

**Estación
Experimental
del Zaidín**

**Report
2021**

Estación Experimental del Zaidín



Report 2021

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FOREWORD

In 2021 we still continued facing the SARS-CoV2 threat in our everyday working routines, but our institute proved that it had adapted well to pandemic stress developing different strategies to maintain the level of scientific production, funds from competitive projects, technology transfer and presence in society, while at the same time preserving the health of its staff.

We have reinforced our commitment with the sustainable development goals in the context of agri-food and environmental preservation: No Poverty, Zero Hunger, Good Health and Well-being for People, Responsible Consumption and Production, Climate Action, Life on land. More than ever we must pay particular attention to the concept of “One Health”, considering that human and animal health are interdependent and linked to the ecosystems in which they coexist.

We have also experienced an important growing trend in terms of regional, national and international project funding with respect to the previous 2014-2017. We have also been actively involved in the design of the new 2022-2025 Strategic Plan.

We have increased the number and quality index of our publications and carried out an enhanced editorial work with the edition of books and special issues in relevant journals. Efforts have been made to reinforce industrial partnerships in research projects and contracts with industries. Infrastructures in scientific services have been improved and updated with state-of-the-art equipment, thanks to the corresponding programmes of the Ministry of Science and Innovation.

We have started and we have continued working on relevant European projects as PATHWAYS for transitions to sustainability in livestock husbandry and food systems and HOLORUMINANT on studies on the ruminal microbiome, both financed by Horizon 2020. The main goal of EPJ SOILS, also supported by Horizon H2020, is to improve the contribution of agricultural soils to key societal challenges, including climate change and future food supplies. The project SUMHAL, Sustainability for Mediter-

anean Hotspots, integrating LifeWatch ERIC, involves different EEZ groups whose aim is to contribute to the conservation of biodiversity in natural or semi-natural systems in the western Mediterranean area.

The reconstruction and refurbishment of the building known as Casa Roja (3973 m²) has been completed and the building was inaugurated by the President of the CSIC in the first quarter of 2022. The updated building houses the Department Biochemistry and Molecular and Cellular Biology of Plants as well the scientific and general services and expands the laboratory space available. This will favour the growth of the institute and will be used to attract young scientists to the EEZ.

The Centre is strongly committed with the communication of research results and scientific information to society, and with the training of high quality PhD students and post-doctoral scientists. The increase in attendance to these activities after a period where most of them occurred on line has favoured the scientific life in our institute.

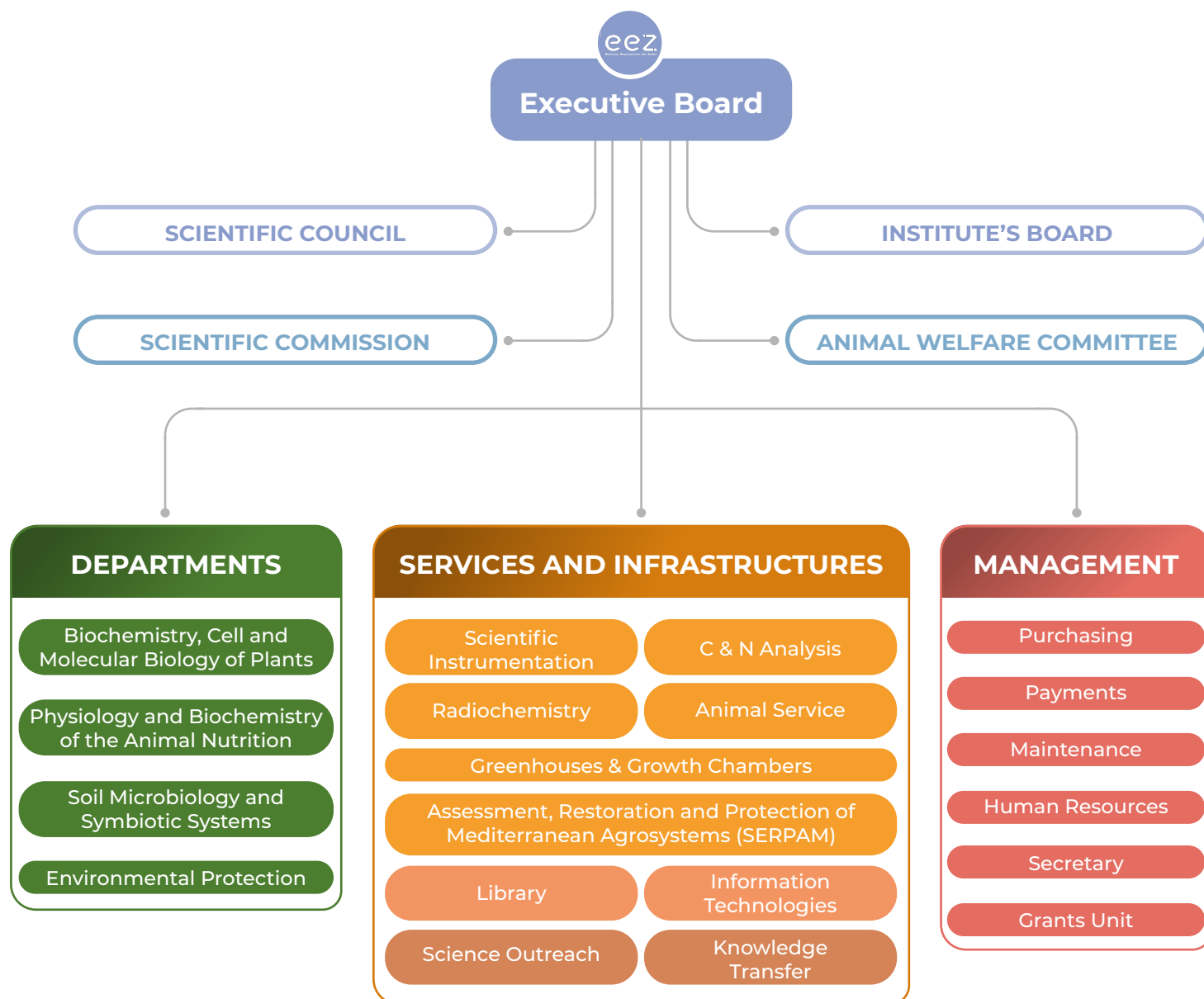
We trust that after these challenging years both from the professional and personal point of view, there will be a wide horizon for us to carry out our research under the motto “Science for a sustainable world” in the context of societal challenges: sustainable agriculture and farming, climate change, environmental protection, crop defence against adverse conditions, food quality and security, and global health. The approaches to tackle these global objectives will combine fundamental research essential to expand the current body of knowledge regarding biological processes and agricultural systems, and the development of applied or close-to-application strategies that will allow knowledge transfer to the productive sector.

MATILDE BARÓN AYALA
Director of the EEZ



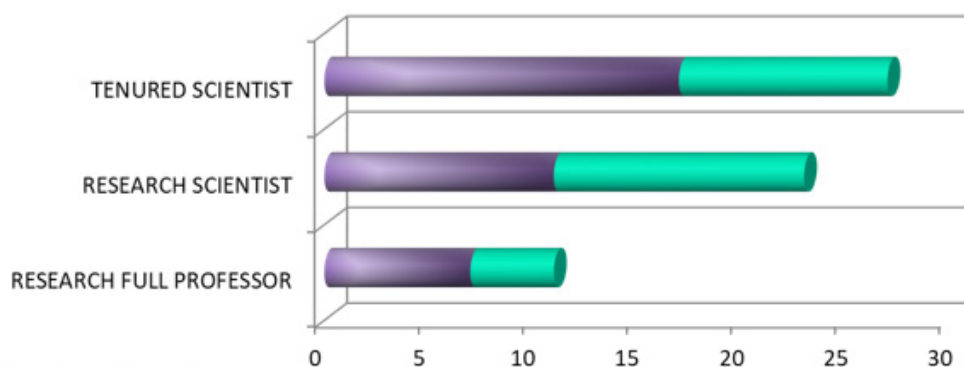
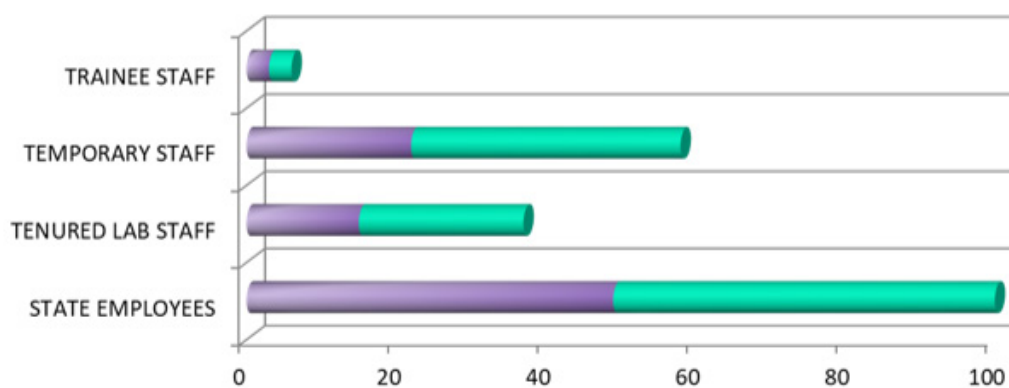
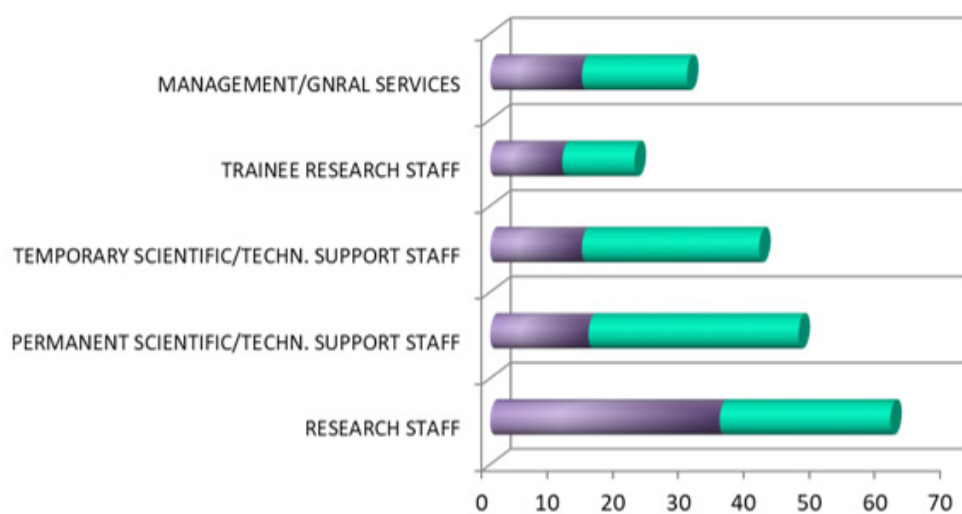
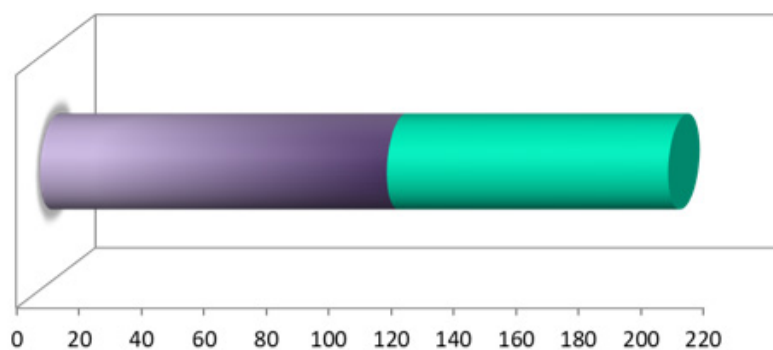
THE INSTITUTE

ORGANIZATION CHART



STAFF

■ MALE ■ FEMALE



(GEP Database on personnel assigned to the EEZ, 15 thDecember 2021)

DIRECTION AND MANAGEMENT

- **Dr. Matilde Barón Ayala**
Director
- **Dr. Nuria Ferrol González**
Deputy Director
- **Dr. Alfonso Clemente Gimeno**
Deputy Director
- **José Luis Sánchez Justicia**
General Manager (until 15th July 2021)
- **M^a del Rocío Santiago Rejón**
General Manager (from 27th July 2021)

ADMINISTRATION AND GENERAL SERVICES

■ SECRETARY

Inés Abril Martí
Ana M^a Esteban Muñoz
Carmen Lorente Vázquez

■ PAYMENTS

Isabel Abril Álvarez
Salomé García Jiménez
Jorge García Salazar
Juan M^a Pérez Torres

■ HUMAN RESOURCES

M^a del Mar Fandila Enrique
M^a Paz Montesinos Parra

■ GRANT UNIT

Rosario Molina Quesada
Susana A. Gómez Lopera
Carmen Lorente Navarro
Eva M^a Sánchez Abolafia
Ascensión Valderas Jiménez
Juan Carlos Vílchez Rojas

■ PURCHASING

Álvaro Mérida González
Carmen Camacho Guzmán
Luis Miguel García Rodríguez
Jaime Cecilio Ramírez Melguizo
Rafael Miguel Ruiz García

■ MAINTENANCE

Samuel Martínez Marruecos
Fernando Caro Fernández
Fernando Flores García
Pedro Palomares Martínez
Juan Pablo Vera Padial (*Armillá*)

INSTITUTE'S BOARD

PRESIDENCY

Dr. Matilde Barón Ayala	<i>Director</i>
Dr. Nuria Ferrol González	<i>Deputy Director</i>
Dr. Alfonso Clemente Gimeno	<i>Deputy Director</i>

SECRETARY

José Luis Sánchez Justicia	<i>General Manager until 15th July</i>
M^a del Rocío Santiago Rejón	<i>General Manager from 27th July</i>

HEADS OF DEPARTMENTS

Dr. María C. Romero Puertas <i>Dept. of Biochemistry and Molecular and Cellular Biology of Plants</i>
Dr. Ignacio Martín García <i>Dept. of Physiology and Biochemistry of the Animal Nutrition</i>
Dr. M^a Jesús Delgado Igeño <i>Dept. of Soil Microbiology and Symbiotic Systems</i>
Dr. Rogelio Nogales Vargas-Machuca / Dr. M^a Antonia Llamas lorente <i>Dept. of Environmental Protection</i>

STAFF REPRESENTATIVES

Dr. Cristina Delgado Andrade
Dr. José Luis Garrido Sánchez
Jaime C. Ramírez Melguizo
Dr. M^a Eugenia Ramos Font

SCIENTIFIC-TECHNICAL SERVICES

The **EEZ** has several services available both to the Centre's groups and to the scientific community and companies that require them. All in-

formation and fees are available on the Centre's website. These services belong to the Scientific and Technical Services Network of **CSIC**.

ANIMAL SERVICE

Head

Isaac Abdel Gálvez

Technicians

Francisco Funes Madrid



Facilities and equipment

This animal facility makes its installations available to researchers from the Department of Physiology and Biochemistry of Animal Nutrition, as well as provides the conditions and requirements necessary for carrying out research projects with pigs, small ruminants, birds and rodents. The facilities consist of exercise yards, animal housing, testing rooms, a quarantine area, operating theatre, hayloft and feed warehouse. These facilities offer opportunities for collaboration with private companies.

Analyses / Services offered

General services:

- Supply of EEZ-breed animals
- Reception of external animals, identification, weighing
- Maintenance of small ruminants, pigs, birds and rodents: Housing, feeding, cleaning of enclosures and sanitary control
- Collaboration in experimental procedures

Technical services:

- Waste management: SANDACH (carcasses/manure/slurry/milk)
- Management of animals' transport
- Participation in the Animal Welfare Authority (OEBA)
- Organization of workshops and seminars for training in handling and experimental techniques

- Management of access to facilities
- Administration of the animals' census: records, of discharges and casualties

Laboratory services:

- Execution of necessary health checks to ensure the proper health status of the animals
- Assistance and prescription of medication
- Euthanasia following the legal criteria
- Necropsies
- Surgeries
- Technical assistance in experimental procedures

Activities in 2021

- Maintenance of small ruminants, pigs and hens (accommodation, food, cleaning and sanitary control)
- Surgery on small ruminants (Project 18/03/2019/042)
- Visit Coordination: José Miguel Mayor Moreno (President ICOV Granada) and Fausto Brandao (Specialist in Endoscopy and Minimally Invasive Surgery)
- Implementation of new identification systems in pens (QR codes)
- Adaptation to new enclosures. Promotion and maintenance of environmental enrichment, measures to improve animal welfare
- Compliance with operating regulations of the Animal Service Facilities. Documentation management (treatment book, transport, procedures, SANDACH, etc.)



Animal Facility ES180210000016. Department of Physiology and Biochemistry of Animal Nutrition

CARBON AND NITROGEN ANALYSIS SERVICE

Personnel

Rafael Hueso Ibáñez
José Luis Luque Ojeda



Facilities and equipment

- Elemental analyzers (Leco TruSpec CN and Leco CN828)
- Analytical balance and drying oven

Analyses / Services offered

- Quantitative determination of total Nitrogen (by Dumas method) and Carbon (by infrared detector) in a wide range of matrices (water, biological fluids like milk or urine, animal feed, forage, animal or plant tissues, faeces, soils, etc.)
- Quantification is performed with certified standards from Leco

Activities in 2021

- Installation of a new carbon nitrogen analyzer
- Quantification of organic carbon by low temperature combustion



N/C Analyzer (Leco CN828)

GREENHOUSES AND PLANT GROWTH CHAMBERS SERVICE

Head

Andrés Belver Cano

Technician

Francisco Sires Navarrete



Facilities and equipment

- 14 walk-in growth chambers provided with LED illumination and ventilation, with a total cultivation area of approximately 130 m². One chamber is dedicated to the cultivation of plants under short-day conditions, other to *in vitro* cultivation,

2 are conditioned for studies at high ambient CO₂ concentrations and 2 are exclusively devoted to the cultivation of plants infected with pathogenic bacteria and fungi

- 10 greenhouses, providing a total area for plant cultivation of 154 m², with additional lamps to provide artificial light, three of them also equipped to set up hydroponic cultures
- Phenotyping platform, with the possibility of incorporating different sensors (CCD, thermal or multispectral cameras)
- Latest generation imaging fluorimeter

Activities in 2021

- New walk-in Growth Chamber (number 15) in operation, conditioned for studies at high temperature and high ambient CO₂ concentrations

- Improvement of climatization and ventilation systems in Greenhouses: installation of 7 Inverter Air Conditioning units in 7 Greenhouses (1, 2, 3, 5, 8, 9 and 10) and 10 ventilation systems in the 10 Greenhouses
- Horizontal autoclave for steam sterilization in operation
- Floor tile change in Greenhouse number 9



Growth Chamber 15

CONFOCAL AND TRANSMISSION ELECTRON MICROSCOPY SERVICE

Head

José Carlos Jiménez López

Technician

Alicia Rodríguez Sánchez



Facilities and equipment

- Confocal Laser Scanning Microscope (Nikon C-1)
- Transmission Electron Microscope (JEOL JEM-1011)
- Inverted Epifluorescence Microscope (Leica DMI600B)
- Epifluorescence Stereomicroscope (Leica M165FC)
- Different tissue processors for electron and laser microscopy: Automatic tissue processor for electron microscopy samples (Leica TP1020), processor for paraffin inclusion (Leica EG1150), vibratome (Leica VT1200s), microtome (Leica RM 2165) and ultramicrotome (Reichert-Jung ULTRACUT)

Activities in 2021

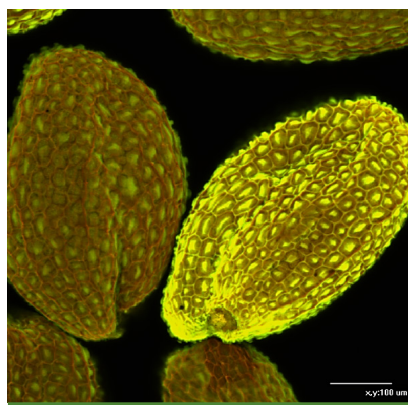
Technician attendance at training courses and webinars:

Courses:

- Spectral Confocal and Super-resolution microscopy. University of Barcelona
- Processing and analysis of digital images in microscopy: ImageJ/FIJI. CSIC Granada

Webinars:

- "Huygens Workflow Processor use". Scientific Volume Imaging bv
- "Launch of Imaris 9.7: Diving into structure and function". Oxford Instruments
- "Image Analysis Software for Immunology". Oxford Instruments
- "Introduction to Time lapse in Imaris". Oxford Instruments
- "Ultramicrotomy for room temperature and cryo applications". Leica Microsystems



Arabidopsis seeds. 20X magnification Laser Scanning Confocal microscopy image

RADIOCHEMISTRY LABORATORY

Head

Francisco Martínez-Abarca Pastor



The EEZ has authorization to operate the 2nd category radioactive facility IR/GR-06/73 (IRA 159, according to the CSN nomenclature). The authorized activities are the use of non-encapsulated radioactive material.

Authorized isotopes:

- ^3H (50mCi); ^{14}C (30mCi); ^{33}P (20mCi); ^{35}S (10mCi); ^{125}I (5mCi); ^{32}P (10mCi)
- Encapsulated radioactive source of ^{137}Cs of 32.25 μCi (1.19 MBq) of maximum activity used in the scintillation counter

Facilities and equipment

- Two units, one located on the ground floor of the Microbiology building that consists of two areas (monitored area and controlled area), and a second laboratory located at the Armilla headquarters
- Geiger-Müller contamination detectors
- Liquid scintillation counter (Beckman Coulter, model LS 6500)
- Phosphorimager Autoradiography, Digital detection System of radioactivity. (Personal Molecular ImagerTM (PMITM System, BioRad)
- Fume hood, thermal cycler, hybridization oven, freezer, refrigerator and microcentrifuges
- Adequate radioprotection and decontamination equipment

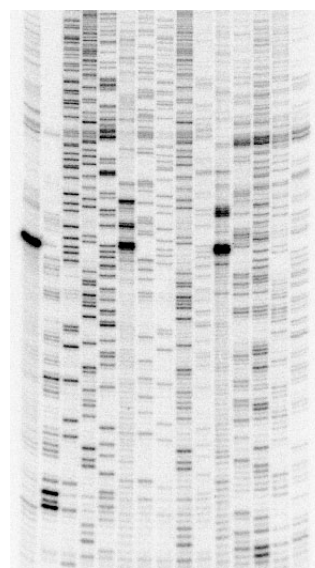
Performed techniques

- Microbiology Building: DNA and RNA labeling and probes-hybridization, autoradiography, incorporation of radioisotopes into cells, protein phosphorylation, *in vitro* transcription, etc.
- Armilla headquarters: Radioimmunoassays for determination/quantification of animal hormones
- Phosphorimager Autoradiography, Digital detection System of radioactivity. (Personal Molecular ImagerTM (PMITM System, BioRad)

- Fume hood, thermal cycler, hybridization oven, freezer, refrigerator and microcentrifuges
- Adequate radioprotection and decontamination equipment

Performed techniques

- Microbiology Building: DNA and RNA labeling and probes-hybridization, autoradiography, incorporation of radioisotopes into cells, protein phosphorylation, *in vitro* transcription, etc.
- Armilla headquarters: Radioimmunoassays for determination/quantification of animal hormones



Autoradiography of denaturing acrilamide gel for Nucleic Acids analysis



SCIENTIFIC INSTRUMENTATION SERVICE

Head

Tino Krell

Technicians

Virginia Cuéllar Maldonado

Rafael Núñez Gómez

Lourdes Sánchez Moreno

Miryam Rojas Gómez

Beatriz Sánchez Romera



- Determination of elemental composition of liquid and solid samples using ICP-OES
- Analysis of molecular interactions by microcalorimetry
- Custom-tailored development of extraction protocols of analyte compounds from different biological samples

Activities in 2021

- Installation of a high-potency microwave digester of solid samples for subsequent analysis of the elemental composition using ICP-OES
- Organization of a training course on chromatographic separation techniques by facility members

Facilities and equipment

Equipment for Liquid Chromatography and mass spectrometry:

- HPLC Waters Alliance 2695
- UPLC Waters Acquity H-Class
- UV, fluorescence and refractive index detectors
- Electrospray ionization mass spectrometer with triple quadrupole detector (Quattro micro)
- Electrospray ionization mass spectrometer with qTOF detector (Vion IMS-QToF)

Equipment for Gas Chromatography (GC):

- Gas Chromatograph coupled to mass spectrometer Varian 450-GC-240MS
- Gas Chromatograph 490 Micro GC

Equipment for elemental analysis:

- Inductively coupled plasma optical emission spectrometry (ICP-OES) Varian ICP 720-ES
- Isothermal Titration Calorimeter (ITC)
- Nano Isothermal Titration Calorimeter (T.A. Instruments)
- Electron Paramagnetic Resonance (EPR) Spectrometry:
- EPR spectrometer EMXnano (Bruker)

Analyses / Services offered

- Detection and quantification of a wide range of low molecular weight compounds by liquid chromatography or gas chromatography separation followed by infusion into mass spectrometers
- Quantification of permanent gases by GC (methane, CO, CO₂, N₂O, etc.)



