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Table of contents

Crop Resilience and Genetics

Agronomy and Crop Management

Soil Science and Environment

Rice Research Across Institutions

Crop Resilience and Genetics

Deciphering the grammar of stress resilience: the case of jasmonates in rice

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Oral presentation

Specificity and versatility are cardinal features of the plant-stress response. How are they achieved? Principally, there exist two possibilities that might act in concert. Parallel signalling: each stress input would be sensed by a separate signal transduction chain activating the appropriate adaptive responses. For stress combinations, the overall response would be composed by the partial responses to the individual stress components. For instance, salinity stress would elicit a response that would sum up from the response to the osmotic stress component and the response to the ionic stress component. Combinatorial signalling: different stress inputs would share one or more transducing elements, that can be recruited for different downstream pathways. Stress combinations would then result in mutual interaction between signalling chains that can be both, synergistic and antagonistic, depending on the effect of the shared component. With such a mechanism, the plant response to a stress combination would not be the mere addition of the responses seen for the individual stress components, but it would be qualitatively different. For instance, the responses to osmotic stress would differ when the osmotic component is accompanied by ionic stress (as it is the case in salinity) compared to the osmotic stress acting alone.

Using a panel of rice mutants, where jasmonate biosynthesis or catabolism is modulated, we used salinity stress as paradigm to demonstrate that specificity is achieved by a temporal jasmonate signature. The timing and duration of jasmonate fluctuations define the type of physiological output. The combination of individual stress components is more than the sum of the parts, it is a novel stress quality.

By engineering a salt-responsive change of jasmonate signatures, we can shift the response from salt necrosis to salt adaptation. This shifts promoter alleles into the focus for resilience breeding to buffer rice cultivation against the challenges of global climate change.

PINE1 controls stem elongation in rice

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Oral presentation

Heading in rice results from the coordination between the switch to reproductive development of the shoot apical meristem and the elongation of the stem below it. Once the panicle is mature, the stem must bring it to the top of the plant. Few years ago, we cloned a gene that we named PREMATURE INTERNODE ELONGATION 1 (PINE1), that is required to maintain the stem unelongated during vegetative growth and needs to be downregulated to allow stem elongation during heading (Gomez-Ariza et al., 2019). This gene responds to the rice florigens, that abolish its transcription when they reach the shoot apex. PINE1 has also been independently characterized as a regulator of stem elongation in response to flooding in deep water rice (Nagai et al., 2020). PINE1 is therefore part of a general repressing mechanism of stem elongation that can be removed in response to different environmental conditions. We have recently shown that PINE1 modulates Gibberellin sensitivity of the stem by changing chromatin accessibility at downstream gene sites.

Different strategies for rice yield improvement under a challenging environment

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Oral presentation

Rice is the staple food for more than half of the world's population, which is growing rapidly and demanding higher crop yields. To improve rice yield in challenging environments, it is crucial to better understand the molecular mechanisms underlying plant responses to external conditions. We have identified and characterised several key rice transcription factors (TFs) and other regulatory proteins involved in the rice response to various adverse environmental conditions (e.g., drought, cold, heat, high salinity, and Zn deficiency). Additionally, we have studied the rice response to light at the seedling stage and to photoperiod at the flowering stage. Phytochromes (Phys), the red/far-red light photoreceptors, play an important role in plant architecture, stress tolerance, and productivity. Phytochrome-Interacting Factors (PIFs) act as central hubs in integrating external stimuli to regulate plant development (Cordeiro et al., 2022). We have produced CRISPR/Cas9 knockout mutants for all rice PIFs and Phys and investigated their involvement in different stages of rice development. Our findings show that PIF15 and PIF16 are essential for coleoptile elongation (unpublished results), and that phyB plays a crucial role in regulating rice flowering time through the photoperiod via the Evening Complex (EC) (Andrade et al., 2022). In our lab, we have also explored ways to improve rice photosynthesis efficiency, either by implementing C4 metabolism in rice (a C3 plant) or enhancing its C3 photosynthesis. We have identified and characterised several rice transcription factors regulating C4 PEPC1 promoters in rice (Carvalho et al., 2024). Moreover, we have demonstrated that improving non-photochemical quenching (NPQ) dynamics can significantly boost plant yield. By over-expressing ZEP, VDE, and PsbS (NPQ dynamics) alongside LOX, LDH, and CAT (O2 scavenging) in rice, we have observed that the simultaneous integration of both strategies is possible and enhances NPQ dynamics and photosynthetic efficiency.

Ascorbate redox regulation for abiotic stress tolerance in rice

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Oral presentation

Iron (Fe) toxicity and drought are critical abiotic stresses that severely affect global rice (*Oryza sativa* L.) production. While ascorbate (AsA) is renowned for its antioxidant properties, its functional roles, particularly concerning its redox state, are complex and stress-specific. Our genetic and physiological analyses of Fe toxicity tolerance in rice have unveiled novel insights, most notably an unexpected prooxidant function of AsA conferring stress tolerance.

Central to these findings is ascorbate oxidase (AO), an enzyme modulating AsA oxidation. We have demonstrated that the ascorbate redox state, influenced by AO, is pivotal not only for enhanced Fe toxicity tolerance but also significantly contributes to drought stress resilience. Intriguingly, while AO is a common enzymatic factor, its activity appears to drive distinct downstream physiological adaptations tailored to each stress. This suggests that ascorbate redox regulation may be used in complex and potentially contrasting ways. For instance, AO-mediated prooxidant activity of AsA appears beneficial for Fe toxicity tolerance. Conversely, under drought conditions, AO's modulation of the ascorbate pool may be more critical for fine-tuning plants' antioxidant capacity, thereby contributing to overall plant adaptation.

Understanding AO's specific contributions and these multifaceted roles of ascorbate redox regulation illuminate the intricate networks governing plant stress resilience. This knowledge is crucial for developing innovative breeding strategies aimed at developing more resilient rice varieties. Such strategies could integrate marker-assisted selection for optimal AO alleles with advanced breeding techniques like precise gene-editing (e.g., CRISPR/Cas). These approaches would allow for the meticulous modulation of the ascorbate redox system - for example, by fine-tuning AO activity to harness the beneficial prooxidant effects of AsA for maximal iron toxicity tolerance, or by optimizing ascorbate recycling for enhanced drought resilience.

Targeting these strategies will enable the development of rice varieties with improved resilience to abiotic stress such as iron toxicity and drought. Ultimately, our work aims to contribute to rice varieties capable of thriving under multiple stress conditions, thereby fostering sustainable agriculture and bolstering global food security.

Stress response and growth regulation in rice – the role of signaling pathways

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Oral presentation

Calcium-dependent protein kinases (CDPKs) are central components of plant signaling networks that integrate growth and defense responses. Their unique ability to translate dynamic changes in intracellular Ca^{2+} levels into specific phosphorylation events, along with their diverse gene family and widespread expression, makes them ideal molecular relays for integrating multiple environmental and developmental signals.

In response to external cues, CDPKs phosphorylate downstream targets to fine-tune plant growth and stress responses. Recent advances highlight their role in coordinating metabolic, transcriptional, and protein–protein interaction networks, including direct effects on carbon/nitrogen (C/N) balance and nutrient homeostasis.

To uncover CDPK targets, we use quantitative proteomics and phosphoproteomics, enabling the identification of key phosphorylation events and candidate proteins regulated by CDPK activity.

For example, we showed that OsCPK17 is required for an effective cold stress response in rice by regulating aquaporin activity and modulating C/N metabolism. Interestingly, our recent findings suggest that OsCPK17 also coordinates with SnRK1, prioritizing aquaporin control over metabolic regulation. Similarly, OsCPK13 influences rice growth by modulating inorganic phosphate (Pi) homeostasis and microbial interactions, affecting Pi perception, root architecture, and root-to-shoot Pi allocation.

These findings support the view that CDPKs are pivotal hubs linking rapid cellular responses to long-term metabolic and developmental adjustments. As such, they represent promising targets for improving rice resilience to increasingly unpredictable climate conditions.

Integrative genomic and transcriptomic insights into allelopathy in temperate japonica rice

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Poster presentation

Weed infestation poses a major challenge to rice cultivation, particularly in Europe, where there is an increasing need for sustainable alternatives to chemical herbicides. Allelopathy—the ability of plants to release bioactive compounds that influence neighboring species—offers a promising natural strategy for weed suppression. While rice varieties display varying degrees of allelopathic potential, the genetic and molecular basis underlying this trait remains largely unexplored. We used both genome-wide association studies (GWAS) and transcriptomic analyses to uncover the genetic factors and biological processes involved in allelopathy in temperate japonica rice. WE identified Ganao as a variety with the capacity to inhibit the growth of barnyardgrass (*Echinochloa crus-galli*) roots at early stages of growth. GWAS identified four key quantitative trait loci (QTLs), with major loci on chromosomes 2 and 5 harboring genes involved in secondary metabolism, such as Phenylalanine Ammonia Lyase (PAL) and R2R3-type MYB transcription factors. Complementary RNA-seq analysis during co-cultivation with barnyardgrass revealed a time-dependent activation of the phenylpropanoid pathway in the allelopathic variety Ganao, contrasting with a non-allelopathic variety, Bomba. Interestingly, diterpenoid phytoalexin biosynthesis was suppressed in Ganao, suggesting a distinct allelopathic mechanism that relies on phenylpropanoid metabolism and associated detoxification and cell wall pathways. These findings provide valuable insight into the genetic and molecular architecture of allelopathy in rice and lay the groundwork for breeding programs aimed at developing competitive, weed-suppressive rice cultivars.

Introduction of MaxAce® technology in Italy rice growing system

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Poster presentation

Cultivation of herbicide-tolerant rice in Italy has progressively increased in the last 20 years, representing more than 60% of rice total surface in 2024.
At the same time, weed resistance has also increased. The species that most concern rice growing from this point of view, due to the limited number of available Mode of Actions, are belonging to Alismataceae, Cyperaceae and two main rice grass weeds: weedy rice and *Echinochloa* spp. (barnyardgrass). Since 2006, the number of barnyardgrass populations resistant to ALS-inhibitors in Italy have exceeded 130, and populations with multiple resistance to ALS and ACCase inhibitors have also dramatically increased, overcome 80, in 2020.
There are four herbicide-tolerant rice technologies authorized in Italy. Clearfield® and Provisia®, introduced since 2006 and 2017, are the most widespread. These technologies are resistant to Imazamox, an ALS-inhibitor and Cycloxidim, an ACCase inhibitor, respectively.
In 2020, RiceTec Inc, a world leader in hybrid rice seed production, has patented a new resistance to Imazamox, registered as FullPage® and another technology, called Max-Ace®, with hybrids resistant to Quizalofop-p-ethyl. These two technologies are expanding in the Italian rice area in the last three years, meeting the interest and satisfaction of farmers, both for weed control efficacy and huge grain yield potential. FullPage® and Max-Ace® hybrids are only long B grain at the moment, but RiceTec's genetic resistances are starting to be introduced into varieties too, thanks to the collaboration with Norverisi company.
It is very likely that these resistance technologies will become widely available in the future.
While it is true that these new technologies offer a great opportunity for rice cultivation, it is also true that optimizing their management is essential to maintain their effectiveness in the long term and to limit problems related to resistances that develop as a result of their repeated and incorrect use. For these reasons, since 2022 a collaboration among Ricetec Inc, Isidro, Norverisi and Adama is promoting the development of Max-Ace® technology, with the aim of reducing as much as possible the onset of multiple and cross resistance to ALS and ACCase inhibitors in rice weed populations and to prolong the effectiveness of this technology as much as possible, integrating it into a rotation system with other resistance technologies.
Max-Ace® hybrid seed started to be commercialized in 2024, and a technical farmers support and monitoring began. Trials and large field activity conducted so far showed promising results but indicate the need to adopt a more precise and targeted approach to optimizing the control of weedy rice and barnyardgrass.
Herbicide field trials were carried out with randomized plots treatments in 2022 and 2023.
Future research directions are going to investigate:
- managing barnyard grass populations not perfectly controlled with herbicide coupled with Max-Ace® technology
- understanding the best rotations of existing technologies applicable
- defining the best herbicide mixtures applicable depending on weeds and biotypes present.

Rice breeding and variety development in Europe

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Poster presentation

Rice breeding is quickly changing the set of rice varieties grown and consumed in Europe. Thanks to new available technologies for the farmers and to change in consumption habits of the consumers the European breeders are working on a silent revolution of the variety types. The new developed varieties are living close by the old traditional ones but, step by step, are occupying their place in the fields and in the dishes.
The state of the art is presented and the trend in rice breeding and variety development is described

Rosa Marchetti rice: comparison of cultivation systems in terms of yield, protein profile, and antioxidant properties

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Poster presentation

Rice (*Oryza sativa* L.) is one of the most important staple foods worldwide, and Italy plays a leading role in its European production. While well-known varieties such as Arborio, Carnaroli, and Roma dominate large-scale cultivation and international markets, the country also preserves lesser-known traditional cultivars. Among them, there is Rosa Marchetti, a semi-fine grain variety introduced in 1972 by Domenico Marchetti. Recently, interest has shifted from focusing mainly on productivity to exploring rice's nutritional and functional characteristics. At the same time, the growing emphasis on sustainable agriculture has led to greater attention on how different farming systems influence the nutritional profile of rice grains. This study investigates the biochemical properties of Rosa Marchetti rice grown under three contrasting cultivation methods: organic, agroforestry, and conventional.

The seed storage protein fractions -albumins, globulins, prolamins, and glutelins- were sequentially extracted using the Osborne method. Quantitative analysis of protein concentration was performed with the Bradford assay. Protein profiles were further characterized by SDS-PAGE electrophoresis and MALDI-TOF mass spectrometry. In addition, the antioxidant activity of globulin fractions was assessed using the ABTS radical cation decolorization assay.

Both organic and agroforestry samples showed notably higher protein concentrations across all fractions when compared to conventional samples. Salt-soluble globulin fractions reached mean concentrations above 1 mg/ml in sustainable samples, while the albumin fraction ranged from 0.2 to 0.3 mg/ml. SDS-PAGE analysis revealed a broader molecular weight distribution in organic and agroforestry samples, particularly in the 10–20 kDa range, indicative of a more diverse proteome. While MALDI-TOF spectra did not show distinct peak differences, principal component analysis revealed a clustering pattern that partially separated conventional samples from those grown under sustainable conditions. ABTS assay results confirmed significantly higher antioxidant activity in organic and agroforestry rice's globulin fractions. Trolox equivalent values averaged 776.2 µM and 837.9 µM, respectively, compared to only 389.2 µM in conventional samples.

This study underscores the strong influence of cultivation method on the proteomic and functional quality of Rosa Marchetti rice. The use of organic and agroforestry systems not only enhances the nutritional profile of the grain but may also support broader goals in health-oriented food production and sustainable crop development.

Agronomy and Crop Management

The combined effects of biostimulant and herbicide application on rice crop

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Oral presentation

Reducing fertilizer use through the use of biostimulants can lead to lower weed pressure on crops and higher yields, especially in combination with herbicide applications.
Objectives. The main objective of the present study was to evaluate the combined effects of reduced basal fertilization rates, biostimulant application and herbicide application on weed growth, crop growth and yield of rice (*Oryza sativa* L.) in a temperate Mediterranean environment.
A Randomized Complete Block Design (RCBD) field trial was conducted with five treatments replicated four times during the 2022 summer growing season in Western Greece. The treatment list included: 100% basal fertilization (T1), 20% basal fertilization + biostimulant application (T2), 100% basal fertilization + herbicide application (T3), 20% basal fertilization + biostimulant application + herbicide application (T4) and 20% basal fertilization + two biostimulant applications per 15 days + herbicide application (T5). NitroStim®, containing N2-fixing bacteria (1 × 1012 colony forming units; CFU L−1), was the microbial biostimulant applied at a rice height of 15–20 cm. Cyhalofop-butyl + florpyrauxifen-benzyl was the prepackaged herbicide mixture applied at a rate of 400 + 30 g a.i. ha^{-1} when rice plants were at tillering stage. *Echinochloa crus-galli* (L.) P.Beauv., *Cyperus difformis* L. and *Leptochloa fusca* subsp. *fascicularis* (Lam.) N. Snow were the dominant weeds. At 30 days after treatment (DAT), the total biomass of weeds in the T1 plots was 22%, 80%, 93% and 94% higher than in the T2, T3, T4 and T5 plots, respectively. The application of herbicide in the T3, T4 and T5 plots reduced the dry weight of weeds by 75–92% compared to the T2 treatment. Compared to treatment T1, treatments T2, T3, T4 and T5 increased rice height by 8%, 17%, 24% and 27%, respectively. The effects of the treatments on the Normalized Difference Vegetation Index (NDVI) of rice were similar. In addition, treatments T4 and T5 resulted in the highest grain yields at the end of the growing season ($p < 0.001$). The number of panicles and 1,000-grain weight were the yield components that were influenced by the treatment factor ($p < 0.05$).
These findings underline the role of biostimulants as “green” alternatives to conventional synthetic fertilizers and also as components of Integrated Weed Management (IWM) in rice fields. Further research is required to evaluate such agronomic practices in rice and other economically important crops and under different soil-climatic conditions.

Small RNAs, big impact: miRNAs mediated regulation of herbicide resistance in *Echinochloa crus-galli* and *Echinochloa oryzicola*

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Oral presentation

Herbicide resistance is an increasingly serious phytosanitary issue, leading to significant reductions in crop yields and substantial economic losses. Although the physiological and molecular mechanisms underlying herbicide resistance have been widely studied, the role of epigenetics, especially mechanisms regulating the expression of genes involved in herbicide resistance occurrence, has only recently begun to be investigated.

This study aims to explore the miRNA-mediated regulation of enzymes involved in herbicide detoxification in two of the most problematic weed species in Northern Italian rice cropping territory: *Echinochloa crus-galli* (L.) P. Beauv. (barnyardgrass) and *Echinochloa oryzicola* (Vasinger) Vasinger (late watergrass). This research focuses on miRNAs predicted to target genes encoding cytochrome P450 monooxygenases (CYPs), glutathione S-transferases (GSTs) and eIF4B, key components of herbicide detoxification pathways.

