 2025. DDC-treated vines did not exhibit further esca symptoms. Leaf gas exchange, stem water potential, and biochemical analyses were assessed in these plants at the beginning of and throughout the growing season and compared with asymptomatic vines. Results did not reveal significant differences in the physiological parameters or in proline and NSC contents, suggesting that DDC may be an effective defense strategy against esca disease. Further anatomical and productivity-related analyses were carried out during the season.

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