View of the main laboratory of the Scientific Instrumentation Service that houses the instruments for gas- and liquid chromatography

EEZ
Estación Experimental del Zaidín

ASSESSMENT, RESTORATION AND PROTECTION OF MEDITERRANEAN AGROSYSTEMS (SERPAM)

Heads

Ana Belén Robles Cruz

Technicians

M^a Eugenia Ramos Font

Mauro Tognetti Barbieri

Antonio Jesús Pérez Luque



SERPAM is an environmental research and advisory service (natural and agricultural environments), whose pillars are:

- Knowledge of Mediterranean pasture systems and resources: flora, wild forage crops, vegetation, pastures, plant covers, and agrosilvopastoral systems
- Management of the natural environment: evaluation and management of natural pastures, livestock carrying capacity, restoration of degraded lands, enhancement of mountain areas and preventive silviculture alternatives with livestock

Analyses / Services offered

- Herborization, identification and determination of flora
- Evaluation and analysis of plant resources (floristic composition, structure, production)
- Evaluation of the carrying capacity of natural pastures
- Management of plant covers
- Management of vegetation cover with livestock
- Germplasm bank of native plant and forage species
- Collection of native seeds
- Characterization and seed germination tests
- Restoration and improvement of natural pastures
- Evaluation of the livestock impact on the vegetation cover
- Pastoral planning in fire prevention systems
- Training and participatory activities in the management of the natural and agricultural environment

Activities in 2021*

- Participation in 4 research projects funded by international and national agencies
- Publication of 3 peer-review articles
- Participation in various dissemination activities and training courses

**Reported in the corresponding sections*



Vegetation sampling within the LifeWatch ERIC - SUMHAL Project

EEZ
Estación Experimental del Zaidín

TECHNICAL RESEARCH SUPPORT UNITS

INFORMATION TECHNOLOGIES SERVICE (ITS)

Head

Francisco Javier Mengual Maldonado

Other members

César Azorín Márquez

Lourdes Salmerón García (*Armillá headquarters*)

Víctor Baena Vílchez (*Integra S.A.*)

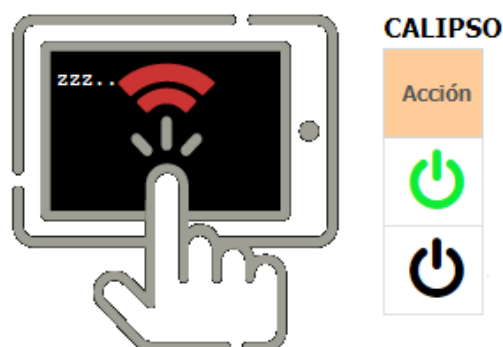


The IT Service maintains and supports the entire communications infrastructure (voice and data) at the two headquarters of the EEZ. It also manages different services, such as the Centre's website and intranet and offers support to the users' incidences.

Activities in 2021

- Migration to Linux systems on servers with guaranteed upgrade support through 2029
- Installation of a data connection through a Macrolan to CSIC central services at the Zaidín headquarters. This replaces the cabling from EEZ to the IAA. It represents a considerable improvement in the availability of Internet service
- In response to energy consumption and to improve the environmental impact, a software called Calipso has been developed by the Service to allow remote start-up of the computers
- Development of computer inventory software, automatically compiling hardware characteristics of installed equipment
- Installation of new Xerox photocopying machines. The Service has developed customized software or drivers to improve the printing/scanning experience and productivity

- Migration of telephony, including all telephones, to the Telefónica provider, thereby integrating us into the CORA project
- Updating of the EEZ incident report systems, providing more capabilities to the staff of the Maintenance and Greenhouses Services
- Implementation of web and applications filters in firewalls to block access to unsafe web pages; as well as the installation of Microclaudia, tool that protects us from data encryption for ransomware
- Upgrading of the clocking and security systems of the two headquarters, renewing the computers and allocating two servers dedicated to the databases. Customized software has been developed for use in Human Resources
- Installation in the EEZ cloud of all the Growth Chambers and simultaneous remote access to them, for an easier intervention of the technicians, and to increase availability in the event of failures
- Web hosting on our servers to the investigation groups, development and maintenance. During this year the groups server has received 13.065 visits and the EEZ website 86.616 visits



KNOWLEDGE TRANSFER UNIT

Head

Alfonso Clemente Gimeno

In collaboration with:

Juan Carlos Vílchez Rojas



This Unit provides support to the Centre's research groups, managing the transfer of the knowledge generated through its technological offer and promoting collaboration with companies and institutions. Its activities include consultancy and management of research contracts, support in the application for public aid in collaboration with companies, the development of an updated portfolio of technology-based companies, as well as the protection, promotion and commercialization of research results.

Services offered

- Advice to research groups for the management of contracts, patents and *collaborations* with companies and institutions

- Management of contracts for Technological Support, R&D (Research and Development), Confidentiality Agreements (NDA), Material Transfer Agreements (MTA), Patents and Services

Activities in 2021

- Advice on the signing of contracts with 30 companies (23 Spanish and 7 foreign), including 17 Technology Support contracts, 6 NDA and 2 MTA

Meetings and attendance at trade fairs and congresses:

- Fruit attraction Live Connect (Online, 5-7 October, 2021)
- Transfiere, European Meeting on Science, Technology and Innovation (Málaga, 14-15 April, 2021)
- Programa de Inteligencia Competitiva en I+D+I Ciencia-Empresa (CEOE-FGCSIC) (October-December, 2021)



LIBRARY

Head

Felicitas Ramírez Malo

Librarian

Francisca González Iglesias



This is a public research library with collections specialised in plant biotechnology, soil microorganisms interacting with the plants, and animal nutrition physiology.

Its mission is to attend the scientific and specialized information needs of the scientific staff of the EEZ, as well as to provide it to any other institution or library that requests it.

Although it keeps paper editions since 2000, it offers access to 90% digital books and journals.

Services offered

- Reading room with internet access
- Access to digital journals and books
- Book loans
- Interlibrary loans
- Bibliographic information and assistance
- Access to documents for staff personnel
- Reproduction of documents

- Access to scientific bibliographic databases
- Archive integrated in the Institutional repository

Activities in 2021

- Exhibit “What is Science for you?” (Casa de la Ciencia, Seville, from September 2020 to July 2021)
- Addition to the Library of graphic material donated by the family of Dr. Pablo Prieto Fernández, a former researcher of the EEZ who passed away in 2005
- Edition of two videos commemorating the World Book Day, 23rd April



[Youtube.com/](#)
Día del Libro 2021

and the International Archives Day, 9th June



[Youtube.com/](#)
Día Internacional de los Archivos 2021



Legacy of Pablo Prieto Fernández

SCIENCE OUTREACH UNIT

Head

Manuel Espinosa Urgel

Other members

Máquina Cruz Caballero



Public outreach and Science education

• *The sailor's Solitude; Science and Resilience*. A project funded by the Fundación General CSIC and FECYT, coordinated by EEZ with the collaboration of two other CSIC institutes (IACT and IAA). It focused on collectives that do not usually receive scientific contents and which have been particularly vulnerable to the confinement during the pandemics: elders in retirement homes, immigrants, and prison inmates. The activity combined

images, live music and narration based on the confinement and isolation associated with scientific exploration, to present research done in the three institutes

- *European Researchers' Night*. Funded by the EU, it combined on-line and on-site activities. EEZ scientists took part with several talks, encounters with students, and scientific videos (microscopy techniques and botanical tour of EEZ gardens)
- CAOS. Research projects carried out by high school students, supervised on-line by a scientist. Results were presented in an on-line meeting and published in High School Students for Agricultural Science Research, Vol. 10, ISSN 2340-9746
- *Exhibits*. “Mushrooms” remained open at Casa de la Ciencia (Sevilla) until April, and was then shown at the Museo de la Ciencia (Valladolid) from May to November; “Global change with an artist's look”, a combination of art and research projects on global change, with support from FECYT through VACC, was installed at the Granada Townhall, and a video was created to present it online; “Mnemosyne” remained open at the EEZ Library

- *International Year of Fruits and Vegetables*. Activities included an on-line round table on plants, nutrition and health during Fascination for Plants Day, and “My favorite fruit/vegetable”, a series of short videos with EEZ scientists and didactic material for schools

Press releases and social media

During 2021, the Unit has issued 32 web news and press releases. The highest coverage by the media corresponded to projects on an additive that reduces methane emissions by livestock; the organic transformation of “alperujo”; and the discovery of a bacterium that degrades ibuprofen

Data for our social media show a steady increase in impact:

- Twitter: 2.546 followers (+9% with respect to 2020)
- Facebook: 2.126 followers (+7%)
- Instagram: 520 followers (+93%)
- Youtube: 300 suscriptors (+51%)

Women in Science

- *International Day of Women and Girls in Science* (11th February): several on-line talks by female EEZ scientists with high school students
- *Women’s Day* (8th March): “Coffee with Science”, an activity organized with Fundación Descubre, where several Andalusian female scientists explain their work to groups of students. This edition was held on-line, with five researchers presenting their work to around 60 high school students
- *Other activities*: Several talks on the role of female scientists throughout history were presented in different locations



Advertisement of the exhibit “Mushrooms”, Museo de la Ciencia, Valladolid



Exhibit “Global change with an artist's look”, Granada Townhall



Presenting “The sailor's solitude”, Residencia Fray Leopoldo, Granada



eez
Estación Experimental del Zaidín

DEPARTMENTS AND RESEARCH GROUPS

DEPARTMENT OF BIOCHEMISTRY AND MOLECULAR AND CELLULAR BIOLOGY OF PLANTS

Antioxidants,
Free Radicals and
Nitric Oxide in
Biotechnology and
Agro-Food (ARNOBA)

Plant Reproductive
Biology

Ion Homeostasis
and Membrane
Transporters

Redox Regulation,
Signaling by Sugars
and Phenotyping
using Imaging
Techniques to Detect
Plant Stress

Reactive Oxygen and
Nitrogen Species
Signaling under
Stress Conditions in
Plants

Estación Experimental del Zaidín

DEPARTMENT OF PHYSIOLOGY AND BIOCHEMISTRY OF THE ANIMAL NUTRITION

Animal Nutrition

Small Ruminants
Production

Gastrointestinal
Health

Estación Experimental del Zaidín

DEPARTMENT OF SOIL MICROBIOLOGY AND SYMBIOTIC SYSTEMS

Biofertilization and
Biodegradation by
Rhizospheric Fungi

Structure, Dynamics
and Function of
Rhizobacterial
Genomes

Genetics of
Phytobacterial
Infections

Plant-Bacteria
Interactions

Nitrogen Metabolism

Mycorrhiza

Estación Experimental del Zaidín

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Environmental
Microbiology and
Biodegradation

Plant-Soil
Relationships

Estación Experimental del Zaidín



REPORT | 2021 |

DEPARTMENT OF BIOCHEMISTRY AND MOLECULAR AND CELLULAR BIOLOGY OF PLANTS

Antioxidants, Free Radicals and Nitric Oxide in Bio-
technology and Agro-Food (ARNOBA)

Plant Reproductive Biology

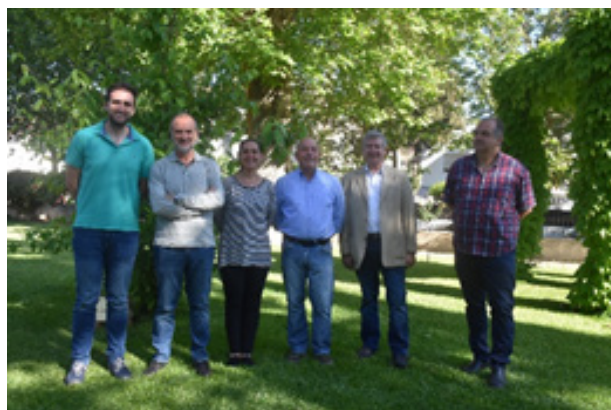
Ion Homeostasis and Membrane Transporters

Redox Regulation, Signaling by Sugars and Phe-
notyping using Imaging Techniques to Detect
Plant Stress

Reactive Oxygen and Nitrogen Species Signaling
under Stress Conditions in Plants

ANTIOXIDANTS, FREE RADICALS AND NITRIC OXIDE IN BIOTECHNOLOGY, FOOD AND AGRICULTURE (ARNOBA)

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OVERVIEW

The Group investigates, at the cell and molecular levels, the role of antioxidants, free radicals and nitric oxide in the physiology of horticultural species (pepper, tomato, olive, pea, etc.), for the development of biotechnological tools/strategies which allow a better exploitation of the nutritional features of these crops. To address these objectives, our Group applies high throughput approaches (transcriptomics, proteomics, and metabolomics), and collaborates with leading companies and foundations in the food and biotechnology sector, such as Syngenta Seeds Ltd., Sakata, United Caro Research and Development, S.L.U., Lactalis Puleva, S.L.U., Deoleo Inc., Agrosol, and MEDINA Foundation. In addition, we carry out research in *Arabidopsis* and pea, as model plants, to generate basic science knowledge to be further used in the applied objectives of the Group's activity.

This Group started in 1983 and, from the beginning, it focused its objectives on the study of antioxidants and cell signaling by Reactive Oxygen, Nitrogen and Sulphur Species (ROS, RNS and RSS, respectively) in plants of agronomic interest. Without refusing to basic research, the Group's activity is also aimed at applied research to ease the knowledge transfer to the productive sector. After greatly contributing to the advance of the knowledge, the Group has gained the expertise to potentially exploit it in the Biotechnology and Agro-food fields.

LINES OF RESEARCH

1. Study of the fruit physiology from crop species. Ripening and post-harvest are basically investigated in pepper, tomato and olive, through the analysis of enzymatic and non-enzymatic antioxidants. The involvement of nitric oxide (NO), ROS, RNS and RSS in those physiological processes is also accomplished. The influence of these molecules in the quality parameters of the selected products is analysed as well. To address this objective, whole fruits and subcellular fractions, mainly peroxisomes, are used, and transcriptomic, proteomic and metabolomic approaches are developed.

2. Role of NO and RNS in germination, development and abiotic stress in higher plants. The biochemical and molecular characterization of the endogenous cell targets (proteins, lipids and nucleic acids) involved in post-translational modifications promoted by ROS, RNS and RSS species is investigated, as well as the analysis of their participation in cell signaling processes during germination and development, and in abiotic stresses (salinity, wounding, high and low temperature, heavy metals and metalloids). *Arabidopsis* and pea are used as model plants, but also pepper, tomato, wheat, rice and olive, and the use of bio-markers induced in those plants in response to the above stress conditions are investigated. These approaches will contribute to the development of strategies and tools for biotechnological applications, which allow modifying the regulation of the germination and developmental processes, as well as the selection of plants more tolerant to several environmental stresses.

3. Search for natural bioactive compounds coming from vegetables with nutritional and biotechnological applications. Due to the Group's evolution, this objective is addressed to the nutritional and biotechnological sectors. New bioactive compounds (capsaicin, proteins and/or peptides, flavonoids, etc.) and antioxidants from tomato, olive and pepper with beneficial health effects, applied either through biomedical therapies or as dermatological products, are investigated. In connection with the productive sector, our Group carries out the characterization and selection of vegetable varieties especially rich in antioxidants, focused at improving their competitiveness in the markets.

HIGHLIGHTS

- Corpas *et al.* 2021. *Journal of Experimental Botany*, 72: 830-847: This article makes a review and propose models on how NO and H₂S interact in the NADPH metabolism in higher plants. NO and H₂S are key molecules that participate, directly or indirectly, as regulators of protein functions through derived post-translational modifications in a wide range of cellular processes, either physiological or under stressful circumstances, where NADPH plays a relevant role.
- Guevara *et al.* 2021. *International Journal of Molecular Sciences*, 22: 4476: This work is the first contribution of the Group in which pepper fruit is considered as a nutraceutical food due to its potential therapeutic properties against, for example, cancer episodes. Several compounds having those characteristics and possibly modulated by NO were identified from pepper fruits.
- López-Huertas *et al.* 2021. *Food Chemistry*, 342: 128291: Another contribution of the Group about the potential incidence of its research in human health in a journal of high impact in its field. In this case, it was found how our results could also have potential application for the industrial production of a category of healthy antioxidant olive oil.

- Functional involvement of nitric oxide, hydrogen sulfide and antioxidants in pepper fruit ripening and quality. Plan Estatal (PID2019-103924GB-I00): This project is the central axis of the research initiated 20 years ago in the Group. As in all cases since the beginning, a FPI contract was associated to this project.
- Identification and characterization of compounds from pepper fruits with anti-tumoral activity (Junta de Andalucía, P18-FR-1359/CA11098): This is a frontier project about the physiology of pepper fruit and how it can be handled to see this product as a nutritional food due to its potential therapeutic uses.



Picture of a pepper fruit at ripening stage, a process which has been modulated by the Group thanks to the treatment of fruits with nitric oxide (NO)



eez
Estación Experimental del Zaidín

PLANT REPRODUCTIVE BIOLOGY

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OVERVIEW

The main goal of the research Group is to advance into the knowledge of the reproductive developmental biology of plants, including model plants (e.g. *Arabidopsis*, *Lilium*...) and particularly in species of agronomic interest like the olive tree, lupine and argan, in order to further manipulate the plant reproductive cycle improving crop productivity and quality. In addition, we aim to understand the impact of different components from reproductive tissues (pollen, fruit, seed) and other industrial derived products (e.g. oils, flours, isolates, etc.) in allergy, their nutritional and nutraceutical properties, and in the development of molecular tools of agro-food interest. To achieve these objectives, we use multidisciplinary approaches, encompassing integrative omics, and biochemical, molecular and cellular methods, with special emphasis in advanced microscopy techniques. Current research lines include the study of the functional role of reactive oxygen and nitrogen species in developmental physiology, storage

lipids and oxylipins in signaling and metabolism during plant reproduction, and the characterization of the potential health benefits of seed constituents as anti-inflammatory and anti-diabetic molecules. These research lines have also broad practical applications, which are explored through the development of patentable and transferable industrial collaborations.

LINES OF RESEARCH

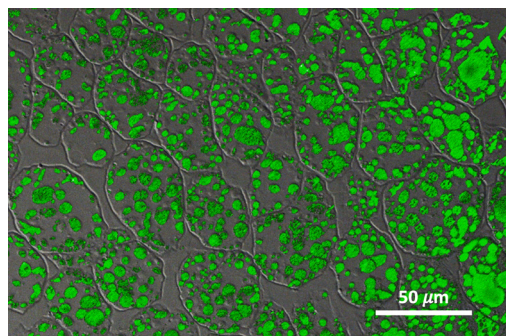
1. Identification, characterization and functional analysis of gene products involved in the development of flower, pollen, pistil, seed, and the germination and growth of the pollen tube. Analysis of the cellular and molecular basis of self- and cross- pollination. Signaling mechanisms involved in orientation and focused growing of the pollen tube.
2. Characterization of seed storage proteins and other proteins of interest in the olive seed, and in new by-products resulting from the alternative processing of the olive fruits and other species of agronomical interest. Identification of proteins in olive oils. Description of protein-derived components (protein isolates, digests, peptides...) and applications to alimentary or pharmaceutical use.
3. Allergy to olive pollen, pollen grains from other species and allergens from seeds involved in food allergy and pollen-food syndromes. Molecular allergology: isolation and characterization of allergenic proteins, including panallergens like profilin, lipid transfer proteins, polcalcins, glucanases.... Characterization of genetic and functional variability of allergens, and its physiological and clinical implications. Development of advanced molecular techniques for allergy diagnosis and therapy and allergens detection and quantitation.
4. Proximal characterization of new foods derived from plant reproductive tissues and assessment of their nutritional value and potential toxicity in animal models, including mouse and zebrafish.
5. Assessment of the immunological, antioxidant, antiinflammatory, antidiabetic and other nutraceutical effects of new agri-food components of high biological value derived from the alternative processing of olive, lupinus, argan, and other plant reproductive tissues on healthy and pathological human adults through *in vivo* nutritional interventions and *ex vivo* assays.

HIGHLIGHTS

- Castro *et al.* 2021. Data in Brief, 35: 106822: This publication complements the previous one Castro *et al.* 2020. Food Chemistry: X, 7: 100099, showing evidence of the presence of relevant proteins in the olive oil with potential nutraceutical activity.
- Alché *et al.* 2021. Challenge 5: Food allergy. In: White Paper 4: Challenges in Biomedicine & Health: This is a review of food allergy as one of the most important issues affecting human population nowadays, with prevalence showing and increasing trend for the near future. Most relevant topics including strategies to develop tolerance are reassessed.
- Olive seed germinates as alimentary, agronomical and ornamental source (Plan Estatal, RTC-2017-6654-2): This project characterizes and explores the alimentary properties and uses of olive germinates as a new food, which may represent an important contribution to the establishment of a circular economy in the olive industry.
- Two pollen lipid body-associated caleosins with distinct subcellular localization are involved, through their peroxxygenase activity, in the oxylipin-mediated regulation of germination

and pollen tube tip growth processes, which are essential for fertilization in oleaginous plants (Plan Estatal, AGL2017-84298-P).

- A short project envisaged to extend previous industrial collaboration, and focused to the further characterization of olive seeds as a source of proteins of interest for human consumption. (Junta de Andalucía, CA8313/AT17_5247).



Immunolocalization of seed storage proteins (SSPs) of the 7S-type in pistachio (*Pistachia vera*) seeds. 7S proteins (in green) are located in protein bodies present in the endosperm cells. Thin section (1 μ m) observed with fluorescence microscopy combined with bright field (Nomarsky optics)

ION HOMEOSTASIS AND MEMBRANE TRANSPORTERS

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OVERVIEW

We use an integrated approach to study the biochemical and molecular mechanisms of ion homeostasis in plants in order to develop biotechnological applications to improve salt tolerance, mineral nutrition and water use efficiency in crop plants. The ongoing research makes special emphasis on the functional characterization of ion transporters in economically important crops, as tomato and citrus, and model organisms, such as *Arabidopsis* and yeasts. In our Group we develop two separate research lines. One of the lines uses a genetic and molecular approach focusing on quantitative traits (QTL) of agronomical interest functionally supported by ion transporters. Thus, we study the function of ion transporter encoding genes (HKT, NPF, etc.) that control the exclusion of Na⁺ and Cl⁻, as functional determinants of QTLs or loci, which control salt tolerance in tomato and citrus rootstock-mediated fruit production. The identification of genes that functionally underlie QTLs by combining QTL mapping, candidate gene analysis and reverse genetics (RNAi, CRISPR/Cas, OEX), facilitates their monitoring in genetic

improvement programs (genomic selection or their manipulation through genetic engineering) in order to obtain tolerant plants to abiotic stress or their use as rootstocks of commercial varieties. Another approach deals with the functional characterization of ion transporters at the biochemical and molecular level. We study ion transporters involved in regulating proton, potassium and chloride gradients that play primordial roles in photosynthesis. Currently we study the role of chloroplast KEA K^+/H^+ antiporters in photosynthesis efficiency in *Arabidopsis* and characterize the function of the tomato KEA1,2 homologue using transgenic plants in which these genes are disrupted by CRISPR/Cas. Inhibition of photosynthesis contributes substantially to the negative effects of abiotic stresses like salinity, drought or K^+ deficiency on crop productivity. In this context we are performing a characterization of K^+/H^+ and Na^+/H^+ antiport in chloroplasts of halophytic and salt tolerant species.

LINES OF RESEARCH

1. Analysis of genetic factors related to ion homeostasis by identifying genes that encode Na^+ and Cl^- transporters involved in salt tolerance in terms of fruit yield in tomato and citrus.
2. Study of the molecular basis of ion transport (Na^+ , K^+ , Cl^- , Ca^{2+}) across chloroplast membranes of glycophytic and halophytic species and their relevance for chloroplast function and photosynthesis under normal and stress condition.