Seeds from plants survived herbicide administration were germinated and grown under controlled conditions. Plant susceptibility/resistance was assessed via visual inspection and biomass measurement. The expression profiles of predicted miRNAs and their gene targets were analyzed by RT-qPCR before and after herbicide application in both susceptible (SUS) and resistant (RES) biotypes.In *E. crus-galli*, after bispyribac-Na treatment, five miRNAs (gra-miR7487c, gma-miR396f, gra-miR8759, osa-miR395f, and ath-miR847) were upregulated in both biotypes, with higher expression in RES plants. This correlated with reduced expression of target genes (CYP72A254, GSTF1, eIF4B, CYP81A68, CYP71AK2), suggesting post-transcriptional silencing. Three other miRNAs (ata-miR166c-5p, ath-miR396b-5p, osa-miR5538) were unaffected by herbicide application and showed no biotype-specific differences.

In *E. oryzicola*, profoxydim treatment led to distinct patterns. In RES biotypes, some miRNAs (osa-miR2099-5p, ath-miR396b, osa-miR395f, osa-miR396a-5p, osa-miR166a-5p, osa-miR166d-5p, gra-miR8759, and gma-miR396f) were not triggered, allowing expression of cytochromes P450 of the 81A subfamily, GSTF1 and eIF4B. The other miRNAs (ata-miR166c-5p, ath-miR847, osa-miR5538, gra-miR7487c) were upregulated, reducing the expression of CYP71AK2, CYP72A254, and EcGST. In SUS biotypes, the herbicide stimulated ata-miR166c-5p, ath-miR847, osa-miR5538, gra-miR7487c, osa-miR166a-5p, and gra-miR8759, down-regulating their respective target genes (CYP72A122, CYP71AK2, EcGST, CYP72A254, CYP81A12, and eIF4B).

These results indicate that miRNA-mediated regulation plays a significant role in modulating herbicide resistance occurrence through gene silencing in *Echinochloa* species.

Elucidating the miRNA-mediated regulation of herbicide resistance can enhance targeted, sustainable weed control and optimize precision weed management (PWM). miRNAs also show promise as biopesticides due to their cross-organism mobility and gene regulatory roles.

Integrated strategies for sustainable management of *Pomacea* spp. in Mediterranean rice agroecosystems

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Oral presentation

The invasive apple snail (*Pomacea* spp.) is a pest that poses an increasing challenge to rice cultivation in Mediterranean Europe, particularly in the Ebro Delta. Its rapid spread has disrupted weed control practices, increased herbicide dependency, and threatened the ecological balance of aquatic agroecosystems. However, this species also presents an untapped potential due to its weed predation and the possibility of commercially exploiting its calcium-rich shell.

Thus, this species, typically considered harmful, can be revalorized as both a biological control agent for weeds and a source of high-value biomaterials.

Five experiments were conducted: (1) The reproductive cycle, fecundity, and oviposition dynamics were studied under mesocosm conditions to assess seasonal patterns; (2) the viability of egg masses and juvenile survival were evaluated under controlled environments; (3) field trials measured the impact of biomass consumption by *Pomacea* spp. on *Heteranthera reniformis*, a dominant aquatic weed, using different snail densities across three rice farms; (4) the snail was deployed as a biological control agent in flooded rice plots with and without herbicide application, assessing effects on weed biomass and rice yield; and (5) shells were processed to obtain calcium oxide (CaO), which was transformed into hydroxyapatite (HAP) via hydrothermal synthesis and characterized through FTIR, XRD, and SEM-EDS analyses.

Preliminary results showed that reproductive activity and hatching success increased with ambient temperature and water availability, confirming the species' adaptive plasticity. Juvenile growth and survival were density-dependent, indicating ecological thresholds for effective application. In flooded field conditions, herbivory by *Pomacea* spp. significantly reduced weed biomass, particularly in high-density treatments. Its use as a low-input biocontrol agent proved effective and feasible under real-world conditions. Additionally, the shell yielded CaO with 77.3% purity, and the synthesized hydroxyapatite exhibited a porous microstructure and functional chemical groups comparable to commercial-grade materials.

This study presents a transformative vision of *Pomacea* spp.: traditionally regarded as a pest, can be repositioned as a multifunctional resource in rice agroecosystems, contributing to sustainable agriculture, environmental restoration, and innovative bioeconomy models in Europe.

Innovations for weed control in paddy rice among models, nano- and bio- technologies

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Oral presentation

One of the purposes of the European Green Deal is to reduce reliance on herbicides and encourage integrated weed management strategies that are more environmentally sustainable and less hazardous to animal and human health. The only way to achieve sustainable agriculture is to invest in technical and scientific innovation and the integration with non-chemical methods has become the rule in many cropping systems. In this context, the RiWeCIS (Rice Weeds Control with Innovation Systems) project aims to develop several strategies to improve the sustainability of the Italian rice cultivation by optimizing/reducing/avoiding herbicide use. The aim is to preserve productivity while protecting human health and the environment. Pilot experiments will be performed to show the potential of integrating the different technologies developed in the project. In RiWeCIS, three activities were proposed at different Technology Readiness Levels and different timeframes to achieve potential field applicability.

1) The development of a predictive model for the main rice weed, *Oryza sativa* (weedy rice), adapted to the complexity of rice fields. Proper weed management is crucial in rice cultivation, significantly impacting yield. The success of chemical and non-chemical weed control methods depends on precise application timing. To address this, predictive models have been developed to understand weed emergence patterns, enabling more accurate treatment scheduling, optimizing chemical and mechanical methods, and reducing herbicide use.

2) The development of nanoformulations encapsulating an active ingredient used to control rice weeds. A potential solution to reduce the environmental impact of herbicides without reducing their efficacy could be to formulate them using nanotechnology, aiming to reduce the dispersion into the environment, while maintaining the efficacy. Two clay-based imazamox nanoformulations were synthetized and their efficacy was compared with that of technical grade imazamox and a commercial product on two weed species: *Echinochloa* spp. and *Oryza sativa* (weedy rice).

3) The development of a gene-technology solution based on RNA interference (RNAi), that is a dsRNA-mediated gene silencing mechanism, as a possible alternative/integrative non-chemical tool for the control of major rice weeds. We are working on the two major limits for the development of this technology a) identifying targetable sequences using VIGS (Virus-Induced Gene Silencing) tool and b) increasing the stability and delivery of RNA molecules using nanoencapsulation.

The future challenge is to find a way to integrate these innovative technologies with each other and with the management strategies currently used for weed control in rice fields. This could be done in the short term for the herbicide application model, which could also be implemented with the use of nanoformulations, while more time and study will be necessary to obtain genetic technologies for weed control in the field.

Evaluation of irrigation management practices in the Baix Ter rice agroecosystem (Girona, Spain)

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Oral presentation

The Baix Ter (Girona, Spain) rice agroecosystem, likewise many other Mediterranean rice cropping areas, faces water scarcity due to competing water demands. In this context, implementing water management practices that reduce water use while maintaining the crop yield is crucial for its environmental preservation and crop profitability. The objective of this work is to assess the viability and water-saving potential of different irrigation practices in the Baix Ter rice cropping area.

The dry seeding and continuous flooding (DFL) and subsurface drip irrigation (SDI) were tested and compared to wet seeding and continuous flooding (WFL) in 4 non-saline commercial rice fields in Baix Ter during the 2020 – 2023 irrigation seasons. Data related to the water balance terms, crop development and agronomic practices was collected using sensors, manual measurements and interviews with the farmers. Deep percolation was the closure term of the water balance. The WFL and DFL fields, with silty clay loam and loam textures, respectively, were located within the rice district. The SDI system was implemented in 2 different fields. One of the fields was located at the perimeter of the traditional rice cropping area, had a silty clay soil and a very shallow aquifer (SDI-SiCl). The other, outside the rice area, had a sandy loam soil and a deeper aquifer (SDI-SaL). Different installation configurations and water management criteria were tested in both cases.

Average irrigation was 1,392 mm (WFL), 1,356 mm (DFL), 812 (SDI-SiCl) and 1,057 mm (SDI-SaL), showing a 2.6% reduction in DFL and 24 – 41% reduction in SDI compared to WFL. Paddy rice yield averaged 5.4, 6.5, 5.5 and 4.3 t ha^{-1} in WFL, DFL, SDI-SiCl and SDI-SaL, respectively, resulting in an irrigation water productivity (IWP) of 0.39, 0.48, 0.68 and 0.40 kg m^{-3}. Additionally, data related to the rice yield and irrigation water distribution within the soil profile in both SDI fields highlighted the importance of an adequate design of the SDI installation as function of the soil texture. Deep percolation was the highest water output in all irrigation methods, accounting from 58 to 86% of irrigation. As expected, the lowest percolation rates were computed in SDI-SiCl, while the highest ones were registered in WFL.

Overall, the results demonstrated that both DFL and SDI are suitable practices to be implemented for rice irrigation under the tested conditions. Specifically, DFL showed low water savings compared to WFL, but resulted in higher yields, which increased IWP. SDI resulted in greater water savings, but a high variability was observed as function of the soil texture and groundwater depth. Further research on DFL is currently being undertaken in other areas of the Baix Ter district to better assess its effect on different soil conditions.

Opportunities and challenges for sustainable rice irrigation in the Mediterranean region

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Oral presentation

Rice cultivation covers around 1.3 million hectares in the Mediterranean basin, with Egypt, Italy, Turkey and Spain being the main producers. In Europe, Italy and Spain account for 72% of EU rice production, with around 345,000 hectares under cultivation, while Egypt and Turkey account for almost all the production in non-EU Mediterranean countries, with around 789,000 hectares. In these regions, rice is traditionally cultivated using Wet Seeding and continuous Flooding irrigation (WFL), which requires more water than non-flooded rice cultivation and contributes to significant methane emissions. However, it also preserves unique biodiversity-rich agro-ecosystems. Nevertheless, rice remains a strategic crop for food security, particularly in Egypt, and its consumption is steadily increasing across the Mediterranean region. To address the issue of excessive water usage associated with WFL, the most promising alternative irrigation methods were tested as part of the MEDWATERICE PRIMA-Section2-2018 project in seven case studies conducted under site-specific conditions across five Mediterranean countries (Italy, Spain, Portugal, Turkey and Egypt) between 2019 and 2021. The irrigation strategies were selected with the active involvement of local stakeholder groups. The evaluated techniques included wet seeding and Alternate Wetting and Drying (AWD), Dry seeding and delayed FLooding (DFL), Water Input Reduction (WIR), DFL with enhanced control of ponding water level through automated gates (DFL-aut), hybrid Irrigation (HYBRID), sprinkler irrigation (SPRINKLER), surface drip (DRIP) and Subsurface Drip Irrigation (SDI). These methods were implemented alongside WFL for at least two years, during which time the environmental, economic and social sustainability of each irrigation strategy was assessed. The results showed that AWD, DFL, (DFL-aut) and WIR could improve water productivity (WP) while maintaining yields. More advanced systems, such as SPRINKLER and HYBRID, achieved an increase in WP of around 50%, with yields either maintained or improved. However, these alternatives require changes to irrigation management and the purchase of new equipment, with limited costs for the HYBRID system and greater investment for the SPRINKLER system. DRIP and SDI methods demonstrated the greatest potential for water savings, more than doubling WP; however, yield reductions were observed when the systems were not carefully adapted to local conditions. For all pressurised methods, particularly localised irrigation systems such as DRIP and SDI, site-specific factors must be considered to ensure proper system design and management and thus minimise the risk of yield losses.

Overall, these water-efficient irrigation strategies offer a valuable opportunity to reduce water consumption while sustaining or increasing rice yields in traditional Mediterranean rice-growing areas. Furthermore, they enable rice production to be expanded into new regions to meet rising demand.

Field and spaceborne hyperspectral spectroscopy to retrieve agronomic variables in paddy rice field

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Oral presentation

Agronomic management in paddy rice is critical. Fertilization deficit severely limits growth and yield, while excessive or poorly timed fertilization causes low nutrient use efficiency and environmental problems (i.e. GHG emissions and water pollution). Adaptive agronomic strategies require timely information about rice nutritional status, traditionally provided by destructive field/lab analysis. However, time and costs constraints make this approach difficult to scale at territorial level. Spaceborne remote sensing has been widely proposed as a non-destructive technique to estimate the spatial and temporal dynamics of crop agronomic traits for assessing nutritional status. Current rice monitoring systems use multispectral satellite sensors (e.g. Sentinel-2, Landsat), which provide a few broad-bands across the electromagnetic spectrum. This limits their capability to detect specific traits, particularly the nitrogen-related ones with subtle absorption features in the shortwave region. Last-generation hyperspectral satellite missions (i.e. PRISMA, EnMAP) measure reflectance in the visible, near and short-wave infrared (350-2500 nm) by hundreds of narrow (<10 nm) continuous spectral bands at 30 m spatial resolution. Despite the potential advantages, the capability of these techniques to generate detailed information on crop traits has been still poorly evaluated. This research evaluates the potential of hyperspectral spaceborne sensors to monitor paddy rice biomass and nitrogen content at field scale. To this end, during the summer seasons of 2023 and 2024, from early July to the end of September, we conducted 5 field campaigns in rice paddies located in Jolanda di Savoia (NE Italy) to collect field hyperspectral measurements and agronomic data, including aboveground biomass (AGB), leaf area index (LAI) and nitrogen content (N). Data were collected across 10 Elementary Sampling Units (ESU) of 60x60 m^2 (2x2 EnMAP/PRISMA pixels). Within each ESU, measurements were taken on four plots (i.e., 40 plots for each campaign). Multiple EnMAP and PRISMA satellite images were also acquired in the study area during the rice growing season. The initial phase of the study has focused on the development of XGBoost machine learning (ML) models between field measurements spectrally resampled to satellite hyperspectral bands, and agronomic data at plot scale. The preliminary results on the 2023 data, once 5-fold cross-validated, show good predictive performance, for LAI [-] (R2: 0.85, RMSE: 0.75), AGB [g m^{-2}] (R2: 0.81, RMSE: 630.27), and N content at leaf [%] (R2: 0.71, RMSE: 0.37) and canopy level [g m^{-2}] (R2: 0.80, RMSE: 1.14). The future work will encompass the evaluation of the ML models on 2024 data and their mapping demonstration using EnMAP/PRISMA satellite images for AGB, LAI and N retrieval, and the assessment of spatial and temporal patterns of rice traits in relation to ground knowledge about soil variability and management practices.

Rice fields, mosquitoes and mosquito-borne diseases: public concerns and management strategies in Europe

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Oral presentation

In recent decades, several mosquito-borne diseases (MBD) have emerged or re-emerged in Europe, particularly in southern regions where rice cultivation is more widespread. Rice is a crucial food source and an important economic activity worldwide. Rice fields provide habitats for birds and other organisms but also serve as outstanding breeding grounds for mosquitoes, including potential vectors of the genus *Culex*, *Aedes* and *Anopheles*. Therefore, there is an urgent need to manage mosquitoes associated with rice crops, to reduce nuisance and the risk of pathogen transmission. Effective management should rely on cost-effective, legislative, and environmentally compatible approaches. We gathered information from various sources on surveillance, phenology, mosquito-related issues, vector-borne diseases, control, and management in fourteen of the main rice field areas of the five major rice-producing countries in Europe: four in Italy (Piedmont, Lombardy, Emilia-Romagna, Veneto), four in Spain (Marismas del Bajo Guadalquivir, Vegas Altas, Delta de l'Ebre, Albufera), two in Greece (Thessaloniki Regional Unit, Kavala Regional Unit), three in Portugal (Mondego river, Tagus Estuary, Sado tributaries), and one in France (La Camargue). Across all these regions, mosquito-related issues in rice fields are significant, although the scale and timing of entomological and virological surveillance vary. Different mosquito control strategies are applied, ranging from centralized programs to localized interventions funded by public entities and executed by public or private companies. Biological larviciding with *Bacillus thuringiensis* serovar. *israelensis* is the primary method used, supplemented by adulticiding during epidemic outbreaks in nearby urban areas. These management approaches reflect diverse regional contexts and highlight the importance of adaptive strategies in addressing mosquito-related challenges across rice paddies in Europe.

Only holistic approaches to rice cultivation and mosquito control will ensure both food security and healthier communities. A successful strategy requires a One Health perspective, fostering collaboration among farmers, vector control professionals, public health authorities, and researchers.

Agroclimatic features of main Italian rice areas for modelling purposes

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Poster presentation

Italy, with commercial rice cultivation in place since 14th–15th century, is one of the oldest rice-growing countries in Europe. Rice in Italy has traditionally been grown on soils with water excess, acidic soils (where flooding brings the pH closer to neutrality) or saline soils (where irrigation with fresh waters helps wash away sodium chloride). Today - also due to the spread of sowing on dry soil and the contraction of traditional sowing on flooded fields - rice cultivation is expanding into new areas such as Lodi, Milan and Pavia east of the Ticino River. In Central and Southern Italy, rice cultivation is limited by water scarcity and is mainly found in the areas of Grosseto (Tuscany), Oristano (Sardinia) and Sibari (Calabria).

To understand the agroclimatic basis of the suitability to rice it is necessary to consider the relevant north–south extension (from 35° to 47°N, over 1200 km) of Italy and the influence of various geographical factors - in particular the mountain ranges of the Alps and the Apennines, as well as the influence of the Mediterranean Sea and the Atlantic Ocean. These factors are among the main determinants of the two macroclimates hosting the Italian rice growing areas that are Köppen-Geiger' Csa (Mediterranean climate with summer drought) and Cfa (transitional climate between the Mediterranean Csa and the oceanic Cfb of Central Europe).

To briefly describe the temperature and precipitation patterns of the main rice growing areas of Italy, Bagnouls and Gaussen diagrams were drawn for nine locations representative of these areas. For the same locations, thirty-year time series (1995–2024) were analyzed for the rice growing season (April-September) to obtain radiation resources (PAR), thermal resources (normal heat hours – NHH), number of days with minimum temperatures ≤12°C in July and August (associated with the risk of male floral sterility), precipitation amount and number of rainy days (linked to the risk of rice blast) and hours of thermal stress from high temperatures (HHH). It is worthy to note that Central and Southern Italy are more exposed to heat stress while are much less exposed to cold stress, rice blast and low temperature-related male floral sterility.