HIGHLIGHTS

- Keeping an alkaline pH in the chloroplast stroma is critical to activate Calvin cycle enzymes and CO_2 fixation. Stromal pH could be affected by the activity of ion transporters as KEA proteins located at the chloroplast inner membrane. We have developed methodology to measure stromal pH of isolated chloroplast loaded with a fluorescent pH probe. Our work shows the key role of chloroplast inner membrane ionic transport systems in chloroplast pH regulation under light and dark conditions as well as under light-dark transitions and demonstrates that KEA1 and KEA2 activities are critical for rapid stromal pH regulation and thus for photosynthesis function (Aranda Sicilia *et al.* 2021. *New Phytologist*, 229: 2080-2090).
- The possibility that the loss of function of KEA1 and KEA2 on photosynthesis function is related to a disturbance of ROS and RNS metabolisms was studied. We have demonstrated that loss of function of KEA1 and KEA2 provokes a significant reduction of nitric oxide (NO) levels and a higher drought tolerance in *kea1kea2* double mutant

plants, which could be related to the lower stoma aperture detected in these plants. This work can have a potential biotechnological interest for selecting drought tolerant crop varieties on the basis of the regulation of KEA transporters expression (Sánchez-McSweeney *et al.* 2021. *Plant Physiology and Biochemistry*, 160: 106-119).

- Photosynthesis and carbon fixation efficiency depend critically on the fluxes of protons across thylakoid and envelope membranes. Transport of protons has to be counterbalanced by transport of anions or cations, but little is known about the transporters involved. Our new technology to measure stromal pH enables us to study the role of various envelope ion transporters by evaluation stromal pH variations in several *Arabidopsis* mutants with disruptions in envelope ion transport systems (Plan Estatal, PID2019-105260GB-I00).
- We have investigated the physiological impact of ScHKT1;1/ScHKT1;2 function loss in roots and aerial parts on tomato salt tolerance in a commercial greenhouse, using reciprocal grafting combinations with a NIL, homozygous for ScHKT1;1/ScHKT1;2 and their respective single and double RNAi lines. We have demonstrated that ScHKT1;2 alleviates the negative saline effects on growth and fruit yields. The main function of ScHKT1;2 is xylem Na^+ removal at the aerial part, while ScHKT1;1 function loss in rootstock sharply reduced the Na^+/K^+ ratio in leaves and flowers (Romero Aranda *et al.* 2021. *Plant Physiology and Biochemistry*, 168: 282-293).
- We previously identified QTLs of tolerance to salinity in terms of fruit yields conferred by the rootstock in citrus using a population derived from the cross between the mandarin Cleopatra (*Citrus reshni*, salt-tolerant) and the trifoliate orange (*Poncirus trifoliata*, salt-sensitive). Specifically, a production QTL detected in the Cleopatra mandarin genome, which also coincides with a QTL for leaf Cl^- concentrations in the grafted variety. Following a bioinformatic analysis of the transcriptomes and genomic sequences of two genotypes differing in their Cl^- exclusion capacity, two putative Cl^- transporters from the NPF family were identified in the QTL, which were differentially expressed (DEG) between the two genotypes in both salinity and control conditions. These gene candidates could explain their phenotypic differences in leaf Cl^- concentrations, either individually or jointly (Plan Estatal, AGL2017-82452-C2-R).



WT MoneyMaker tomato plants and 3 CRISPR lines with mutations in a chloroplast K^+ transporter

REDOX REGULATION, SIGNALING BY SUGARS AND PHENOTYPING USING IMAGING TECHNIQUES TO DETECT PLANT STRESS

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OVERVIEW

Understanding redox regulatory mechanisms, by which plants adapt to environmental changes and regulate their metabolism, together with the development of big-data based tools, to monitor crops productivity with non-invasive techniques, are crucial to know how plants would respond and adapt to climate change. These complementary approaches are well represented in the two sub-lines of our research: 1) Redox Regulation and 2) Plant Phenotyping.

LINES OF RESEARCH

1. We investigate the redox regulation carried out by plastid thioredoxins (TRXs) and the photosynthetic processes involved in maintaining redox homeostasis. We also study carbon metabolism and sugar biosynthesis and signalling. Our aim

is to gain more insight into the regulation and biochemical features of the enzymes controlling sucrose and starch accumulation in plants. The functions of the key plastid redox proteins TRXs *f* and *m* are investigated. Our research interest is focused on plastid processes and how they are redox controlled. In addition to the study of classic redox signalling pathways, we also explore novel redox players including both individual proteins as big photosynthetic complexes.

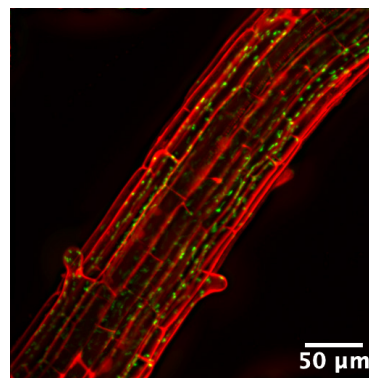
2. Plant phenotyping is mostly based on computer vision: thermography, chlorophyll fluorescence (Chl-F), multicolour fluorescence (MCFI) and hyperspectral reflectance imaging devices. We investigate plant biotic and abiotic stress induced by pathogen infections (viruses, bacteria and fungi), parasitic plants or by challenging environmental cues (high temperatures and CO₂, drought, etc.). We carry out a time-spatial analysis of leaves or fruits for stress detection, identification of developmental stage and mutant characterization. For data handling and analysis, we use artificial intelligence tools (machine learning classifiers) such as artificial neural networks (ANN), support vector machines (SVM), linear discriminant analysis (LDA) or binary linear regression analyses (LRA), among others. These algorithms learn from known data and make predictions on new data, classifying new samples in given categories, according to the experimental design.

HIGHLIGHTS

- The Group has reported new functions for chloroplastic thioredoxins *m* (TRXs *m*) in plant development and acclimation to changing light conditions. Lack of TRXs *m* led to profound changes in the mesophyll structure and stomata distribution in *Arabidopsis thaliana*. Photosynthetic parameters and anthocyanin accumulation in response to high-light intensities were also disturbed (Serrato *et al.* 2021. *Plant Journal*, 108: 120-133).
- Pest and plant diseases are a great challenge in modern agriculture and imaging sensors based methods of stress detection are excellent tools for its diagnosis. Thermography is one of the most widely used sensors, both in proximal and remote sensing scales, as reviewed by our Group (Pineda *et al.* 2021. *Remote Sensing*, 13: 68).

- Signalling mechanisms and regulation of photosynthesis and carbon metabolism in chloroplasts (Plan Estatal, PGC2018-096851-B-C21): This project is aimed to know how plant chloroplasts integrate redox signalling and metabolism. We have 1) proven the importance of the photosynthetic cyclic electron flow on the fine tuning of the redox signalling and 2) broadened the number of processes under the control of TRXs *m* in chloroplasts.
- Phenotyping plant-pathogen interactions under selected climate change projections (Plan Estatal, RTI2018-094652-B-I00): Our world is undergoing a process of climate change process that may have an impact on agriculture, affecting both plant and pathogen physiology. This project applies imaging sensors and machine learning to the early detection of infected plants growing under climate change conditions.
- The effect of thiol redox regulators on seed quality and the aging process (European Project, OPUS 16 project nº 2018/31/B/NZ9/01548): The Group has participated in this project, whose PI is

Ewelina Ratajczak, from the National Science Centre of Poland, with the objective of uncovering redox factors related to climate change responsible for seed aging process in tree species from European forests.



Confocal microscopy image showing plastid thioredoxin expression in Arabidopsis roots

REACTIVE OXYGEN AND NITROGEN SPECIES SIGNALING UNDER STRESS CONDITIONS IN PLANTS

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OVERVIEW

In our Group we are interested in understanding the mechanisms involved in plant responses to different types of abiotic (heavy metal and xenobiotics) and biotic (*Pseudomonas* and *Fusarium*) stress with the aim of applying the knowledge obtained to early stress monitoring and design of improved plant breeding strategies. For that purpose, multidisciplinary approaches will be used: biochemistry, cellular and molecular. The Group focuses on two main lines of research: 1) The study of the function of reactive oxygen and nitrogen species as signaling molecules in the regulation of gene expression and plant metabolism, throughout protein post-translational modifications and autophagy processes in response to stress, and 2) The study of the role of peroxisomal dynamics (peroxules formation and proliferation) and peroxisomal dependent signaling in both the perception and regulation of cell response to their environment.

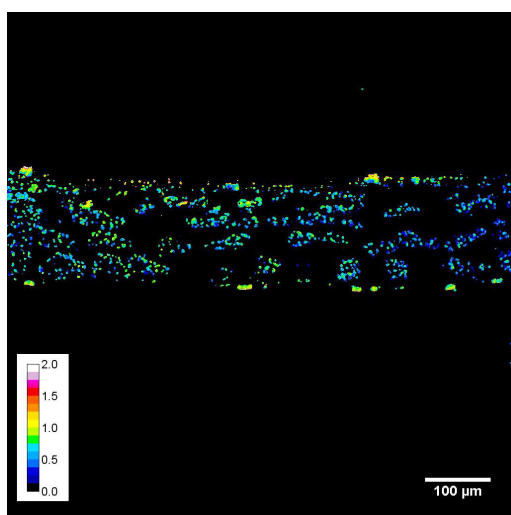
LINES OF RESEARCH

The study of mechanisms involved in the perception of external stimuli and the specificity of cell re-

sponses to a particular type of stimulus constitute two major challenges in the field of plant biology. This study aims to achieve the following objectives:

1. Function of ROS and NO in signaling and plant response to biotic and abiotic stress: To carry out these studies, we have different databases obtained from previous transcriptomic studies involving *Arabidopsis* mutants with ROS and NO levels altered, which allowed us to identify and characterize new genes dependent on these molecules participating in signaling transduction in response to stress. In addition, we study the function of ROS and NO-dependent post-translational protein modifications (S-nitrosylation, nitration and oxidation) in the perception and signal transduction (transcription factors and hormones). The role of autophagy in plant response to heavy metals and its regulation by ROS and NO is also analyzed.

2. Dynamics of peroxisomes and signaling dependent of these organelles: To carry out this objective we dispose of an extensive range of mutants with marked organelles with fluorescent proteins; the software and technology needed to analyse cross-talk between organelles and ROS and NO-dependent dynamic regulation under physiological and patho-physiological conditions. Different mutants expressing ROS bio-sensors are also available in our laboratory to visualize redox changes in response to stress, *in vivo*. On the other hand, we carry out the: a) identification of signalling components in response to stress, which are peroxisome dependent, by transcriptome analysis of mutants with peroxisomal ROS level altered; b) characterization of peroxisomal protein PEX11a interactome and c) screening of mutants with altered levels of peroxisomal dependent transcription factors.



Confocal imaging (Ex405nm/Ex488nm and Em530nm) of Cd induced peroxisomal redox state changes in leaves cross sections of *Arabidopsis* lines expressing the biosensor GRX-roGFP2 in peroxisomes

HIGHLIGHTS

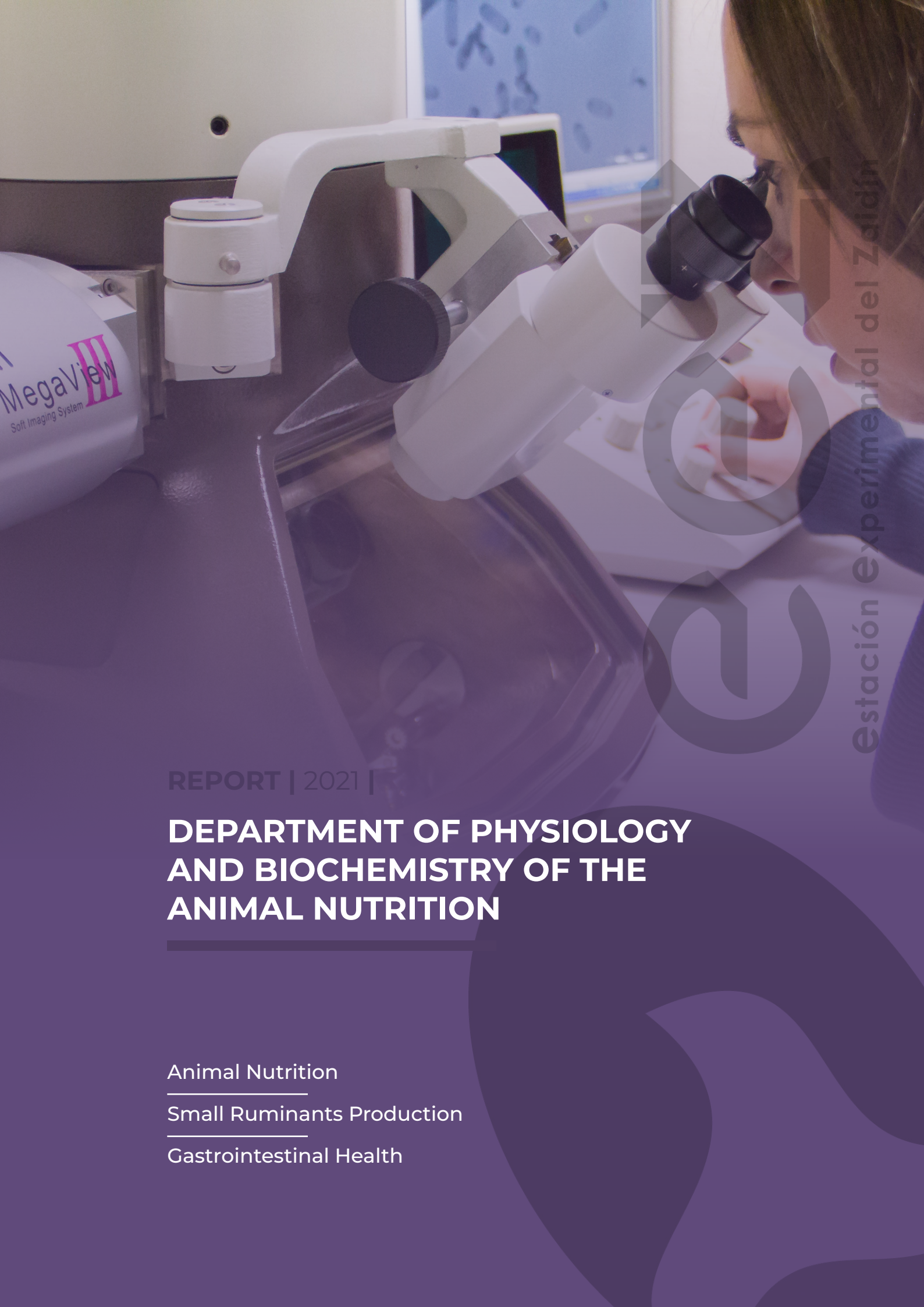
- From an evolutionary perspective, peroxisomes were selected to house a range of metabolic pathways involving the production of certain reactive oxygen species (ROS) such as H_2O_2 to avoid toxicity to other organelles such as mitochondria. Peroxisomes play a diverse range of roles in cell functionality and in the perception of and responses to changes in their environment. As most of these pathways produce ROS and nitric oxide (NO), disturbances in these metabolic processes trigger transitory changes in ROS/reactive nitrogen species (RNS) production. These changes regulate peroxisomal metabolism, leading to peroxisome-dependent signaling and organelle crosstalk, which triggers specific cell responses. This review updates our knowledge of peroxisomal redox homeostasis and the role of ROS and NO in the functionality, biogenesis and abundance of these organelles, as well as their role as redox hubs in metabolic regulation, signaling, and organelle crosstalk (Sandalio *et al.* 2021. *Plant Physiology*, 186: 22-35).

- The synthetic auxin 2,4-dichlorophenoxyacetic acid (2,4-D) functions as an agronomic weed control herbicide at high concentrations inducing plant growth defects, leaf epinasty and stem curvature. Although the 2,4-D triggered reactive oxygen species (ROS) production, little is known about its role in plant response to the herbicide. In this study, by using a null mutant in peroxisomal acyl CoA oxidase 1 (*acx1-2*), we identified acyl-coenzyme A oxidase 1 (ACX1) as one of the main sources of ROS production and, in part, also causing the epinastic phenotype following 2,4-D application. Transcriptomic analyses revealed a ROS-related peroxisomal footprint in early plant responses to 2,4-D, while other organelles, are involved in later responses. A group of 2,4-D-responsive ACX1-dependent transcripts is related to auxin biosynthesis, metabolism, and signalling. We found that the auxin receptor auxin signalling F-box 3 (AFB3), a component of Skp, Cullin, F-box containing complex (SCF) (ASK-cullin-F-box) E3 ubiquitin ligase complexes, which mediates auxin/indole acetic acid (AUX/IAA) degradation by the 26S proteasome, acts downstream of ACX1 and is involved in the epinastic phenotype induced by 2,4-D. Protein degradation associated with ubiquitin E3-RING and E3-SCF-FBOX in ACX1-dependent signalling in plant responses to 2,4-D was significantly regulated over longer treatment periods (Romero-Puertas *et al.* 2021. *Plant Cell and Environment*, 45: 572-590).

- In this manuscript, we focus on crosstalk between plant responses to biotic and abiotic stresses, in addition to possible plant protection against pathogens caused by previous abiotic stress. Bioinformatics analyses of transcriptome data from cadmium- and fungal pathogen-treated plants focusing on redox gene ontology categories were carried out to gain a better understanding of common plant responses to abiotic and biotic stresses. The role of reactive oxygen and nitrogen species in the complex network involved in plant responses to changes in their environment is also discussed (Romero-Puertas *et al.* 2021. *Journal of Experimental Botany*, 72: 5857-5875).

- Plant acclimation to environmental conditions involves multiple interactions between hormones and other signaling molecules. A lot of attention has been devoted to the signaling function of reactive oxygen species and their relationships to thiol-dependent redox regulations. Recently, new developments in proteomic techniques have revealed the relevant signaling effect of reactive nitrogen species and reactive sulfur species. Together, they cause post-translational modifications in proteins that participate in signaling networks, such as those responding to hormones, allowing the rapid response of plants (Cejudo *et al.* 2021. *Journal of Experimental Botany*, 72: 5785-5788).





REPORT | 2021 |

DEPARTMENT OF PHYSIOLOGY AND BIOCHEMISTRY OF THE ANIMAL NUTRITION

Animal Nutrition

Small Ruminants Production

Gastrointestinal Health

ANIMAL NUTRITION

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OVERVIEW

The activity of the Group is focused on the study of energy and nutrient utilization in non-ruminant, and on the identification of processes and specific compounds involved in the metabolic response to feed intake, including bioaccessibility and bioavailability of nutrients (amino acids, minerals, antioxidant compounds, etc.) using *in vitro*, *ex vivo* and *in vivo* techniques.

The research activity is nowadays focused on pigs and it is carried out mainly on native breeds (Iberian pig), known to have a wide genetic variation and high adaptability to local production systems. These breeds give rise to high-quality products with regional identity and highly appreciated by consumers, an aspect also covered by current research activities. However, autochthonous breeds show comparatively lower productivity than the

modern, high yielding, commercial breeds. In this way, a contribution to the preservation and development of the diversity of local breeds will also be achieved. On the other hand, the efficiency of livestock production systems will be optimized by accurately defining the nutritional requirements of these local breeds and by increasing the quality and nutritional value of their products, while decreasing the environmental footprint associated. Whenever possible, local feeding resources and by-products will be involved in practical feeding and production systems. The effects of climate change, particularly, heat stress effects on productive and physiological traits of Iberian pigs is currently under investigation.

LINES OF RESEARCH

1. Use of local feeding resources and agroindustrial by-products as ingredients in practical balanced diets for swine.
2. Impact of heat stress on physiology and productivity of pigs and nutritional strategies to mitigate its detrimental effects.
3. Effects and mechanism of action of substances with biological activity naturally present in feed-stuffs or incorporated. Focus on additives which may alter the efficiency of nutrient utilization and the quality and healthy properties of animal products.
4. Effects of innovative management practices on productivity, animal welfare and product quality of local porcine breeds.
5. Nutritional and organoleptic evaluation of pig meat under different nutritional management and environmental challenges.

HIGHLIGHTS

- Betaine and conjugated linoleic acid are natural metabolic modifiers that may improve pig performance and increase lean mass, but the mechanisms are not well understood. We proved that supplementation with betaine increased net portal appearance of essential and non-essential amino acids of growing Iberian pigs and, potentially, the amino acids availability for peripheral tissues. However, supplementation with conjugated linoleic acid decreased the net portal appearance of most essential amino acids (Lachica *et al.* 2021. *Animal Feed Science and Technology*, 273: 114825).

- Betaine is an osmolyte with the potential to increase volatile fatty acids production. Volatile fatty acids are the product of bacterial fermentation of undigested carbohydrates in the hindgut of monogastric animals. The present study investigated how betaine affects portal and arterial concentrations and net portal absorption of volatile fatty acids in growing Iberian pigs. We showed that betaine increased portal appearance and absorption of volatile fatty acids, contributing to cover maintenance energy requirements and improving intestinal health (Lachica *et al.* 2021. *Animal*, 15: 100197).

- Immunocastration is an alternative to surgical castration to prevent boar taint in male pigs reaching high animal welfare standards. This could be very convenient for autochthonous breeds raised up to heavy weights -usually outdoors- to obtain high-quality products. Increased growth performance and lean tissue accretion potential have been found in immunocastrated Iberian males compared to surgically castrates before the second dose of the vaccine is administered. This opens the possibility of obtaining pigs of greater lean mass before finishing outdoors contributing to a higher sustainability for Iberian pig producers (Palma-Granados *et al.* 2021. *Animal*, 15: 100187).

- Heat stress is associated with impaired meat quality in pigs and disruption of redox balance. We induced heat stress conditions in Iberian pigs maintaining the animals at 30°C for 28 days to study the impact of climate change in meat quality. Findings of the present study support an adaptive response of the Iberian pig to high temperatures through antioxidant mechanisms and show the high Iberian meat quality even under adverse climate situations (Pardo *et al.* 2021. *Antioxidants*, 10: 1911).

- The gastrointestinal tract is predominantly sensitive to thermal stress which could be caused by increasing environmental temperature as result of climate change. Since Zn is a crucial element for maintaining the normal functionality of the gastrointestinal tract, we performed a study aimed to examine the effects of Zn supplementation in intestinal cell cultures under heat stress. In Caco-2 cells grown with supplemental Zn the intestinal damage evoked by high temperatures was significantly attenuated and monolayer integrity was preserved (Pardo *et al.* 2021. *Journal of Functional Foods*, 83: 104569).



Iberian pigs enjoying EEZ outdoor facilities



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SMALL RUMINANTS PRODUCTION

MEMBERS



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OVERVIEW

The activities focus on the nutrition of the ruminant and work on develop feeding strategies to lower the cost of the diet and paying special attention on the optimization of the ruminal fermentation. Identifying the main mechanisms of action of those rumen microorganisms involved in methane production and fatty acids biohydrogenation are key areas of work in the Group. The activity of the Group fits within some pillars of the priority areas of H2020: Food Security, Sustainable Agriculture and Forestry, Maritime Research and Bioeconomy, Climate change and energy sustainability, and Blue Growth.

The Group has four major objectives: 1) Nutritional

evaluation of conventional and non-conventional foods (by-products, wastes, algae) as a strategy to reduce the cost of feeding ruminants, to improve animal health and to optimize ruminal fermentation. The cost of the diet represents 70-80% of the total cost of production. The use of non-conventional ingredients could help to achieve this goal. The supply of diets that include by-products, wastes or algae can have added value by improving animal health and welfare and the quality of meat, milk and dairy products and by reducing the production of methane, a greenhouse gas; 2) Study of the effects and mechanisms of action of additives (plant extracts, essential oils, synthetic compounds, secondary compounds) and probiotics on the utilization of nutrients, fermentation and ruminal microbiota. According to a recent EFSA report, the use of antimicrobials in animals far exceeds European recommendations, especially in Italy and Spain. Developing alternatives to maintain healthy and profitable animal production is critical in the coming years; 3) Study of the potential of *in vitro* technologies to simulate ruminal fermentation and reduce the use of experimental animals; 4) Evaluation of the factors involved in the microbial colonization of the rumen in early stages of ruminant life and the microbiome specificity of the host to develop nutritional interventions that allow programming the microbial ecosystem and the efficiency of the animal in adulthood.

LINES OF RESEARCH

Metabolism of nutrients and energy: productive and health beneficial aspects.

HIGHLIGHTS

- Pathways for Transitions to Sustainability in Livestock Husbandry and Food Systems (European Project (H2020-FOOD/0809 / RIA - Research & Innov. / EU217598_01): Coordinated by the Swedish University of Agricultural Sciences (SLU) and comprising 29 partners from 12 countries, PATHWAYS is a 5-year (2021-2026), €9 million Horizon 2020 project aiming to reduce environmental impacts while addressing societal demands for safe, nutritious and affordable meat and dairy products by identifying and increasing sustainable practices along the supply and production chains of the European livestock sector.

- Understanding Microbiomes of the Ruminant Holobiont (European Project (H2020-FOOD/0811 / RIA - Research & Innov. / EU217601_01): HoloRuminant is a multi-actor project aiming to elucidate the role of ruminant-associated microbiomes and their interplay with the host animal in early life and throughout fundamental life events (e.g. weaning, feed transitions and lactation) that are known to affect health, welfare and environmental efficiency in ruminant production systems. HoloRuminant will use a holistic multi-omics approach to characterize the establishment and dynamics of microbiomes. In this way, HoloRuminant will determine the connectivity between microbiomes from different body sites, their heritability and their influence on the host's key performance indices (KPIs) of efficiency of production, growth, resistance to disease, methane emissions, carbon footprint and phenotypic resilience to changing environmental conditions. The main outputs of the project will be the creation of an expandable benchmark dataset of ruminant-associated microbes, microbiomes and methods for analysis that will be used for answering essential (who, what, where and when) scientific questions and will be the knowledge foundation for innovation.

- Newborn ruminants possess an underdeveloped rumen which is colonized by microorganisms acquired from adult animals and the surrounding environment. This microbial transfer can be limited in dairy systems in which newborns are separated from their dams at birth. This study explores whether the direct inoculation of fresh or autoclaved rumen fluid from adult goats to newborn kids has a beneficial effect on rumen microbial development and function (Palma-Hidalgo et al. 2021. *Animal Microbiome*, 3: 11).



In vitro incubation of rumen fluid

GASTROINTESTINAL HEALTH

MEMBERS



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OVERVIEW

The research activity of the Group of Gastrointestinal Health focuses on the study of aspects such as the digestive and metabolic use of nutrients, and the physiological effects at the local (intestine) or systemic level of food chemical fractions (proteins, carbohydrates, fibre, etc.). Through a multidisciplinary approach, special attention is paid to the study of the mechanisms of action and biological effects, both nutritional and/or non-nutritional, of active substances either present in food or added to the diet.

LINES OF RESEARCH

1. To study the nutritional use, biological effects and digestive behaviour of legume food proteins (peas, chickpeas, lentils, among others) and compounds with putative biological effects (e.g., protease inhibitors, oligosaccharides) involved in the prevention of inflammatory and carcinogenic processes within the gastrointestinal tract by using *ex vivo*, *in vivo* (rodents) and *in vitro* (cell models, faecal homogenates) approaches.

2. To study the correlation between variations in the composition of the digestive microbiota and specific physiological, health and productive parameters in productive birds (broilers).

3. To develop *in vitro* digestion models designed to investigate the relationships between protein structure and functionality, digestibility and antigenicity as well as bioaccessibility of processing contaminants; and to design colonic fermentation models to determine carbohydrate fermentability, nutrient availability, and survival of probiotic strains.

4. To evaluate the prebiotic potential of oligosaccharides of different origin, both natural and from enzymatic synthesis, and their biological activities.

5. To develop mathematical models (R programming) capable of simulating intestinal bacterial growth.

HIGHLIGHTS

- Nutritional properties, bioaccessibility and functionality of new legume-derived foods (Junta de Andalucía, PY20_00242/CA17182): The project focuses on the investigation of the nutritional and healthy properties of the new legume-derived foods, trying to understand if these new elaborations which are trending in the food market preserve the bioactive profile of the original legumes. Actually, the scientific community has very limited information on key aspects about these new products, for that reason the project will study the nutritional characteristics of new foods marketed derived from legumes, the bioaccessibility of their fundamental components and their functionality with the aim of evaluating the quality and health benefits of the new elaborations.

- Acrylamide exposure and bioaccessibility in foodservices and traditional cooking (ACRINTAKE) (Plan Estatal, RTI2018-094402-B-100): The project

focuses on the evaluation of acrylamide exposure in the field of collective catering (school, university, work and elderly centers), considering the variability coming from different settings. The effects of the dietary matrix and the interactions with other nutrients on acrylamide bioaccessibility after gastrointestinal digestion are investigated. A novel aspect is the consideration of the possible effect of the microbiota on the non-bioaccessible acrylamide. The conclusions will help to evaluate acrylamide exposure in a more realistic way according to the dietary habits of different population sectors. They will also provide scientific basis for the risk assessment approaches developed by the competent entities on Food Security.

- González-Mulero *et al.* 2021. *L. Foods*, 10: 2008: This paper published in a Q1 journal derives from the ACRINTAKE Project and it deals with contribution of eleven groups of processed foods commonly consumed in Spain to the acrylamide exposure. Samples were collected from three different settings (household, catering and industrial) to evaluate the influence of the food preparation site on acrylamide formation. The highest concentrations were observed in French fries, especially those prepared at home. Industrially processed foods had the lower contribution, probably due to the more stringent control of processing in this setting.



Pisum elatius



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DEPARTMENT OF SOIL MICROBIOLOGY AND SYMBIOTIC SYSTEMS

Biofertilization and Biodegradation by Rhizospheric Fungi

Structure, Dynamics and Function of Rhizobacterial Genomes

Genetics of Phytobacterial Infections

Plant-Bacteria Interactions

Nitrogen Metabolism

Mycorrhiza

BIOFERTILIZATION AND BIODEGRADATION BY RHIZOSPHERIC FUNGI

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OVERVIEW

Arbuscular mycorrhiza (AM), established between the endosymbiotic AM fungi and higher plants, is the most widespread symbiosis in the plant kingdom. In the cortical cells of the roots, the AM fungi develop specialized intraradical and highly branched structures, called arbuscules, where bidirectional exchange of nutrients between plant and fungi partners occurs. During the establishment of the symbiosis, the interaction is highly regulated by both partners at the cellular, molecular and genetic levels. Research in this Group is particularly focused on the improvement of the Arbuscular Mycorrhizal symbiotic association in order to optimize plant nutrition.

We use a broad range of approaches, technologies and experimental systems to investigate the phenomenon of compatibility between plants roots and AM fungi that implies the elucidation of the recognition mechanisms and molecular signaling and regulatory events involved in AM formation, especially in the development and turnover of arbuscules.

AM fungi establish relationships with other soil microorganisms, particularly saprobic fungi, and research in the Group addresses questions related to how this relationship can alleviate abiotic stresses such as heavy metals, and examines a range of biological activities of saprobic fungi related to degradation of phytotoxic compounds in order to valorize agricultural waste, particularly from the olive oil industry, as bio-stimulatory fertilizer and contaminant adsorbent.

Other research in the Group focus on the design, formulation and production of mycorrhizal ultra-pure inoculants and biostimulants, such as the unique, patented gel-type products, nowadays commercialized in over 70 countries. The members of the *in vitro* laboratory are co-promoters of two biotechnological companies, and involved on innovative research and technology transfer to SMEs. A particular attention is given to alleviation of heavy metal and other recalcitrant contaminant stresses in plants and soils via autochthonous arbuscular mycorrhizal fungi through tailor-made inoculants.

LINES OF RESEARCH

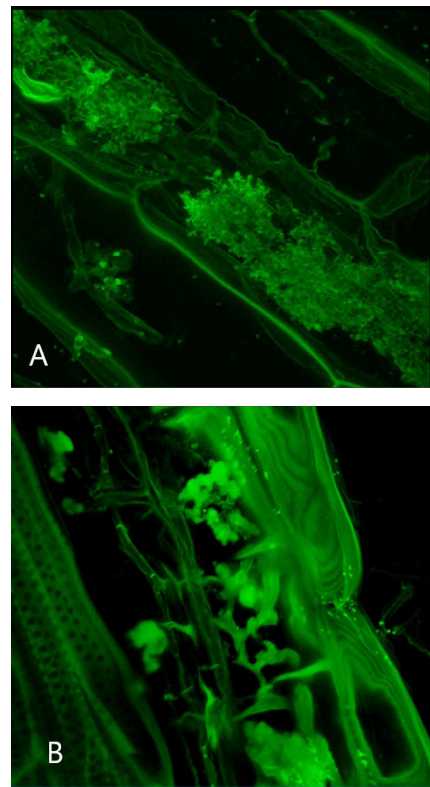
1. Regulation of the formation and function of arbuscules in Arbuscular Mycorrhiza.
2. Role of the transcription factors of the GRAS family in arbuscule homeostasis and Mycorrhizal autoregulation (AOM).
3. Use of AM and saprobic fungi in the bioremediation of soils contaminated with heavy metals and aromatic hydrocarbons and in the conservation of soil biodiversity.
4. Optimization of the valorisation of agricultural waste from the olive oil industry by saprobic fungi to use as bio-stimulatory fertilizer and adsorbent for soil decontamination.
5. Formulation and production of mycorrhizal ultra-pure inoculants.

6. Alleviation of heavy metals and other recalcitrant contaminant stresses in plants and soils combining saprobic fungi and autochthonous arbuscular mycorrhizal fungi through tailor-made inoculants.

HIGHLIGHTS

- Our study highlights the role of the extraradical mycelium of arbuscular mycorrhizal fungi (AMF) in Pb transport, its accumulation in wheat roots and how the protection effect exerted by AMF seemed to rely on mycoremediated dry olive residue application by increasing the P uptake rather than Pb.
- Significant contribution has been made on the field of symbiosis and Strigolactone/Karrikin (SL/KAR) signalling. This manuscript showed importance of tomato DLK2 protein in arbuscular formation in plant-Arbuscular Mycorrhizal fungi interaction. This is the first report for functional validation of roles of DLK2 in AM symbiosis although upregulation of DLK2 gene expression upon SL or KAR treatment, and AM symbiosis has been known for several years. Furthermore, the work presented showed biochemical property of SID-LK2, including hydrolase activity, ligand binding specificity (Ho-Plágaro *et al.* 2021. *New Phytologist*, 229: 548-562).
- Reva *et al.* 2021. *HortScience*, 56: 396-406: This paper has importantly contributed to enhance the knowledge on the effectivity of the use of arbuscular mycorrhizas in heat stress alleviation, and it has been named the ASHS Outstanding Cross-commodity Publication Award winner for papers published in 2021. It opens wide field for the use of arbuscular mycorrhizas in intensive agriculture, specially under greenhouse conditions, as so it is actually used as a rule by technical recipes given to producers.

- Members of the research Group are involved in the development of research projects financed by the Spanish Ministry of Science and Innovation and the Junta de Andalucía. These projects related to the implementation of a bioremediation strategy for soils contaminated by heavy metals based on the use of symbiotic and saprobic microorganisms (Plan Estatal, RTI2018-094327-B-I00), and in the characterization of plant molecular elements as key regulatory factors to improve Arbuscular Mycorrhizal symbiosis functionality (Plan Estatal, PID2020-115336GB-I00; Junta de Andalucía, PY20_00362/CA17184).



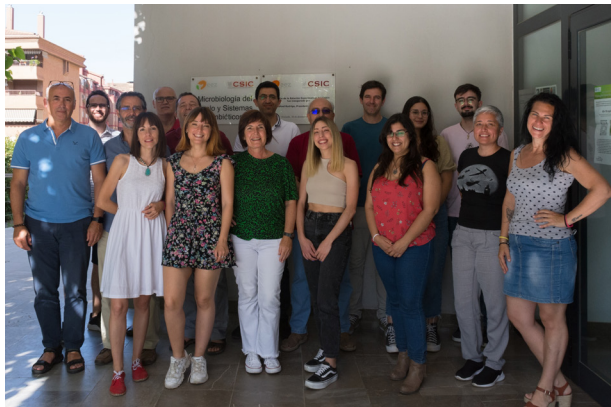
Arbuscules of *Rhizophagus irregularis* developed in wild-type (A) and DLK2 overexpressing (B) tomato cortical root cells



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STRUCTURE, DYNAMICS AND FUNCTION OF RHIZOBACTERIAL GENOMES

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Ascensión Martos Tejera

Pablo José Villadas Latorre

OVERVIEW

The Group focuses its research lines on the ecology of rhizospheric microorganisms and their use in the recovery of degraded soils, in the application of genomic approaches for the study of woody plant microbiomes, the characterization of the structure and function of the non-coding transcriptome in symbiotic microorganisms, and finally, in the basic knowledge and biotechnological development of

reverse transcriptases in prokaryotes, those associated with CRISPR-Cas systems and others related to novel anti-phage systems.

LINES OF RESEARCH

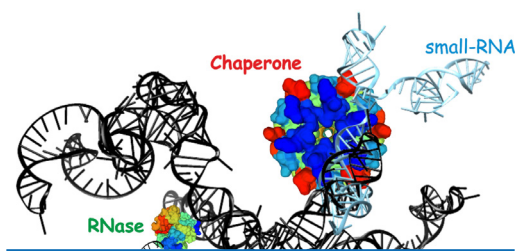
1. Microbiology of agroforestry ecosystems.
2. Bacterial Reverse Transcriptases associated to Phage-Defense Systems.
3. Regulation by RNA in nitrogen-fixing symbiotic bacteria (RhizoRNA).

HIGHLIGHTS

- Banana (*Musa* spp.) is one of the most important fruit and cash crop in terms of production volume and trade in the world; but its crop is affected by Fusarium wilt of banana (FWB), estimated affected area of 100,000 ha and around US \$2 billion losses. In this work, the biocontrol agent (BCA) *Pseudomonas simiae* PICF7 is assessed against the pathogen, and also the root microbiome dynamics of mother and sucker plant in relation to the BCA along time (Cabanás *et al.* 2021. *Journal of Fungi*, 7: 194).
- In this pioneering article, the expression of olive root genes under drought conditions is correlated with the microbial communities that inhabit the root endosphere. This new approach, studying the relationship between gene expression and microorganisms, will help us to understand how the holobiont respond to abiotic stress (Fernández-González *et al.* 2021. *Computational and Structural Biotechnology Journal*, 19: 4777-4789).
- The prokaryotic Reverse Transcriptases are attracting considerable attention, both for use in cutting-edge technologies, such as genome editing, and as an emerging research topic. In this review, we discuss what is known about the diversity of this type of enzymes, and the exciting evidence for their domestication from retroelements to create specialized defense systems (González-Delgado *et al.* 2021. *FEMS Microbiology Reviews*, 45: fuab025).
- The complete genome (chromosome and one plasmid) of the type strain of the species *Halomonas venusta* is presented as a reference for the analysis of metagenomic data (mainly in the ma-

rine environment). Likewise, this genome of the Type strain is the base for the knowledge of this species, facilitating its use as a model system (Martínez-Abarca *et al.* 2021. *Microbiology Resource Announcements*, 10: e00144-21).

- Metk is the synthetase of S-adenosyl methionine (SAM), which operates as the major methyl donor for macromolecule methylation in prokaryotes. In this work, we have discovered an unprecedented MetK feature, its ability to bind widely diverse RNA species, including the regulatory sRNAs. This finding suggest a non-canonical role of Metk in ribo-regulation, which we are investigating further (Robledo *et al.* 2021. *RNA Biology*, 18: 1111-1123).



Post-transcriptional silencing mediated by non-coding RNAs in bacteria

GENETICS OF PHYTOBACTERIAL INFECTIONS

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OVERVIEW

The general objective of the Group is to decipher the molecular mechanisms that explain how bacteria are capable of colonizing and infecting plants using the *Rhizobium*-legume symbiosis as a model. We are especially interested in identifying chemical signals and bacterial components involved in the early stages of the interaction and that can affect the colonization of plant tissues, an essential step required for the establishment of both pathogenic and mutualistic plant-bacteria associations.

To achieve our goal, we focus our studies on the regulatory mechanisms that control rhizobial life on surfaces and on the role played by bacterial airborne metabolites. The knowledge acquired during these investigations can provide the basis for the development of agrobiotechnological solutions aimed at the control of phytopathogens and/or the production of biofertilizers/biostimulants in the context of sustainable agriculture.

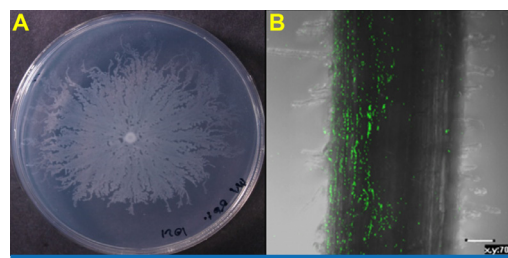
LINES OF RESEARCH

1. Studies of the volatilome of *Rhizobium* and its role in interkingdom communication with plants: Identification of the regulatory mechanisms that affect the volatile profile in rhizobia, the bioactivities associated to the different volatile compounds produced by these bacteria, their mechanism of action and biosynthetic pathways.
2. Identification of the molecular bases responsible for the different types of surface motility exhibited by *Sinorhizobium meliloti* as a strategy to unveil mechanisms with a role in plant colonization.

HIGHLIGHTS

- Publication of a perspective article that compiles evidence indicating that plants can perceive and respond to volatile compounds emitted by rhizobia and raises the possibility that these metabolites might play a role in interkingdom signalling with legumes and influence the symbiotic interaction (Soto *et al.* 2021. *Frontiers in Plant Science*, 12: 698912).

- An ongoing Research Project investigates the biological role of volatile methylketones produced by *Sinorhizobium meliloti* in the establishment of plant-bacteria interactions, as well as the mechanism of action and synthesis of these compounds in bacteria (Plan Estatal, PGC2018-096477-B-I00).
- Initiation of a multidisciplinary Research Project aimed at investigating the effect of the *Sinorhizobium meliloti* volatilome in the interaction with host and non-host plants and in shaping the plant microbiome (Junta de Andalucía, PY20_00225/CA17213).



A) Surface motility and B) Alfalfa root colonization by *Sinorhizobium meliloti*, representing the research line of the Group.

PLANT-BACTERIA INTERACTIONS

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Socorro Muñoz Rodríguez

Predoctoral Researchers

Ariana Casas Román

LINES OF RESEARCH

1. Identification of bacterial components and plant responses during the establishment of beneficial and pathogenic bacteria-plant associations.
2. Molecular signaling through cyclic di-GMP in mutualistic and pathogenic bacteria-plant interactions.
3. Bacterial pathways involved in signal exchange and infection of the host.
4. Discovery and biotechnological exploitation of bacterial extracellular polymers.
5. Genetic and functional diversity of plant beneficial bacteria.
6. Probiotics for plants.

OVERVIEW

The general objective of the Group is understanding molecular mechanisms governing bacteria-plant interactions and their biotechnological applications.

NITROGEN METABOLISM

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Germán Tortosa Muñoz

OVERVIEW

To gain knowledge about denitrification using the endosymbiotic bacterium *Bradyrhizobium diazoefficiens* as a model to study the process both in free living-conditions and in symbiosis with legumes. For this purpose, the integrated study of the environmental factors, genes and enzymes involved in denitrification is contemplated, paying special interest to the identification of the transcriptional regulators that control their expression and activity, and to the characterization of the molecular mechanism of these regulators. Furthermore, the aim is to analyze the metagenome, including the relative abundance, functional diversity and activity of denitrifying bacteria populations in environmental samples, mainly nitrate-contaminated water and sediments. In the plant-bacteria-environment interaction, the Group seeks to establish the N_2 fixation-denitrification interrelationship and to understand the processes,

environmental factors and regulatory mechanisms involved in the production of the highly reactive nitric oxide (NO) and the potent greenhouse gas nitrous oxide (N_2O) by endosymbiotic bacteria of leguminous plants. These latter serve as a basis for the development of solutions to reduce their emissions in agricultural soils. Our Group also offers knowledge transfer on the development and assessment in organic and biological fertilisers, especially on plant-growth promoting bacteria (PGPB).

LINES OF RESEARCH

1. Study the environmental factors, genes, enzymes and redox processes involved in the denitrification process of legume endosymbiotic bacteria.
2. Unravel the molecular mechanisms that control the expression, activity and regulation of denitrification and nitrogen fixation-related processes during symbiosis.
3. Analyse the molecular ecology of nitrifying and denitrifying bacteria in soils, waters and sediments contaminated with nitrates. Effect of nitrogen fertilization.
4. Determine the environmental and regulatory factors involved in reducing the emission of the greenhouse gas nitrous oxide by endosymbiotic bacteria associated with legume crops.
5. Development of organic and biological fertilisers based on agricultural organic wastes composting.

HIGHLIGHTS

The FixK₂ protein plays a pivotal role in a complex regulatory network, which controls genes for microoxic, denitrifying, and symbiotic nitrogen-fixing lifestyles in *Bradyrhizobium diazoefficiens*. FixK₂ is a CRP/FNR-type transcription factor, which recognizes a 14 bp-palindrome (FixK₂ box) at the regulated promoters. In this work, we mapped the determinants for discriminatory FixK₂-mediated regulation at protein and at DNA levels. Our results have revealed that position 11 within the FixK₂ box constitutes a key element that changes FixK₂ targets specificity, and consequently, it might modulate *B. diazoefficiens* lifestyle as nitrogen fixer or as denitrifier. So, this is an example how a single nucleotide exchange at the DNA recognition site changes specificity of a bacterial transcription factor in response to a certain signal (Cabrera *et al.* 2021. *Environmental Microbiology*, 23: 6194-6209).

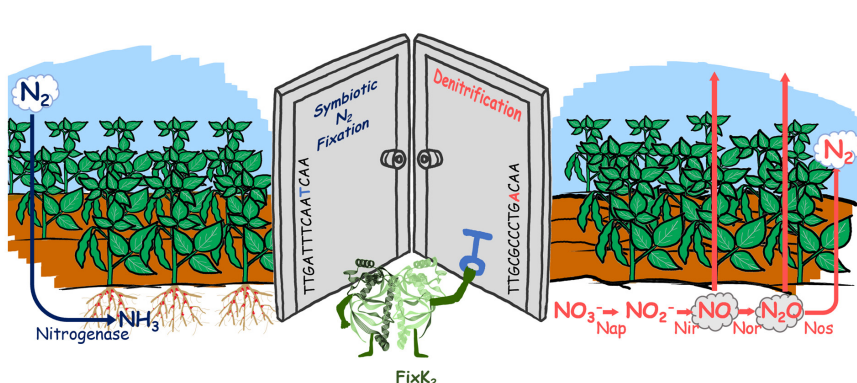
Nitric oxide (NO) is a reactive gaseous molecule that has several functions in biological systems depending on its concentration. At low concentrations, NO acts as a signaling molecule, while at high concentrations, it becomes very toxic due to its ability to react with multiple cellular targets. A better understanding of the sinks and sources of NO in rhizobia is essential to protect symbiotic nitrogen fixation from nitrosative stress. In this present review, updated knowledge about the NO metabolism in legume-associated endosymbiotic bacteria is summarized (Salas *et al.* 2021. *Advances in Microbial Physiology*, 78, 261-300).

- RNA-based high-throughput sequencing is a valuable tool in the discernment of the implication of metabolically active bacteria during composting. In this study, “alperujo” composting was used as microbial model for the elucidation of structure-function relationships with physicochemical transformation of the organic matter (Tortosa *et al.* 2021. *Science of the Total Environment*, 789, 147975).

Integrated study of the mechanisms affecting the production of greenhouse gases by legume en-

dosymbiotic bacteria, (Junta de Andalucía, P18-RT-1401): This proposal will contribute to develop new solutions for agricultural greenhouse gas mitigation through a better understanding of the contribution of rhizobial denitrification, as well as new emerging processes, to NO and N₂O production by legume root nodules.

Cross-regulation insights of nitrogen fixation and denitrification in the soybean endosymbiont and model organism *Bradyrhizobium diazoefficiens* (Plan Estatal, PID2020-114330GB-I00): The aim of this grant is to improve our understanding of the regulatory mechanisms underpinning the control of biological nitrogen fixation and denitrification, two key processes involved in the maintenance of the balance of combined nitrogen in the biogeochemical nitrogen cycle. This could be applied to enhance the productivity and sustainability of soybean crops, which will contribute to global food security, human health and the environment.