Rice crop yield and quality are driven by the above-described resources and limitations and other key factors like nutrients availability and weeds competition. The aim of our research is to integrate information about these factors into production models of the rice agroecosystem capable of simulating growth, development and production scenarios under different environmental and agronomic conditions. We are working on developing a new model and comparing existing ones, with the aim of improving predictive accuracy and applicability in the context of climate variability and change and sustainable resource management.

Cyperus difformis resistance to rice herbicides in south Portugal

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Poster presentation

Smallflower umbrella sedge (*Cyperus difformis* L.; Cyperaceae) is not a very competitive weed against rice. However, resistance to ALS-inhibiting herbicides (HRAC-B/2) have made them some of the most problematic and difficult to control weed species. Integrated weed management (IWM) strategies are needed to overcome this problem. Early detection and the knowledge about the mechanism responsible for resistance contributes to tackle the weeds before the next campaign. In our lab we developed a RT-q-PCR method for detection of resistance at seed level, without the need for waiting for whole plant development or overcome seed dormancy. The first step was to extract DNA with quality for molecular studies from tiny seeds of *C. difformis* (1000-seed weight, or TSW, CYPDI= 0.03 g) compared to larger seeds of *Echinochloa phyllopogon* (TSW ECHPH= 0.52 g) or *Amaranthus retroflexus* (TSW AMARE= 0.50 g) where DNA extraction from seeds was already published in literature.
Sanger sequencing was used to determine possible ALS mutations conferring resistance to penoxsulam in two selected accessions per species. A PCR amplification with specific primers was developed to quickly genotype all accessions, by using DNA extracted from single seeds. Resistance based on non-target mechanisms is not identified by these DNA-based methods; metabolic resistance will be the next step on evaluation of the mechanism of resistance in *Cyperus difformis* to explain cross resistance pattern among potential different modes of action.

Environmental regulation of dormancy release in *Echinochloa crus-galli* (L.) P. Beauv. seeds

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Poster presentation

Echinochloa crus-galli is a problematic weed of summer crops. Understanding how *E. crus-galli* seed dormancy and germination is regulated by environmental factors is critical for effective management. This study investigated the effect of (i) post-maturation conditions (stratification and after-ripening), (ii) light and alternating temperatures (AT), (iii) wide variations in soil temperature, and (iv) seed water content (SWC) on dormancy release in *E. crus-galli* seeds. To achieve these objectives: (a) seeds were stored under two regimes: moist stratification at 5°C and 10°C, and dry after-ripening at 15°C and 25°C, for 80 days, (b) seeds were exposed to wide soil thermal fluctuations (10 → 5 → 15 → 20°C, 7 days per temperature) after 40 and 80 days of stratification at 10°C, and (c) seeds were stored at 10°C under a range of SWC (5.5 - 36.8%). During storage under the different experimental condition's germination was periodically assessed across a thermal range (10–35°C) and under different light (red, far-red and darkness) and AT conditions (10/24°C and 20/30°C). Our results showed that stratification provoked *E. crus-galli* seeds dormancy release and that 10°C is more effective than 5°C. The effect of light and AT on seed germination were dependent on dormancy level: highly dormant seeds required both light and AT to achieve higher germination values, whereas seeds with low dormancy bypassed the light requirement and germinated under any light condition with AT. Wide variations in soil temperature have opposite effects on *E. crus-galli* seeds, breaking dormancy if seeds are dormant or inducing dormancy if seeds are non-dormant, with optimal germination occurring at higher constant temperatures and under AT. Finally, SWC was found to modulate the rate of dormancy release during stratification above 16%, while below this value the dormancy release rate is almost constant. These findings advance our understanding of the environmental regulation of *E. crus-galli* seeds on dormancy and germination, offering insights for developing adaptive weed management strategies.

Evaluation of allelopathic effects of three aqueous extracts in rice weeds

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Poster presentation

Resistance to herbicides in rice weeds has been increasing at a faster rate than in any other crops in Portugal. There are serious problems with *Echinochloa phyllopogon* and other Monocot weeds resistant to acetolactate synthase (ALS) -inhibiting herbicides. Allelopathy has been exploited as a weed control tool in order to reduce the use of herbicides and improve weed management strategies, both for integrated weed management and organic farming. Bioerbicides derived from allelopathic compounds (botanics) may have new target sites, important in managing herbicide resistance. Plants from natural vegetation such as *Ditrichia viscosa* and *Daphne gnidium* are known to have allelopathic activity against pests and diseases organisms, albeit their efficacy against weeds and particularly rice weeds are unknown. Aquatic/sea organisms, such as algae have also potential for botanical bioherbicides. The aims of this study were to evaluate allelopathic potential of aqueous leaf extracts (ALE) of two dicot plants – *Dittrichia viscosa* (L.) Greute and *Daphne gnidium* L. – and one algae – *Fucus spiralis* L. – against garden cress (*Lepidium sativum* L.; Brassicaceae), and *Echinochloa phyllopogon* (Stapf) stapf ex. Kossenjko. Fresh leaves of *D. viscosa*, *D. gnidium* and stalks of *F. spiralis* were collected at flowering stage, cut in small pieces, soaked in distilled water for 24-h and then filtered obtaining aqueous extract (10 % w/v). Petri bioassays were carried out with dilutions of ALE of all plants (0, 1.25, 2.5, 5, 7.5 and 10 % w/v concentrations) in order to compare their effect on seed germination and seedlings growth of *L. sativum* (used as test specie) and against *E. phyllopogon*. Fifty seeds of each species were treated with the six-extract concentrations mentioned before, placing Petri dishes in a growth chamber in a completely randomised design with three replications. Germination percentage, radicle and hypocotyls/coleoptyle lengths were determined. Data were subjected to a non-linear regression analysis by using a dose-response model and EC_{50} (Effective Concentration) were derived from root length, the most sensitive parameter. EC levels showed that the extracts from *D. gnidium* had a lower inhibitory effect than *D. viscosa* on both plants and their allelopathic activity was, as expected, higher on *L. sativum* than on *E. phyllopogon*. The extract of *F. spiralis* inhibited seed germination and growth of the tested species but did not affect germination or seedling growth of *E. phyllopogon*. These laboratorial results pointed to the possibility to use *D. viscosa*, *D. gnidium* allelopathic potential in practical relevance, in order to reduce the use of herbicides and improve the management of herbicide resistant weeds. Further studies on selectivity to rice crop and efficacy studies under semi-field and field conditions are needed.

Herbicide resistance in *Echinochloa* species and soil microbial diversity: perspectives for sustainable weed management

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Poster presentation

The withdrawal of many plant protection products (PPPs) from the EU market due to Reg. EC/1107/2009 and the lack of new modes of action (MoAs) have led to the evolution of herbicide resistance (HeR) that represents a very serious problem particularly for those territories traditionally dedicated to rice cultivation in Northern Italy. In this area, a survey on the spread of herbicide resistance is underway through monitoring studies and laboratory tests with the aim of highlighting the causes favoring the phenomenon.
In our study we evaluated the relationship between the soil microbial composition of paddy fields in Lombardy and the incidence of resistance to acetolactate synthase (ALS) and acetyl-CoA carboxylase (ACCase) inhibitors in *Echinochloa* species.
Soil samples were collected in 32 rice farms, located in the provinces of Pavia and Milano and managed according to the Directive 2009/128 EC, where *Echinochloa* species surviving herbicide treatments were recognized. The incidence of surviving specimens was recorded through cover/abundance values in accordance with Braun-Blanquet. Seeds were collected and controlled green-house growth trials were performed applying the same herbicides used in fields. Three weeks after treatment, the sensitivity/resistance of plants to herbicides was tested following EPPO standards. Total DNA was extracted from soil samples and was amplified. Metagenomic amplicons of bacterial and fungal communities were sequenced and bioinformatic analysis was performed.
Specimens of *Echinochloa crus-galli* (L.) P. Beauv and *Echinochloa oryzicola* (Vasinger) Vasinger resistant to herbicide treatments were detected. A relation between the soil microbiomes diversity and the herbicide resistance incidence was observed. A low microbial diversity was recorded in highly infested paddies (resistant *Echinochloa* coverage ≥ 60%) while a high microbial diversity was recorded in poorly infested paddies (resistant *Echinochloa* coverage ≤ 5%). Fungal communities appeared to be more involved in the phenomenon than Bacteria and Archaea. Two different microbial profiles related to the high or low incidence of herbicide resistance in *Echinochloa* species were identified: Lactobacillales, Malasseziales and Diaporthales resulted in a positive relation with high HeR incidence, otherwise Rhizobiales and Solibacterales resulted in a positive relation with low HeR incidence.
The relation between HeR incidence variability and different microbial communities allows us to make hypotheses on the greater or lesser probability of herbicide resistance occurrence, based on the composition and α-diversity of the soil microbiome. Understanding complex interactions of weeds with soil microorganisms and improving the biodiversity of soil microbial communities could be strategic in developing more effective approaches to herbicide-resistant weed management and plant protection, with the final aim of optimizing precision weed management (PWM) technologies.

Herbicide-resistant weeds threaten Italian rice sustainability: status and perspectives.

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Poster presentation

Italy is the largest European rice-producing country with around 230000 hectares mostly located in the northern regions of the Po Valley (Lombardy, Piedmont, Veneto and Emilia Romagna regions). Rice crop production is threatened by the selection and spread of herbicide-resistant weeds. Resistance appears primarily where monoculture or short-term crop rotations and frequent use of herbicides with the same mode of action (MoA) are common practices.

The withdrawal of many herbicides from the European Union market due to strict regulation and the paucity of active substances with a new MoA have further reduced the available chemical options. Rice varieties tolerant to the acetolactate synthase (ALS) inhibitor imazamox (Clearfield® and FullPage®) or to acetyl CoA carboxylase (ACCase) inhibitors, cycloxydim (Provisia®) or quizalofop P ethyl (Max-Ace®) have been increasingly adopted by farmers because they effectively control weedy rice and late-emerging weeds in post-emergence. However, this technology requires an adequate management to avoid the risk of transfer of the tolerance-endowing trait to weedy rice or conventional rice varieties grown nearby. Only 4 years after the introduction of the first rice variety tolerant to the ALS inhibitor, ALS-resistant populations of weedy rice were found, Recently, a biotype of weedy rice highly resistant to ACCase inhibitors used in rice was found in a field that had been cultivated with a Provisia® variety for a couple of years. Other recently found biotypes are *Digitaria sanguinalis*, *Panicum dichotomiflorum* and *Oryza sativa* (weedy rice) highly resistant to ACCase inhibitors, and *Ammannia coccinea* resistant to ALS inhibitors. To date, eleven weed species belonging to eight genera are affected and five MoA herbicides are involved. Of particular concern is the appearance of weed species resistant to more than one MoA such as of *Echinochloa* spp. multiple resistant to ALS and ACCase inhibitors and *Alisma plantago-aquatica* resistant to ALS inhibitors and the auxin mimic herbicide florpyrauxifen-benzyl. These situations reduce the chemical options available and make their control almost impossible without the introduction of agricultural practices. The management of resistant weed populations is generally more complicated for weed species producing long-lived seeds such as *Echinochloa* spp. or weed species producing perennial rhizomatous organs as is the case for *Cyperus esculentus* and *Bolboschoenus maritimus* that recently evolved resistance to ALS inhibitors.

The sustainability of rice production is at risk and there is a need to design rice cropping systems less dependent on synthetic pesticides. More effort is still required to convey the right message to farmers, stressing the importance of implementing integrated weed management as a component of their cropping system design for a more sustainable rice crop system.

How levee management influences weed diversity in paddy fields: insights from DNA metabarcoding

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Poster presentation

In rice farming, levee vegetation management often consists of herbicide treatment, with the intention of preventing weeds to colonise adjacent paddy fields. However, levees can also serve as refuges for many organisms, playing and important role in safeguarding vegetal and animal biodiversity. In this study, we compare the effect of levee management on weed biodiversity within the field. Six paddy fields were selected in the Piedmont region (Italy), with two management approaches: conventional (herbicide treatment both on field and levees) and sustainable weed management with reduced herbicide use in the field and mowed levees (mowing). Moreover, on the farm adopting conventional approach, some levees neighbouring a canal were mowed ("untreated"). Soil cores were collected along transects perpendicular to the field boundaries, extending from the levee into the field at distances of 0, 10, and 20 meters. Weed diversity was assessed via DNA metabarcoding, which consisted of DNA extraction, followed by DNA amplification of the ITS2 region, and high-throughput sequencing, which indicates the list of plant species detected. Alpha and Beta biodiversity were assessed based on the metabarcoding, including species richness and phylogenetic diversity, along with the analysis of similarities (ANOSIM) and Permutational Multivariate Analysis of Variance (PERMANOVA). Alpha diversity results showed that fields with herbicide-treated levees had a higher community evenness, while fields with untreated levees had the highest species richness. Both PERMANOVA and ANOSIM demonstrated significant compositional differentiation between levees and adjacent fields both in case of mowed and untreated levees (PERMANOVA $R^2 \approx 0.26–0.29$, ANOSIM $R > 0.7$, $p < 0.001$), whereas herbicide-treated levees resulted in a more homogeneous community ($R^2 < 0.1$, frequently non-significant). Furthermore, in-field soil samples of "untreated" levees were compositionally more similar to the herbicide-treated levees, on the other side of the field, than their corresponding "untreated" levee. To our knowledge, this is the first recorded use of DNA metabarcoding for the assessment of weed biodiversity in an agronomic setting, offering a rapid and exhaustive insight into the impact of agricultural practices on weed diversity. Furthermore, a complementary study is ongoing to evaluate the impact of levee management on the fields' soil seedbank.

Integrated strategies for sustainable nitrogen use in rice cultivation

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Poster presentation

Nitrogen (N) management in rice (*Oryza sativa* L.) cultivation presents a critical challenge in Mediterranean Europe, where intensive production systems rely on mineral fertilizers. While essential for crop productivity, excessive or inefficient N use has led to significant environmental concerns, economic inefficiencies, and stagnating yields. This study addresses the broader issue of optimizing nitrogen use efficiency (NUE) in rice systems through an integrated, multidisciplinary approach.

The transition to more sustainable and self-reliant agriculture has boosted interest in organic fertilizers and precision agriculture. To address this, field experiments were conducted using long-term organic fertilization strategies involving local pig slurry (PS) and chicken manure (CM) as partial substitutes for synthetic N fertilizers. Results showed that while organic amendments promoted nutrient recycling and reduced nitrogen leaching (particularly with PS) they also led to modest yield declines due to slower nutrient release rates. Key issues in nitrogen management were further explored through crop nutrient deficiency monitoring, which emphasized the need for timely N application during critical growth stages, such as the vegetative and panicle initiation phases. The use of remote sensing technologies proved effective in tracking crop nutritional status and spatial variability in the field, which was particularly important in organically fertilized rice crops to prevent nutritional deficiencies. Building on these insights, the Nitrogen Fertilizer Optimization Algorithm (NFOA) was developed to deliver spatially explicit, data-driven recommendations, regardless of the fertilizer source. It effectively generated precise N application guidelines for both mineral- and organic-fertilized crops, resulting in a 28% increase in agronomic NUE compared to traditional uniform application practices. The algorithm was successfully scaled up and applied in commercial farming conditions. In parallel, genome-wide association studies (GWAS) of 170 temperate Japonica rice varieties identified key genetic loci linked to NUE, offering new opportunities for breeding high-efficiency cultivars tailored to sustainable systems.

Future perspectives emphasize the value of integrating organic fertilization, digital tools, and plant genetics to design more sustainable and resilient rice production systems. Scaling up and validating these approaches under real-world conditions will be essential to achieving long-term environmental and economic sustainability.

PROMEDRICE: Site-specific agronomic practices to enhance the sustainability of rice cultivation

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Poster presentation

Rice cultivation is a significant agricultural activity across the Mediterranean region. However, the area faces serious issues like water scarcity and soil degradation. Moreover, rice cultivation is often in or near protected natural ecosystems making sustainable management a delicate issue. In this context, the PROMEDRICE project aims to develop appropriate agricultural practices that reduce negative impacts and enhance possible environmental benefits. As part of this project implemented in six Mediterranean countries, the University of Milan collaborates with the Ente Nazionale Risi (ENR) research centre in Castello d'Agogna. The study evaluates the effect of agronomic practices on mitigating the impact of pesticides in water and soil. To this end, three treatments were tested during 2024 agricultural season: liming, compost application, and cover crop incorporation.

The experimental platform, located at the ENR, consisted of four plots: three treatments and one control. The agronomic management was uniform across all plots except for the treatments under study. At different cultivation stages, were collected soil and water samples to study the treatments effects on the pesticide impact. Water samples were sampled from inlet water entering the rice fields and within each plot. In the plots, surface and subsurface water was collected, the latter at two depths: 15 and 70 cm. Soil was sampled before the experimental treatment application and post-harvest. Ultimately, soil and water samples underwent multi-residual analysis at an external laboratory, which covered a selection of pesticides previously detected in the area. The experiment also assessed the concentration of the main inorganic contaminants in rice grains, including total and inorganic arsenic, cadmium, nickel, lead, and mercury. Finally, it was evaluated the production performance by measuring agronomic parameters, including yield, 1000-seed weight, number of spikelets per panicle, head rice and milled yield.

Analysis of the soil and water samples from last season is still ongoing. These findings and the new data from the upcoming season will be incorporated into a comprehensive analysis scheduled for early September. Contaminant analysis on grain showed uniformly low concentrations of all elements examined, leading to no statistically significant differences among the treatments. Regarding the production, the compost-treated plots recorded a significantly lower yield. This reduction was mainly due to the exceptionally low temperatures in September 2024 that affected the grain-filling phase. The compost-treated crop, due to the nitrogen input, developed greater biomass and experienced delayed grain maturation, making the plants more susceptible to these adverse climatic conditions.

In the 2025 agricultural season will be replicated the experiments previously described, ensuring consistency and allowing for robust comparisons.