A key for two doors: how the regulatory protein *FixK₂* controls *Bradyrhizobium diazoefficiens* symbiotic and denitrifying lifestyles



MYCORRHIZA

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M^a José Pozo Jiménez

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Ana Isabel Molina Santiago

OVERVIEW

The Group of Mycorrhiza is interested in aspects of the ecology, physiology, biochemistry, molecular biology and biotechnology of arbuscular mycorrhizal (AM) symbiosis and AM fungi in relation to plant nutrition and health. Special attention is given to the signaling processes in AM symbioses, as well as to their role in plant protection against biotic (pathogens, pests and parasitic weeds) and abiotic (nutrient deficiency, metal toxicity, salinity and drought) stresses, and to the mechanisms involved in these processes. The diversity of mycorrhizal fungi in natural communities and the plant-fungus interaction networks they establish are also investigated. The final goal is to promote the rational use of mycorrhizas, in association with other soil microorganisms, with the aim of achieving sustained productivity with the minimal disturbance of the environment and in the current context of accelerated climate change.

LINES OF RESEARCH

1. Plant-AM fungi communication: Understanding the molecular signaling in the rhizosphere during the early stages of mycorrhizal colonization. The final goal is the promotion of symbiosis establishment.
2. Mycorrhiza and nutrient transport: Understanding the molecular mechanisms involved in nutrient transport processes in AM symbioses and in the tolerance of AM plants to heavy metals.
3. Mycorrhiza and protection against osmotic stresses: Understanding the physiological and molecular mechanisms underlying the tolerance of AM plants to drought and salinity. Aquaporins regulation by AM fungi in combination or not with other soil beneficial microorganisms.
4. Mycorrhiza and protection against biotic stresses: Understanding the molecular mechanisms by which AM fungi are able to boost plant defence responses making them more resistant/tolerant to diseases and pests.
5. Ecology of mycorrhizas and AM fungi: Studies of the diversity of AM fungi in Mediterranean environments. Factors driving AM fungal communities' assemblages. Life-history of AM fungi. Plant-fungus interaction networks and their implication in the recruitment dynamics in natural plant communities.

6. Interactions of AM fungi with other beneficial microorganisms. Multitrophic interactions. Mechanisms underlying the beneficial effects of PGPR.

HIGHLIGHTS

- We are participating (and co-leading one of the working groups) in an EU macro-project aimed at taking advantage of recent developments to characterize and quantify ecological functions within complex networks of ecological interactions among species. There are three main objectives: 1) Updating and development of databases on ecological interactions, focused on areas of the RN2000; 2) Development of a cluster of eLabs platforms to inventory, document, and analyze the biodiversity of ecological interactions in protected natural spaces; 3) Outreach and training activities (European Project, UE-LifeWatch ERIC-2019/LIFE-WATCH-2019-09-CSIC-1, WP5).
- At the request of the journal, a review has been published on the role of the plant mycobiome in the development and resilience of plants to environmental stresses. The recent technical and scientific advances in the field of fungal molecular and systems biology were analysed and the possible biotechnological applications of fungal inoculants and mycobiome manipulation in agrosystems and natural ecosystems discussed (Pozo *et al.* 2021. *Current Opinion in Plant Biology*, 60: 102034).
- Through the exposition of a semiarid shrubland to experimental warming and/or rainfall reduction it was shown that climate aridification impacts on vegetation can cascade belowground through shifts in fungal guild structure that alter ecosystem biogeochemistry and accelerate soil organic matter decomposition (Querejeta *et al.* 2021. *New Phytologist*, 232: 1399-1413).

- The analysis of the dynamics of the local and systemic responses of tomato to oligogalacturonides (OGs) -a well characterized damage associated molecular pattern-, revealed that local responses in leaves were transient, while distal responses were stronger and more sustained. Remarkably, changes were more conspicuous in roots than in leaves, even upon foliar application of the OGs. Overall, this study shows the differential regulation of tomato defences upon OGs perception in roots and shoots and reveals the key role of roots in the coordination of the plant responses to damage sensing (Gamir *et al.* 2021. *Plant, Cell and Environment*, 44: 275-289).

- In this opinion paper the controversial results of the different studies about the role of strigolactones (phytohormones that are also exuded from roots and act as signaling molecules in the rhizosphere) in plant-parasitic nematodes interaction are discussed. Future research challenges to develop new management strategies against the harmful plant parasitic nematodes species are also proposed (Marro *et al.* 2021. *Plant and Soil*, 462: 591-601).



Detection of Fe in spores of the arbuscular mycorrhizal fungus *Rhizophagus irregularis* developed under Fe toxicity by Perls staining. Blue precipitates indicate Fe accumulation



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REPORT | 2021 |

DEPARTMENT OF ENVIRONMENTAL PROTECTION

Environmental Microbiology and Biodegradation

Plant-Soil Relationships

ENVIRONMENTAL MICROBIOLOGY AND BIODEGRADATION

MEMBERS



Senior Researchers

Miguel Ángel Matilla Vázquez, *Group Leader*

Estrella Duque Martín de Oliva

Manuel Espinosa Urgel

Tino Krell

Marian Llamas Lorente

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Félix Velando Soriano

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Tamara M^a Gómez Gallego

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Miriam Rico Jiménez

Ana Sánchez Jiménez

Staff Technicians

Jesús de la Torre Zúñiga

Alicia Inmaculada García Puente

Patricia Marín Quero

M^a Antonia Molina Henares

M^a Luisa Travieso Huertas

OVERVIEW

Our research focuses on the interactions between bacteria and their environment, and especially those interactions that are beneficial for the ecosystem, with the final goal of exploiting microbial activities and capacities in a number of biotechnological applications. Using multidisciplinary approaches, we aim to understand the molecular basis for these microbial activities through two main research lines: 1. Understanding the processes that are crucial in the interaction of the bacteria with their environment, such as chemotaxis, motility, antibiotic production, biofilm formation, and cell signaling; 2. Improving bacterial biodegradation capacities to implement efficient bioremediation strategies or recycling to produce added-value chemicals.

Within the first line of research, we use bacteria of the genus *Pseudomonas* as model systems. The root-colonizing strains *Pseudomonas putida* and *P. stutzeri* are our models to analyse relevant mechanisms involved in plant-microbe interactions in the rhizosphere, such as the development of biofilms during root colonization, the chemotactic response towards root exudates components and signaling pathways between bacterial cells or with the plant. We analyse the role of surface determinants (exopolysaccharides, adhesins and other extracellular proteins) in planktonic and sessile bacterial populations, and how the levels and transduction of the second messenger cyclic diguanylate modulates the switch between lifestyles. Recently the vascular phytopathogen *Xylella fastidiosa* has been included in our studies as an original counterpart with a sessile lifestyle very relevant for its persistence. The human opportunistic pathogen *Pseudomonas aeruginosa* is our model to study host-pathogen interactions, in particular those required for the infection process, with the ultimate goal of finding new antimicrobial compounds that block such interactions and therefore bacterial virulence. Using these bacteria, we study different mechanisms by which bacteria sense environmental and host signals, including chemosensory pathways, one- and two-component systems, and cell-surface signaling systems. Sensory mechanisms currently studied modulate a number of important bacterial functions like chemotaxis, biofilm formation, stress responses, iron uptake, virulence and synthesis and degradation of antibiotics. The identification of environmental signals which define different features of bacterial physiology, and of the specific signal

molecules that interact with the sensor proteins, is a necessary requisite for diverse biotechnological applications.

Our research on biodegradation especially targets mono- and polycyclic aromatic hydrocarbons, nitroaromatics, and polychlorinated aromatic compounds, as well as pesticides, among others. We are looking for novel aerobic and anaerobic pathways, their genetic determinants, and the molecular mechanisms controlling their expression. The objectives include the construction of improved strains through metabolic engineering and the molecular analysis of pathway enzymes and regulatory proteins. We are using synthetic biology approaches to export the metabolic diversity to produce from wastes aromatic compounds of industrial interest. We are also interested in the bacterial diversity of polluted and pristine sites to investigate the response of microbial communities towards environmental changes and explore them as a source for new activities of biotechnological relevance using metagenomic approaches. The biological control of pathogens, pollutant elimination and phytoremediation are potential applications of our research.

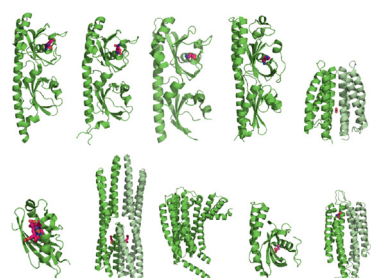
LINES OF RESEARCH

1. Biofilm and plant-*Pseudomonas* interactions.
2. Bacterial sensing and signal transduction, in particular chemotaxis.
3. Signal transduction by cell-surface signaling systems and virulence.
4. Anaerobic biodegradation, pathways and regulation.
5. Aromatics and pesticide biodegradation, metabolic engineering.
6. Biodegradation and biodiversity.
7. Rhizoremediation and synthesis of biofuels.
8. Biosynthesis of added value compounds and polymers, and circular economy.
9. Bacterial signaling, antibiotic production and regulation in phyto bacteria.

HIGHLIGHTS

- Aguilar-Romero *et al.* 2021. *Environmental pollution*, 274: 116536: This study describes metabolically and genetically how a newly isolated bacterium can degrade and eliminate ibuprofen, an emerging contaminant, from contaminated water.
- The conversion of lignocellulosic waste into value-added products is an essential part of the circular economy. We have the technology to make corn stover sugars accessible for *Pseudomonas* to transform them into aromatic amino acids that are the basis for hydrocarbon synthesis (Godoy *et al.* 2021. *Microbial Biotechnology*, 14: 1931-1943).

- Post-transcriptional regulation is an important step in the control of bacterial gene expression in response to environmental and cellular signals. This is the first combined global analysis of the network of processes subjected to this type of regulation in *Pseudomonas putida* (Huertas-Rosales *et al.* 2021. *Frontiers in Molecular Bioscience*, 8: 624061).
- Matilla *et al.* 2021. *Microbiology and Molecular Biology Reviews*, 85: e00151-20: Chemosensory pathways are complex signaling mechanisms widespread in bacteria and that regulate flagellar chemotaxis, second messenger levels or surface motility. In this article, the function and physiological relevance of the four different chemosensory pathways of the human pathogen *Pseudomonas aeruginosa* was reviewed. The regulatory mechanisms that govern pathway function were also analyzed.
- *Novosphingobium* sp. HR1a is a good polycyclic aromatic hydrocarbons (PAHs) degrader and rhizospheric colonizer. PahT regulates the uptake of carbohydrates, exudated by roots, and the central carbon fluxes, favouring PAH degradation and inducing the dioxygenase responsible of PAH degradation. Therefore, PahT confers an advantage for survival in contaminated rhizospheric environments. (Segura *et al.* 2021. *Environmental Microbiology*, 23: 2969-2991).
- Martín-Rodríguez *et al.* 2021. *NPJ Biofilms and Microbiomes*, 7: 9: This article reports for the first time a biological phenomenon that was termed Respiration-Driven Biofilm Formation (RDBF). Several pieces of evidence suggest that RDBF is widely spread among bacteria and corresponds to a strategy to extend the ecological niches that can be colonized by bacteria.
- TRACE-Soils: Mechanisms underlying TRAded-offs between Carbon sequestration, greenhouse gas Emissions and nutrient losses in Soils under conservation agriculture in Europe (Towards climate-smart sustainable management of agricultural soils) (European Project, H2020-FOOD/0648): The project aims to establish the relationship between C, N and P cycles in agricultural soils in the European Union. We analyse organic and inorganic phosphorus pools along a North-South European axis. We develop bioinformatics tools to identify acid and alkaline phosphatases involved in phosphorus mobilisation.



Diversity of *Pseudomonas aeruginosa* chemoreceptor sensor domains. Adapted from Matilla *et al.* (2021) *Microbiology and Molecular Biology Reviews*, 85: e00151-20

PLANT-SOIL RELATIONSHIPS

MEMBERS



Senior Researchers

Rogelio Nogales Vargas-Machuca, *Group Leader*

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Esperanza Romero Taboada

Predoctoral Researchers

Lisanne Smulders

Hired Researchers

Rafael Alcalá Herrera

Staff Technicians

Celia Cifuentes Urién

M^a Luisa Fernández Sierra

Beatriz Moreno Sánchez

Hired Technicians

Beatriz Sánchez Romera

OVERVIEW

The Group of Plant Soil Relationships (PSR) was created in 1989. The main research goals of this research Group is generate basic and applied knowledge, within the framework of a circular and a green economy, contributing to the protection of soil, water and crops through the use of low-cost agro-environmental technologies and the promotion of agrosystems by sustainable alternatives. This is approached from a triple perspective: 1) the development of biotechnological processes for recycling and reusing of organic and inorganic wastes, 2) the development of low-cost biotechnologies for the prevention and protection of soils and waters against diffuse and punctual pollution induced by organic pollutants (pesticides, emerging pollutants), and 3) the de-

velopment of methods for the sustainable management of agrosystems and their implication in the maintenance of multiple ecosystem services. For these approaches, innovative fields, chemical, enzymatic and molecular biology tools are used at different spatial scales.

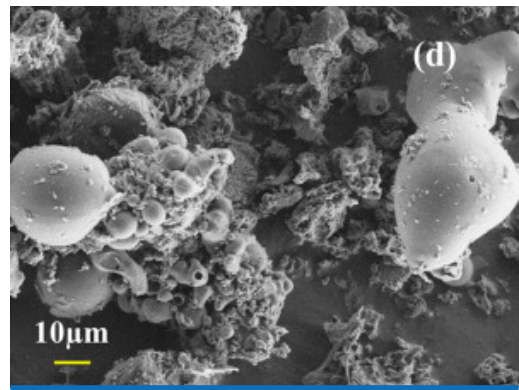
LINES OF RESEARCH

1. Bioconversion of organic wastes into value-added products.
2. Low-cost remediation technologies for minimizing environmental pollution.
3. Identification of agricultural practices for the maintenance of multiple ecosystem services.

HIGHLIGHTS

- Aguilar-Romero *et al.* 2021. *Environmental Pollution*, 274: 116536: This study showed that the *Sphingopyxis granuli* strain RW412, an alphaproteobacteria isolated from the river Elbe, can persist and remain active under environmentally relevant conditions, and may be a useful innovation to accelerate the elimination of ibuprofen and their metabolites, emerging contaminants present in secondary effluents from the wastewater treatment plants.
- We have demonstrated that the biopurification systems constituted by soil, straw and different organic materials contain diverse indigenous microbial populations (archaeal and bacterial communities) capable of degrading pharmaceuticals and personal care products (PPCPs) with different properties. These biopurification systems can be useful to prevent point source contamination due to the disposal of PPCP-contaminated waters (Delgado-Moreno *et al.* 2021. *Agronomy*, 11: 1507).
- Smulders *et al.* 2021. *Plants*, 10: 1942: In this study we found that core bacterial microbiome were similar between tomato landraces and modern commercial cultivars with small differences with wild tomato, concluding that all ancestral functional characteristics of bacteria have been conserved across time. Therefore, it becomes apparent that the capacity of soil bacteria to provide ecosystem services is affected by agronomic practices linked to the domestication process, particularly those related to the preservation of soil organic matter.

- Delgado *et al.* 2021. *Science of the Total Environment*, 752: 141838: This study revealed for the first time that unmodified hydrochars from pitted and reprocessed wet olive mill wastes are inexpensive, sustainable and environmentally friendly adsorbents which can be used in water treatments to efficiently remove emerging pollutants frequently detected in water resources such as ibuprofen, diclofenac and specially triclosan.
- New strategies to enhance the biological control of pests in olive trees (Junta de Andalucía, PY20_00139/CA17181): The aim of this multidisciplinary project is to establish relationships between biodiversity conservation and regulation of pests, in order to define adequate tools for a pest control program in olive orchards.



Scanning electron micrographs (SEMs) of a hydrochar from reprocessed wet olive mill waste at 4.66Kx magnification (Delgado *et al.* 2021. *Science of the Total Environment*, 752: 141838)

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R&D&I ASSOCIATED UNITS

Cell Signaling and Metabolic Integration. 2014-2023. Group of Metabolic Integration and Cell Signaling, Department of Agricultural Sciences from the Jaume I University in Castellón, PI: Víctor Flors Herrero. Group of Mycorrhiza, EEZ-CSIC, PI: M^a José Pozo Jiménez.

Plant Phenotyping by Imaging Techniques and Studies of Stomata Development for Stress Analysis. 2018-2024. Group of Biotechnology and Plant Molecular Biology, University of Castilla-La Mancha, PI: Carmen Fenoll Comes. Group of Redox Regulation, Sugar Signaling and Plant Phenotyping by Imaging Techniques for Stress Detection, EEZ-CSIC, PI: Matilde Barón Ayala.

Soil Bioremediation. 2020-2023. Department Soil Science and Agricultural Chemistry, University of Granada, PI: Fco. José Martín Peinado. Group of Biofertilization and Biodegradation by Rhizospheric Fungi, EEZ-CSIC, PI: Inmaculada García Romera.



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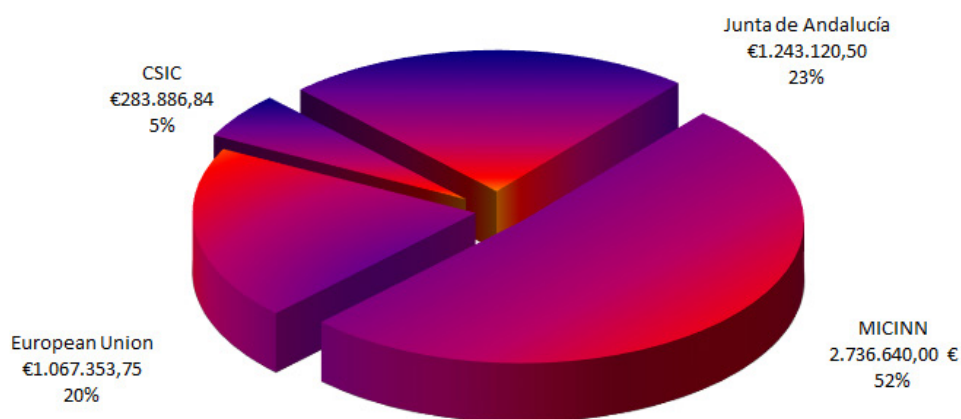
FUNDING 2021

TOTAL INCOME 2021

7.772.957,50€

Administrative Budget	1.213.312,85 €
Services Revenues	24.175,18 €
Investments & Special Actions (Buildings, constructions, etc.)	952.494,74 €
Competitive Calls Incomes	5.331.001,09 €
Contracts & Agreements Incomes	251.973,64 €

FUNDING AGENCIES OF COMPETITIVE CALLS



(Sources: PCO2021, SAICI and PAI)

ONGOING RESEARCH PROJECTS DURING 2021

NATIONAL CALLS

SPANISH R&D PLAN (PLAN ESTATAL MICINN)

A GRAS TFs network plays an essential role in transcriptional reprogramming for arbuscule homeostasis and mycorrhizal autoregulation (AOM) in tomato. Generación del Conocimiento (PID2020-115336GB-I00). PI: José Manuel García Garrido. 2021-2024.

Acrylamide exposure and bioaccessibility in foodservices and traditional cooking. Retos de la Sociedad (RTI2018-094402-B-I00). PIs: Cristina Delgado Andrade, Marta Mesías García (IC-TAN-CSIC). 2019-2022.

Arbuscular mycorrhizal fungi as biotechnological tools to increase plant resilience to climate change. Retos de la Sociedad (RTI2018-098756-B-I00). PIs: Nuria Ferrol González, Concepción Azcón González de Aguilar. 2019-2022.

Bacterial microaerophilic production of value added polymers from wastes and pollutants. Physiology, regulation and maximisation. Retos de la Sociedad (PID2020-113144RB-I00). PI: Silvia Marqués Martín. 2021-2024.

Bacterial reverse transcriptases and their associated systems as engines for biotechnology. Generación del Conocimiento (PID2020-113207GB-I00). PIs: Nicolás Toro García, Francisco Martínez-Abarca Pastor. 2021-2024.

Biofilms and colonization of plants by beneficial and pathogenic bacteria: Environmental and metabolic signals, regulation by c-di-GMP and relevance to plant protection. Generación de Conocimiento (PID2019-109372GB-I00). PIs: Manuel Espinosa Urgel, M^a Isabel Ramos González. 2020-2023.

Bioremediation of aromatic compounds under oxygen-limiting conditions, with emphasis on the production of value-added polymers from polycyclic aromatic hydrocarbons. Retos de la Sociedad (BIO2017-82242-R). PI: Silvia Marqués Martín. 2018-2021.

Boosting the use of nanocellulose for the development of new sustainable materials in cosmetics, biofertilizers and bioplastics applications. Líneas Estratégicas (PLEC2021-008210). PI: Silvia Marqués Martín. 2021-2024.

Closing the gap for the industrial production of bacterial nanocellulose from wastes: upscaling and profitability analysis for the development of market products. Pruebas de Concepto (PDC2021-121193-I00). PI: Silvia Marqués Martín. 2021-2023.

Combating the human pathogen *Pseudomonas aeruginosa* through inhibition of sigmaECF-mediated signalling. Generación del Conocimiento (PID2020-115682GB-I00). PI: M^a Antonia Llamas Lorente. 2021-2024.

Cross-regulation insights of nitrogen fixation and denitrification in the soybean endosymbiont and model organism *Bradyrhizobium diazoefficiens*. Generación del Conocimiento (PID2020-114330GB-I00). PI: M^a Socorro Mesa Banqueri. 2021-2024.

Deciphering *Sphigomonadaceae*-plant interactions: analysis for advanced rhizoremediation. Generación del Conocimiento (BIO2017-85994-P). PI: Ana Segura Carnicero. 2018-2021.

Directed evolution of improved microbial consortia for biocontrol of Fusarium wilt of banana in the Canary Islands. Líneas Estratégicas (PLEC2021-007777). PI: Manuel Fernández López, Antonio di Pietro (UCO). 2021-2024.

Effects of heat stress on physiological and productive traits in Iberian pigs: nutritional strategies. Retos de la Sociedad (AGL2016-80231-R). PIs: Ignacio Fernández-Fígares Ibáñez, Isabel Seiquer Gómez-Pavón. 2016-2021.

Emission of nitric oxide and nitrous oxide by legume crops: Processes involved, their control and mitigation strategies. Retos de la Sociedad (AGL2017-85676-R). PI: M^a Jesús Delgado Igeño. 2018-2021.

Exploitation of aquaporins and phytohormones for the improvement of root water transport by soil beneficial microorganisms under a scenario of drought and climate change. Retos de la Sociedad (PID2020-112816RB-I00). PIs: Juan Manuel Ruiz Lozano, Ricardo Aroca Álvarez. 2021-2024.

Functional analysis of the oxylipins derived from the peroxygenase activity of pollen caleosins, and their impact on fertilization in oleaginous crops. Generación del Conocimiento (AGL2017-84298-P). PI: Antonio Jesús Castro López. 2018-2021.

Functional characterization of regulatory elements in the arbuscular mycorrhizal symbiosis: GRAS transcription factors, apocarotenoids and alpha/beta-hydrolase receptors. Generación del Conocimiento (AGL2017-83871-P). PI: José Manuel García Garrido. 2018-2021.

Functional involvement of nitric oxide, hydrogen sulfide and antioxidants in pepper fruit ripening and quality. Generación del Conocimiento (PID2019-103924GB-I00). PIs: F. Javier Corpas Aguirre, José Manuel Palma Martínez. 2020-2024.

Innovation of biobed bioremediation systems by bioaugmentation and novel adsorbent materials for the removal of emerging pollutants and pesticides from waters. Retos de la Sociedad (CTM2017-86504-R). PIs: Esperanza Romero Taboada, Pieter van Dillewijn. 2018-2021.

Intra- and inter-kingdom signalling during rhizoremediation. Generación del Conocimiento (PID2020-116766GB-I00). PI: Ana Segura Carnicero. 2021-2024.

Ion transporters likely involved in major QTLs controlling citrus and tomato salt tolerance in terms of fruit yield. Retos de la Sociedad (AGL2017-82452-C2-1-R). PIs: Andrés Belver Cano, M^a Remedios Romero Aranda (EELM-CSIC). 2018-2021.