Remote monitoring of water levels in rice paddies using an open-IoT device: SmartWT

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Poster presentation

Water management is a very time-consuming aspect of rice cultivation, especially when the AWD (Alternate Wetting and Drying) irrigation technique is adopted. This technique requires the water level in water tubes installed into the paddies to be monitored daily in order to determine the optimal time for submerging the field. This study proposes a remote monitoring system for the continuous monitoring of ponding water levels in flooded rice fields. Based on open-source architecture, the system uses an Arduino Nano in conjunction with a GSM board to acquire and transmit data for remote communication purposes. Data is measured by an ultrasonic distance measuring sensor installed on a tube inserted into the soil, perforated below the soil surface and lind above (i.e. named Water Tube). This enables the water level to be measured not only above the soil surface, but also below it to a depth of 30 cm. The entire system has been optimised for this operating environment and features a waterproof sensor and container. The device has been designed to operate using minimal power, facilitating installation in the field and minimising maintenance requirements. The device is designed to run on batteries alone, with a lifespan of approximately three months when transmitting every two hours. To extend this duration or to send data more frequently, either the batteries must be replaced, or a photovoltaic panel must be added. Several tests have been carried out in the laboratory and in the field to verify the sensor's accuracy, assess issues associated with using an ultrasonic sensor inside a pipe in a field application, and investigate the influence of pipe diameter and environmental temperature. These tests have shown that accurate measurements require the use of an appropriately sized tube.
Based on this research, the SmartWT was used to monitor the ponding water level and manage the AWD irrigation strategy in five fields belonging to three productive rice farms during the 2023 and 2024 agricultural seasons.

Rice N fertilization guided by plant nutritional status in Switzerland

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Poster presentation

With warming climate, the conditions north of the Swiss Alps become more favorable for growing paddy rice as a niche product to diversify the crop production, while keeping wetlands flooded, and so maintaining their benefits for high biodiversity and the prevention of soil organic carbon (SOC) depletion. However, growing paddy rice in these climatic conditions remains challenging, and therefore, nitrogen (N) availability might not be a dominant limiting factor to reach the relatively low yield objectives of Swiss growers (3-4 t ha^{-1}). Here, we assess the occurrence of N deficiencies in paddy rice fields across Switzerland and the relative importance of the two main fertilizations (basal at transplantation and at panicle initiation). We used proximal sensing (SPAD) as a fast and affordable method for targeted fertilization to determine N and chlorophyll critical values for the short duration rice variety (Loto) in Switzerland.

In nine paddy rice fields, proximal sensing measurements were performed before panicle initiation. In addition, in one field we implemented an experiment consisting of four treatments: a standard practice, where the field was fertilized once at transplantation directly in the soil together with the plant (40 kg N ha^{-1}) and once before panicle initiation (40 kg N ha^{-1}) in the water, a zero fertilization plot, and two treatments of only one fertilizer application, namely one only at transplantation, and one before panicle initiation.

Plant leaves were measured with two proximal sensing devices, (Hansatech SPAD meter and SpectraVue leaf spectrometer) before the second fertilization, and in the case of the experiment, also one week after fertilizer application. In parallel, plant samples were collected to be analyzed for biomass, leaf N content and phenology.

Preliminary results of the SPAD values showed a clear response to the N fertilization treatments and clear differences between the status in the nine fields.

In terms of yield, the experiment resulted in significantly different ($p<0.05$) grain yield between the treatment without fertilizer and with the two doses of fertilizer applied. The SPAD values showed significant differences after the second fertilizer application between the treatments that received the second fertilization and those who didn't. No effect could be seen from the first fertilization in that case as the recent fertilization overrode the other differences.

Using proximal sensing, the study shows that N deficiency at panicle initiation is frequent in Switzerland and confirms that this method can be used in the future to guide precision fertilization based on crop needs and to account for the high interannual variability. This enables to optimize the trade-offs between the production objectives and the environmental benefits of rice production.

Shifting weed dynamics in Italian rice fields (2021–2024): emergence and management challenges of *Cyperus esculentus*, *Polygonum persicaria*, and *Alisma plantago-aquatica*

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Poster presentation

In 2024, rice was cultivated on 226,129 hectares in Italy, with production primarily concentrated in the provinces of Vercelli, Pavia, and Novara. Italian rice is entirely direct-seeded—either by dry or water seeding—and typically grown under continuous cropping systems. In this context, weed management has become increasingly critical, as several key herbicides have been progressively withdrawn from the market, significantly limiting chemical control options. While species such as *Echinochloa* spp. and weedy *Oryza sativa* (weedy rice) remain predominant, a significant shift in the weed community composition has been observed in recent years. Field data collected through a national survey conducted by Innova-tech (2021–2024), involving more than 400 farms (covering approximately 20% of Italy's rice acreage), revealed a consistent increase in infestations by increasingly aggressive species, including *Polygonum persicaria*, C*yperus esculentus,* and *Alisma plantago-aquatica*. In many fields, herbicide escapes exceeded 50%, highlighting a growing mismatch between agronomic needs and the available herbicide toolbox. Although herbicide-tolerant varieties (e.g., Clearfield®, Provisia®, FullPage®) have provided targeted control of specific weeds, their repeated use has constrained rotational flexibility and accelerated the evolution of herbicide resistance. This situation underscores the urgent need to adopt more diversified agronomic strategies. A noteworthy example from 2024 illustrates this potential: by altering the proportion of dry- and water-seeded fields from 69:31 in 2023 to 43:57, farmers achieved a 57% reduction in *Cyperus esculentu*s pressure. This outcome highlights the effectiveness of alternating seeding methods not only as a cultural control measure but also as a means to disrupt weed life cycles and reduce reliance on herbicides. Complementary practices—such as stale seedbeds and early sowing of short- cycle cultivars—further enhance these benefits. The evolving weed scenario in Italian rice systems calls for a transition from herbicide-centric approaches to integrated, rotation-based weed management. Alternating seeding techniques, combined with timely agronomic interventions, provides a practical pathway to maintain productivity while achieving sustainable weed control under increasingly restrictive regulatory frameworks.

Weed control in rice cultivation in Spain

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Poster presentation

In the 2024 rice season, the cultivated area in Spain reached 81.285 hectares, with a total production of 576,5 thousand tons. The main rice-growing regions are Cataluña, Andalucia, Extremadura and Comunidad Valenciana, followed by Aragon, Navarra and Murcia to a lesser extent. Soils in these areas are predominantly silty clay loam, and most tend to be alkaline. However, soils in the Extremadura region are more acidic, with pH values between 5.5 and 6. In general, the organic matter content is low. Water quality in terms of salinity is generally acceptable, although some coastal rice-growing areas may occasionally face salt-related issues that can limit high yield potential. In last years in some Spanish growing rice regions have been a slow decrease in the area under cultivation, with very significant drops in some areas mainly due to the lack of water availability (Andalucia and Extremadura). The reasons for this decline are several: lower crop profitability due to stagnant prices coupled with an increase in production costs, a shortage of phytosanitary products used in the fight against pests, diseases and weeds that has caused a greater proliferation of these in the crop, resulting in cost increases and decreases in production. Most of the authorized herbicides available fall into two main modes of action: ALS inhibitors (acetolactate synthase) and ACCase inhibitors (acetyl-CoA carboxylase). Weed control, especially grasses such as *Echinochloa* spp. and *Leptochloa* spp. has been an increasing challenge due to herbicide resistance. Resistance to ALS and ACCase inhibitor herbicides (the most widely used in this crop) has increased, leading to increased costs and production losses. Resistance to ALS inhibitors has been confirmed in *Echinochloa* spp., *Leptochloa* spp., *Cyperus difformis* and *Alisma plantago-aquatica*, while resistance to ACCase inhibitors has been reported in *Echinochloa* spp. and *Leptochloa* spp. across various parts of the country.

At present, Extremadura is the Spanish rice-growing region most affected by weed pressure and confirmed herbicide resistance. When the issue becomes deeply established, resorting to alternative control strategies can significantly alter conventional agricultural practices. In this area, the severity of problems related to weed competition has compromised the viability of the crop in many plots. For this reason, among others, the adoption of dry seeded rice versus flood systems (almost 90% of crop area last year) and the use of Clearfield®/Full Page® (resistant to imazamox, an ALS inhibitor) and Provisia® (resistant to cycloxydim, an ACCase inhibitor) varieties have significantly increased in this region.

The likelihood of new herbicides with different modes of action becoming available in the near future appears to be low, highlighting the importance of making better use of existing alternative strategies following integrated weed management programs.

Soil Science and Environment

Impact of the protist *Acanthamoeba castellanii* on the methanotrophic activity and methane-driven community in rice paddy soil

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Oral presentation

Phagotrophic protists are important members of the soil microbiome, being part of the microbial food web, as they exert top-down control on bacterial communities, thereby affecting soil processes, including methane oxidation. Methane oxidation is performed by methanotrophic bacteria, a microbial guild that acts as an effective biofilter by converting methane to carbon dioxide, before it is released into the atmosphere. Methanotrophs may exude intermediates like methanol, which leads to cross-feeding with non-methanotrophic bacteria like methylotrophs. Such microbes in turn can stimulate methanotrophic activity as well as growth. We hypothesize that phagotrophic protists exert a negative impact on the methanotrophic and methane-driven community as well as associated methane consumption. Thus, the common soil protist *Acanthamoeba castellanii* was inoculated into rice paddy soil microcosms to address this hypothesis. Stable isotope probing with ^{13}C-labelled methane (13C-CH_4-SIP) was used to track the flow of methane-derived carbon into the actively growing methanotrophs and cross-fed non-methanotrophs. Preliminary results showed that neither methane oxidation rates, nor methanotroph abundances were affected by the presence of *A. castellanii*, although 18S rRNA gene amplicon analysis and enhanced carbon dioxide production revealed growth of the amoeba during incubation. 16S rRNA gene based community analysis of the ^{13}C-labelled DNA revealed *Methylobacter* sp. as the predominant active methanotroph, as well as methylotrophs typically occurring alongside the methanotrophs (e.g., *Methylobacillus*, *Methylovorus*), irrespective of amoeba addition. However, the abundance of a *Methylosarcina* sp. was significantly lower compared to the control, indicating species-specific predation. These findings highlight that the methanotrophic activity and the composition of the methane-derived community are only marginally affected and thus stable with respect to the apparent growth and activity of the predator in rice paddy soil microcosms.

Reduced greenhouse gas emissions with paddy rice cultivation on organic soils in a mesocosm experiment

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Oral presentation

In Europe, large peatland surfaces are drained and used for agriculture. Drained peatlands have high greenhouse gas (GHG) emissions, a problem that can only be solved by re-wetting. One option to re-wet these soils and at the same time maintain agricultural production that provides farmers with a decent income is paddy rice cultivation. Since a few years, the rice cultivar 'Loto' is grown in Switzerland, north of the Alps, suggesting this is a potential GHG mitigation option. It is expected that paddy rice cultivation on peatland soils should reduce their CO_2 and N_2O emissions, compared to the typical drained agricultural management of these soils. However, some of the reduction in the GHG balance might be counteracted by increased CH_4 emissions.

The objectives were: 1) To test whether paddy rice cultivation reduces the GHG balance of peatland soils, compared to (drained) grassland cultivation of these soils, representing typical management. 2) To test the effectiveness of a 30 cm deep mineral soil cover on these soils in reducing the GHG balance further.

In an outdoor mesocosm experiment under ambient conditions, we measured and compared GHG emissions from paddy rice cultivation on a peatland soil, i. with and ii. without a mineral cover; and iii. grassland on a drained peatland soil. CO_2, N_2O and CH_4 fluxes were measured using manual chambers, over one year. Harvest exports were also included, allowing a full GHG balance to be calculated.

Compared to drained management, paddy rice cultivation improved the GHG balance by 38%. The GHG balance was dominated by CO_2 with CH_4 accounting for only 10%. Most CO_2 emissions from rice plots occurred during the fallow period (October – April) when these plots were drained. N_2O emissions were reduced by 84 % with paddy rice. Adding a mineral cover to organic soil did not significantly improve the GHG balance further.

Paddy rice is a promising alternative to drained agriculture on organic soils while maintaining food production and reducing GHG emissions. Research priorities for Switzerland include testing whether maintaining flooded conditions in the fallow period further improves the GHG balance of paddy rice cultivation, as well as measuring GHG emissions from (*in-situ*) paddy rice fields.

Winter cover cropping in rice enhances microorganisms involved in phosphorus cycling

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Oral presentation

Phosphorus cycling in paddy soil is fundamental for meeting the growing global demand for rice production. However, mineral fertilization is critical, given the rapid depletion of phosphate rock resources. Moreover, the bioavailability of phosphorus in rice paddy might be critical, due to adsorbtion/co-precipitation with soil minerals. Incorporating winter cover crops before rice seeding offers a sustainable strategy to improve organic matter cycling and nutrient availability. These improvements are hypothesized to be mediated by plant growth-promoting microorganisms, which play a key role in increasing the bioavailability of phosphorus.
This study aimed to determine whether specific microbial signatures related to phosphorus cycling could be detected in the rice rhizosphere microbiome of plants cultivated under winter cover cropping with hairy vetch (*Vicia villosa*).
High-throughput Illumina sequencing of bacterial and archaeal 16S rRNA genes and of fungal ITS regions were combined with Real-Time quantitative PCR and the functional characterization of rice rhizospheres' plant growth-promoting (PGP) bacterial strains.
Both plant species (rice, vetch) and root-associated compartments (rhizosphere soil, rhizoplane, root endosphere) significantly shaped microbial community diversity and composition. Phosphate-solubilizing and -mineralizing bacteria and fungi were boosted in winter cover cropped rice paddies, where bioavailable phosphorus significantly increased with respect to conventional paddies. Other PGP traits, such as diazotrophy, the production of indole acetic acid, extracellular polymeric substances and siderophores, as well as endo- and ectomycorrhizal fungi were also promoted. Rhizosphere, and rhizoplane in particular, hosted most PGP bacteria, highlighting the importance of the root-associated biofilm in plant-microbiome interaction. The role of fungi in the ecological interactions within rice and vetch rhizosphere microbiomes was also highlighted.
Conclusions. This study provides a microbial perspective to the benefits of winter cover cropping in improving nutrient bioavailability and rice productivity. Culturomic efforts should be pursued to develop a comprehensive rice microbiome collection, paving the way for the identification and application of microbial bioinoculants in sustainable agriculture.

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Influence of paddy rice cultivation on chemical and physical properties of two contrasting soil types in Switzerland

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Oral presentation

Recently, paddy rice cultivation has become possible north of the Alps in Switzerland. This new cultivation system has raised many questions regarding the suitability of different soil types and the practicability of crop rotation.
In this study, we focus on two contrasting soils (Gleysol and Cambisol) that differ in their soil hydraulic properties and carbon content but are both managed by the same farmer. We collected soil samples before the fields were converted to paddy rice cultivation, after the first growing season before harvest, and one year after the initial sampling to observe changes in chemical and physical soil properties.
Results suggest that both soils experienced significant deterioration in their physical properties (pore connectivity, permeability, bulk density, and porosity) in the topsoil and plow layer, even without puddling measures. However, after winter fallow, the Cambisol showed signs of structural recovery by increasing porosity and connectivity in topsoil macropores, while the Gleysol's soil structure mostly remained unchanged. Links between soil structure, aggregate stability, and carbon dynamics will be presented at the conference.
Preliminary conclusions indicate that the Gleysol is better suited for paddy rice cultivation compared to the Cambisol, as water infiltration is easily inhibited by disrupting the pore system after just one season. However, the limited recovery potential of the Gleysol's soil structure also indicates more challenging conditions if farmers want to rotate paddy rice with upland crops, making the Cambisol more suitable for different crops

Local-scale estimation of methane emissions from temperate rice using empirical models

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Oral presentation

Rice cultivation contributes to methane (CH_4) emissions to the atmosphere and represents approximately 10% of total agricultural emissions. Accurate estimation of greenhouse gas emissions from rice paddies is increasingly crucial for evaluating agricultural management strategies aimed at mitigating global warming, as well as for reporting emission inventories at regional and national scales. While emission models are well-established for tropical regions, their performance in temperate zones such as Europe and North America remains limited and poorly validated. These regions not only contribute substantially to global rice production but also represent critical zones where current CH_4 prediction models show the highest uncertainty. This study addresses this gap by focusing on rice-producing regions in temperate regions including Europe and the USA, which are characterized by high mechanization, artificial irrigation, and comparable agronomic practices.

A systematic literature review was conducted to identify field-based studies measuring CH_4 emissions via the non-steady state closed chamber technique in temperate rice systems. The review yielded 40 eligible publications, supplemented by proprietary data from UpToFarm Srl, a spin-off company of the University of Torino, resulting in a dataset of 281 statistical units. For each unit, CH_4 emission factors were calculated as the average daily emission rate (kg CH_4 ha^{-1} d^{-1}) over the cropping season. Emission data were combined with 17 explanatory variables related to water and residue management, soil and climate characteristics, and agronomic inputs.

Three groups of predictors were analyzed using Generalized Linear Mixed Models (GLMMs) and Generalized Additive Mixed Models (GAMMs), assuming a Gamma distribution with log link. GAMMs, which allow non-linear relationships, provided the best model performance across all groups, as confirmed by Akaike Criterion AIC. Then model performance was then tested by root mean square error (RMSE), deviance explained (deviance explained = 69.2%). The most accurate model identified water management (especially continuous flooding and wet seeding), total carbon inputs, pH, and climate zone as significant predictors of CH_4 emissions. GAMM revealed non-linear effects for soil carbon and nitrogen inputs, and significant random effects associated with country and year.

Our findings emphasize the importance of local agronomic and environmental conditions in determining CH_4 emissions in temperate rice systems and highlight the need for tailored mitigation strategies. Including data from Europe and the USA not only strengthens global model reliability but is essential to inform sustainable policy design in these under-represented but high potential emission regions.