Lipidic volatiles produced by *Sinorhizobium (Ensifer) meliloti*: Functional analyses, mechanism of action and biosynthetic pathways. Generación del Conocimiento (PGC2018-096477-B-I00). PI: M^a José Soto Misffut. 2019-2021.

Marine microbiome against cancer. Retos Colaboración (RTC-2017-6405-1). PI: Silvia Marqués Martín. 2018-2022.

Mechanisms of auxin recognition by plant-associated beneficial bacteria. Generación del Conocimiento (PID2019-103972GA-I00). PI: Miguel A. Matilla Vázquez. 2020-2023.

Mechanisms underlying riboregulation of metabolism and symbiotic nitrogen fixation in rhizobia. Generación del Conocimiento (BFU2017-82645-P). PI: José Ignacio Jiménez Zurdo. 2018-2021.

Microbial conversion of lignocellulosic wastes into value-added products. Retos de la Sociedad (RTI2018-094370-B-I00). PIs: Juan Luis Ramos Martín, Estrella Duque Martín de Oliva. 2019-2022.

Molecular biotechnology of Group II intron and related reverse transcriptases. Generación del Conocimiento (BIO2017-82244-P). PI: Nicolás Toro García. 2018-2021.

Mycorrhiza induced resistance: Bridging the

gap between basic knowledge and application. Retos de la Sociedad (RTI2018-054350-B-C-31). PIs: M^a José Pozo Jiménez, Juan Antonio López Ráez. 2019-2022.

Non-coding transcriptome and RNA regulation of symbiotic metabolism in nitrogen-fixing rhizobia. Generación del Conocimiento (PID2020-114782GB-I00). PI: José Ignacio Jiménez Zurdo. 2021-2024.

Nutritional and functional properties of Bowman-Birk inhibitors from pea (*Pisum sativum* L.). Retos de la Sociedad (AGL2017-83772-R). PIs: Alfonso Clemente Gimeno, Luis A Rubio San Millán. 2018-2022.

Nutritional strategies for a more efficient and sustainable management of dairy goat replacement. Retos de la Sociedad (PID2020-119746RB-I00). PIs: A. Ignacio Martín García, David R. Yáñez Ruiz. 2021-2024.

Olive seed germinates as alimentary, agronomical and ornamental source. Retos Colaboración (RTC-2017-6654-2). PI: Juan de Dios Alché Ramírez. 2018-2021.

Organic fertilization in soils under olive cultivation: evaluation of the sustained flow of ecosystem services. Retos de la Sociedad (AGL2017-84745-R). PIs: Emilio Benítez León, Engracia Madejón Rodríguez (IRNAS-CSIC). 2018-2021

Oxidative and fatty acid-mediated post-translational modifications in pollen, and their role in plant reproduction. Generación del Conocimiento (PID2020-113324GB-I00). PIs: Juan de Dios Alché Ramírez, Antonio J. Castro López. 2021-2025.

Peroxisome-dependent signalling under stress: role of peroxules and peroxisomal homeostasis. Generación del Conocimiento (PGC2018-098372-B-I00). PIs: Luisa M^a Sandalio González, María C. Romero Puertas. 2019-2022.

Phenotyping plant-pathogen interactions under different scenarios of climate change. Retos de la Sociedad (RTI2018-094652-B-I00). PI: Matilde Barón Ayala. 2019-2021.

Regulation of root hydraulic properties by aquaporins, plant hormones and soil beneficial microorganisms. Retos de la Sociedad (AGL2017-88341-R). PIs: Ricardo Aroca Álvarez, Juan Manuel Ruiz Lozano. 2018-2021.

Replacement networks in forests: Ecogeographic variation and influence of phyllosphere fungal communities and plant-soil interactions. Generación del Conocimiento (PGC2018-100966-B-I00). PIs: José Luis Garrido Sánchez, Julio M. Alcántara Gámez (UJA). 2019-2021.

Restoration of soils contaminated by heavy metals: A strategy based on waste recycling and bioremediation by symbiotic and saprobic microorganisms. Retos de la Sociedad (RTI2018-094327-B-I00). PI: Inmaculada García Romera. 2019-2021.

Sensing and response to the environment: Bacterial cell signaling mediated by sigma factors of extracytoplasmic function (ECF). Generación del Conocimiento (BIO2017-83763-P). PI: Marian Llamas Lorente. 2018-2021.

Signalling mechanisms and regulation of photosynthesis and carbon metabolism in chloroplasts. Generación del Conocimiento (PGC2018-096851-B-C21). PIs: Mariam Sahrawy Barragán, Antonio Jesús Serrato Recio. 2019-2021.

Study of proton linked ion transport at the chloroplast envelope. Generación del Conocimiento (PID2019-105260GB-I00). PIs: Kees Venema, M^a Pilar Rodríguez Rosales. 2020-2024.

Systematic, high-throughput identification of signal molecules recognized by bacterial sensor proteins. Generación del Conocimiento (BIO2016-76779-P). PI: Tino Krell. 2016-2021.

The challenge of restoring, monitoring and valorizing biodiversity: above and belowground diversity, fuel load and ES in Mediterranean mountains managed with pyric herbivorism. Retos de la Sociedad (PID2020-116786RB-C32). PIs: Emilio Benítez León, Ana Belén Robles Cruz. 2021-2025.

The olive holobiont: linking plant microbiome and host tolerance to biotic and abiotic stresses. Retos de la Sociedad (PID2019-106283RB-I00). PIs: Manuel Fernández López, Jesús Mercado Blanco (IAS-CSIC). 2020-2024.

Understanding chemoreceptor function in bacterial pathogens. Generación del Conocimiento (PID2020-112612GB-I00). PI: Tino Krell. 2021-2024.

Valorization of hydrothermal carbonization products as new advanced and environmentally safe materials for remove organic contaminants from water. Retos de la Sociedad (PID2020-116210RB-I00). PI: Esperanza Romero Taboada. 2021-2024.

JUNTA DE ANDALUCÍA

Biotechnological potential of *Novosphingobium* sp. HR1a for the synthesis of fuels from plant polymers. Proyectos de Generación de Conocimiento Frontera (PY20_0061/CA17211). PI: Ana Segura Carnicero. 2021-2022.

Collaborative stay for the extension and commercialization of results obtained through the completion of a Thesis in Business. Ayudas a Actividades de Transferencia de Conocimiento entre los Agentes del Sistema Andaluz del Conocimiento y el Tejido Productivo (AT17_5247/CA8313). PI: Juan de Dios Alché Ramírez. 2019-2021.

Contribution of the non-coding transcriptome to symbiotic diversity of rhizobia nodulating agronomically relevant legumes. Proyecto FED-ER-University of Seville (US-1250546). PIs: José M^a Vinardell González (US), José I. Jiménez Zurdo. 2020-2022.

Development of bio-mechanical-chemical systems for environmental CO₂. Proyectos de Investigación orientados a los Retos de la Sociedad Andaluza (PY20-00328/CA17183). PI: Silvia Marqués Martín. 2021-2022.

Effects of the *Rhizobium* volatilome on plants: growth, stress resistance and the associated microbiome. Proyectos de Generación de Conocimiento Frontera (PY20_00225/CA17213). PI: M^a José Soto Misffut. 2021-2022.

Identification and characterization of compounds from pepper fruits with anti-tumoral activity. Proyectos de Generación de Conocimiento Frontera (P18-FR-1359/CA11098). PIs: José Manuel Palma Martínez, F. Javier Corpas Aguirre. 2020-2022.

Identification and characterization of olive seeds components of interest for the agri-food industry and with healthy properties. Proyectos de Investigación orientados a los Retos de la Sociedad Andaluza (P18-RT-1577/CA11203). PIs: Juan de Dios Alché Ramírez, Antonio Jesús Castro López. 2020-2022.

Improving arbuscular mycorrhizal symbiosis by enhancing plant-fungus communication: from the lab to the field. Proyectos de Investigación orientados a los Retos de la Sociedad Andaluza (PY20_00400/CA17185). PI: Juan Antonio López Ráez. 2021-2022.

Integrated study of mechanisms affecting greenhouse gas production by legume endosymbiotic bacteria. Proyectos de Investigación orientados a los Retos de la Sociedad Andaluza (P18-RT-1401). PIs: M^a Jesús Delgado Igeño, M^a Socorro Mesa Banqueri. 2020-2023.

Ion homeostasis and metal toxicity: regulation by reactive oxygen species and autophagy. Proyectos de Generación de Conocimiento Frontera (PY20_00364/CA17214). Investigador Principal: Luisa M^a Sandalio González. 2021-2022.

Molecular characterization and evolution of acid phosphatases for industrial applications.

Proyectos de Investigación orientados a los Retos de la Sociedad Andaluza (PY20_0049/CA17180). PI: Juan Luis Ramos Martín. 2021-2022.

New strategies to enhance the biological control of plagues in olive trees.

Proyectos de Investigación orientados a los Retos de la Sociedad Andaluza (PY20_00139/CA17181). PI: Emilio Benítez León. 2021-2022.

Nutritional properties, bioaccessibility and functionality of new legume-derived foods.

Proyectos de Investigación orientados a los Retos de la Sociedad Andaluza (PY20_00242/CA17182). PI: Alfonso Clemente Gimeno. 2021-2023.

Opening new frontiers in RNA targeting: unique reverse transcriptases-encoding type III and type VI CRISPR-Cas systems.

Proyectos de Generación de Conocimiento Frontera (PY20_0047/CA17210). PI: Nicolás Toro García. 2021-2022.

Physiological and functional studies of the activity of symbiotic GRAS transcription factors: effects on the development of arbuscular mycorrhiza in tomato.

Proyectos de Investigación orientados a los Retos de la Sociedad Andaluza (PY20_00362/CA17184). PI: José Manuel García Garrido. 2021-2022.

Redox molecular basis for sugar production and stress tolerance in plants.

Proyectos de Generación de Conocimiento Frontera (PY20_00401/CA17215). PI: Mariam Sahrawy Barragán. 2021-2022.

RNA regulation of nodulation and nitrogen fixation in legume symbionts of agronomic interest.

Proyectos de Generación de Conocimiento Frontera (PY20_00185/CA17996). PI: José Ignacio Jiménez Zurdo. 2021-2023.

Signaling mechanisms in *Pseudomonas aeruginosa*: New strategies to combat this human pathogen.

Proyectos de Generación de Conocimiento Frontera (P18-FR-1621/CA11199). PIs: Tino Krell, M^a Antonia Llamas Lorente. 2020-2022.

CSIC

Agricultural Sciences Online in Secondary School (CAOS).

Fundación General CSIC-IV Edición del Programa Cuenta la Ciencia-2020 (FGCCLG-2021-0015). PI: Francisco Martínez-Abarca. 2021.

Bioremediation of aromatic compounds under oxygen-limiting conditions, with emphasis on the production of value-added polymers from polycyclic aromatic.

Ayudas Extraordinarias para preparación de Proyectos en el Marco del PE 2020 (2020AEP091, Project BIO2017-82242-R). PI: Silvia Marqués Martín. 2021.

Deciphering Sphigomonadaceae-plant interactions: analysis for advanced rhizoremediation.

Ayudas Extraordinarias para preparación de Proyectos en el Marco del PE 2020, CSIC (2020AEP085, Project BIO2017-85994-P). PI: Ana Segura Carnicero. 2021.

Dissection of the regulatory network that controls the FixK₂ protein of *Bradyrhizobium diazoefficiens*, a key transcriptional factor for symbiosis.

Ayudas Extraordinarias para Preparación de Proyectos en el Marco del PE 2019 (2019AEP193, Project AGL2015-63651-P). PI: M^a Socorro Mesa Banqueri. 2020-2021.

Effect of arbuscular mycorrhizal fungi with different life strategies and functional characteristics on their colonization dynamics and effects on plant development and stress tolerance.

Proyecto Intramural (201940E025). PI: Concepción Azcón González de Aguilar. 2019-2021.

Functional characterization of regulatory elements in the arbuscular mycorrhizal symbiosis: GRAS transcription factors, apocarotenoids and alpha/beta-hydrolase receptors.

Ayudas Extraordinarias para Preparación de Proyectos 2020 (2020AEP088, Project AGL2017-83871-P). PI: José Manuel García Garrido. 2021.

Impact of dietary protein intake on mineral metabolism in a porcine model.

Proyecto Intramural (202040E006). PI: Rosa M^a Nieto Liñán. 2020-2022.

Impact of oligogalacturonides on tomato defense responses and the study of their role in mycorrhiza induced resistance.

Proyecto Intramural CSIC (201840E130). PI: M^a José Pozo Jiménez. 2018-2021.

Innovation of biobed bioremediation systems by bioaugmentation and novel adsorbent materials for the removal of emerging pollutants and pesticides from waters.

Ayudas Extraordinarias para preparación de Proyectos en el Marco del PE 2020 (2020AEP087, Project CTM2017-86504-R). PIs: Esperanza Romero Taboada, Pieter van Dillewijn. 2021.

Integrated study of factors modulating polyhydroxybutyrate balance in *Bradyrhizobium diazoefficiens* for its use as both a more competitive soybean inoculant and a bioplastics producer.

Programa CSIC de Cooperación Científica para el Desarrollo I-COOP+ 2020 (COOPB20505). PI: M^a Socorro Mesa. 2021-2022.

Molecular biotechnology of Group II intron and related reverse transcriptases. Ayudas Extraordinarias para Preparación de Proyectos 2020 (2020AEP090, Project BIO2017-82244-P). PI: Nicolás Toro García. 2021-2021.

Molecular mechanisms of signaling mediated by the phytohormone indole acetic acid in phyto bacteria beneficial to plant crops. Proyecto Intramural Especial-Incorporación Personal Científico (202040I003). PI: Miguel A. Matilla Vázquez. 2020-2021.

Navigator's Loneliness: Science and Resilience. Fundación General CSIC-IV Edición del Programa Cuenta la Ciencia-2020 (FGCCLC-2021-0016). PI: Manuel Espinosa Urgel. 2021.

Pastoralism and environment. Proyecto Intramural (202140E014). PI: Ana Belén Robles Cruz. 2021-2023.

Physiological response of plants of agronomic interest to *Piriformospora indica*. Proyecto Intramural (201640E057). PI: Nuria Ferrol González. 2016-2022.

Regulation of root hydraulic properties by aquaporins, plant hormones and soil beneficial microorganisms. Ayudas Extraordinarias para Preparación de Proyectos 2020 (2020AEP086, Project AGL2017-88341-R). PIs: Ricardo Aroca Álvarez, Juan Manuel Ruiz Lozano. 2021.

Sensing and response to the environment: Bacterial cell signaling mediated by sigma factors of extracytoplasmic function (ECF). Ayudas Extraordinarias para preparación de Proyectos en el Marco del PE 2020, CSIC (2020AEP089, Project BIO2017-83763-P). PI: M^a Antonia Llamas Lorente. 2021.

Study of methane production in sheep and goats fed with new nutritional alternatives. Proyecto Intramural (202140E003). PI: David R. Yáñez Ruiz. 2021-2022.

Study of the nutritional composition and antioxidant properties of whey and their relationship with mineral bioavailability. Proyecto Intramural (202140E009). PI: Isabel Seiquer Gómez-Pavón. 2021-2022.

Systematic, high-throughput identification of signal molecules recognized by bacterial sensor proteins. Ayudas Extraordinarias para preparación de Proyectos en el Marco del PE 2020 (2020AEP092, Project BIO2016-76779-P). PI: Tino Krell. 2021.

NATIONAL EXTERNAL PROJECTS

Comprehensive study of plant-induced defenses through exogenous application of fluorescent derivatives of MSB, Vitamin K3 and sodium bisulfite. Agencia Canaria de Investigación, Innovación y Sociedad de la Información (ProID2020010082). PI: Antonio Jesús Herrera González. Participants of the EEZ: Luisa M^a Sandalio González. 2020-2022.

Evaluation in a microcosm model of the efficacy of probiotic strain implantation and phytobiotic treatments on the intestinal microbiota in species of agricultural interest. Plan Estatal, Retos de la Sociedad (B-BIO-604-UGR20). PI: Manuel Martínez Bueno, University of Granada. Participant of the EEZ: Luis A. Rubio San Millán. 2021-2022.

Lifestyle switch regulation in *Pseudomonas syringae* and its implications for plant infection. Ayuda I+D+I del Plan Andaluz de Investigación, Desarrollo e Innovación (P20_00834). PI: Fernando M. Govantes Romero, Pablo de Olavide University, Seville. Participants of the EEZ: M^a Trinidad Gallejos Fernández. 2021-2022.

Novel sustainable protein sources meeting human health. CSIC, ILINKA (ILINKA 20292). PI: Isidra Recio Sánchez, CIAT-CSIC. Participants of the EEZ: Alfonso Clemente Gimeno, Raquel Olías Sánchez. 2020-2021

Recovery of the high mountains vegetation after wildfire of year 2019 at Teide National Park. Proyectos de I+D por organismos de investigación y empresas en las áreas prioritarias de la Estrategia de Especialización Inteligente de Canarias RIS-3 (ProID2020010103). PI: Milagros Alicia León Barrios, University of La Laguna, Tenerife. Participants of the EEZ: Manuel Fernández López, Pablo J. Villadas Latorre. 2020-2022.

EUROPEAN & INTERNATIONAL PROJECTS

Biostimulant Academy. ERASMUS+ 2019 (2020-1-FR01-KA202-080329). PI: Ricardo Aroca Álvarez. 2020-2022.

Improvement of symbiotic nitrogen fixation by modulating NO formation in soybean nodules. Japan Society for the Promotion of Science (JSPS, Japan). PI: Toshiki Uchiumi, University of Kakoshima, Japan. Participants of the EEZ: María J Delgado. 2020-2023.

Integrated Crop-Ruminant Livestock Systems as a Strategy to increase Nutrient Circularity and promote Sustainability in the Context of Climate Change. AEI/MICIINN Proyectos Colaboración Internacional/European Project CIRCULARITY 2021 (PCI2021-122107-2A). PI: David R. Yáñez Ruiz. 2021-2024.

Microbe induced resistance to agricultural pests (MIRA). European Project (H2020-MSCA-ITN-ETN/0359). PI: M^a José Pozo Jiménez. 2017-2021.

Microbiome Applications for Sustainable food systems through Technologies and Enterprize. European Project (H2020 LC-SFS-03-2018 / EU189746_31). PI: David R. Yáñez Ruiz. 2019-2023.

Pathways for Transitions to Sustainability in Livestock Husbandry and Food Systems. European Project (H2020-FOOD/0809 / RIA - Research & Innov. / EU217598_01). PI: David R. Yáñez Ruiz. 2021-2026.

Reducing bioprocess of the solubility rhizospheric Cd. Call 2020 Fontagro: Innovations for the sustainable increase of agricultural productivity in Latin America and the Caribbean in the context of climate change (ID401/ATN-RF-18951-RG). Coordinator: M^a Luisa Izaguirre Mayoral, Technical University of Manabí, Ecuador. CSIC PI: Inmaculada García Romera. 2021-2023.

Scenarios for providing multiple ecosystem services and biodiversity in viticultural landscapes. Acciones de Programación Conjunta Internacional/EraNet H2020/BiodivScen 2017 (PCI2018-092938). PI: Emilio Benítez León. 2019-2022.

Sustainability for Mediterranean Hotspots in Andalusia integrating LifeWatch ERIC (SUMHAL). WP5: eLabs-BioINTERACT: Ecological interactions as biodiversity and ecosystem service components. European Project UE - LifeWatch ERIC - 2019 (LIFEWATCH-2019-09-CSIC-1 WP5). PIs: José Luis Garrido Sánchez / Pedro Jordano Barbudo (EBD-CSIC).

Sustainability for Mediterranean Hotspots in Andalusia integrating LifeWatch ERIC (SUMHAL). WP7/LWE2021-03-025: Improving sustainability of Mediterranean forests and silvopastoral agrosystems under climate change. European Project UE - LifeWatch ERIC - 2019 (LIFEWATCH-2019-09-CSIC-13 WP7- LWE2103025). PI: Manuel Fernández López. 2019-2023.

Sustainability for Mediterranean Hotspots in Andalusia integrating LifeWatch ERIC (SUMHAL). WP7/LWE2021-03-026 and WP7/LWE2103027: Improving sustainability of Mediterranean forests and silvopastoral agrosystems under climate change. European Project UE - LifeWatch ERIC - 2019. (LIFEWATCH-2019-09-CSIC-13 / (WP7) LWE2103026 / LWE2103027). PI-Coordinator of both subprojects: Ana Belén Robles Cruz. 2019-2023.

Sustainable management model for the mountain open spaces preservation (Open2Preserve). European Project, Interreg-SUDOE 2017 (SOE2/P5/E0804). PI: Ana Belén Robles Cruz. 2018-2021.

The effect of thiol redox regulators on seed quality and the aging process. National Science Centre of Poland (OPUS 16 project n^o 2018/31/B/NZ9/01548). PI: Ewelina Ratajczak, Institute of Dendrology, Polish Academy of Sciences. Participants of the EEZ: Mariam Sahrawy, Antonio Jesús Serrato. 2019-2021.

TRACE-Soils: Mechanisms underlying Trade-offs between Carbon sequestration, greenhouse gas Emissions and nutrient losses in Soils under conservation agriculture in Europe (Towards climate-smart sustainable management of agricultural soils). European Project (H2020-FOOD/0648). PI: Juan Luis Ramos Martín, European Project Coordinator: Marta Goberna, INIA. 2020-2025.

Understanding Microbiomes of the Ruminant Holobiont. European Project (H2020-FOOD/0811 / RIA - Research & Innov. / EU217601_01). PI: David R. Yáñez Ruiz. 2021-2026.

Valorization of Mediterranean small-scale FARMS by cropping wild unexploited species. Proyectos Colaboración Internacional/H2020 PRIMA Programme (PCI2020-112091). PI: M^a del Mar Alguacil García. 2020-2022.

NATIONAL AND INTERNATIONAL NETWORKS

Ammonia and greenhouse gas emission from animal production housing. COST Action LivAGE CA16106, H2020 Programme. Action Chair: Thomas Bartzanas, Centre for Research and Technology Hellas, Institute of Bio-Economy and Agritechnology, Greece. Participant of the EEZ: David R. Yáñez Ruiz. Participation of 29 countries. 2017-2021.

Network for updating emission values in Spanish agriculture. Redes de Excelencia, (AGL2017-90924-REDT). PI: David R. Yáñez Ruiz. 2018-2021.

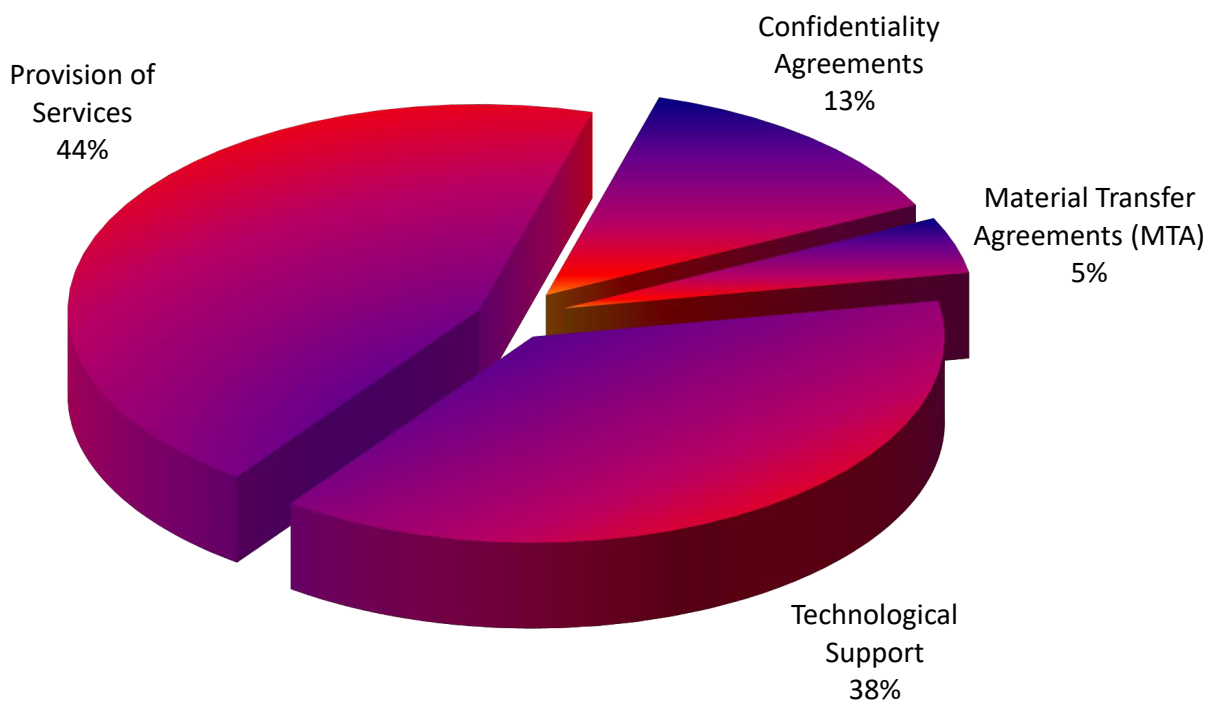
Redox signaling and post-translational regulation in plant development and stress response. Acciones de Dinamización-Redes de Investigación (RED2018-102397-T). PI: Luisa M^a Sandalio González. 2020-2021.