Impacts of climate change on rice arsenic accumulation

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Oral presentation

Several recent studies have demonstrated that climate change can increase concentrations of arsenic in rice. Arsenic is a toxin and carcinogen commonly found in rice paddy soil around the world. This finding presents a looming public health threat as climate change is expected to increase average temperatures in rice growing regions around the world. In this presentation, I will summarize recent advancements in our understanding of temperature-driven increases in rice arsenic which utilizes temperature-controlled growth chambers to simulate future levels of warming as predicted by the International Panel on Climate Change (IPCC). Using biogeochemical and plant ecophysiological principles, this research attempts to gain a more mechanistic understanding of the underlying processes driving temperature-fuelled increases in rice arsenic uptake along the entire soil-water-plant uptake system. I will conclude with a discussion of upcoming work from the University of Bern which seeks to understand the relationship between climate change and the speciation of arsenic in rice, including a frequently misidentified and highly toxic form of organic arsenic, dimethylated monothioarsenate (DMMTA).

Mechanistic insights into ethylene- and ethephon-induced inhibition of methanogenesis in anoxic rice soils

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Oral presentation

Rice feeds over half the world's population, but rice agriculture is a major source of methane (CH_4). CH_4 is a potent greenhouse gas with a 25 times higher global warming potential than carbon dioxide (CO_2), and rice makes up ~12% of CH_4 emissions from global agriculture. Mitigating CH_4 emissions from rice paddies is thus critical for both global warming and sustainable rice production. Ethylene (C_2H_4) is known to reversibly inhibit methanogenesis in sediments, but its effects and mechanisms in rice paddy soils remain poorly understood. To explore its potential as an innovative CH_4 mitigation tool in rice agroecosystems, anoxic microcosm incubations were conducted, with increasing concentrations of ethylene gas and ethephon (2-chloroethyl phosphonic acid), a common agricultural C_2H_4-releasing compound, as a potentially practical alternative to C_2H_4 gas. CH_4 fluxes were determined along with expression of the methyl-CoM-reductase (Mcr) encoding gene (mcrA) as a marker for methanogenic activities. Both C_2H_4 and ethephon significantly decreased CH_4 production at ≥0.4 μmol g^{-1}, while mcrA gene expression was suppressed at ≥4.0 μmol g^{-1}, with near-complete suppression at 4.0 μmol and 40 μmol g^{-1}, suggesting a higher C_2H_4 sensitivity of the mature Mcr than mcrA gene expression. This inhibitory effect was stronger with ethephon, likely due to additional acidification of the soil by ethephon. Notably, low-dose ethephon (0.04 μmol g^{-1}) slightly increased mcrA gene expression, suggesting an adaptive upregulation of key gene expression to a mild stress induced by ethephon. Except in high-dose ethephon treatments (>4.0 μmol g^{-1}) affected by acidification, CH_4 production rates quickly recovered or even surpassed the unsupplemented control after C_2H_4 was removed from headspaces. Since mcrA gene expression didn't increase relative to the control, the higher CH_4 production likely resulted from accumulated CH_4 precursors, hydrogen/CO_2 and acetate, during C_2H_4 exposure. Therefore, ethylene and ethephon can inhibit methanogenesis at the enzyme and transcriptional levels, and low-dose ethephon could serve as a practical, temporary inhibitor during peak CH_4-emitting phases before mid-season drainage.

Soil redox tuning for regulating Ni, As and Cd uptake by rice

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Oral presentation

Considered an emerging contaminant in rice, nickel (Ni) will be subject to European regulatory limits starting from 2026. Its presence in rice grain raises food safety concerns due to its toxicity and allergenic potential, alongside carcinogenic elements like arsenic (As) and cadmium (Cd). European rice is mainly grown in the Mediterranean area, where geogenically Ni-rich soils increase the risk of grain accumulation, although agronomic strategies capable to limit its mobility are still to be developed. The modulation of soil redox potential (Eh) in paddy fields, achieved through a dry–wet alternating irrigation regime with controlled timing, represents a key strategy for regulating the mobilization of contaminants through redox-sensitive processes. Alternate wetting and drying (AWD), increasingly adopted by rice farmers to reduce water use and methane emissions, has contrasting effects on the accumulation of As and Cd in rice. Water management, when aligned with plant development, can reduce the accumulation of As and Cd by acting differentially on key uptake phases: reproductive phase for As, pre-flowering to maturity for Cd. In contrast, the effect of water regime on Ni behaviour in the soil–plant system—particularly in relation to phenological stage and mechanisms of uptake and translocation—remains poorly understood. To explore these dynamics, a mesocosm experiment was conducted by applying eight irrigation treatments, including continuous flooding (CF), AWD, and short drying periods timed to specific growth phases. Drying periods applied in the early growing phases often reduced Ni availability in solution and its uptake during stem elongation and panicle initiation but had limited impact on final Ni accumulation in plant tissues. In contrast, late-season dry treatments (applied at milky and dough stages) were more effective in reducing Ni content in rice plant, suggesting root–shoot remobilization mechanisms occurring during advanced growth phases. Although drying led to a moderate reduction in Ni concentration in solution, a drop in the Fe/Ni ratio was observed, which may affect the ionic competition at the root level and influence Ni uptake through non-specific transporters shared with Fe. These results provide a basis for optimizing soil redox tuning through appropriate water management. The alternation of soil submersion with short periods of aerobic conditions applied at targeted growing phases could support the simultaneous reduction of Ni, As, and Cd concentrations in rice grains.

Amphibian conservation and Swiss rice paddies

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Poster presentation

This study explores the role of newly established rice paddies in the Swiss lowlands as alternative habitats for amphibians. Specifically, it evaluates how local habitat characteristics, surrounding landscape, past amphibian presence in surrounding areas, and biodiversity promotion measures influence amphibian occurrence and abundance in these fields. The study uses field surveys to assess factors that may enhance the conservation potential of rice paddies. Key elements include the presence of early-flooded ditches, water chemistry parameters, and nearby previous amphibian sightings. Findings suggest that rice paddies can support amphibians, with some species showing comparable or even higher abundances than in remaining natural wetlands. These insights suggest that rice paddies, when managed with ecological considerations, can contribute to amphibian conservation and supporting areas with fragmented landscapes.

An innovation strategy for methane emission control: dry-cultivated water-saving and drought resistance rice (D-WDR) in rice cultivation

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Poster presentation

Methane is the world's second-largest greenhouse gas after carbon dioxide. Its global warming potential is 28 times that of carbon dioxide over a 100-year timescale and even reaches 81 times over a 20-year timescale. Furthermore, it has a relatively short atmospheric lifespan (~12 years). Global methane emission control became a crucial component of international climate action at the COP26 held in 2021. Rice cultivation is one of the significant sources of global methane emissions, which contribute approximately 30% of global agricultural methane emission. However, due to the scarcity of methane reduction technologies that are highly effective and scalable, the achievement of methane control targets in rice paddies is hindered. This study tried to elucidate the methane emission control by an innovation strategy based on in-situ monitor and processed model.

A new rice type, water-saving and drought-resistance rice (WDR), has been developed to satisfy both rice yield and quality while with high water use efficiency and good drought resistance. WDR can be planted and promoted under dry cultivation with the sink of CH_4, which is similar as upland crop system. This study estimated GHG emissions from two rice cultivation systems, F-R and D-WDR (common rice under flooding management, and WDR under dry cultivation), to determine the mitigation potential of WDR variety under dry cultivation by biogeochemical process model (DNDC). In addition, the best agricultural management practice of CH_4 emission mitigation was established and discussed.

By optimizing water management and expanding new rice cultivation (D-WDR), the rice production-induced CH_4 emissions decreased more than 90% while maintaining rice yields by in-situ monitor method. The processed model (DNDC) demonstrated “good” performance when simulating rice yield and CH_4 emissions based on normalized RMSE (nRMSE) < 10%, index of agreement (d) > 0.9. The GHG mitigation of D-WDR system should be 0.69 million ton CO_2-eq for 100 thousand hectares of rice field in Anhui province. Overall, the D-WDR system has remarkably potential on balancing the relationship between CH_4 mitigation and stable rice yield through dry cultivation from paddy field.

Coupling of rice variety innovation and water management patterns alters the CH_4 source-sink characteristics in paddy fields

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Poster presentation

The traditional paddy soil system, which requires continuous flooding irrigation, persists in an anaerobic condition over extended periods. Consequently, this environment facilitates the substantial production of CH_4 in paddy soils. Over a long period, paddy systems have been widely recognized as a predominant source of CH_4 emissions. Recent research centered on water-saving and drought-resistant (WDR) rice cultivation has revealed that through the reduction of flooding irrigation practices, WDR paddy fields can achieve a remarkable 90% reduction in CH_4 emissions when compared with conventionally irrigated counterparts. Furthermore, in specific growth periods of rice, these WDR paddy fields can even function as a sink, absorbing CH_4 from the environment.

This study aims to precisely define CH_4 source-sink features of the WDR paddy system under varied irrigation regimes and quantify CH_4 exchange fluxes across different plant-soil-atmosphere interfaces. Continuous monitoring of CH_4 emissions was performed in WDR rice fields under conventional irrigation (CI) and drought cultivation (DC) conditions. Synchronous in-situ 13C pulse labelling was applied during the tillering and booting stages to quantify CH_4 emission and absorption at the plant-atmosphere (P-A) and soil-atmosphere (S-A) interfaces. Under CI conditions, the seasonal cumulative CH_4 emissions from WDR rice fields amounted to 85.1 ± 18.5 kg CH_4 ha^{-1}, whereas DC led to a net seasonal absorption of 1.1 ± 0.11 kg CH_4 ha^{-1}. The results of the ^{13}C in-situ pulse labelling indicate that the substantial reduction in CH_4 emissions from WDR rice fields under DC treatment, compared to CI treatment, is primarily due to decreased CH_4 emissions at the P-A and S-A interfaces during the tillering stage. The net absorption of CH_4 under DC treatment is mainly attributed to enhanced absorption fluxes at these interfaces during the booting stage.

This study quantitatively assesses how diverse irrigation patterns affect CH_4 emission and uptake at distinct rice field interfaces. Results show that these irrigation patterns alter CH_4 release patterns and affect rice fields' ability to absorb atmospheric CH_4, providing crucial data for promoting irrigation-based tech research to mitigate rice farming CH_4 emissions.

Distance-decay of similarity in rice field ostracod (Crustacea: Ostracoda) communities across spatial scales

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Poster presentation

Rice fields are anthropized temporary aquatic ecosystems that play a crucial role in sustaining aquatic biodiversity, especially in regions where natural wetlands are disappearing or degraded. Due to their relative environmental homogeneity across different regions, they can be used as model habitats to study spatial effects on community differentiation. In this study, we examined the distance-decay of similarity in assemblages of Ostracoda, a passively dispersal crustacean group, comparing two different spatial scales: rice fields in the Iberian Peninsula and in the Valencian Region (eastern Iberian Peninsula). At both scales, the increase in geographical distance between sites produced the expected decay in community similarity, and higher mean similarity between sampling sites within the smaller extent region. However, no difference in the slopes of the relationship between community similarity and geographical distance was observed when comparing both scales. These results suggest that the influence of spatial distance on similarity is consistent regardless of the spatial scale analysed, at least when considering a homogeneous habitat type in nonmarine ostracods, providing key insights into the role of dispersal and connectivity in shaping aquatic metacommunities. Further work increasing spatial extent and widening taxonomic scope would inform whether or not this pattern holds for other organisms and at wider spatial scale gradients.

Effects of winter cover crops on organic matter and nitrogen inputs, and methane emissions from temperate rice paddies

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Poster presentation

The increasing need to reduce synthetic inputs and enhance soil health in paddy systems is driving the adoption of sustainable practices such as cover cropping and green manuring. In Italian rice-growing areas, where access to livestock-derived organic matter is often limited, the use of leguminous cover crops represents an opportunity to improve soil fertility and nitrogen (N) supply while potentially mitigating environmental impacts. However, the integration of green manure into flooded systems raises concerns about increased methane (CH_4) emissions due to the addition of labile organic matter in proximity of field flooding.
This study aimed to evaluate the agronomic and environmental outcomes of introducing *Vicia villosa* as a winter cover crop in rice-based systems in the Lomellina region (Northern Italy) in combination with dry seeding of rice followed by continuous flooding. The experimental design included two treatments: with and without green manure, replicated in two pilot farms. *Vicia villosa* was sown after rice harvest and terminated at flowering, with a growth period of approximately 200 days. In both the 2022/2023 and 2023/2024 growing seasons, soil properties, porewater composition, and gas fluxes were monitored. Biomass data indicated that *Vicia villosa* contributed 5–6 t ha^{-1} of dry matter and around 170–180 kg ha^{-1} of mineralisable nitrogen. Cumulative methane emissions over the entire rice growing cycle showed no statistically significant differences between the treatments, the cover crop contributed around 2 t C ha^{-1}. These findings suggest that combining *Vicia villosa* green manure with dry-seeded rice allows to benefit from the higher inputs of organic matter and N without increasing CH_4 emissions, thereby representing a viable strategy for reducing mineral N fertilizers, sustaining yields and increasing the environmental sustainability of temperate rice paddies.

Greenhouse gas emissions and soil carbon sequestration in rice-wheat rotation systems with different straw treatments: a ten-year *in situ* observation in Yangtze River Delta, China

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Poster presentation

Rice–wheat rotation system is one of the most prevalent rice-based rotation patterns in the Yangtze River Delta, which greatly contribute to the food security in China. Previous studies indicated that the incorporation of crop straw can effectively improve soil carbon sequestration in rice paddy fields. However, the application of crop straw may increase methane emissions significantly due to the flooding anaerobic soil condition.

This study tried to elucidate carbon budget between greenhouse gas emissions and soil carbon sequestration in rice-wheat rotation systems.

Three treatments with different carbon sources incorporation strategies were employed in this study, including conventional chemical fertilization without straw incorporation (CF), chemical fertilization with straw incorporation (CF-S), and chemical fertilization with straw-derived biochar (CF-B). Methane (CH_4) and Nitrous oxide (N_2O) fluxes were measured once a week during rice and wheat seasons through 10 years while soil samples were taken twice a year after rice or wheat harvest to measure carbon content.

The total CH_4 emission in rice season contributed up to 99.6% to the annual total emission, while the total N_2O emission in rice season could only contributed 20-39% to the annual total emission. The CF-S significantly increased annual total CH_4 emissions by 144% while the CF-B showed similar CH_4 emission compared to CF. Total N_2O emissions from CF-S and CF-B were reduced by 43% and 39% relative to CF, respectively. Totally, the CF-S significantly increased annual CO_2-eq emissions by 67% and CF-B depressed by 15% compared to CF. On the other hand, CF-S and CF-B treatments significantly increased soil carbon sequestration rates by 52% and 134% in comparison with CF. Consequently, the effect of soil carbon sequestration in CF-S with crop straw incorporation was offset by straw induced excess CH_4 emissions, which resulted in net carbon emission. In contrast, the application of straw-derived biochar significantly promoted soil carbon sequestration while depressed CO_2-eq, which resulted in net carbon sink.

The application of straw-derived biochar can mitigate greenhouse gas emissions from rice paddies while significantly promote soil carbon sequestration ability.

Paddy rice in Switzerland: a win-win for biodiversity and agriculture

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Poster presentation

Wetland biodiversity in Switzerland is continuously declining due to the loss of about 90% of wetlands because of land use changes. In addition, Switzerland's average annual temperatures increased by 2.5°C compared to pre-industrial times, forcing agriculture to rethink the standard cropping practices in the light of climate change. Introducing better-suited crops for warmer temperatures, like paddy rice, could be beneficial to meet the upcoming challenges due to climatic extremes, ensure food production, and promote wetland biodiversity at the same time. Since 2017 a group of farmers have been pioneering ecological paddy rice production in the lowlands north of the Swiss Alps. Biodiversity surveys showed a variety of wetland fauna and flora, among other endangered species, that use paddy rice as habitat. Since paddy rice is a new crop to this geographical location, not much is known yet about the effect of crop management practices, such as the application of fertilizers, or the use of heavy machines, on the species that are attracted to these fields. Therefore, our research evaluates the opportunities and limitations of biodiversity promotion through cultivating paddy rice in Switzerland.

Rice straw management practices and GHGs emission

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Poster presentation

The global warming potential (GWP) of rice (*Oryza sativa* L.) farming is approximately four times greater than wheat or maize cultivation. Rice paddy mainly contributes to methane (CH_4) emission due to the anaerobic conditions of flooded fields but also releases nitrous oxide (N_2O) during draining cycles and nitrogen fertilization.

A proper straw management, such as incorporation into soil, increases soil organic matter content and improves soil fertility, but may enhance CH_4 emissions due to increased fermentation of organic matter in flooding condition. On the contrary, burning crop residues is considered to have a high environmental impact by producing air pollutants (e.g. particulate matter (PM) and volatile organic compounds (VOC)).

In this framework, the quantification of GHG emission from different rice-straw managements is needed to develop effective agricultural practices for the reduction of rice global warming potential. This could be particularly relevant in Italy, which is Europe's largest rice producer accounting for 53% of European production.

The aim of the present study is to compare the climate impact of two different rice straw management practices - straw incorporation versus straw burning - in the Po valley. CO_2, CH_4 and N_2O flux exchanges will be measured during two rice cultivation seasons. A further aim will be to assess the emission of air pollutants from crop residues burning by sampling and identifying volatile organic compounds (VOC). The field experiment will be conducted in two rice plots where two different residue management will be tested: in the first one, the residual straws will be incorporated into the soil whereas in the second scenario the rice straw will be burned.

Gas measurements will be performed using the following methods:

1) CO_2 and CH_4 fluxes will be monitored at ecosystem level using the Eddy Covariance (EC) methodology, a standard micrometeorological method for the direct measurement of CO_2, CH_4, water vapor and heat fluxes over a large area and at a high temporal resolution.

2) NO_2 emissions from soil will be measured in real time using a dynamic chamber coupled to an infrared gas detector (LICOR 7820).

3) VOC composition from burning straw will be determined with GC–MS analysis.

4) Soil samples will be collected to quantify soil nitrogen (total and mineral) and soil organic carbon (SOC) content.

The knowledge gathered in the present project will contribute to the development and implementation of good agricultural practices in rice cultivation. In addition, the data collected will represent an important contribution to the Italian GHGs emissions inventory.

Rice: a sustainable future for agriculture on peatland in NW Europe?