Research Network "Learning from nature: multitrophic interactions for crop and forest protection". Acciones de Dinamización-Redes de Investigación (RED2018-102407-T). PI: Isabel Díaz Rodríguez, Centro de Biotecnología y Genómica de Plantas. Participants of the EEZ: M^a José Pozo Jiménez, Juan Antonio Lopez Ráez. 2020-2021.

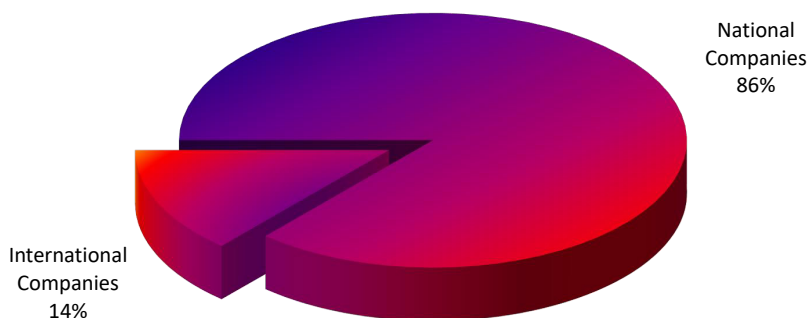
Soil network. Acciones de Dinamización-Redes de Investigación (RED2018-102624-T). PI: Ana Segura Carnicero. 2020-2021.

RESEARCH, DEVELOPMENT & INNOVATION CONTRACTS AND COLLABORATION AGREEMENTS WITH COMPANIES

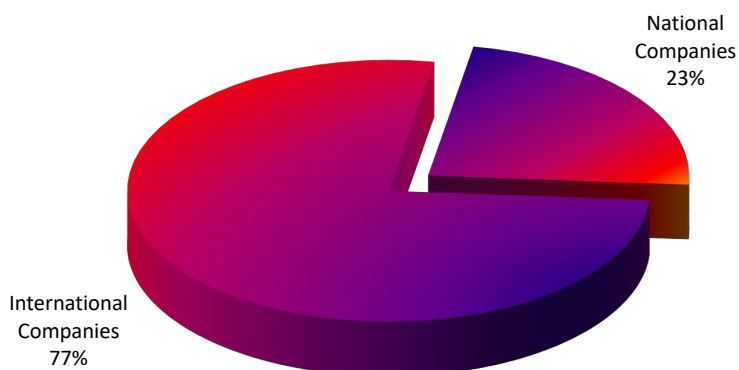
During 2021, 53 new contracts were signed, including 9 addenda, for a total amount of 192.669,23 €. This is the distribution according to the type of contract and the national/international scope.



SCOPE OF CONTRACTS - FUNDING



SCOPE OF CONTRACTS - NUMBER



ONGOING CONTRACTS / COLLABORATION AGREEMENTS DURING 2020

Altitud 1.080. Altiplanum Oleum, University of Granada (20192738). PI: Isabel Seiquer Gómez-Pavón. 2019-2023.

Biochemical and nutritional study of the maturation of meat products prepared with natural and artificial casings. United Caro Research and Development, S.L.U. (20216532). PI: Eduardo López-Huertas León. 2021-2022.

Effect of the inclusion of a feed additive (SILVA-TEAM) on ruminal fermentation parameters. INDUNOR, S.L., Argentina (20210234), PI: A. Ignacio Martín-García. 2020-2021.

ES 631289: Ensiled cultivated macroalgae as a sustainable ruminant feedstuff (En Mac). Nord University, Norway (20192480), PI: Eduarda Molina Alcaide. 2019-2021.

Evaluation of mycorrhizal inoculants. Agro-
genia Biotech, S.L. (20202563), PI: Juan Antonio López Ráez. 2020-2022.

Evaluation of plant extracts as rumen fermentation modifiers. Mojac Technologies, France (20210580), PI: David R. Yáñez Ruiz.

Evaluation of the effect of a biostimulant (Betaser) on young fruit tree plants under heat stress. SERVALESA (20203213). PI: Mariam Sahrawy Barragán. 2020-2021.

In vitro evaluation of bromoform metabolism in the rumen. Blue Ocean Barns, Inc., USA (20215208), PI: David R. Yáñez Ruiz. 2021.

In vitro study of the effect of essential oil-based additives to reduce methane emissions in ruminants. Innofarm, S.L. (20212896), PI: A. Ignacio Martín García. 2021-2022.

In vivo evaluation of diets for livestock including avocado by-products. La Caña, S.L. (20194638), PI: A. Ignacio Martín García. 2019-2021.

In-vitro cultivation of AMF isolates from the EEZ collection and efficacy tests. Koppert Biological Systems, R.V. (20180727), PI: M^a José Pozo Jiménez. 2017-2022.

Isolation and identification of plant growth promoting bacteria (PGPR) and analysis of their viability in liquid media using molasses as the main component. Establecimiento HEFE, S.L. (20210359), PI: Eulogio Bedmar Gómez. 2021-2022.

Monitoring of the urban waste treatment process using different bio-drying and composting technologies. Ayuntamiento de Getxo (20214778), PI: Germán Tortosa Muñoz. 2021.

New generation compounds based on copper complexes: study of the dynamics of accumulation of this metal and its action mechanism in plants. Beneficial effects on plant pathogen resistance. SERVALESA, (20210387), PI: Mariam Sahrawy Barragán. 2021.

New strategies for the prediction and quality control parameters and animal welfare in the Iberian pig. Sánchez Romero Carvajal Jabugo, S.A. (20214120). PI: Rosa M^a Nieto Liñán. 2021-2024.

Nutrition of Iberian sows. Sánchez Romero Carvajal Jabugo, S.A. (20191276). PI: Rosa M^a Nieto Liñán. 2019-2021.

Optimisation of the TOGO-Big Hanna composting system for the treatment of biowaste from selective collection. Berca Brand, S.L. (20213831), PI: Germán Tortosa Muñoz. 2021-2022.

Preparation of meals and focused feeding of animal models with components isolated from the olive tree. Elayotecnia, S.L. (20201357), PIs: Juan de Dios Alché Ramírez, José Carlos Jiménez López. 2020-2022.

Production of high added-value organic and biological fertilisers. Ecoindustria del Reciclado, S.L. (20215068), PI: Germán Tortosa Muñoz. 2021-2022.

Reduction of the use of antibiotics in the organic animal production. Asociación Valor Ecológico, CAAE (20186638), PI: David R. Yáñez Ruiz. 2018-2022.

Screening CACHE domains for novel ligand capabilities. Ohio State University, United States (20200752), PI: Tino Krell. 2020-2021.

Study of methane production via new methane inhibitor formulation. DSM Nutritional Products AG, Switzerland (20214597), PI: David R. Yáñez Ruiz. 2021.

Study of methane production via new methane inhibitor in vivo in sheep. DSM Nutritional Products AG, Switzerland (20203282), PI: David R. Yáñez Ruiz. 2020-2021.

Study of the amino acid composition of ingredients for animal feeding. NUTEGA, S.L. (20214648). PI: Rosa M^a Nieto Liñán. 2021-2022.

Study of the effect of CCPA additive on goat kids' performance, digestive tract development, diet digestibility and milk production on composition during the adulthood. Deltavit, France (20182343), PI: A. Ignacio Martín García. 2018-2021.

Study of the immune-modulator effect of INNOFARM on the health and immune system and on productive parameters of lactating goats. INNOFARM, S.L. (20203851), PI: A. Ignacio Martín-García. 2020-2021.

Technical support for animal experimentation. Abbott Laboratories, S.A. (20201507), PI: A. Ignacio Martín García. 2020-2022.

The role of *Ascophyllum nodusum* in root colonisation. MCA Algas y Derivados, S.L. (20217021), PI: Juan Luis Ramos Martín. 2021-2022.

Valorisation of mycoremediated olive mill waste (*alpeorujo*) as biofertiliser and biopesticide. Aceites Sierra Sur, S.A. (20214664), PIs: Inmaculada García Romera, Ana Azuzena González Coloma (UGR). 2021-2023.

PATENTS

Bacterial nanocellulose production

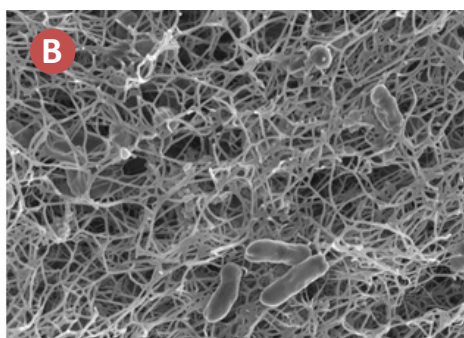
Priority patent application

Authors: Silvia Marqués Martín, Sophie Marie Martirani von Abercron, Patricia Marín Quero, Daniel Pacheco Sánchez

Entity: CSIC

Application number: 202030505

Date: 1st June 2021



A Nanocellulose biofilm produced from CECT30088 strain growing with CO₂ as sole carbon source.

B Scan electron micrograph (SEM) of nanocellulose biofilm produced by CECT30088 strain growing with CO₂ as sole carbon source.

C Nanocellulose biofilm

PUBLICATIONS

SCI PUBLICATIONS

Aguilar-Romero, I.; de la Torre-Zúñiga, J.; Quesada, J.M.; Haïdour, A.; O'Connell, G.; McAmmond, B.M.; Van Hamme, J.D.; Romero, E.; Wittich, R.M.; van Dillewijn, P. 2021. Effluent decontamination by the ibuprofen-mineralizing strain, *Sphingopyxis granuli* RW412: Metabolic processes. *Environmental Pollution*, 274: 116536.

Aguilera, J.F.; Molina, E. 2021. An estimation of enteric methane emissions from small ruminants in a Mediterranean ecosystem. *Journal of Agriculture and Environmental Sciences*, 10: 42-58.

Aguilera, J.F.; Molina-Alcaide, E. 2021. Enteric methane production in adult sheep of the Segureña breed fed diets containing alkali-treated olive cake. *Small Ruminant Research*, 194: 106295.

Alami, S.; Lamin, H.; Bennis, M.; Bouhnik, O.; Lamrabet, M.; El Hachimi, M.L.; Abdelmoumen, H.; Bedmar, E.J.; Missbah El Idrissi, M. 2021. Characterization of *Retama sphaerocarpa* microsymbionts in Zaida lead mine tailings in the Moroccan middle Atlas. *Systematic and Applied Microbiology*, 44: 126207.

Aranda-Sicilia, M.N.; Sánchez-Romero, M.E.; Rodríguez-Rosales, M.P.; Venema, K. 2021. Plasmidial transporters KEA1 and KEA2 at the inner envelope membrane adjust stromal pH in the dark. *New Phytologist*, 229: 2080-2090.

Arce-Rodríguez, A.; Nikel, P.I.; Calles, B.; Charvarría, M.; Platero, R.; Krell, T.; de Lorenzo, V. 2021. Low CyaA expression and anti-cooperative binding of cAMP to CRP frames the scope of the cognate regulon of *Pseudomonas putida*. *Environmental Microbiology*, 23: 1732-1749.

Arnaiz, A.; Rosa-Díaz, I.; Romero-Puertas, M.C.; Sandalio, L.M.; Díaz, I. 2021. Nitric oxide, an essential intermediate in the plant-herbivore interaction. *Frontiers in Plant Science*, 11: 620086.

Belanche, A.; Martín-Collado, D.; Rose, G.; Yáñez-Ruiz, D.R. 2021. A multi-stakeholder participatory study identifies the priorities for the sustainability of the small ruminants farming sector in Europe. *Animal*, 15: 100131.

Belanche, A.; Martín-García, A.I.; Rose, I.; Martín-Collado, D.; Yáñez-Ruiz, D.R. 2021. A collaborative multi-stakeholder analysis of the sheep and goats sector challenges in Europe. *Options Méditerranéennes*, 125: 27-32.

Belanche, A.; Martín-García, I.; Jiménez, E.; Jonsson, N.N.; Yáñez-Ruiz, D.R. 2021. A novel ammoniation treatment of barley as a strategy to optimize rumen pH, feed degradability and microbial protein synthesis in sheep. *Journal of the Science of Food and Agriculture*, 101: 5541-5549.

Belanche, A.; Patra, A.K.; Morgavi, D.P.; Suen, G.; Newbold, C.J.; Yáñez-Ruiz, D.R. 2021. Editorial: Gut microbiome modulation in ruminants: enhancing advantages and minimizing drawbacks. *Frontiers in Microbiology*, 11: 622002.

Bhat, J.A.; Ahmad, P.; Corpas, F.J. 2021. Main nitric oxide (NO) hallmarks to relieve arsenic stress in higher plants. *Journal of Hazardous Materials*, 406: 124289.

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Carmona-Molero, R.; Jiménez-López, J.C.; Caballo, C.; Gil, J.; Millán, T.; Die, J.V. 2021. Aldehyde dehydrogenase 3 is an expanded gene family with potential adaptive roles in chickpea. *Plants*, 10: 2429.

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EDITION OF BOOKS

Antioxidants in Foods. 2021. Editors: Seiquer, I.; Palma, J.M. Multidisciplinary Digital Publishing Institute (MDPI AG) Switzerland. 420 pages. ISBN: 978-3-0365-0579-4.

Grain and Seed Protein Functionality. 2021. Editor: Jiménez-López, J.C. InTech Open Access Publisher. 200 pages. ISBN: 978-1-83968-591-0.

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EEZ
Estación Experimental del Zaidín

WORKSHOPS AND MEETINGS

II WEBINAR Spanish Group for Free Radical Research: Oxidative and Nitrosative Stress and Signaling in Plants

Member of the Scientific Committee:
José Manuel Palma Martínez
28th April 2021 (Online)

XII Workshop Spanish Society of Microbiota, Probiotics and Prebiotics (SEMiPyP) / I Workshop Ibero-American Society of Microbiota, Probiotics and Prebiotics (SIAMPyP)

Member of the Scientific Committee:
Alfonso Clemente Gimeno
15-18 September 2021 (Online)



International Workshops in Environment: Understanding Plant Responses to Climate Change: Redox-Based Strategies

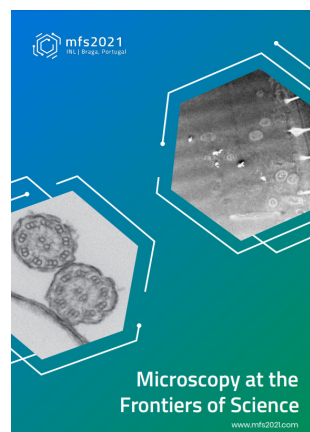
Member of the Organizing Committee:
Luisa M^a Sandalio González
Baeza (Jaén), 20th September 2021



Participants of the UNIA Workshop in Baeza

Microscopy at the Frontiers of Science. Joint Meeting of the Spanish and Portuguese Societies of Microscopy (MFS2021)

Member of the Scientific Committee:
Juan de Dios Alché Ramírez
Braga, Portugal, 29th September-1th October 2021



Final Event of the OPEN2PRESERVE Project.

Members of the Organizing Committee:
Ana Belén Robles Cruz, M^a Eugenia Ramos Font.
Almería, 13-14 December / Pamplona, 17-18 December 2021.



Participants at the Final Event of the OPEN2PRESERVE Project in their visit to Calar Alto

Desgranando Ciencia VII

Member of the Organizing Committee:
Germán Tortosa Muñoz.
Granada, 17-18 September 2021.



AWARDS

Matilde Barón Ayala, director of the EEZ-CSIC, was named **Adoptive Daughter of the Province of Granada** by the President of the Provincial Council. 10th November 2021.



Extraordinary Award in Higher Education in Chemistry, to Gloria González Cañas, Technician at the Department of Physiology and Biochemistry of the Animal Nutrition.

granadahoy.com/granada/premios-extraordinarios

Honourable Mention in the Modality Biology Laboratory, SEBBM Award, Ciencia en Acción 2021: "El DNA: cuatro letras con mensaje (Curso acelerado de bioinformática para estudiantes de Secundaria". Authors: **Francisco Martínez-Abarca, Lola Bernal, Carmen Ontiveros, Marina Roldán, Rabab Limane, Paula Blázquez, Adam Nidame, Javier Gutiérrez, María Hernández**, Estación Experimental del Zaidin-CSIC. Atarfe (Granada), 3rd October 2021.

cienciaenaccion.org/premiados/premiadospresencial



eez
Estación Experimental del Zaidín

TEACHING ACTIVITIES

DOCTORAL PROGRAMMES

Doctoral Programme in Biochemistry and Molecular Biology. University of Granada

Academic Committee member:

Mariam Sahrawy Barragán

<https://doctorados.ugr.es/bioquimicaybiologiamolecular/>

Doctoral Programme in Fundamental and Systems Biology. University of Granada

Academic Committee secretary:

Nuria Ferrol González

Academic Committee members:

José Manuel Palma Martínez, Adela Olmedilla

Arnal, M^a Jesús Delgado Igeño

Committee for Internal Quality members: Nuria

Ferrol González, Juan Manuel Palma Hidalgo

https://escuelaposgrado.ugr.es/doctorado/escuelas/edcti/pages/programas#_doku_biolologia_fundamental_y_de_sistemas

Doctoral Programme in Nutrition and Food Sciences. University of Granada

Academic Committee members:

Cristina Delgado Andrade, Isabel Seiquer Gómez-Pavón

Committee for Internal Quality members: Cristina Delgado Andrade

<https://doctorados.ugr.es/nutricion-alimentacion/>

MASTER PROGRAMMES

Participation in Committees and/or teaching activities in the next Master programmes:

Master in Advances in Agricultural Biology and Aquaculture. University of Granada

Academic Committee members:

María C. Romero Puertas, A. Ignacio Martín García

Committee for Internal Quality member:

Juan de Dios Alché Ramírez

<https://masteres.ugr.es/agraria-acuicultura/>

Master in Biotechnology. University of Granada

Academic Committee member:

[Manuel Fernández López](#)

<https://masteres.ugr.es/biotecnologia/>

Master in Genetics and Evolution. University of Granada

Academic Committee member:

Francisco Martínez-Abarca Pastor

<https://masteres.ugr.es/genevol/>

Master in Research and Advances in Microbiology. University of Granada

Academic Committee member:

M^a Socorro Mesa Banqueri

Committee for Internal Quality member:

M^a Socorro Mesa Banqueri

<https://masteres.ugr.es/microbiologia/>

Master in Molecular Biology Applied to Biotechnology Companies (BioEnterprise). University of Granada

<https://masteres.ugr.es/bioenterprise/>

Master in Microbiota, Probiotics and Prebiotics. European University Madrid and Spanish Society of Microbiota, Probiotics and Prebiotics (SEMIPyP)

Co-director of the Master:

Alfonso Clemente Gimeno

<https://universidadeuropea.com/master-microbiota-probioticos-prebioticos-online/>

Master in Advanced Biotechnology. University of Málaga and International University of Andalusia
<https://www.uma.es/master-en-biotechnologia-avanzada/>

Master in Agroecology, Food Sovereignty, Urban Ecology and Cooperation in Rural Development. University of La Laguna (ULL), Institute of Ecological and Sustainable Agriculture Foundation and Agricultural Research Institute of Canarias (ICIA)
<https://www.ull.es/titulosproprios/master-propio-agroecologia-soberania-alimentaria/>

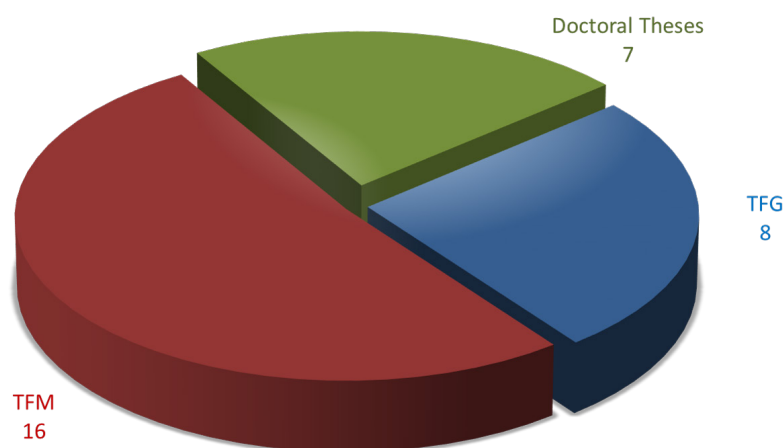
Master in Management, Treatment and Use of Organic Waste. Miguel Hernández University of Elche
<http://masterresiduos.edu.umh.es/>

Master in Organic Agriculture and Livestock. International University of Andalusia (UNIA)
<https://www.upo.es/postgrado/Master-Oficial-Agricultura-y-Ganaderia-Ecologicas>

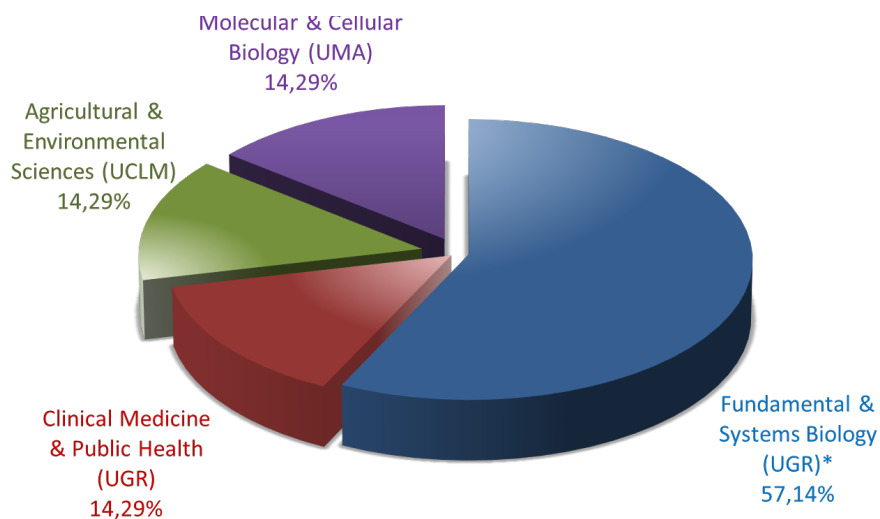
Master in Molecular Life Sciences. Wageningen University, Germany
<https://www.wur.nl/en/education-programmes/master/msc-programmes/msc-molecular-life-sciences/programme-of-molecular-life-sciences.htm>

International Master in Animal Nutrition, International Center for Advanced Mediterranean Agronomic Studies-Mediterranean Agronomic Institute of Zaragoza (IAMZ-CIHEAM), University of Zaragoza
<http://www.masteranimalnutrition.com/>

DOCTORAL THESES, MASTER´S THESES (TFM) & FINAL DEGREE PROJECTS (TFG)