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Poster presentation

Most peatlands in NW-Europe are used as intensively managed grasslands to feed dairy cows. Currently, drained peatlands are a major source of greenhouse gas emissions due to peat oxidation, a process causing land subsidence. Rewetting peatlands is generally seen as the way to make these systems part of the solution rather than part of the problem, for which paludiculture (wet agriculture) has been proposed as a key strategy.

In this project, we explore the potential of rice cultivation as a paludiculture crop in NW Europe, to strongly limit or even stop land subsidence, reduce net greenhouse gas emissions, and increase biodiversity. Moreover, since wetland rice cultivation benefits from higher temperatures, it is potentially also a climate adaptation option. Yet many questions remain unanswered in terms of the suitability of rice cultivation in NW Europe: can rice be cultivated successfully? what are the synergies and trade-offs with environmental objectives? which are the transition pathways that can introduce this novel crop?

In this contribution we will present results from two years of pilot experiments (2023 and 2024) with rice on peatland in the Netherlands that will provide some preliminary answers and discuss future research plans. Screening early-flowering rice cultivars (n = 33) from Japan, Russia, China, and several other countries in both climate chambers and open field conditions has shown that rice cultivars suited to current climatic conditions of the Netherlands, and possibly beyond, exist.

In a four-year project that started this spring, we plan to further screen rice cultivars and optimize agronomy in field experiments on peatlands with contrasting soil characteristics, balancing yield and environmental objectives. We will closely monitor the effects of cultivation in two multiyear field experiments on emissions of CO_2, CH_4 and N_2O; measure N and P fluxes in water flows; quantify N, P and K balances at the field scale, and assess impacts of biodiversity at the landscape level. Measured plant growth parameters will then be used to calibrate the ORYZA model and map the suitability of rice cultivation across NW Europe under current and future climate conditions. Finally, we plan to evaluate the potential for transitioning and transforming the current (dairy-based) farming systems. We will host workshops with stakeholders and farmers and conduct semi-structured interviews with potential rice farmers to determine best entry points for a transformative systems change, identifying motivations and limitations for farmers to adopt rice or rice with fish as a component of their future farming system. Collectively, the project will further provide scientific understanding of the functioning of rewetted peatlands used for crop production and provide an evidence base for informed decision making related to rice production in restored peatlands in NW Europe.

Shifts in microbial CUE as a function of available organic C resources and electron acceptors under changing soil redox conditions

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Poster presentation

Soil microbial carbon use efficiency (CUE) affects the fate of below-ground C, making it either a C source or sink. This CUE is largely affected by environmental factors but also organic C and electron acceptors availability, this is particularly the case in soils under anaerobic conditions. Indeed, under reduced conditions, like in rice paddies, microorganisms will start using not the unavailable O_2 but rather NO_3^- gradually followed by Fe(III) and Mn^{4+}, as they start to get depleted. These changes in metabolic activities may also be accompanied by a change in microbial communities which are more adapted to such an environment and use their resources more efficiently affecting the overall CUE. The aim of this work is to explore the effects of short-term (i.e. 15 days) changes in soil redox conditions (i.e. from aerobic to anaerobic) on microbial physiology in rice paddy soils, particularly on growth, respiration and CUE, as a function of the availability of labile organic C substrates (electron donors) and electron acceptors known to be influenced by soil properties and management practices, as well as their dependence on changes in microbial structure and composition. For this we have set up a microcosm experiment where rice straw and NO_3^- where added as sources of C and electron acceptors, and on days 4 and 17 an incubation with D_2O took place to trace the microbial activity. From our preliminary results, we can see that the NO_3^-, in flooded soils, was very rapidly (< 96h) utilized by microorganisms for all treatments. Moreover, the release of C in the soil solution is enhanced in the presence of rice straw and under anaerobic conditions. While the microbial biomass carbon (MBC) decreases under both anaerobic and aerobic conditions when the soil is supplied with a C source (i.e. rice straw). However, these different microbial C uses, and the fast electron acceptor depletion may be due to a change in microbial community or a change in their metabolism. And this will be uncovered in the next few months through the analysis of phospholipid fatty acid (PLFA) biomarkers.

Stabilization of organic carbon in temperate paddy fields

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Poster presentation

The mechanisms of organic carbon (OC) stabilization in paddy soils are difficult to predict due to complex OC stabilization processes under fluctuating redox conditions. Compared to semi-natural forests, we expect rice paddies to store more OC thanks to slower mineralization under anoxic conditions and interactions between OC and soil minerals (in particular Fe oxides). To assess OC storage in rice paddies and co-located semi-natural forests, we focused on a soil age gradient in Northern Italy. Total OC stocks were comparable between these two land uses, but more OC was mineral-associated in the paddy topsoil—possibly as a result of stronger redox-driven OC stabilization. Older soils had higher clay contents and more crystalline pedogenetic Fe stocks in the topsoil, but OC stocks were higher in the subsoil of the younger soils, where short-range ordered pedogenetic oxides were more abundant. We suggest that in the younger and coarser soils more intense hydrological flows transports Fe and dissolved OC to the subsoil. Overall, these results highlight the interplay between hydrological properties associated to soil age and redox fluctuations associated to water management in rice paddies.

Toxic trace elements speciation and fate in Swiss rice paddies: insights into arsenic, antimony, mercury, and other trace elements under varied cultivation practices

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Poster presentation

The contamination of rice with toxic trace elements such as arsenic (As), antimony (Sb) and mercury (Hg) represents a significant risk to food safety and environmental health as well as potential yield losses. Our research group investigates the biogeochemical dynamics of As, Sb, Hg, and other trace elements in Swiss rice paddies, focusing on their speciation, mobility, and accumulation in soils and different plant compartments. We conducted multi-year field sampling campaigns during the 2022 and 2023 harvest seasons in 9 farms, collecting samples from soil, shoots, and rice grains to evaluate the effects of soil properties and agricultural practices on trace element uptake. Additionally, different rice samples were collected in 2024 from various experimental plots to assess the influence of rice variety, soil properties, and nitrogen fertilization (type and application timing) on As concentration, speciation, and accumulation in rice grains. Our study includes detailed As speciation analyses using HPLC-ICP-MS/MS, providing insights into the distribution of inorganic and organic As species across the plant-soil continuum. We also followed the evolution of volatile As and Sb emissions during the growing season, offering important data on volatilization pathways and their contribution to trace element cycling in agroecosystems.

Unexpected improvements in the global sustainability of rice production by suppressing CH_4 emissions through optimized nitrogen fertilization

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Poster presentation

Rice production creates globally significant CH_4 emissions influenced by nitrogen fertilization (NF). Studies, including meta-analyses, show conflicting NF effects on CH_4 emissions, confounding attempts to optimize NF for climate mitigation. A three-field manipulation experiment incorporating RNA-based microbial analysis demonstrated for the first time that the response of CH_4 emissions to NF was determined by total nitrogen (TN) concentrations, with cyanobacteria-driven oxygen dynamics affecting methanotrophic activity. A systematic meta-analysis confirmed elevated initial TN levels represent a previously unrecognized factor that consistently fosters reduced CH_4 emissions following NF. Using global-scale simulations incorporating machine learning, we demonstrate that in rice paddies with TN exceeding 2.1 g kg^{-1}, increasing NF beyond conventional rates reduces CH_4 emissions up to 45.0% while enhancing rice yields up to 31.9%. These findings indicate that in a time of increased concern about food security and global warming, reassessing NF practices in rice paddies to promote sustainability is long overdue.

Rice Research Across Institutions

Rice breeding activities at the IVIA rice department

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Poster presentation

The IVIA Rice Department's primary activity is rice breeding. Our aim is to generate varieties towards an efficient, resilient, profitable, and environmentally sustainable system. To this end, we focus on developing new rice varieties that maintain high productivity under both optimal and adverse conditions. Our breeding efforts target increased yields, resistance to blast *Magnaporthe oryzae* (blast), reduced dependency on phytosanitary products and fertilizers, and improved tolerance to abiotic stresses—particularly salinity. Our objectives align with the needs of the rice sector which is in constant communication with us. We also consider the environmentally protected status of regional rice fields and the anticipated impacts of climate change.

Our approach includes a molecular breeding programme that uses the introgression of genes conferring high yield and salinity tolerance, along with the pyramiding of resistance genes effective against blast in our region. We have advanced breeding lines that outperform parental varieties in yield and include lines selected under saline conditions. These were developed in collaboration with an IRTA research group, who assessed their productivity under high salinity. Additionally, we employ genome editing techniques to introduce precise mutations in genes associated with key agronomic traits. We are currently developing gene-edited plants with broad-spectrum resistance to pathogens and evaluating their effectiveness in local varieties.

As a strategy, we exploit rice's genetic diversity by studying the genetic factors associated with agronomic traits in *japonica* rice adapted to the Mediterranean climate and identifying donor varieties with desirable traits to add value to our local varieties. Our collection of rice varieties was genetically characterized, allowing the identification of molecular markers associated with key traits and the selection of parent lines carrying beneficial alleles and facilitates marker-assisted selection throughout the breeding process. In addition, we have developed a Multi-parent Advanced Generation Intercross (MAGIC) population derived from eight varieties with different grain quality, yield, salinity tolerance, and blast resistance that serves both as a resource for gene discovery and as a tool for breeding.

These two populations are currently undergoing phenotypic and genotypic evaluation for yield, salinity tolerance, and disease resistance. In this context, under the BestRice project—conducted in collaboration with the UV, CRAG, IRTA, and Copsemar—we evaluated our collections under different N fertilization levels. Using genome-wide association studies (GWAS), we identified QTLs linked to nitrogen use efficiency (NUE) and candidate genes involved in yield under low N inputs. We also assessed the allelopathic potential of the collection of varieties and studied the interaction between rice and *Echinochloa crus-galli* through GWAS, RNA-Seq, and metabolomics analysis.

Advancing rice monitoring and management: ten years of remote sensing research

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Poster presentation

Rice plays a vital role as a staple food in food-insecure regions and holds significant economic, cultural, and environmental value in European and Italian agriculture. However, climate change increasingly threatens the sustainability and productivity of rice cropping systems. In this context, geospatial science and Earth Observation (EO) technologies are essential for developing advanced monitoring tools that deliver spatially explicit, timely information on crop conditions and practices. These tools are key to enabling more adaptive, sustainable, and climate-resilient rice production. The Natural Resources Monitoring Laboratory (NR-Lab) of CNR-IREA—a multidisciplinary group working on geoinformation for environmental, agricultural, and forestry challenges—has long been engaged in developing EO-based methods for rice monitoring. By acquiring, processing, and integrating multisource remote sensing data, the NR-Lab generates value-added geoinformation tailored to user needs. In the Copernicus era, NR-Lab has focused on the development of prototype downstream services for agriculture. The group has collaborated with the International Rice Research Institute (IRRI) and is currently conducting joint research with ITC, University of Twente. Among its key initiatives, NR-Lab led the ERMES project (Earth obseRvation Model-based RicE information Service), which developed EO-based services for the rice sector in Italy, Spain, and Greece. The project used moderate-resolution satellite data to support regional-scale crop monitoring, flood mapping, abiotic/biotic risk assessments, and yield estimation, serving regional authorities and the insurance sector. More recently, leveraging Copernicus Sentinel-2 data, the team has developed digital tools to support precision agriculture application at farm level, including automatic identification of management zones (MZs) and optimized field scouting for assessing crop nutritional status. Thanks to advances in radiative transfer modeling and machine learning, current efforts focus on the direct estimation of crop traits, particularly nitrogen content. Current research explores the potential of hyperspectral satellite sensors such as PRISMA and EnMAP for spectroscopic crop analysis from space. These data are being explored for applications including nitrogen monitoring, yield prediction, and grain protein content estimation. Another research stream targets the detection of phenological stages using decametric time series, supporting the analysis of multi-year trends in rice cropping practices and climate variability. This presentation will provide an overview of remote sensing research and EO-based innovations developed by IREA-CNR, in collaboration with UNIMI, as a contribution to the EURICE Research Network and the broader goal of advancing sustainable rice systems through geospatial science.

Arsenic speciation in rice, beyond inorganic arsenic. Methods and research conducted in the Soil Science Group of Uni. Bern (CH)

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Poster presentation

The Soil Science Group studies the biogeochemistry of soils under global change to improve environmental health and food production. We use advanced analytical approaches to understand potentially toxic trace element dynamics in response to land management and climate change. We investigate matter fluxes between soils and atmosphere, biota, ground and surface water from nano to field scale.
Here, we will showcase key instrumentation and methods that allows us to investigate arsenic species in the soil-plant system, with a focus on rice paddies. These include high performance liquid chromatography coupled with inductively coupled plasma tandem mass spectrometry (HPLC-ICP-MS/MS). We will briefly introduce case studies related to rice and soil-plant transfer as well as the Swiss rice paddies that we use for our investigations.

Biodiversity conservation and ecosystem services in rice agroecosystems

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Poster presentation

Rice farming (*Oryza sativa*, L) plays a pivotal role in ensuring global food security and fostering freshwater biodiversity conservation. Rice farming is one of the three most extensive agroecosystems in the world, occupying around 11% of arable land, producing around 780 million tonnes of rice in 2022, and serving as a staple food for more than half of the world's population. This global expansion of rice farms has come at a cost to natural ecosystems, replacing ~620,000 km2 of the world's wetlands over the last three centuries. Fortuitously, however, rice agroecosystems can be managed to act as surrogate habitat for the wetlands they have replaced. Indeed, rice fields are quite often biodiversity hotspots harboring a broad diversity of aquatic organisms that complete essential parts of their lifecycles in flooded fields, including aquatic macroinvertebrates, fishes, reptiles, amphibians, or waterbirds.

Our research group overall focuses on identifying and evaluating potential sustainable rice farming practices that allow to balance rice production with biodiversity conservation and the provision of essential regulatory ecosystem services. Specifically, we stem on three main lines of research:

• First, we investigate how restoring seminatural habitat in non-productive areas (e.g., field margins) can enhance biodiversity and multiple biodiversity-mediated ecosystem services (e.g. biological pest and weed control, soil protection, protection against invasive species, etc).

• Second, we investigate potential trade-offs between climate change mitigation and biodiversity conservation in rice agroecosystems. We study how water-saving irrigation (e.g., Alternate Wetting and Drying) reduces greenhouse gas emissions but impacts aquatic biodiversity and regulatory ecosystem services. By adopting spatiotemporal approaches, we aim to design sustainable management strategies that balance emissions reduction, biodiversity protection, and water use efficiency.

• Finally, we study how landscape complexity shapes multi-taxa biological communities and ecosystem services in rice agroecosystems. By quantifying the influence of landscape composition, heterogeneity, and connectivity on species distribution and ecological interactions, we aim to identify landscape designs that support resilient, multifunctional rice agroecosystems.

Through these research lines, our lab seeks to generate practical knowledge to guide the transition toward rice farming systems that conserve biodiversity, mitigate climate change, and promote key regulatory ecosystem services.

Compilation of strategies to improve the sustainability of rice crop fertilization (IRTA)

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Poster presentation

Sustainability in rice fertilization focuses on optimizing fertilizer use, minimizing pollution, and promoting environmentally friendly practices. This is achieved through efficient nutrient management, the use of organic fertilizers, and the adaptation of fertilization practices to the specific needs of each soil.

With the aim of improving the applicability of various practices that contribute to enhancing fertilization sustainability, the following trials and projects are being conducted at IRTA-Amposta: 1. Optimization of fertilization through organic fertilizers (chicken and pig manure, green manures): their use returns nutrients to the soil, improves soil structure, and enhances water retention. 2. Efficient use of chemical fertilizers: agronomic response trials to nitrogen fertilization (doses and splitting) have been conducted. It is crucial to apply the appropriate quantities at the right time to achieve the highest agronomic and economic efficiency. In this regard, efficiency trials are also being carried out with slow-release and encapsulated fertilizers, which release nutrients gradually and reduce losses due to runoff or volatilization. 3. Results dissemination and assessment services to farmers: through training programs for rice farmers, which enhance field knowledge through soil analysis. This allows for an accurate diagnosis of soil fertility and the adjustment of fertilization to the specific needs of the plot, avoiding the excessive use of nutrients that could later lead to groundwater contamination. 4. Use of remote sensing technologies: Trials on the transition towards precision fertilization through the development of algorithms for optimizing fertilizer use.

Contributions of Ente Nazionale Risi to rice pest and disease management

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Poster presentation

Ente Nazionale Risi conducts experimental trials and research projects to manage the major pests and diseases affecting Italian rice cultivation. These studies are carried out through both field trials and plant pathology laboratory activities, with the aim to promote sustainable and integrated management strategies.

Rice blast, caused by *Pyricularia oryzae*, remains a major concern for Italian rice cultivation. On this topic, a research program was conducted to assess the effects of agronomic practices - specifically nitrogen fertilization and two water management regimes (continuous flooding and Alternate Wetting and Drying, AWD) - on the incidence and severity of the disease. The findings also contributed to the development of a rice blast forecasting model, created in collaboration with the University of Turin. The model, currently under validation, is based on weather data and data of disease progression in the fields, with the aim to support farmers in the best timing of fungicide applications. It also considers agronomic factors influencing crop susceptibility, providing a decision-support tool to enhance disease management strategies.

Complementing these researches, fungicide efficacy trials are being conducted to identify optimal chemical control strategies. Among fungicides approved for use in Italy, quinone outside inhibitors (QoIs) are the most widely applied and effective against *P. oryzae*. However, the emergence of resistance to this mode of action represents a growing concern. Since 2020, a dedicated monitoring program has been evaluating the presence of QoI-resistant *P. oryzae* populations across the main Italian rice-growing regions using in vitro assays and sequencing for the identification of the mutation associated with resistance. This research led to the first confirmed report of QoI resistance in *P. oryzae* in Europe and revealed that the resistance is widely distributed across the country.

The rice root-knot nematode, *Meloidogyne graminicola*, is an emerging problem in Italy, especially in the sandy soils of certain areas of Lombardy. Since its first detection in 2016, Ente Nazionale Risi has been involved in annual monitoring surveys in Piedmont to assess its distribution. Field experimental trials demonstrated that maintaining continuous flooding during rice cultivation is an effective practice to control plant symptoms, as it prevents nematode colonization and reduces roots damages.