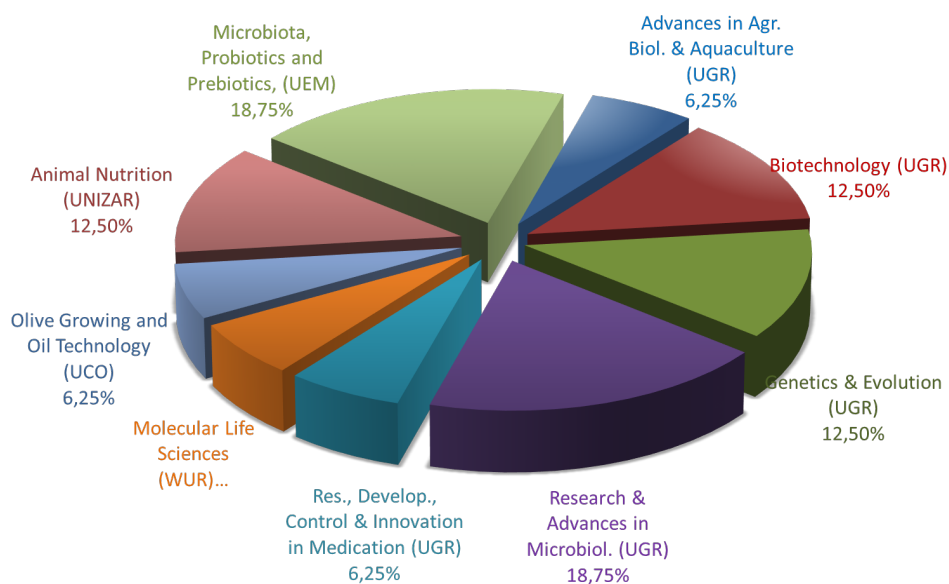


Number of Doctoral Theses, Master's Theses (TFM) & Final Degree Projects (TFG) defended at EEZ during 2021

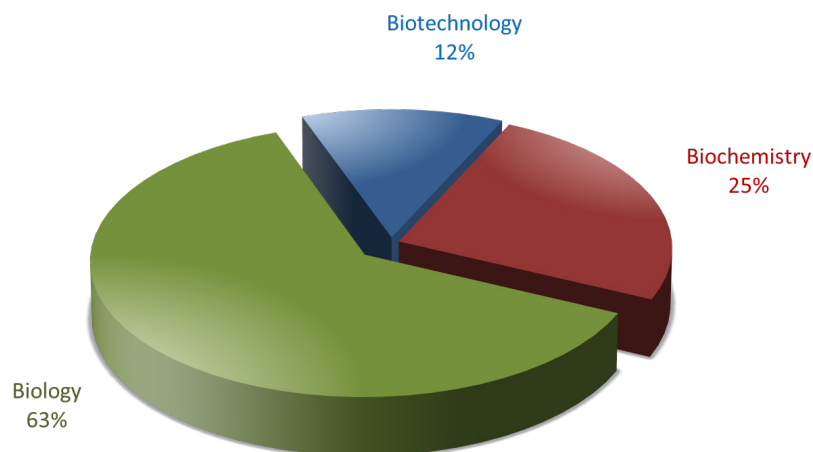


PhD Theses distribution in different Doctoral Programmes

* One was carried out both in FSB-UGR and Molecular Biology and Biotechnology (National University of General San Martín (UNSAM), Argentina) Programmes



TFM distribution in different Master Programmes



TFG distribution in different UGR Degree Programmes

DOCTORAL THESES

Evaluation of the immunological effects of new components of high biological value produced by the food industry

Author: Víctor Alché Ramírez

Supervisor: Juan de Dios Alché Ramírez, Elena Lima Cabello

University of Granada, 7th April 2021

Bioinformatic study of the reproductive transcriptome of olive (*Olea europaea* L.) and applications

Author: Rosario M^a Carmona Muñoz

Supervisor: Juan de Dios Alché Ramírez, Manuel Gonzalo Claros Díaz (IHSM-CSIC)

University of Málaga, 20th July 2021

Adaptation of rhizobia and phosphate solubilizing bacteria to saline-alkaline conditions for the development of efficient biofertilizers for *Lotus tenuis* and identification of bacterial genes involved in the tolerance to this condition

Author: Liz Marjory Stefanny Cumpa Velásquez

Supervisors: Juan Sanjuán Pinilla, M^a Julia Estrella (UNSAM), Analía Inés Sannazzaro (UNSAM)

University of Granada, National University of General San Martín (UNSAM), Argentina/Carolina Foundation Scholarship

27th July 2021

The Reverse Transcriptases associated with CRISPR-Cas systems: phylogenetic relationships and functional characterization

Author: Alejandro González Delgado

Supervisors: Nicolás Toro García, Francisco Martínez-Abarca Pastor

University of Granada, 26th March 2021

International Doctorate Mention

Interaction of nitric oxide (NO) and antioxidants in pepper (*Capsicum annuum* L.) fruit: a transcriptomic, proteomic and functional study

Author: Salvador González Gordo

Supervisors: José Manuel Palma Martínez, F. Javier Corpas Aguirre

University of Granada, 23rd September 2021

International Doctorate Mention

Characterization of *Biscutella auriculata* L., a new species tolerant to heavy metals: antioxidant defense and accumulation strategies

Author: Jesús Daniel Peco Palacios

Supervisors: Luisa M^a Sandalio González, Pablo León Higuera Higuera (UCLM), Juan Antonio Campos Gallego (UCLM)

University of Castilla-La Mancha, 19th July 2021

International Doctorate Mention

Peroxisomal-dependent signalling in plant response to abiotic stress

Author: M^a Ángeles Peláez Vico

Supervisor: María C. Romero Puertas, Luisa M^a Sandalio González

University of Granada, 15th December 2021

International Doctorate Mention

MASTER'S THESES

Early life nutritional interventions in kid goats to improve animal's health and welfare

Author: Refka Chebbi

Supervisor: David Yáñez-Ruiz, Alejandro Belanche Gracia

University of Zaragoza

Caracterización de la composición nutricional proximal de los germinados del olivo y determinación de su uso alimentario potencial

Author: Yassine El Arabi

Supervisor: Juan de Dios Alché Ramírez, M^a Elena Lima Cabello

University of Córdoba

Efecto del H₂S exógeno en la maduración de frutos de pimiento y efecto en los sistemas antioxidantes

Author: María Gallego Gallo

Supervisors: Francisco Javier Corpas Aguirre, José Manuel Palma Martínez

University of Granada

Diseño de una ruta semisintética para la mineralización del TNT

Author: Alejandro García Miró

Supervisor: Pieter van Dillewijn

University of Granada

Caracterización in silico de la familia génica LDAP/REF e inmunolocalización de la proteína LDAP/REF2 en *Olea europaea* L.

Author: Verónica Garrido Hurtado

Supervisor: Antonio Jesús Castro López

University of Granada

Potential of agro-industrial by-products in ruminant nutrition

Author: Mahmoud Hassan

Supervisor: David R. Yáñez Ruiz

University of Zaragoza

Papel de las tioesterasas de *Sinorhizobium meliloti* en la síntesis de metilcetonas volátiles: análisis in silico y funcional

Author: Antonio Manuel Martín Belmonte

Supervisor: M^a José Soto Misffut

University of Granada

Evaluación del potencial del alpeorajo biotransformado por hongos saprobios en la remediación de suelos contaminados con metales pesados

Author: Alicia Martínez Hurtado

Supervisors: Inmaculada García Romera, Gloria Andrea Silva Castro

University of Granada

Supervivencia digestiva de cepas probióticas comerciales utilizando modelos de digestión *in vitro*

Author: Fernando Alonso Medina Monroy

Supervisor: Alfonso Clemente Gimeno

European University of Madrid

Análisis del potencial de enterobacterias asociadas a plantas como fuente de nuevos metabolitos secundarios bioactivos

Author: Laura Monge Olivares

Supervisors: Miriam Rico Jiménez, Miguel A. Matilla Vázquez

University of Granada

Microbiota en la enfermedad inflamatoria canina intestinal

Author: Yaiza Muñoz Aznar

Supervisor: Alfonso Clemente Gimeno

European University of Madrid

Caracterización molecular y alergénica de las enzimas aldehído deshidrogenasas de olivo

Author: Salvador Priego Poyato

Supervisors: José Carlos Jiménez López, Juan de Dios Alché Ramírez

University of Granada

Uso de HMO en formulaciones infantiles y población adulta

Author: Nelson Enrique Ramírez Rodríguez

Supervisor: Alfonso Clemente Gimeno

European University of Madrid

Caracterización molecular y funcional de proteínas alergénicas transportadoras de lípidos (nsLTP) de semillas de altramuza (*Lupinus angustifolius* L.)

Author: María Rodrigo García

Supervisors: Jose Carlos Jiménez López, Sonia Morales Santana

University of Granada

Análisis de la expresión de genes de pimiento (*Capsicum annuum* L.) con aplicaciones farmacológicas: Quercetina

Author: Verónica Ruiz Trujillo

Supervisors: José Manuel Palma Martínez, Francisco Javier Corpas Aguirre

University of Granada

The evolution of the DSF signalling system - a quorum sensing system involved in cellulose production - of *Starkeya* sp. N1B

Author: Jaccoline Zegers

Supervisor: Silvia Marqués

Wageningen University, Germany

FINAL DEGREE PROJECTS

Búsqueda de proteínas que interaccionan con las tres isoformas de fructosa-1,6-bisfosfatasa de *Arabidopsis thaliana*

Author: Lucía Cañete de Pinedo

Supervisor: Antonio Jesús Serrato Recio

University of Granada

Inclusión de harinas de insecto en dietas para tenca (*Tinca tinca*). Repercusiones en el equilibrio redox del digestivo

Author: Gloria Corpas Guerrero

Supervisor: María del Carmen Hidalgo Jiménez,

José Manuel Palma Martínez

University of Granada

Señalización dependiente de peroxisomas en *Arabidopsis*

Author: Paula García Galán

Supervisor: María C. Romero Puertas

University of Granada

Control de la producción del gas invernadero óxido nítrico por bacterias endosimbióticas de leguminosas

Author: Raquel A. Juárez Martos

Supervisor: María Jesús Delgado Igeño

University of Granada

Análisis predictivo de la carbonilación en tejidos reproductivos del olivo y validación funcional preliminar

Author: Ignacio López Rojas

Supervisor: Juan de Dios Alché Ramírez

University of Granada

Función del óxido nítrico (NO) y del sulfuro de hidrógeno (H₂S) en plantas superiores sometidas a estreses medioambientales y su posible interacción

Author: Carmen Medina Alonso

Supervisor: Francisco Javier Corpas Aguirre

University of Granada

Caracterización in-silico de la peroxina PEX11a de *Arabidopsis thaliana*

Author: José Rafael Pérez Moraga

Supervisor: María C. Romero Puertas

University of Granada

Análisis fenotípico del efecto de la melatonina y del sulfuro de hidrógeno sobre plántulas de *Arabidopsis thaliana* crecidas en presencia del herbicida 2,4-diclorofenoxiacético (2,4-D)

Author: Almudena Triguero Cueva

Supervisor: Francisco Javier Corpas Aguirre, José

Manuel Palma Martínez

University of Granada

JAE-INTRO STUDENTS

M^a Ángeles Chico Lozano

Supervisor: Juan Antonio López Ráez

Germán Orlando Gómez Fernández

Supervisor: M^a José Pozo Jiménez

Raquel Adriana Juárez Martos

Supervisor: M^a Jesús Delgado Igeño

Salvador Muñoz Mira

Supervisor: Miguel A. Matilla Vázquez

Alba Ortigosa Palomo

Supervisor: José Manuel Palma Martínez

Oriana Carolina Ortigoza Dempster

Supervisor: María C. Romero Puertas

Salvador Priego Poyato

Supervisor: Juan de Dios Alché Ramírez

Esther Rodríguez de Haro

Supervisor: José Carlos Jiménez López

ERASMUS PLUS STUDENTS

Jaccoline Zegers

Supervisor: Silvia Marqués

Maite Wachter Galindo

Supervisor: María Isabel Ramos González

IN-HOUSE COURSES

LVII EDAPHOLOGY, SOIL FERTILITY AND PLANT BIOLOGY INTERNATIONAL COURSE

The LVII edition of the International Course of Edaphology, Soil Fertility and Plant Biology started in 2020, but unfortunately it had to be suspended due to the COVID pandemic. On 15th March, 2021, it was resumed mostly on an online platform. This Course, hosted by the CSIC and the University of Granada, is one of the most emblematic activities of the EEZ, since it has been imparted during 57 years continuously. Since 2021 it is coordinated by Dr. Concepción Azcón.

The EEZ supports this Course with most of the professors, installations and equipment. The Andalu-

sian Institute of Earth Sciences and the University of Granada also support the Course with lecturers. It includes from biogeochemical aspects of the soil to plant biology, passing through plant-microbe interactions, environmental microbiology and biotechnology.

This Course is recognized by the University of Granada as an "Own Training", dispatching an official diploma to the students. Ten students completed the entire course over the two years.

STUDENTS

M^a del Carmen Aguilera Serrano
Mónica Burrueco Duro
Raquel Colorado Rosa
Fernando Manuel García Rodríguez
Zuleima González Rodríguez

Ylenia M^a Jabalera Ruzzz
Marcos F. Martínez Moreno
Lázaro Molina Delgado
M^a Dolores Molina Sánchez
Martín Ramos-Alvelo Cancellieri

The closing ceremony was held also online on 16th July. It was presided by the Rector of the University of Granada, Dr. Pilar Aranda Ramírez, and the Director of the EEZ, Dr. Matilde Barón Ayala. The "last lesson" of the Course, entitled "Personality,

Creativity and Artificial Intelligence", was given by Dr. Coral del Val, member of the Department of Computer Science and Artificial Intelligence of the University of Granada.

CSIC SPECIALISATION COURSES

Microscopy Techniques

Organization: CSIC Training Office, Deputy General Secretary for Human Resources, in collaboration with the EEZ Confocal and Transmission Electron Microscopy Service and the Group of Plant Reproductive Biology

Granada, 20-24 September, 2021

Teachers: Juan de Dios Alché Ramírez, Antonio Jesús Castro López, José Carlos Jiménez López

Electrophoretic Techniques and their Applications in Agri-Food Research

Organization: CSIC Training Office, Deputy General Secretary for Human Resources, in collaboration with the EEZ Department of Biochemistry and Molecular and Cellular Biology of Plants

Granada, 4-8 October, 2021

Teachers: Antonio Jesús Castro López, Juan de Dios Alché Ramírez, José Manuel Palma Martínez, F. Javier Corpas Aguirre, Carmelo Ruiz Torres

Chromatographic Techniques: GC-MS, LC-MS

Organization: CSIC Training Office, Deputy General Secretary for Human Resources, in collaboration with the EEZ Scientific Instrumentation Service Granada, 18-22 October, 2021

Teachers: Rafael Núñez Gómez, Lourdes Sánchez Moreno

Biosafety Training for Transgenic Plant and Plant Pathogen Facilities

Organization: CSIC Training Office, Deputy General Secretary for Human Resources, in collaboration with the National Centre for Biotechnology-CSIC Granada, 29th November-3rd December

Teachers: Fernando J. Usera Mena (CNB-CSIC), Jorge Pérez Bruzón, Lab Safety Consulting

Reproductive Biology in Higher Plants. Agromomic and Biotechnological Implications

Organization: CSIC Department for Postgraduate and Specialisation

Granada, 23rd November, 2021

Teachers: Juan de Dios Alché Ramírez, Antonio Jesús Castro López, Adoración Zafra Álvarez, José Carlos Jiménez López, M^a Elena Lima Cabello

OTHER COLLABORATIONS IN TRAINING & SCIENTIFIC EDUCATION

1st International Specialization Course on Use of Microorganism in Agriculture, Section Mycorrhizal Fungi, organized by the University of Murcia and the Polytechnic University of Cartagena (Murcia). Teacher: Alberto Bago Pastor.

Agricultural Sciences Online in Secondary School (CAOS) Programme, organized by EEZ-CSIC in collaboration with the IES Francisco Ayala, Granada. Teachers/Researchers: Alché, J.D.; Campos, M.J.; Espinosa, M.; Martínez-Abarca, F.; Palma, J.M.; Ramos, M.E.; Ruiz, C.; Tortosa, G.

Expertise Training in Composting, 2nd Level, organized by: Composta en Red. Teacher: Germán Tortosa Muñoz.

International Agroecology Course: Bases and Strategies for a Fair, Solidary and Sustainable Rural Development, organized by Spanish Agency for International Development Cooperation (AECID), Institute of Ecological and Sustainable Agriculture Foundation, Agricultural Research Institute of Canarias (ICIA), Maquita and Manos Unidas. Teacher: Rogelio Nogales Vargas-Machuca.

Online Training Course "Clinical applications of the use of probiotics and prebiotics", organized by FAES FARMA. Teacher: Alfonso Clemente Gimeno

Technical Specialization Conference: Vermiculture, organized by the Technology Transfer Service, Generalitat Valenciana. Teacher: Rogelio Nogales Vargas-Machuca.

Technology Transfer Annual Plan (PATT), organized by the Ministry of Agriculture, Livestock, Fisheries and Food, Generalitat de Catalunya. Teacher: Ana Belén Robles Cruz.

The World of Carotenoids: Colors, Food and Health. Online summer course. University of the Balearic Islands. Teacher: Juan Antonio López Ráez.

Training programme "Microbiota, probiotics and prebiotics", organized by General Council of Official Associations of Pharmacists. Teacher: Alfonso Clemente Gimeno.

Waste valorization for the agroforestry sector (Valorización de residuos para el sector agroforestal), organized by Temuco Catholic University, Chile. Teacher: Germán Tortosa Muñoz.

X Edition Andalusian Shepherds School, organized by Andalusian Institute for Research and Training in Agriculture, Fishery, Food and Ecological Production, Junta de Andalucía. Teacher: M^a Eugenia Ramos Font.

XXXIV Training Programme in Sustainability at the Centre for Forestry Training and Experimentation in Cazorla, organized by the Ministry of Agriculture, Livestock, Fisheries and Sustainable Development, Junta de Andalucía. Teacher: Ana Belén Robles Cruz.

SEMINARS

Scientific and informative seminars are organized annually at the EEZ. During 2021 the coordinators of these cycles were Drs. M^a José Soto Misffut (until May), David R. Yáñez Ruiz (since June), and Emilio Benítez León. The variety of topics and invited speakers reflects the multidisciplinary nature of the EEZ. Attendance to these seminars is also open to the rest of the scientific and university community of Granada. The seminars are part of the training plan for personnel hired through the Youth Guarantee Fund and for students in Doctoral Programmes, for whom the corresponding certificates of attendance are issued.

Since 2020, due to the situation generated by COVID-19, the seminars cycle was held virtually using the CONECTA platform of the CSIC (<https://conectaha.csic.es>).

Dr. Antonio J. Fernández González. Department of Soil Microbiology and Symbiotic Systems, EEZ-CSIC. "The role of olive microbiome in the defence against pathogens". 15/01/2021

Dr. David R. Yáñez Ruiz. Department of Physiology and Biochemistry of the Animal Nutrition, EEZ-CSIC. "Heat stress in ruminants, adaptation strategies to climate change". 30/04/2021

Dr. Isidro Abreu Sánchez. Department of Plant Science of the University of Oxford. "How rhizobia incorporate metals into nitrogenase and do not die trying. Objectives and methodologies of the IronFeRhizo project". 18/06/2021

Oliver Meyerhoff. Heinz Walz GmbH, Effeltrich, Germany. "Use of the Imaging-PAM fluorimeter, virtual training". 13/10/2021

Dr. Tino Krell. SIC-EEZ. "Use of the microcalorimeter of the Scientific Instrumentation Service (SIC) of the EEZ". 19/11/2021

Germán Tortosa Muñoz. Department of Soil Microbiology and Symbiotic Systems, EEZ-CSIC. "Microbiology of olive mill waste ("alperujo") composting: a very applied basic science". 3/12/2021



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VISITING SCIENTISTS

Rahma Azri. Centre of Biotechnology of Borj Cedria CBBC (INSAT), Tunisia. Group of Mycorrhiza.

Wided Ben Slima. Centre of Biotechnology Borj-Cedria (CBBC), Tunisia. Group of Reactive Oxygen and Nitrogen Species Signaling under Stress Conditions in Plants.

Liz E. Cumpa Velásquez. National University of General San Martín, Buenos Aires, Argentina. Group of Plant-Bacteria Interactions.

Natalia Andrea di Clemente. National University of La Plata, Argentina. Group of Biofertilization and Biodegradation by Rhizospheric Fungi.

Rocío Díaz Peña. University of Buenos Aires, Argentina. Group of Nitrogen Metabolism.

Juan Ignacio Quelas. CONICET/Universidad Nacional de La Plata, Argentina. Group of Nitrogen Metabolism.

Nicolás Marro. Institute of Botany AS CR in Průhonice, Czech Republic. Group of Mycorrhiza.

Victoria Miranda. Regional Research Center for Scientific Investigation and Technology Transfer of La Rioja (CRILAR), Argentina. Group of Biofertilization and Biodegradation by Rhizospheric Fungi.

Ernestina Solórzano Álvarez. University of La Habana- Higher Institute of Technologies and Applied Sciences (InSTEC), La Habana, Cuba. Group of Antioxidants, Free Radicals and Nitric Oxide in Biotechnology, Food and Agriculture.

Aleksandra Staszak. University of Białystok, Poland. Group of Redox Regulation, Sugar Signaling and Phenotyping Using Imaging Techniques to Detect Plant Stress.

Maite Wachter Galindo. IMC Fachhochschule Krems, University of Applied Sciences, Wels, Austria. Group of Environmental Microbiology and Biodegradation.

EEZ STAFF STAYS

Eliaana Molina Moya.
Edinburgh University, Scotland.

Pedro J. Pacheco Márquez.
University of East Anglia, Norwich, United Kingdom.

LOCATION AND CONTACT



www.eez.csic.es



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GRANADA CENTRAL HEADQUARTERS

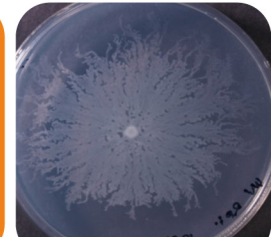
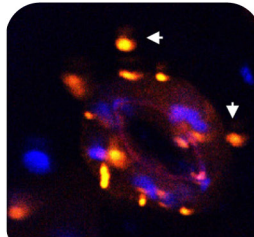
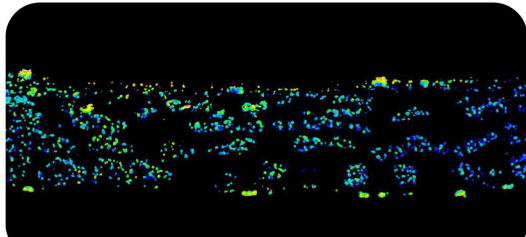
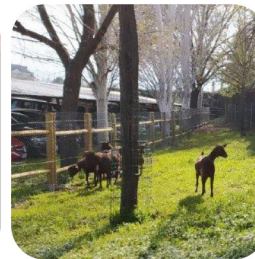
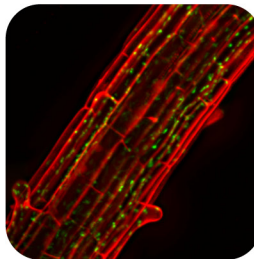
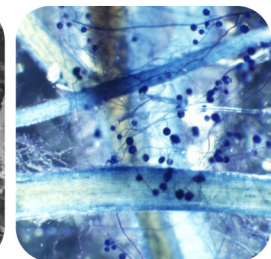
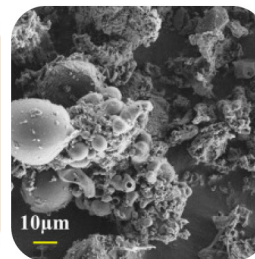
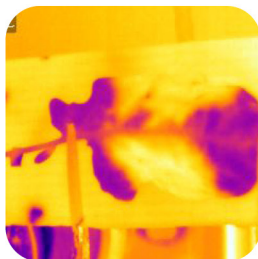
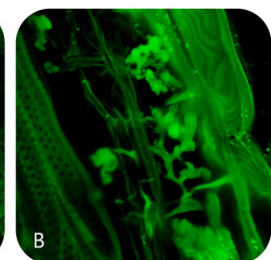
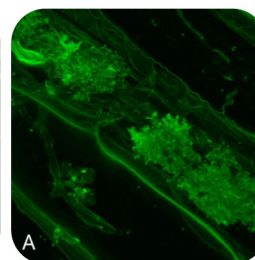
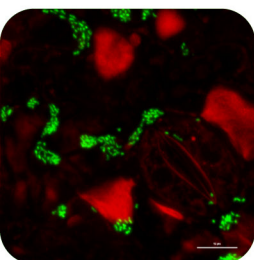
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