Minor diseases have also been considered. The efficacy of fungicide treatments was evaluated against *Bipolaris oryzae*, while the effects of water management and nitrogen fertilization were assessed for their impact on rice stem rot caused by *Sclerotium oryzae*.

Cultivar selection as a sustainable strategy for rice crop enhancement

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Poster presentation

Rice (*Oryza sativa* L.) holds significant sociocultural and economic value in Europe, while also providing crucial ecological support in environmentally sensitive areas that require protection. It is cultivated in wetland regions, as it is one of the few species that can tolerate flooded soil. Given these conditions, the use of chemical treatments is increasingly restricted, making the prioritization of agronomic techniques essential for sustainable rice production. However, rice cultivation is still exposed to numerous adverse factors that threaten its optimal development. These factors can be classified into biotic (caused by living organisms) and abiotic (non-living) categories. Notable biotic factors include fungal diseases, weeds, and pests, while significant abiotic factors encompass climate change, salinity, and drought.

A key factor in sustainably improving crop production is the selection of cultivars that are best suited to withstand these environmental and biotic challenges. The morphological and agronomic characteristics of different rice cultivars can offer advantages in addressing these adversities. For instance, some cultivars may exhibit varying degrees of tolerance to diseases and enhanced nitrogen utilization efficiency, among other traits. In terms of competition with weeds, taller plant height and increased tillering capacity can suppress weed growth. Moreover, recent studies suggest that certain rice cultivars may have an allelopathic effect on weed species such as *Echinochloa* spp.

At the IRTA Research Center in Amposta, ongoing studies focus on developing a platform of selected rice cultivars tailored to address these adverse factors. Specifically, a collection of cultivars has been identified that are better adapted to organic production systems, where weed and disease management are the primary challenges. Additionally, cultivars with enhanced salinity tolerance have also been selected. Currently, research is also focused on the selection of drought-tolerant varieties that can exhibit a better response under water restriction scenarios.

The objective of these efforts is to select rice cultivars that serve as a sustainable tool to provide farmers with an initial response to the agronomic challenges they must address. In this context, the aim is to develop a platform for the classification of varieties based on their performance, enabling the identification of those that offer the most suitable response according to the specific requirements of each field or particular environmental condition. However, it is equally imperative to implement sustainable and efficient resource management strategies to safeguard the long-term viability and profitability of rice production.

Enhancing the use of rice genetic resources through systematic characterization at the CREA-DC Vercelli Office

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Poster presentation

Plant genetic resources (PGRs) drive crop improvement and agro-ecosystem efficiency, yet many remain underused because their traits are unknown. Purposeful, precise characterization and evaluation of PGRs bridge this gap, connecting available genetic diversity to breeding and farming outcomes. The CREA-DC Office in Vercelli operates at this critical interface for the European rice sector.

Key activities were:

- DUS and VCU testing. Each year we conduct distinctness, uniformity, and stability (DUS) and value for cultivation and use (VCU) tests, underpinning the inclusion in the EU Common Catalogue and the granting of Plant Variety Rights.
- Multi-environment field trials. We have phenotyped more than 1000 accessions across contrasting sites, recording morpho-physiological descriptors, yield components, and blast resistance.
- Data dissemination. Over the years, we have released six descriptor books covering 583 European varieties, along with several peer-reviewed papers and open datasets. These datasets also support disease and crop models to forecast blast risk and crop development at multiple spatial and temporal scales.

To deliver these outputs at scale, we developed Kora, a free and open-source platform for managing PGR data. It supports the full germplasm evaluation cycle — from passport data to field observations — enabling the creation of comprehensive databases aligned with international standards. Kora manages crop metadata, descriptor lists, variety descriptions, germplasm collections, and links evaluation data with environmental factors. It prioritizes data ownership, usability, and adaptability to diverse workflows.

Kora supports breeders, evaluators, genebank curators, and researchers by improving data quality and accessibility. Designed to support FAIR data sharing, Kora offers an API and an embedded crop modeling framework.

We plan to extend phenotyping and modeling activities and promote broader adoption of Kora to connect germplasm data, evaluation results, and stakeholders. Integrating systematic germplasm characterization with digital tools like Kora fosters the effective use of genetic resources.

Ente Nazionale Risi and its research activities on the agronomy of rice

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Poster presentation

The Agronomy Department of Ente Nazionale Risi (ENR) holds significant expertise in the development and implementation of experimental programs regarding the agronomic management of rice crops. Apart from having an in-depth knowledge of all the rice-growing realities, the extension service of ENR guarantees an intimate contact between the Department's staff, technicians and farmers that allows for an overall vision of the agronomic problems the Italian rice industry is facing, as well as an effective transfer of knowledge. It mainly deals with subjects concerning the sustainability and safety of rice production. Regarding the agro-environmental sustainability of rice cultivation, numerous projects have been dedicated to developing guidelines both for adapting to as well as mitigating the effects of climate change, by promoting the adoption of management practices that require less water resources and reduce methane emissions into the atmosphere. In this context, within the RISWAGEST project, the adoption of AWD (Alternate Wetting and Drying) was evaluated and demonstrated to reduce methane emissions by up to 60% without compromising yields. With the RISTEC project, the positive effect of winter flooding on mitigating methane emissions was confirmed and attributed to the accelerated degradation of crop residues during the winter period. Additionally, autumn ploughing was found to reduce emissions compared to spring straw incorporation.

Soil fertility—an essential factor in sustainability—was also addressed. Within RISTEC, the use hairy vetch as a green manure was evaluated, showing its ability to increase soil organic matter and reduce the need for mineral nitrogen fertilization. Numerous studies also focused on improving Nitrogen Use Efficiency, including a varietal calibration project to assess nitrogen needs at panicle differentiation. This aimed to support Variable Rate Application techniques in precision agriculture, as well as the development of nitrogen fertilizers combined with nitrification inhibitors, urease inhibitors, and synthetic polymer coatings.

In terms of rice safety, extensive monitoring and experimental work have been carried out on the management of inorganic contaminants, particularly cadmium, arsenic and nickel which are subject to strict maximum concentration limits in rice under European regulations. Annual monitoring of grains across the rice cropping area and periodic assessment of contaminant levels in paddy soils have been implemented, together with agronomic trials focusing on the identification of water management practices that regulate soil redox conditions and consequently the bioavailability of contaminants. These studies led to the introduction of a drying-phase management plan designed to ensure minimum contaminant uptake. Soil liming proved highly effective in reducing cadmium concentrations in rice, with only minor effects on nickel. Lastly, field trials were conducted to evaluate the varietal influence.

Functional roles of rice rhizosphere microbiomes in nutrient acquisition and in food safety improvement

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Poster presentation

The connection between rice rhizosphere and its microbiome has long fascinated researchers, encouraging interdisciplinary collaborations. At AgEM-Lab (Facoltà di Scienze Agrarie ed Alimentari, UNIMI), as agricultural microbiologists, we have been studying rice rhizosphere microbial communities for the past ten years. Working closely with plant physiologists, soil chemists and agronomists in the frame of national and international projects, we focus on microbial functions related to plant nutrition (N, P, S, Fe) and to biogeochemical cycling of heavy metals and organic pollutants. New methods were established to study microbiomes at different microniches from ecto- to endo-rhizosphere. Since the very beginning, we developed next-generation sequencing (NGS) approaches for soil and plant microbial communities, along with Real Time qPCR biomarkers to detect and quantify microbial functions directly in the environment. Moreover, assays for plant growth promoting (PGP) traits and metal/metalloids transformation were implemented to ascertain bacterial functionalities at multiple scales, including in vitro tests, germination pouch assays and greenhouse pot experiments. Advanced bioinformatic and statistical pipelines have been designed to validate retrieved data and correlate them with environmental and agronomic drivers. Thanks to collaborations with Prof. Elisabetta Barberis's group at DISAFA (UNITO) and Dr. Marco Romani (ENR, Castello d'Agogna), we investigated the ecology of microbial populations affecting As and Fe mobilization to soil porewater and rice grain. The functional plasticity of microbial communities was elucidated, evidencing that functions can be modulated by water management and agronomic schemes, thus affecting grain safety (Zecchin et al., 2017a, 2017b, 2019).

In partnership with international-reputed scientists, we proposed a new rice rhizosphere bacterial genus, revealed by a metagenomic study, with expanded N and S metabolisms (Zecchin et al., 2018).

Together with Prof. Maria Martin (DISAFA-UNITO) and Prof. Planer-Friedrich (University of Bayreuth), we further explored the intricate connections between S and Fe bacteria that shape speciation of inorganic and thiolated As (Zecchin et al., 2023).

More recently, our collaboration with DISAFA moved to N and P cycling. Together with Prof. Luisella Celi, we studied how winter cover cropping in paddies promotes the establishment of PGP bacteria involved in N and P bioavailability (submitted manuscript). A PGP bacterial strain collection was established, contributing to the rice microbiome collection at DSMZ-Germany (manuscript in preparation).

Our current research is related to the role of PGP bacteria in limiting Cd uptake in aerobic rice and of electroactive microorganisms in As cycling.

As a perspective, we aim to expand our focus to the transmission and legacy of PGP bacteria in rice plants, in order to propose microbial solutions for climate-resilient agroecosystems.

Integrative genomics and phenotyping strategies to advance sustainable cultivation of European rice varieties with enhanced nutritional quality

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Poster presentation

Rice is a traditional crop in Portugal, supplying around 55% of the country's domestic consumption. At the Plant Functional Genomics Lab, we are developing an integrative approach that combines genomics and phenotyping tools to better understand how rice interacts with its environment and how different varieties have adapted to diverse climates.

In recent projects, we have been characterizing the genomic landscape of traditional rice varieties circulating in the European market, as well as wild relatives with contrasting vitamin B content, using whole-genome sequencing (Illumina and Oxford Nanopore platforms). We are identifying single nucleotide polymorphisms (SNPs), insertions and deletions (indels), and structural variants, and correlating these with key traits related to environmental resilience, grain quality, and yield. Additionally, we are exploring gene regulatory networks involved in the biosynthesis of vitamins B1 and B2 through co-expression analysis of extensive RNA-seq datasets from rice grain development. This work will support hypothesis generation and the identification of candidate regulatory genes for functional validation, accelerating the development of nutritionally enhanced rice varieties.

In the area of plant phenotyping, we are implementing a FAIR-compliant data management infrastructure to store phenotypic data from diverse sources and develop shared analysis workflows. We are also exploring image-based phenotyping to monitor rice growth and build machine learning models to predict agronomically relevant traits in commercially important rice varieties. Specifically, these models aim to: (i) predict soil water content to support irrigation scheduling and mitigate drought-related yield losses; and (ii) detect early signs of rice blast disease to enable timely intervention and prevent disease spread. This work is being carried out within the framework of European infrastructures in which we participate, including EMPHASIS for plant phenotyping and ELIXIR for biological data management.

We also partner with COTArroz, the Portuguese rice breeding center and InnovPlantProtect, a collaborative laboratory dedicated to the development of biobased solutions to mitigate biotic stress in plants.

IRTA: research and innovation for sustainable rice cultivation

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Poster presentation

The Institute of Agrifood Research and Technology (IRTA) is a public research institute that supports the Catalan agri-food sector through science, technology development, and innovation transfer.

The IRTA research center in Amposta is strategically located in the Ebro Delta, the main rice-growing area in Catalonia and one of the most important in Spain. The center, renowned for its expertise in rice cultivation, is recognized as a national benchmark in this area.

IRTA features dedicated rice fields and specialized infrastructure, facilitating applied research in close collaboration with key rice stakeholders. A highly adapted field trial platform enables rigorous evaluations of new agronomic practices, advanced technologies, and newly released rice varieties under real field conditions.

IRTA research addresses critical challenges in rice production, including invasive pests (e.g., apple snail), climate-related stressors (e.g., drought, salinity), plant nutrition (e.g., precision agriculture, organic fertilization), and major diseases (e.g., blast, fusarium). Through innovative agronomic approaches, we promote sustainable and efficient crop management.

IRTA works closely with farmers, public institutions, and private companies to co-develop and validate innovative solutions, fostering resilience and sustainability. Its outreach efforts have a significant impact on society and the primary sector, enhancing awareness, innovation uptake, and sustainable food production in Spain.

Past, present and future of research focused on rice of the Irrigation Engineering and Management Research Group (Universitat de Girona - Spain).

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Poster presentation

After a quick introduction of the Irrigation Engineering and Management Research Group from Universitat de Girona, an overview of its activities carried out within the rice irrigation research line from 2016 up to date will be presented.

A chronological snapshot of different projects (including their respective objectives, scope, geographical scale, partnerships and collaborating entities) will help to understand the progress of the rice irrigation research line as well as the tools and capacities developed within the Group. The research activities have been characterised by a strong collaboration with the productive sector and the Irrigation Consortium of the region, focusing on their concerns regarding water management. Specifically, the Research Group's initial work consisted in the assessment of different water management strategies in the agroclimatic conditions of the area. Later, the on-field monitoring activities and data analysis was scaled up at farm and irrigation district levels. This progression has been facilitated through continuous partnerships with both national and international research institutions.

Nowadays, the activities of the Research Group within the rice irrigation research line are developed in the framework of the PROMEDRICE project (www.promedrice.org). Crop development, soil salinization and water flux data, including both quantity and quality perspectives, is being collected at commercial field, farm and district scales. This dataset is integrated into crop and water models to assess the impact of different irrigation practices on water and soil quality, generating scientific evidence to guide policymakers in sustainable water resource management.

The main objective of the presentation is to foster networking and potential future collaborations with other EURICE participating entities.

Research by the Environmental Control of Flowering group

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Poster presentation

The Environmental Control of Flowering Time Group at the Institute of Plant Molecular and Cellular Biology (IBMCP) in Valencia, Spain, investigates how plants perceive and integrate environmental cues to regulate the transition to flowering, a key developmental switch with major implications for plant fitness and crop productivity. Flowering time determines reproductive success and is a critical trait in agriculture, especially as climate change intensifies abiotic stress conditions and threatens food security. Our research addresses how environmental factors, primarily temperature and water availability, interact with genetic pathways to influence flowering time. We focus on two model species: *Arabidopsis thaliana*, a reference for dicotyledonous plant research, and *Oryza sativa* (rice), a staple monocot crop and model for grasses. By comparing responses in these evolutionarily distant species, we aim to uncover both conserved and lineage-specific regulatory networks. A major objective is to define the molecular basis of temperature-dependent flowering, especially in rice, where these mechanisms are less well understood. We integrate transcriptomics, functional genomics, and proteomics to identify thermoresponsive gene networks and validate candidate regulators through mutagenesis and expression analyses under variable thermal regimes.

Another core area of our work is the investigation of flowering-time responses under combined environmental stresses. Plants in field conditions often face multiple abiotic stresses simultaneously, such as heat and drought, with complex and sometimes opposing effects on development. We study how these stresses converge on flowering-time pathways and examine gene expression dynamics and physiological responses under such conditions. Particular attention is given to Mediterranean climates, where high temperatures and water scarcity often coincide during the growing season, affecting critical reproductive phases.

Our group also explores natural genetic variation in flowering-time regulators to understand how allelic diversity contributes to phenotypic plasticity and stress adaptation. We analyze cultivated rice germplasm to identify favorable alleles that modulate flowering under environmental constraints, providing valuable targets for breeding programs. This research contributes directly to efforts to develop crop varieties that flower at optimal times, thereby escaping terminal stresses and maximizing yield potential.

By advancing our understanding of how flowering is environmentally regulated at the molecular and systems levels, we aim to support the development of climate-resilient crops. Our work sits at the interface of basic and applied plant science, combining cutting-edge technologies with translational goals to address global agricultural challenges.

Rice fields as surrogates of wetlands: biodiversity conservation in modern agriculture

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Poster presentation

In the majority of the Mediterranean countries, natural marshes often cover small surfaces and undergo high level of anthropic pressure. Even if modified for agricultural purposes, rice-dominated landscapes may be seen as wet environments maintained by human activities and have been worldwide recognized as potential habitats for animals and plants, including species of conservation concern. However, modern practices such as laser-levelling, conversion to dry cultivation, and use of pesticides have negatively impacted these communities, reducing refugee areas and favouring opportunistic species. Hence, sustainable management of rice systems is crucial for conservation of wetland species that partly or completely depend on it. Scientific activities mainly focused on the development of environmentally-friendly practices in order to make the improvement of habitat quality for biodiversity compatible with good husbandry. From 2009 to 2025, several collaborations were implemented between research institutes (e.g. University of Pavia, Milano, Milano-Bicocca and Torino), NGO (e.g. LIPU and Legambiente), parks (e.g. Parco Lombardo della Valle del Ticino) and productive stakeholders (e.g. Parboriz Srl and rice farms), with funding of private and public bodies (e.g. Lombardy Region, Fondazione Cariplo, Fondazione Lombardia per l'Ambiente, Parboriz Srl). Research focused on both vertebrate and invertebrate, on the following topics:

- Herons and egrets, flagship species of rice fields, in terms of food resources and reproductive success, also by means of radiotracking. Modification in foraging condition in paddy fields from 1970 to nowadays, a period in which consistent changes in agronomic techniques occurred, was tracked.
- Optimal strategies to manage spontaneous vegetation developing on field banks, comparing the effect of mechanical and chemical control, seeding of nectariferous flower mix and no control at all, on different arthropod taxa providers of ecosystem services such as pollination or biological control (e.g. ground beetles, butterflies and bees).
- Water cycle management and its impact on birds, anurans and invertebrates. In particular, the effect of the presence of a water retention structure inside the field during the vegetative season, that act as refugee habitat for aquatic organisms, the seeding techniques (i.e. water- and dry-seeding), that imply an earlier or later submersion of the paddy, and winter flooding were tested.
- Different techniques of fertilizer distribution and their effects on soil fauna (i.e. soil microarthropods and worms).

In a framework of worldwide biodiversity loss, sustainability is widely considered a goal to be achieved in agriculture. As a consequence, research focused on procedural aspects that may favour straightforward application of environmentally-friendly practices among farmers, such as the preparation of bank "seedbed" and seeding density for flower mix, are certainly needed.

Rice research at CIRAD–AGAP Institut: toward climate-resilient and sustainable rice systems

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Poster presentation

Rice research at Cirad-AGAP Institut is mainly centered on understanding how the crop interacts with its current and future environments, with a strong emphasis on reducing its environmental footprint. Our researchers aim to decipher the physiological and genetic mechanisms that give rice the ability to adapt and mitigate climate change. A key part of our investigation is mobilised to develop the rice varieties that will be performing in future conditions while contributing to food security and quality. Such activities rely in pre-breeding but also genetics, breeding activities and systems agronomy, all developed in close interaction with partners, essentially in the South. Ongoing research and capacity-building activities are based in partners' sites across Latin America (Colombia, Brazil), West Africa (Sénégal), Southern Africa (Madagascar) and South East Asia (Cambodia, Vietnam).

Our pre-breeding activities require close connections with rice physiologists and pathologists in order to identify the genetic and physiological controls that will improve the rice's response to environmental stresses, whether abiotic or biotic, and guarantee acceptable grain quality. We develop segregating populations and introgression lines to address fundamental research questions and provide relevant genetic material that can be used in breeding programs.

Our activities include simulating breeding schemes to optimize programs' efficiency, using advanced molecular and omics assisted selection through the development of prediction models, and integrating participatory selection with farmers to shape future varieties. Upstream research in breeding focuses on proof-of-concept innovations to manipulate recombination and reproduction mechanisms, using genome editing.

To make an impact at the farm level, we combine all the relevant technologies and knowledge, both scientific and indigenous, within agroecosystems specifically designed for rice cultivation. This holistic, multi-stakeholder approach—bringing together farmers, geneticists, and agronomists—aims to sustainably boost both yield and grain quality while preserving ecosystem and human health.

While the AGAP Institut dedicates most of its activities to challenges encountered in the South, our research is highly relevant in European conditions. Living labs are thus foreseen in collaboration with our national partner in Camargue (France) to explore transferring innovations from South to North. The poster we will present highlights some of our research activities. The objective is to develop the necessary collaboration within the EURICE network to stimulate exchange and mutual benefits, to discuss our research advances and to capitalise on what has been done globally and widely.

Rice Research at CIRAD–Plant Health Institute of Montpellier: adaptation of rice fungal pathogens to their environment.

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Poster presentation

At the Plant Health Institute of Montpellier (PHIM) we study the interactions between plants, microbial organisms or insects (whether pathogenic or beneficial) and the environment. We study how these complex interactions impact plant health, growth and productivity. Rice research at Cirad is centered on fungal pathogens causing diseases on aerial part (leaves and panicles). We have long term experience on the Blast disease (caused by *Pyricularia oryzae*) and, more recently, developed expertise on causal agents of Brown spot disease (*Bipolaris* spp, *Exserohilum rostratum* and *Curvularia* spp.). Our goal is to provide durable and sustainable control methods, in particular based on managing rice resistances. Ongoing research and capacity-building activities are based in partners' sites across Europe (France, Italy, Spain), West Africa (Côte d'Ivoire, Burkina Faso), Southern Africa (Madagascar) and South East Asia (Cambodia).

Our research questions are mainly focused on how fungal pathogens adapt to their environment, including their host. We contribute to understand how populations of the blast fungus adapted and are still adapting to rice resistance. We try to understand how Brown spot disease is re-emerging in many countries around the world. Using population biology, genetics and genomics tools, we produced information on population diversity, structure and evolution of the rice fungal pathogens at different geographic scales. We also contribute to developing diagnostic tools for pathogen detection and genotyping tools based on genome sequencing techniques.

RiceClim I: paddy rice cultivation as greenhouse gas mitigation option in degraded temperate peatlands

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Poster presentation

Most peatlands in Europe are intensively managed and drained for agriculture, leading to fast microbial decomposition of peat, resulting in soil subsidence and high greenhouse gas (GHG) emissions. Until now, proposed solutions for reducing the environmental footprint of degraded peatlands have focused on rewetting these soils resulting in the abandonment of agricultural production, or more recently, on the wet cultivation of water-tolerant crops (paludiculture). An emerging water-tolerant crop in temperate regions of Europe is paddy rice, which is successfully grown in Switzerland by pioneer farmers, providing an economically viable niche product. The overall aim of the presented project RiceClim is I) to evaluate whether the cultivation of paddy rice on C-rich soils in the cool temperate zone can improve the GHG budget compared to conventional drained crop cultivation at the field scale; II) to further test specific management options to reduce CH_4 emissions of paddy rice fields and III) to analyse driving factors of GHG emissions including soil properties and bacterial and archaeal communities (see poster RiceClim II).

The four-year RiceClim project starting in May 2025 investigates GHG release at three different scales: a) At the field scale (ha), the full GHG balance (CO_2, CH_4, N_2O) of a crop cultivation on drained carbon rich soils and a paddy rice cultivation will be compared using the eddy covariance (EC) method (aim I, III). b) At the plot scale (m^2), different residue management options (straw removal, straw incorporation, biochar application) will be applied to paddy rice cultivation on organic soil in an open-air mesocosm experiment, and the corresponding GHG fluxes will be measured using manual chambers. By applying 13C-labelled rice straw and analysing the isotopic composition (^{14}C and ^{13}C) of the emitted CH_4 and CO_2, different sources (recent plant assimilates, straw and peat) will be quantified (aim II, III). c) at a micro scale (cm^2), a fully controlled lab incubation experiment will be conducted to quantify the effect of biochar and straw addition on CH_4 release from various soils used for paddy rice cropping in Switzerland (aim II, III). The implemented management options are expected to lead to different GHG emissions. Therefore, this project will offer recommendations for climate-smart agriculture practices on organic-rich soils in the temperate zone. Additionally, a better understanding of the underlying processes will facilitate the transfer of findings to other locations, enabling improvements in future GHG modeling.

RiceClim II: soil archaeal and bacterial diversity in paddy rice cultures north of the Alps

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Poster presentation

Facilitated by climate change, paddy rice is an emerging crop in cool temperate regions of Central Europe. In Switzerland, paddy rice has been successfully cultivated since 2017 at several sites north of the Alps and has become an economically viable local niche product. Paddy rice cultivation in these areas has increased above-ground biodiversity by creating a valuable habitat for wetland species and has reduced soil degradation by rewetting of previously drained degraded peatlands. However, effects on below-ground biodiversity and on the greenhouse gas balance in cool temperate regions remain largely unknown. To address these points, the RiceClim project focuses on two main research areas. On the one hand, soil archaeal and bacterial diversity will be surveyed in paddy rice and adjacent drained fields across Switzerland focusing on methanogenic and methanotrophic organisms. On the other hand, the greenhouse gas balance of paddy rice cultivated on degraded peatlands and adjacent drained fields will be determined, and agricultural management options, which could reduce greenhouse gas emissions, will be experimentally assessed (see poster RiceClim I).

Soil archaea and bacteria will be assessed with two techniques. High-throughput DNA sequencing of taxonomic markers allows to identify entire communities, and sequencing of functional markers allows to assess the diversity of methanogenic and methanotrophic microorganisms more in detail. To describe the diversity of these soil microorganisms in Swiss paddy rice soils and to determine the effect of rewetting of agriculturally used soils, samples will be collected from the approximately 15 Swiss paddy rice fields as well as from adjacent drained agricultural fields. A mesocosm experiment, established at Agroscope (Zurich), is used to quantify the effect of straw and biochar addition on greenhouse gas balances, and a microcosm experiment will be performed to determine effects of different soil types on greenhouse gas emissions. Assessments of soil archaea and bacteria in these two experimental systems will allow to elucidate the microbial drivers of greenhouse gas emissions from paddy rice soils in diverse conditions, and under different agricultural management.

The RiceClim project will provide the first survey of archaeal and bacterial diversity in paddy rice soils across Switzerland. Further, it will inform strategies for a sustainable and productive use of degraded peatlands in cool temperate regions.

Shaping the future of Italian rice cultivation: innovation and sustainability at INNOVA-TECH

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Poster presentation

Innova-tech, founded in 1995, is dedicated to transforming rice cultivation through innovation, technology, and sustainability. What began as a small team has grown into a network of more than 500 partner farms across Italy, ranging from family-run businesses to large-scale enterprises. The company positions itself as a bridge between science and practice, turning data and research into practical strategies that support both productivity and environmental stewardship. Its philosophy is that agricultural innovation must be evidence-based, farmer-oriented, and climate-smart, ensuring that solutions are both relevant and scalable.

Research and development activities are built on close collaboration with farmers, universities, and industry partners. Innova-tech integrates multiple data sources (satellite imagery, drones, soil sensors, weather information, and historical field records) to deliver tailored recommendations for each farm. Outcomes are continuously monitored and refined, combining advanced technologies with hands-on agronomic expertise. This iterative approach has already shown concrete benefits, such as improved yields, reduced fertilizer inputs, greater nutrient efficiency, and measurable reductions in greenhouse gas emissions.

Beyond crop management, Innova-tech is engaged in developing new rice varieties that combine high yield potential with resilience to drought, resistance to pests, and improved grain quality. Experimental lines are evaluated through scientific trials and precision monitoring, ensuring their adaptability to diverse environments. At the same time, the company tests fertilizers, crop protection tools, biostimulants, and digital technologies, always aiming to make farming more efficient, sustainable, and climate resilient.

At the European level, Innova-tech participates in two Horizon Europe projects and one PRIMA initiative, in addition to several national programs. These efforts focus on greenhouse gas mitigation, sustainable resource management, and the resilience of rice-based systems. By linking cutting-edge research with practical applications, Innova-tech provides farmers with validated tools and strategies that support profitability while meeting sustainability targets.

Looking ahead, the company remains committed to working side by side with farmers and stakeholders. Its long-term vision is to help shape the future of Italian rice farming through precision agriculture, integrated crop management, and the adoption of climate-smart practices. By combining innovation, collaboration, and real-world applicability, Innova-tech aims to strengthen the competitiveness of the rice sector while protecting natural resources and contributing to a more resilient and sustainable food system.

The story of the 'grassroots' UK Rice Research Community and the newly formed OryzaNet

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Poster presentation

We will describe recent progress within UK Rice Research Community and aspirations for the future. While the UK cannot grow rice for commercial gain, we increasingly import and consume rice with the associated UK industry worth nearly £1 billion annually. We carry out rice research across important areas including fundamental science, genetics, nutrition, and social science. Rice research provides additional benefit as it is an excellent model system for understanding and improving other cereal crops.

The UK Rice Research Community (UKRRC, www.ukrrc.org) was formed as a 'grassroots' movement in 2018 to help provide focus, strategic direction and to identify roles that the UK community can fulfill. With minimal funding we have held several popular and well attended Early Career Researcher Workshops and identified the challenges facing UK rice researchers.

'OryzaNet' is a new three-year networking project funded by the BBSRC, commencing August 1st 2025. It builds on the needs identified by the UKRRC and has the following objectives:

- Strengthen links between UK, Europe, and global partners by fostering international collaborations that increase the visibility, impact, and global recognition of UK-led rice research.
- Offer training in key technologies and subjects including gene editing, plant phenomics, rice cultivation and bioinformatics.
- Accelerate progress by developing and improving key resources for the UK rice research community. Identify and develop key technologies and resources for the future.
- Empower early career researchers through dedicated funding schemes that will enable them to initiate collaborative research and innovation, ensuring long-term investment in the next-generation of rice researchers.
- Provide strategic leadership in international coordination of bioinformatics. Promoting open data sharing initiatives for large and currently disconnected rice datasets.
- Greater integration across the rice research community, aligning efforts with national infrastructure and global research priorities.
- Recognise and address challenges in equality, diversity, and inclusion within UK and international rice research; develop actionable policies to support equitable, transparent, and mutually beneficial global collaborations.

UNIMI presents: EBi Plant Genetics

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Poster presentation

The rice situation in Italy is peculiar since it is considered a high-value crop, while in many other rice-producing countries it is a staple food. Nevertheless, Italy is the EU's leading rice producer, accounting for 58% of total production across 200,000 hectares. The sector brings a total €700 million annually to the European market, and for now breeding has been successfully carried on by small enterprises relying on conventional methods. However, rice production is now facing serious challenges: climate change, increasing competition from extra-EU producers, evolving pathogens, and the demand for more sustainable production systems all call for a significant technological upgrade.

EBi Plant Genetics, a spin-off from the University of Milan (Departments of Agricultural and Environmental Sciences, and Department of Biosciences), was established to address these challenges. Its aim is to bring cutting-edge technologies into current rice breeding programs. The company combines expertise in genetics, molecular biology, in vitro cultivation and plant regeneration, bioinformatics, and statistics to support both conventional and advanced breeding strategies. Key activities include the development and application of molecular markers for marker-assisted selection (MAS) and marker-assisted backcrossing (MABC), targeting important agronomic traits such as disease resistance (e.g. rice blast), grain quality, nitrogen-use efficiency, and yield. EBi is supported by an ever-increasing panel of local and foreign varieties to support allele hunting, many of which have been fully sequenced. At the same time, EBi has optimized CRISPR-Cas9 genome editing protocols for elite Italian rice varieties, allowing the introduction of targeted genetic improvements into these otherwise recalcitrant, high-value crops. Edited traits include resistance to biotic and abiotic stresses, and traits affecting plant architecture and efficiency.

The research group from which EBi stems boasts solid collaborations with local breeding companies, international Universities and Research Centers such as Nagoya University, Tohoku University and Max Planck Institute.

All innovations are validated through phenotypic and molecular analysis in field and greenhouse conditions. EBi operates at the intersection of academic research and applied breeding, offering solutions to enhance the competitiveness, sustainability, and genetic resilience of Italian rice.

Weed rice research activities of Ente Nazionale Risi

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Poster presentation

Weeds are one of the most significant challenges for rice cultivation in Italy. The Crop Protection Department of Ente Nazionale Risi (ENR) has developed extensive expertise in weed management through decades of experimental activities, conducted in collaboration with private agrochemical companies and scientific institutions. Through its Extension Service, ENR maintains comprehensive knowledge of the Italian rice-growing areas, including weed control challenges and the presence of herbicide-resistant weeds.

In collaboration with agrochemical companies, ENR has conducted experimental trials to assess the efficacy and phytotoxicity of new active ingredients, supporting their authorization for use in rice cultivation.

Within the INNOVAWEEDRICE project, innovative weed control techniques were evaluated through field trials on paddy farms. These activities focused on: (i) mechanical weed control methods using different types of mechanical rice weeders, (ii) precision herbicide distribution in pre-sowing applications, and (iii) extended false seeding periods. The adoption of these agro-techniques can reduce agrochemical residues in paddy water and soil, providing environmental, technical, and economic benefits.

Weed control in organic rice cultivation has also been a priority. Since 2017, through the RISO BIOSYSTEMS project, a long-term experimental platform has been established to evaluate organic weed management techniques such as false seeding and weeder harrowing in dry seeding systems, as well as green mulching in water-seeded systems. In both organic and conventional systems, ENR has carried out monitoring and experimental activities to quantify the presence of agrochemical products in water, soil, plants, and grains, with the aim of studying degradation dynamics.

Regarding innovative weed control technologies, the RiWeCIS project has developed several strategies to enhance the sustainability of Italian rice cultivation by optimizing, reducing, or avoiding herbicide use. In a pilot experiment, encapsulated nanoformulations of active ingredients for controlling *Echinochloa* spp. and *Oryza sativa* L. var. *sylvatica* were tested, aiming to decrease herbicide quantities and environmental leaching while maintaining control efficacy.

Annual monitoring of allochthonous and herbicide-resistant weeds has been implemented, along with herbicide trials to detect new resistance phenomena. Screening tests have been conducted to evaluate the resistance of *Echinochloa* spp. populations to different registered active ingredients. As a member of the Italian Herbicide Resistance Working Group (GIRE), ENR has contributed to confirming the presence of new herbicide-resistant species in Italian rice cultivation, most recently identifying multi-resistant *Alisma plantago-aquatica* L. populations to ALS inhibitors (HRAC 2) and auxin mimics (HRAC 4). Specific greenhouse and field trials have been carried out to confirm these findings and explore new control strategies.

Weed Science Group (Plant Protection Department), Extremadura Scientific and Technological Research Center-CICYTEX (Guadajira, Badajoz, Spain)

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Poster presentation

Our facilities range from experimental farms to greenhouses/growing chambers and a Molecular Biology laboratory. Our specialty is the study of herbicide resistance mechanisms, mainly target site resistance, developing classical techniques and other more novel biochemical and molecular biology techniques. In addition, field-greenhouse-growth chamber assays are carried out to test herbicide efficacy, screening, dose-response, etc. Although we have worked and continue to work on different crops, our “star crop” is rice, where we have developed (and continue to develop) many projects over the years, always in direct contact with the sector and working in collaboration with the Plant Health Service of the Regional Government of Extremadura.

We are currently participating in a European project on agroecological management of weeds, a national plan project on resistance in corn weeds, a network on *Amarathus palmeri*, as well as several projects financed at state-regional level with FEDER funds where we are studying, among other topics, weed resistance in different crops, dispersion and resistance in *Amaranthus palmeri* in Extremadura, rotations in rice cultivation, as well as the adaptation of weed management in new irrigation systems in rice. In addition, we have collaborations with different Universities/Research Centers, mainly on issues of characterization of resistance mechanisms, as well as several technical assistances with different phytosanitary companies and administrations for both herbicide efficacy trials and studies of TSR mechanisms.

At present, we are developing different projects that include among their activities studies related to weed control in rice cultivation:

- Regional Operative Group “Integrated Weed Control in Rice” (CIMh-Rice). The main objective is to establish the best weed control strategies for rice weeds in farmers' plots in Extremadura by integrating agronomic and cultural methods together with chemical ones.
- European Project “Agroecology for Weeds” (GOOD). The main objective is to address this weed problem in rice by developing weed management strategies based on agroecology. The project aims to reduce the use of herbicides by farmers and, at the same time, improve efficiency, resilience and sustainability.
- Projects financed with FEDER funds: “Integrated management of diseases and weeds in agroforestry systems in Extremadura for sustainable development: prevention, monitoring and control, MIP3”, where our group study the use of crop rotation in rice cultivation and “Introduction of drip irrigation in rice as an alternative to flood irrigation, RIGORYZA”, where our group participates studying weed evaluation in this new cropping system and alternatives for its control.

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